FERIC FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA
INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

Skidding with Small Crawler-Tractors

Bruce McMorland

Technical Report No. TR-37
March 1980

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FOREWORD

Data for this project were collected in both Imperial and SI forms of measure. The units actually measured are written first (usually Imperial) followed by their converted equivalents shown in parentheses.

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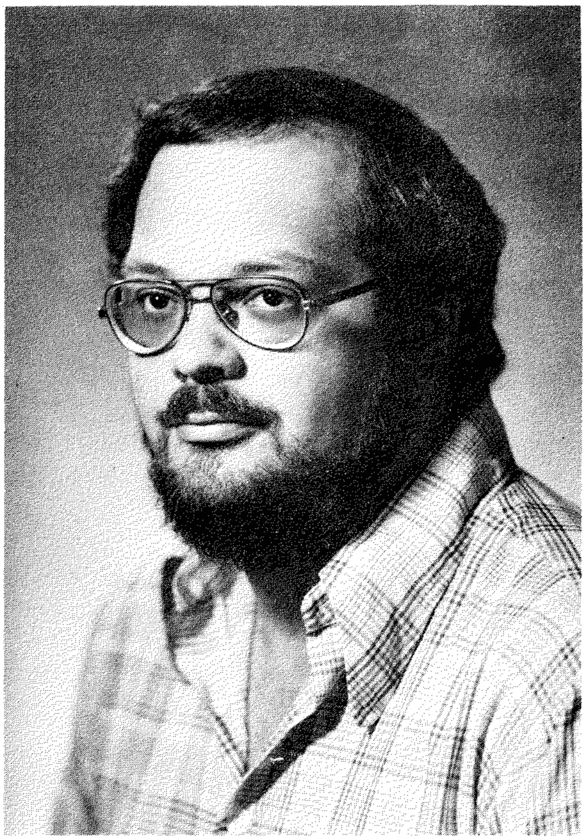
This report was delayed in publication due to an unfortunate accident to the author in September 1978.



Bruce McMorland is a 1971 forestry graduate from The British Columbia Institute of Technology. Until 1972 he was employed in Montreal by various industrial concerns. In 1972, he joined the Logging Research Division of the Pulp and Paper Research Institute of Canada in Pointe Claire, Quebec, where he worked for two years until he transferred to the Vancouver office. At FERIC's inception in April 1975, he joined that organization to work on machine and system evaluations.

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ABSTRACT

FERIC studies show that small crawler-tractors have been successfully introduced for ground-skidding in logging operations in the Interior of British Columbia. These tractors work on flat ground or steep sidehills. Skid trails are built by the same size machine that does the logging.

The tractors fall into two size ranges. Komatsu D31A's, John Deere 450's and Caterpillar D-3's are rated between 63 hp and 65 hp (47 kW-48 kW) and have blade widths ranging from 7.5 ft to 8.8 ft (2.3 m-2.7 m). John Deere 550's, International TD-8's and Caterpillar D-4's are rated between 72 hp and 78 hp (54 kW-58 kW). Their blade widths range from 8 ft (2.4 m) to 10.4 ft (3.2 m).

FERIC evaluated seven contractor-owned John Deere and International tractors, and a company-owned John Deere trailbuilder, for most of the 1977-1978 logging season. The contractor fleet averaged 19.9 cunits (56.3 m^3) per shift worked at a calculated cost of \$23.16/cunit (\$8.19/m^3) for decked wood on a landing. The fleet produced 20,214 cunits (57 240 m^3) during 1,016 shifts with production. Non-productive time (all sources) accounted for 21% of scheduled time.

Site disturbance studies showed that small-tractor-logged areas have approximately one-third less disturbance than areas with trail networks built by larger crawlers, summer or winter. Almost all the reduction resulted from narrower skid trails combined with wider trail spacing. Site-disturbance levels were higher than those measured on cable-logging sites.

RÉSUMÉ

Les études de FERIC montrent que dans les exploitations forestières de la Colombie-Britannique intérieure, on a adopté avec succès l'usage de petits tracteurs à chenilles pour le débardage par traînage. Ces tracteurs travaillent sur un terrain plat ou sur le flanc de montagnes escarpées. Les sentiers de débardage sont construits par des engins de mêmes dimensions que ceux qui feront l'exploitation.

Les tracteurs entrent dans deux gammes de dimensions. Le Komatsu D31A, le John Deere 450 et le Caterpillar D-3 se situent entre 63 hp et 65 hp (47 kW-48 kW) et sont munis de lames dont la largeur varie de 7.5 pi à 8.8 pi (2.3 m à 2.7 m). Le John Deere 550, l'International TD-8 et le Caterpillar D-4 se situent entre 72 hp et 78 hp (54 kW-58 kW). La largeur de leur lame varie entre 8 pi (2.4 m) et 10.4 pi (3.2 m).

Durant la majeure partie de la saison d'exploitation 1977-1978, FERIC a évalué sept tracteurs John Deere et International appartenant à un entrepreneur, et un constructeur de sentiers John Deere appartenant à une compagnie. Le parc de véhicules de l'entrepreneur atteignait en moyenne 19.9 cunits (56.3 m^3) par poste de travail au coût de \$23.16/cunit (\$8.19/m^3), le bois étant empilé à une jetée. La production s'élevait à 20,214 cunits (57 240 m^3) durant 1,016 postes de travail productifs. Le temps non-productif (de toutes sortes) représentait 21% du temps prévu.

Les études de dégradation du site montrent que les étendues exploitées à l'aide de petits tracteurs présentent environ un tiers moins de dégradation que celles où le réseau de sentiers est construit par de plus gros tracteurs à chenilles, et cela en été comme en hiver. On peut attribuer presque toute cette réduction à la combinaison de sentiers plus étroits avec un espacement plus grand entre les sentiers. Les niveaux de dégradation des sites étaient plus élevés que les niveaux mesurés sur les sites où se pratiquait le débardage par câble.

INTRODUCTION

Background, Significance and Objectives

Until the early 1970s most logging in Interior British Columbia was conducted by ground-skidding equipment. This equipment varied from the bulldozer crawler-tractor (D-6 size or equivalent, or larger) to rubber-tired articulated wheeled skidders. These machines worked not only on flat ground without skid trails but also on sidehills with slopes up to 80% using intensive trail patterns. Usually skid trails were built with a bulldozer having a minimum blade width of 10 ft (3 m).

Serious environmental concerns were expressed centering around ground-skidding operations on steep or sensitive terrain. Skid-trail networks in particular were often attacked as being too dense, too unsightly, and the source of unacceptable soil erosion and poor future regeneration.

In 1973, the B.C. Forest Service imposed slope restraints for ground-skidding systems in the Nelson Forest District. Ground skidding would not be approved on slopes exceeding 70% and would be approved only in specific instances on slopes between 50% and 70 percent. Logging companies in the District began experimenting with cable-yarding systems on critical areas. The companies found cable logging difficult to introduce and complex and costly to operate (Cottell, McMorland, Wellburn, 1976). Concurrently, studies were undertaken by the Pacific Forest Research Centre to determine the extent of soil disturbance on areas logged by tractors, skidders and cable machines. Smith and Wass (1976) determined that

> "Erosion, subsequent stream sedimentation and site deterioration would seem to be much less potential problems of yarding than of road construction. The extent of mineral soil exposed from the yarding operation is small compared with that produced by haul roads and skidroads, i.e., 3.6% versus 41.9% of unburned, summer ground skidded clearcuts."

and that

> "From the point of view of potential site deterioration and erosion, it is road-related disturbance that must be reduced. Reduction by about one-half can be attained by ground skidding on snow or by using a cable yarding system."

From these studies a picture began to emerge. If road and trail-related disturbance could be reduced for ground-skidding systems, then it might not be necessary to use the more costly and complex cable-logging equipment.

Crestbrook Forest Industries Ltd. believed there was a ground-skidding machine that would produce logs at an acceptable cost in small timber on steep slopes with less site disturbance. They began experimenting with crawler tractors in the 70-hp (52-kW) range. Figure A shows one of these machines.

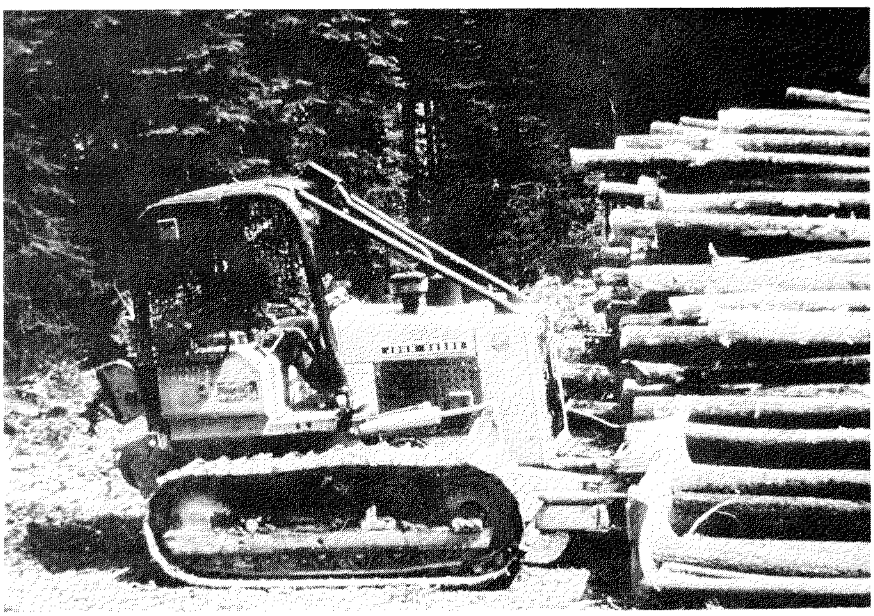


FIGURE A. Contractor-owned John Deere 550 aligning decks on a landing

Several contractors obtained John Deere 450's, 550's and International TD-8's. These machines have a 7.5 ft to 8 ft blade (approx. 2.4 m) and are roughly equivalent in size to Caterpillar D-3's and D-4's. Company personnel theorized that a trail built by a small blade would result in less soil movement, a smaller cutbank, and less erosion than one built by a larger machine. Figure B illustrates this concept. The small trail width excluded the use of large tractors for the skidding phase, and the trail was not wide enough to accommodate the spinning wheels and sliding movements of rubber-tired skidders. Skidding logs would have to be carried out by the same machine, or size of machine, that built the trail.

In theory, soils problems would be reduced. Production and cost, however, still remained unknown. Fortunately, there were historical precedents. As early as the 1950s, gasoline-powered crawler tractors logged successfully in the Kootenay region. Some of Crestbrook's personnel had been involved with those operations and believed the concept would apply equally well in the 1970s.

FERIC was invited to monitor the introduction of these small tractors to current logging operations. There were 3 study objectives.

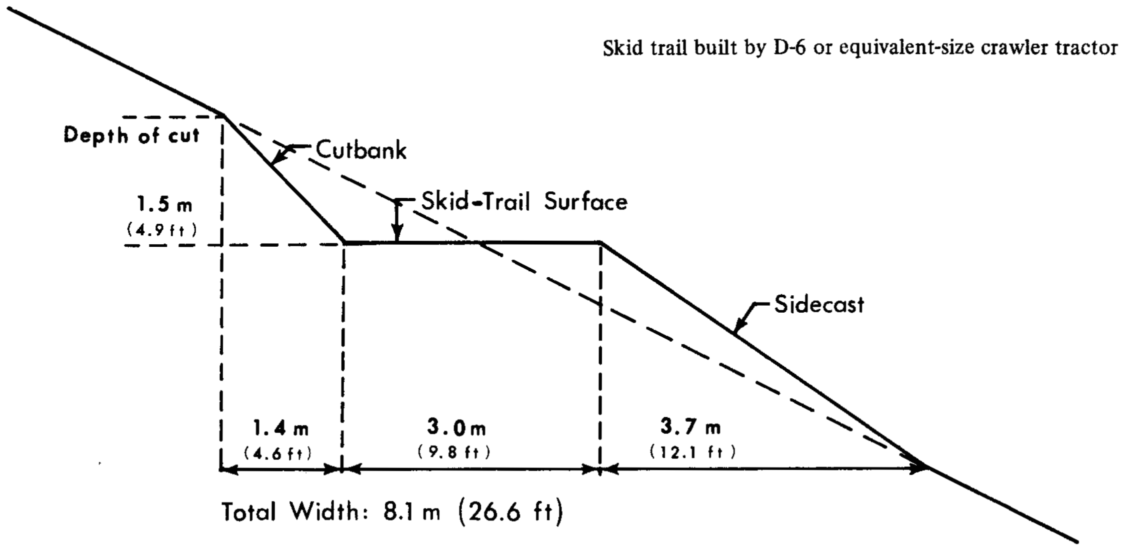
1. Monitor, summarize and evaluate the performance of an experimental skidding operation which uses small tractors in steep terrain.

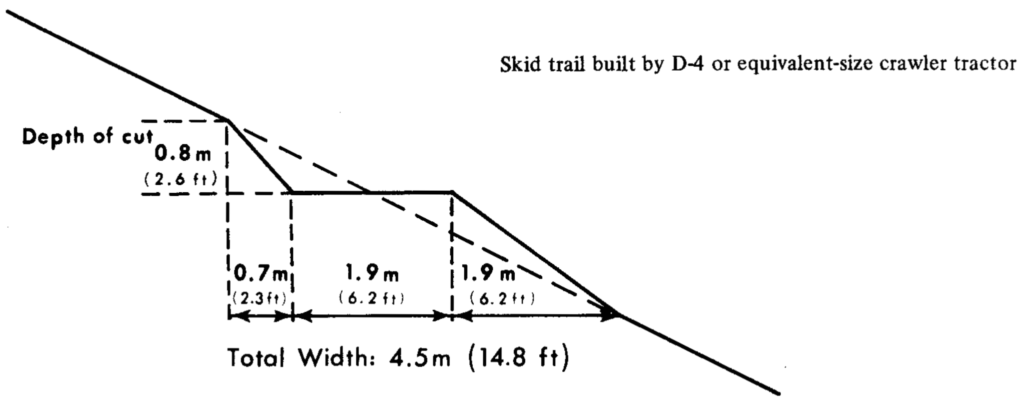
2. Assess ground conditions after logging and compare with site disturbance levels caused by conventional ground-skidding equipment.

3. Compare the productivity and cost of small-tractor logging with cable and other ground-skidding operations conducted by the same company, and determine the range of ground and timber conditions most suited to small-tractor skidding.

This report is directed toward different groups of people. It is expected that machine manufacturers and distributors, regulatory agencies, small-tractor owners, company supervisors, and prospective owners will all find certain sections of particular value. Information is presented on costs, production, repair and service downtime, non-mechanical downtime, site-disturbance levels, and operational techniques used by the machine owners.

Skid-trail surface width is less than the blade width because the blade is angled, and extends into the cutbank. The tractor undercarriage width corresponds more closely to the trail-surface width.





Source: This is a modified version of an original idea from J. Murray of Crestbrook Forest Industries.

FIGURE B. Skid-trail dimensions on a 50% slope

THE STUDY

Operation Description

Crestbrook Forest Industries is a medium-size integrated forest products company owning one pulp mill, several sawmills and one plywood plant. Annual production totals 380,000 cunits (1 076 038 m^3) divided between four divisions. Most of the logging is done by contractors. The company has enough variety of conditions and operational flexibility to stimulate experiments with different logging methods.

The site for these small-tractor trials was Crestbrook's Canal Flats Division located in the western foothills of the Rocky Mountains in Southeastern British Columbia.

Two contractors agreed to try logging with small tractors in the fall of 1976. By midsummer of the next year several additional machines were working. The company also bought a tractor to act as the skid-trail builder.

A 2-man crew worked with each skidding machine. Usually the owner operated the tractor and hired a faller. Each contractor was responsible for falling, skidding, limbing/topping/bucking, and for the preparation of orderly log decks on the landing.

The FERIC study began during the summer of 1977. Eight machines were included--the company-owned trailbuilder (a John Deere 550)--and seven contractor-owned units for skidding. The initial machines included one John Deere 450, two John Deere 550's and four International TD-8's. (Over the next one-year period other loggers obtained different makes and models but these were not included in the study.)

Machine ages ranged from new to 5-years-old at the study startup. Hired employees were usually young but experienced fallers. All machine owners and the company operator were between 35 and 50 years of age. Even though the operators were new to small tractors, most had previous logging experience. The one notable exception was a mill employee with no logging background, but after initial help from supervisors and other operators this contractor experienced no major problems.

Sidehill slopes ranged up to 80% with volumes between 35 and 48 cunits/acre (245 to 336 m^3/hectare). Between 85 and 90% of all timber was lodgepole pine, with the balance composed of Douglas-fir, Western hemlock, spruce and balsam. Because most of the logging was salvage after pine-beetle attacks, long-term systematic planning was difficult. Some areas were logged without cruise or engineering information.

For payment purposes, each contractor had specific landings. Thirty separate landings were used over the course of the study. Logs were loaded with a hydraulic heel-boom each time a landing became full. Standard highway trucks with 8-ft (2.4-m) bunks hauled the wood 30 to 45 miles (48 to 72 km) to the Canal Flats sawmill.

Approach and Procedures

FERIC's standard two-level evaluation methods were used in this study: Shift-Monitoring that followed daily machine activity for several months, and Detailed Time Studies to determine machine capability under specific conditions. Soil disturbance studies were also performed on representative areas logged by the small tractors. All current contractors and the company operator agreed to participate in the study.

SHIFT-MONITORING PROGRAM

Each tractor was equipped with a Model K 12-hr Servis Recorder. Operators provided a time chart and report form to FERIC for each day. Time and production results were keyed to the different landing numbers so that B. C. Forest Service weigh-scale data could be used to obtain total volumes. The study period differed for each contractor depending on startup dates on new landings during the summer, but it was possible to collect information for nearly a full logging season on most of the machines.

Twice monthly the report forms and charts were mailed to FERIC for processing. (Appendix VIII contains an example of the Shift Report form.) At the end of each calendar month a computerized summary was prepared giving working time and downtime information, pieces and turns produced, and delay reasons. When a contractor completed a landing, a separate summary was prepared showing time and production results for that landing. Each contractor was given his own information and all summaries were sent to company supervisors and local machine distributors.

The original study design called for comparison between machines on a seasonal and terrain basis. As the study progressed this became complex because of the many different areas the tractors worked while following the pine-beetle attacks. Cutting restrictions varied between areas as well as block size, slope, species, trail pattern, tree size and lean, machine type, operator experience, and specific techniques or patterns used by each contractor. It appeared less important to draw comparisons between individual machines and areas, and more important to view how the system (or fleet) of small tractors was functioning.

The main study emphasis shifted from machine comparisons to fleet results. It was felt that this would be more useful to forest companies contemplating the introduction of small tractors to their operations. Like Crestbrook, such companies would tend to have a variety of operators with differing experience, logging conditions and machine types. In the text of this report, all time, production and cost results are presented as fleet summaries. (Appendices I through VII summarize each of the seven contractors' individual results. These are included to illustrate the range of time and production values obtained from different machines with operators who have varying experience.)

The company trailbuilder was also included in the Shift-Monitoring Program. This unit is not only an integral part of a small-tractor logging system--it is quite probably the key to it. It was felt important to identify what this machine could do, how much time was involved, and the number of logging machines this tractor could build trail for. The Shift Report form for the trailbuilder is also included in Appendix VIII.

DETAILED TIME STUDIES

The second level of evaluation was the detailed cycle time study. The summer studies were conducted in July, 1977 with the five contractors then operating. Winter studies on all seven contractor operations were added during February of 1978. The basic time elements of any skidding operation are

Load, Unload, Travel, and Delays. Small tractors also follow this pattern but with certain differences. Rubber-tired and large-crawler skidding machines usually have a front-end loader on the landing to do the decking and landing cleaning. Small-tractor operators use their machine for this work. These additional landing phases usually occurred on each turn and were included as sub-elements of the Unload phase.

All timing was conducted with Omega stopwatches inset in a triple-watchboard. No attempt was made by FERIC to "place" machines in specified areas and little advance notice was provided to the contractors for this part of the study. Approximately 30 turns were measured for each operator. Skid distance and slope, sidehill slope, number of loading points, and pieces per turn were recorded in addition to the turn time elements. Turn volumes were hand-scaled on the landing. An example of the detailed timing form is shown in Appendix VIII.

SITE-DISTURBANCE EVALUATION

Three representative areas were chosen for the site-disturbance studies several months after logging was completed. The methodology was similar to that used by the Pacific Forest Research Centre (Smith and Wass, 1976), except that our sample points on the transects were located 2 metres apart instead of three. This was done to increase the sampling accuracy for each area. This part of the study was set up to determine the amount of soil disturbance on small-tractor areas and would be compared to results obtained from similar studies on large-tractor areas.

We have condensed the depth-of-disturbance classes in our Results section from the usual three (0-to-5 cm; 5-to-25 cm; greater-than-25 cm) to two: 0-to-25 cm and greater-than-25 cm. (We measured the field data in the three classes but felt that for the purpose of this report the results would be clearer in two categories.)

SEMINARS

During the course of the nine-month study FERIC conducted two seminars. These were attended by the contractors, company supervisors and employees. Study information was presented and discussed. Following this, discussions took place that covered equipment scheduling and maintenance, operating procedures, site disturbance, and trail construction and placement. All group members expressed satisfaction with the seminars. The exchange of information, techniques and ideas appeared to promote a much greater understanding between all parties.

RESULTS

SHIFT TIME, PRODUCTION AND DELAYS - SKIDDING FLEET

The Shift-Monitoring Program began June 9, 1977, and ended March 21, 1978, although not all machines were studied throughout that period. Two contractors obtained their machines in August. A third contractor had a Servis Recorder malfunction which caused the loss of several weeks' information in the middle of his winter logging season. The study on this contractor was terminated at the end of November at the point where his last identifiable landing change was completed.

Table 1 contains the shift time summary for the fleet of contractor machines. Information was collected for 1,100 scheduled shifts and covered 9,000 Scheduled Machine Hours (SMH). Three-quarters of SMH was spent performing the regular skidding cycles and an additional 5% was spent on two other productive time functions: small amounts of trailbuilding conducted by most of the contractors; and "other work" accounting for decking and landing-cleaning periods that were easily visible on the Servis Recorder time charts. (Some operators performed decking and cleaning as part of each turn. Others preferred to accumulate several turns on the landing before conducting these functions.)

Mechanical Availability (as defined by Bérard et al., (1968)) averaged 90% for the fleet. This can be considered satisfactory based on the average machine age of 3 years. Machine Utilization--which measures the ability of an operation to use scheduled time for productive work--averaged 79% for the fleet. Mechanical Non-Availability (MNA) is a measure of the amount of repair and service hours necessary for a machine to obtain 100 productive hours. MNA for the

TABLE 1. Shift Time Categories - Fleet Summary
Based on 1,110 Scheduled Shifts

	Total Hours	Average Hr/Shift	% of Scheduled Time
Productive Machine Hours (PMH)			
Skidding	6,683.4	6.0	74
Trailbuilding	175.6	.2	2
Other work	223.1	.2	3
Σ	7,082.1	6.4	79
Delays			
Repair	405.9	.4	5
Service	383.8	.3	4
Wait mechanic	3.4	<.1	<1
Wait parts	105.3	.1	1
Change landings	41.1	<.1	<1
Other non-mechanical	971.0	.9	11
Total: Scheduled Machine Hours (SMH)	8,992.6	8.1	100%

*CPPA Mechanical Availability = 90%
*CPPA Utilization = 79%
*MNA (Mechanical Non-Availability) = 11.2 hours

*Machine time calculations are given in Appendix IX.

fleet averaged 11.2 hours. To put this number in perspective, MNA would be 10.3 hours for an 8-hr day that has 15 minutes of service, a 30-minute repair and no other delays.

Figure C graphically illustrates the percentage time distribution for the study.

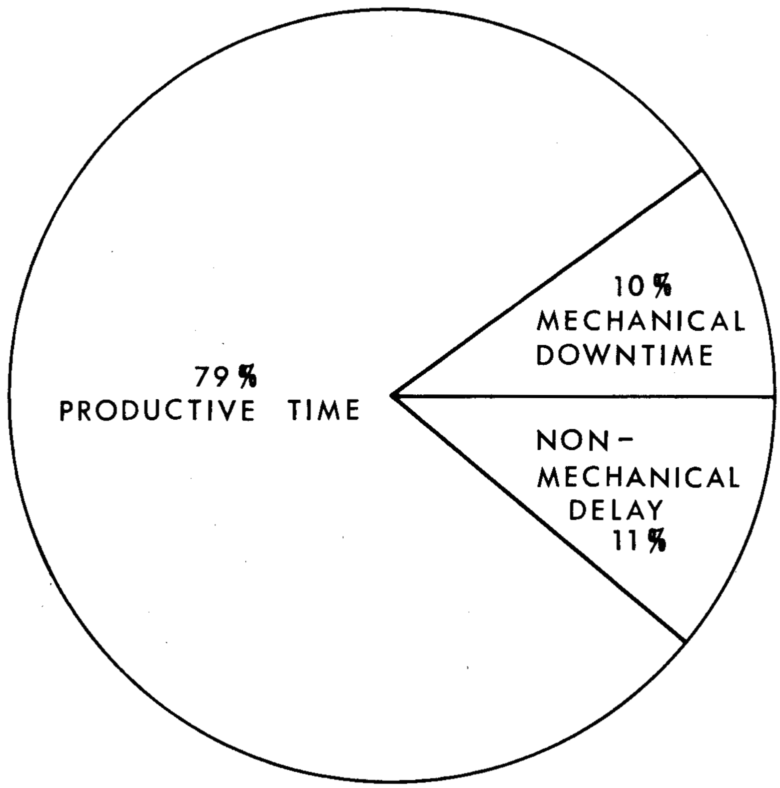


FIGURE C. Shift time distribution

The reader should note that "a standard 8-hour day" is rarely observed by contractors, particularly small owner-operators. Shift lengths varied during this study. Short days were compensated by long shifts, evening work and weekend activity. Any evening work during our study was added to that particular shift. Any weekend activity (if less than 4 hours) was added to Friday's totals--if greater than 4 hours it was treated as a separate shift. Our summaries contain, but do not isolate, overtime or out-of-shift maintenance.

Table 2 contains the production values for the fleet. Volume data came from the B. C. Forest Service weigh-scale tally sheets. Contractors were paid on the basis of those volumes. Piece and turn counts were recorded by each operator on the shift report form. Production averages in Table 2 are calculated on a per-shift-worked basis. A shift worked is defined as any shift with a piece count, no matter how small. Days with no production are not included in these averages.

Over the study period of 1,016 shifts with production, the fleet of tractors produced 20,214 cunits (57 240 m^3), or an average volume of 19.9 cunits (56.3 m^3) per shift worked. Productivity averaged 2.9 cunits/Productive Machine Hour (8.1 m^3).

Reasons for mechanical downtime are shown in Table 3. The 900 hours represent only 10% of scheduled time. Average mechanical downtime per shift was 0.8 hours.

Repairs accounted for 45% of mechanical downtime, with 60% as repairs to the basic machine and 40% to machine attachments. The attachments had more repair occurrences than the basic machine (131 compared to 112). Average time per repair for the skidding fleet was 100 minutes.

The service category made up 43% of mechanical downtime. (Machine warmup has been included as part of service because contractors often performed minor maintenance during this period.)

While "waiting for parts" accounted for 12% of mechanical downtime, time spent waiting for a mechanic was negligible. Contractors performed most of their own repairs.

TABLE 2. Production and Productivity - Fleet Summary Based on 1,016 Shifts Worked

Study Production Totals			
Volume produced, cunits (m^3)	20,214		(57 240)
Pieces skidded		116,646	
Study Averages			
Overall average piece size, ft^3 (m^3)	17.3		(0.49)
Volume/shift worked, cunits (m^3)	19.9		(56.3)
Pieces/shift worked		114.8	
Turn Summary (based on 6 machines)*			
Number of turns		14,048	
Turns/shift worked		16.0	
Volume/turn, cunits (m^3)	1.20		(3.39)
Pieces/turn		7.1	
Productivity			
Volume/PMH, cunits (m^3)	2.9		(8.1)
Trees/PMH		16.5	

*All turn totals or averages are based on six machines only. One contractor did not supply a turn count.

TABLE 3. Mechanical Downtime Categories - Fleet Summary

Downtime Description		Assembly or Category		No. of Repairs or Occurrences	Time (hr)	% of all Mechanical Downtime
REPAIR	BASIC MACHINE	Drive Train and Controls	Fuel system	23	53.9	
			Motor	10	37.8	
			Miscellaneous	13	29.0	
				46	120.7	13.4
		Cab and Canopy		7	47.6	5.3
		Undercarriage		15	35.8	4.0
		Hydraulics		30	18.2	2.0
		Electrical		8	12.9	1.4
		Frame		6	7.3	.8
Average time: 100 min	Subtotal: Basic Machine			112	242.5	27.0
	ATTACHMENTS	Winch and Controls		14	85.3	9.5
Averages per shift		Lines and Chokers		98	48.4	5.4
No. of repairs: 0.2		Blade		11	22.0	2.4
Repair time : 22 min		Fairlead		5	6.0	.7
		Miscellaneous		3	1.7	.2
	Subtotal: Attachments			131	163.4	18.2
Total Repair				243	405.9	45.2
SERVICE		Machine warmup		815	238.6	
		Fuel up, clean or grease tractor		425	87.7	
		Other		42	57.5	
				1,282	383.8	42.7
WAIT PARTS				19	105.3	11.7
WAIT MECHANIC				1	3.4	.4
		Total Mechanical Downtime		1,545	898.4	100%
		Average Mechanical Delay/Shift		1.4	0.8	

Table 4 contains a listing of non-mechanical downtime categories. These delays averaged 0.9 hours per shift, slightly more than all mechanical problems combined. Average delay time per occurrence was 42 minutes and there were 1.3 delay occurrences per shift.

Personnel delays formed the largest category and this accounted for 40% of non-mechanical downtime. This category, however, was highly influenced by two operators who chose to take daily coffee periods. Weather shutdowns involved both partial and full-shift closures. Operational delays were controlled by the contractor, and organizational delays by the company. Neither accounted for a large percentage and together they represent only 3% of scheduled time.

Seasonal time and production comparisons are shown in Tables 5 and 6. (The complete study is not represented by these figures. Four landings accounting for 186 scheduled shifts have been deleted. These landings spanned the fall freeze-up period under a combination of summer and winter logging conditions.) In the winter Machine Availability and Utilization dropped slightly by 2% each. Mechanical support for the machines, as demonstrated by the MNA figure, was increased by 3.6 hours under winter conditions. Daily production was nearly identical between summer and winter, even though skidding time and pieces/day were lower during the winter season. The larger piece size during the winter probably accounts for the similar daily production levels.

DETAILED TIME STUDIES

Results of the summer and winter detailed time studies are shown in Table 7. These evaluations show that the fleet of contractors' winter productivity (expressed as volume/PMH) was 1.7 times greater than their summer productivity. The major reasons for this increase were larger piece size, competition between operators, and the cold weather conditions which assisted log-skidding activity. Increased operator experience and slightly more favourable terrain conditions also contributed to the increase.

The average piece size was 1.5 times larger in the winter. Although this resulted in fewer pieces/turn, the turn volume increased by 18 percent. The smaller piece count meant that contractors handled fewer pieces and this provided time savings of 25% in the loading phase and 30% in the unloading phase.

TABLE 4. Non-Mechanical Downtime Categories - Fleet Summary

Delay Category	Examples of Delay Types	No. of Delays	Time (hr)	% of all Non-Mechanical Downtime
Personnel	Visitors, coffee, illness	967	407.4	40.3
Weather Closure	Snow slides, heavy rain or wind, extreme cold	61	234.4	23.2
Operational	Tractor stuck, wait for trees to be felled, planning	257	159.7	15.8
Organizational	Pull stuck logging trucks, loader and trucks blocking landing, wait low bed	118	131.6	13.0
Moves	Major landing changes	26	41.1	4.1
Other	Crew pickup broken or stuck, install FERIC study equipment	16	37.9	3.7
	Total Non-Mechanical Downtime	1,445	1,012.1	100%
	Average Non-Mechanical Delay/Shift	1.3	0.9	
	Average Delay Time: 42 min			

TABLE 5. Shift Time Summary by Season

	Average Hours per Shift: Summer	Average Hours per Shift: Winter
Number of scheduled shifts	591	333
Productive Machine Hours (PMH)		
Skidding	6.4	5.8
Trailbuilding	.1	.2
Other work	.2	.2
Σ	6.7	6.2
Mechanical Downtime	.7	.9
Non-Mechanical Downtime	.8	.8
Total: Scheduled Machine Hours (SMH)	8.2	7.9
CPPA Mechanical Availability	91%	89%
CPPA Utilization	81%	79%
MNA (Mechanical Non-Availability)	9.2 hours	12.8 hours

TABLE 6. Production and Productivity by Season

	Summer			Winter		
Study Production Totals						
No. of shifts worked		550			308	
Volume produced, cunits (m^3)	11,110		(31 460)	6,165		(17 457)
Pieces skidded		69,840			29,585	
Study Averages						
Overall average piece size, ft^3 (m^3)	15.9		(0.45)	20.8		(0.59)
Volume/shift worked, cunits (m^3)	20.2		(57.2)	20.0		(56.7)
Pieces/shift worked		127.0			96.1	
Turn Summary (based on 6 machines)*						
Number of turns		8,197			4,325	
Turns/shift worked		16.7			16.3	
Volume/turn, cunits (m^3)	1.2		(3.37)	1.2		(3.35)
Pieces/turn		7.5			6.0	
Productivity						
Volume/PMH, cunits (m^3)	2.8		(8.0)	3.0		(8.4)
Trees/PMH		17.7			14.2	

*Turn totals or averages exclude one operator who did not report a turn count.

TABLE 7. Detailed Time Results by Season
Turn Averages and Descriptive Factors

		Summer		Winter	
TIME SUMMARY		minutes	%	minutes	%
Loading Phase	Manoeuvre	.78	30.1	.37	32.8
	Hookup	5.58		4.83	
	Prebunch	.81		.23	
	Move during load	.64		.42	
Unloading Phase	Unhook	2.86	29.3	1.47	29.9
	Limb, top	1.48		.46	
	Align butts	.78		.74	
	Decking	1.14		1.64	
	Clean landing	1.36		1.03	
TERMINAL TIME (load + unload)		15.43	59.4	11.19	62.7
Travel Phase	Empty	2.78	24.8	2.51	29.7
	Loaded	3.38		2.65	
	Winching	.28		.14	
TURN TIME (terminal + travel)		21.87	84.2	16.49	92.4
	Delay Time	4.11	15.8	1.36	7.6
TOTAL TURN TIME		25.98	100%	17.85	100%
STAND AND OPERATING FACTORS					
Distance, ft (m)	Empty	490 (149)		596 (182)	
	Loaded	515 (157)		612 (187)	
Slope - %					
Loaded, on trails - range		-54 to +8		-19 to +16	
- average		-7		-8	
Sidehill - range		0 to 80		0 to 80	
- average		22		44	
No. prebunch points		.19		.15	
No. loading points		2.34		2.14	
No. times load was winched		.69		.56	
PRODUCTION AND PRODUCTIVITY					
Piece count per turn		8.0		6.4	
Turn volume, ft^3 (m^3)		121 (3.43)		143 (4.05)	
Piece volume, ft^3 (m^3)		15.1 (0.43)		22.3 (0.63)	
Potential Productivity	Cunits (m^3)/PMH	2.8 (7.9)		4.8 (13.6)	
	Trees/PMH	18.5		21.5	
SAMPLE SIZE - no. of turns in study		144 from 5 machines		190 from 7 machines	

During the winter study there were several indications of rivalry between contractors, possibly stimulated by the seminar discussions. Winter delay time was reduced to one-third of the summer delay time. A review of the winter delays shows that, while the FERIC study crew was present, virtually all personnel, repair and service delays were eliminated or postponed.

Snow and cold weather conditions reduced travel times. During the winter loads were winched less frequently, even though turn volumes were higher. When it did occur, winching time was reduced 40% from the summer value. Winter conditions also permitted increased travel speed. A comparison of equal loads over equal distance shows winter travel speed averaged 333 ft/min (101 m/min) compared to 184 ft/min (56 m/min) in the summer. The trail slope for these average conditions was only 1% more favourable for the winter study.

On an average-per-turn basis, the one time element that increased during the winter was decking (probably caused by frozen logs sliding off the decks). On an average-per-tree basis, two other elements showed an increased time. Hookup required a few seconds more per tree during the winter and could be due to increased tree size or cleaning snow from the choking point. On the landing, the time element "align butts" had a nominal increase from summer to winter. No reason is apparent.

Figure D provides a graphical representation of the seasonal difference in average time per turn. It is interesting to note that the relative percentages of total turn time did not change to any large degree for the different phases. This suggests that the contractors maintained some degree of consistency in their procedures.

COSTS

The costs presented in this section are examples only. They are not actual logging costs and cannot be used for logging cost appraisal. No allowance has been made for supervision, roads and landings, engineering, overhead or profit. The calculations do account for machine cost, labour and crew transport. Current prices (July 1979) have been used for equipment, supplies and interest charges. Appendix X contains the detailed cost calculations.

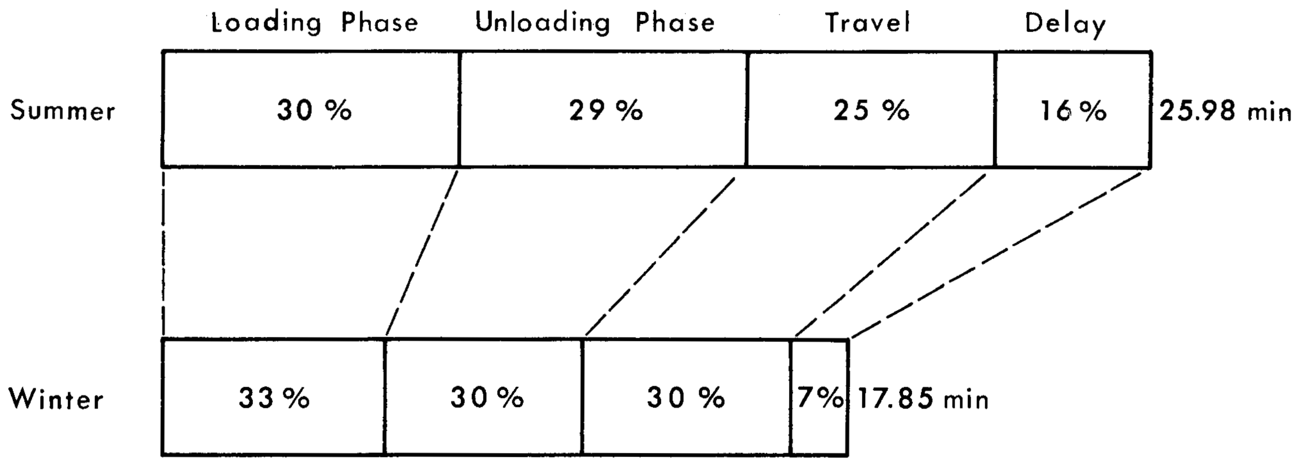


FIGURE D. Summer and winter turn-time distributions

The cost example is based on a machine price of $70,000 and assumes that a prospective owner has no down-payment or trade-in, and must also obtain tools and a vehicle for crew transport. These conditions represent the most expensive situation a new owner would face. The total daily cost to fell trees and operate one small tractor as a skidding unit is $461 (Table 8). When the daily production rate from the study is applied to this figure, the resulting cost is $23.16/ cunit ($8.19/m^3) (Table 9).

The contractors who participated in this study paid less than $70,000 for their machines. Purchase prices in the summer of 1977 ranged from $22,500 for used equipment to $45,000 for a new tractor. Since then, the price for a new tractor of this size has risen between $20,000 and $25,000, due primarily to inflation and exchange rates. In addition, option packages and modifications (particularly for guarding) now being made available have contributed to the price increases.

TABLE 8. Daily Owning and Operating Costs

Cost Item	$ per Shift	
Tractor depreciation	62.22	175.62
Interest	33.22	
Insurance	4.72	
Repair and maintenance	49.78	
Operating supplies	25.68	
Pickup depreciation	14.26	50.36
Interest	3.87	
Insurance	2.78	
Repair and maintenance	16.67	
Operating supplies	12.78	
Faller and saw		135.00
Operator's wage		100.00
Total daily cost		460.98

TABLE 9. Cost per Cunit

Production Rate	Cost/Unit Volume
19.9 cunits/shift (56.3 m^3/shift)	$23.16/cunit ($8.19/m^3)

SITE-DISTURBANCE EVALUATION

The author is greatly indebted to Mr. Ray Krag of FERIC for this information on site disturbance. Mr. Krag conducted these studies, analyzed and interpreted the data and prepared an interim report which formed the basis for this section. This is part of a larger study he has been conducting to develop a site hazard rating system.

Three small-tractor-logged cutblocks were surveyed to determine levels, depths, and sources of site disturbance. In previous years similar surveys were conducted on 22 cutblocks with trails built by large crawler-tractors in the size range of Caterpillar D-7's and D-8's. Skid-trail dimensions and spacing were recorded as part of the surveys.

Total site disturbance: Figure E shows the comparison of total site disturbance between areas logged by large and small tractors. Within the same slope categories (regardless of logging season) small-tractor blocks have soil disturbance levels about 64% of the average for large-tractor blocks. This represents a reduction of disturbance, regardless of depth, of approximately one-third. Information for large tractors operating on areas of less than 20% slope has been included for interest.

Sources of disturbance: Figures F and G show the sources of site disturbance by depth category and season. The percentage of site disturbance caused by roads, landings and logging activity varies little between small- and large-tractor cutblocks. However, skid-trail-related disturbance is considerably lower on the blocks logged by the small machines. In fact, skid-trail-related disturbance has been reduced by about one-half for both summer and winter areas.

Depth of disturbance: In general, Figures F and G indicate that depth distributions for the categories "roads and landings" and "logging" are similar for all blocks and all machines. Roads and landings generate deeper disturbance due to cuts and fills whereas logging activities generate much shallower disturbance levels. There is also close agreement in disturbance-depth amounts between summer and winter operations although winter-logging operations appear to impact slightly more severely in the more-than-25-cm class.

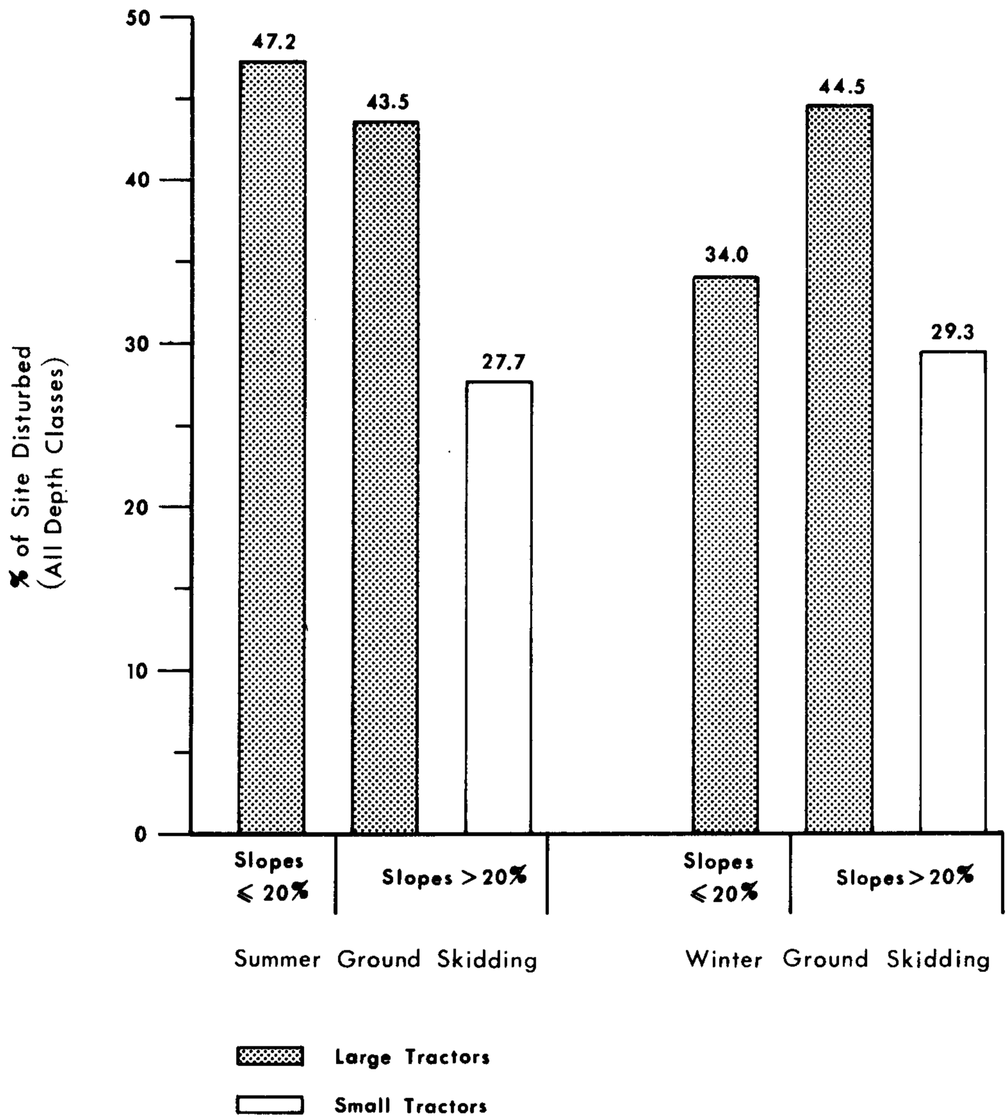


FIGURE E. Percent of site disturbed - large vs. small tractors

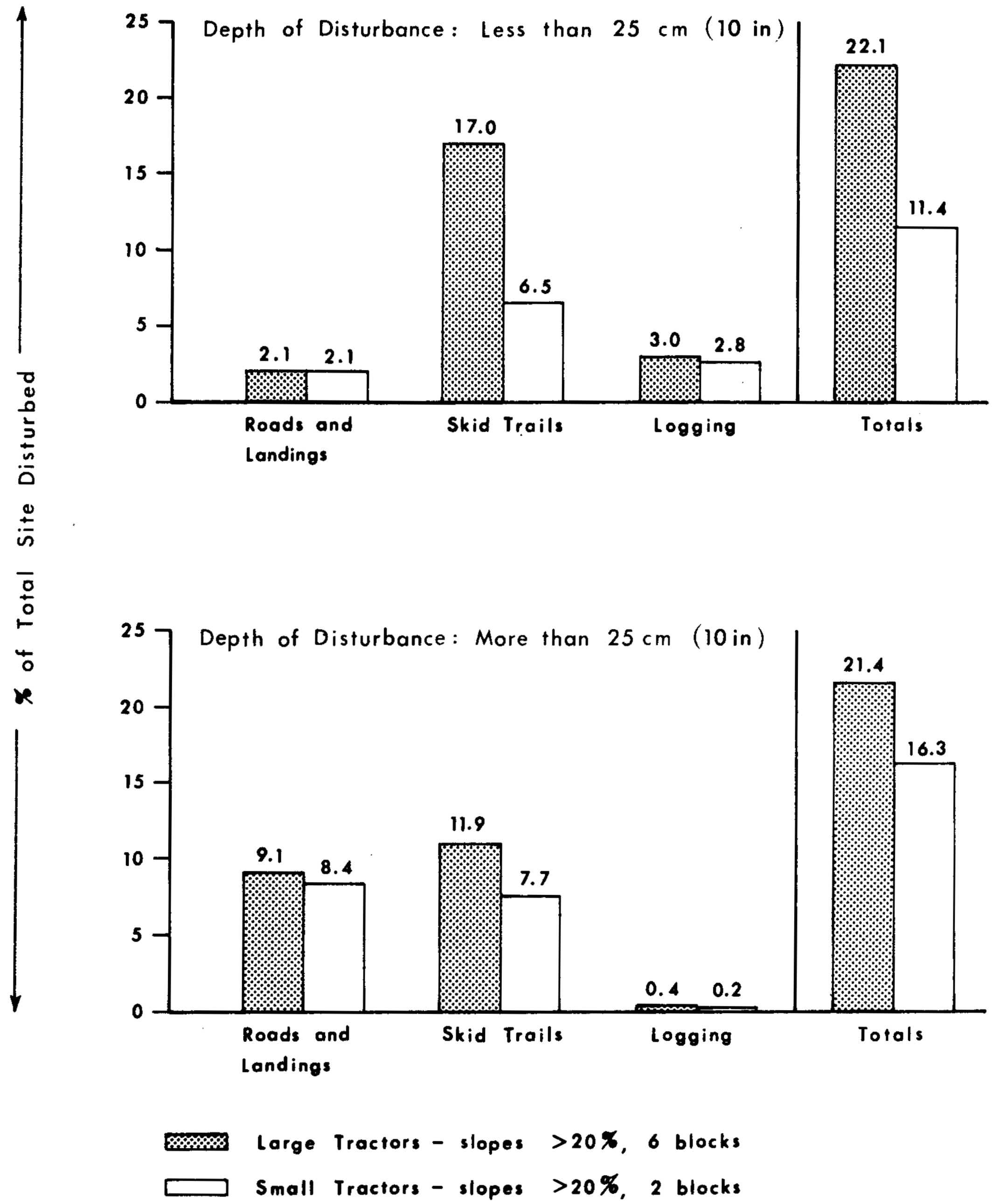


FIGURE F. Depth of disturbance - summer

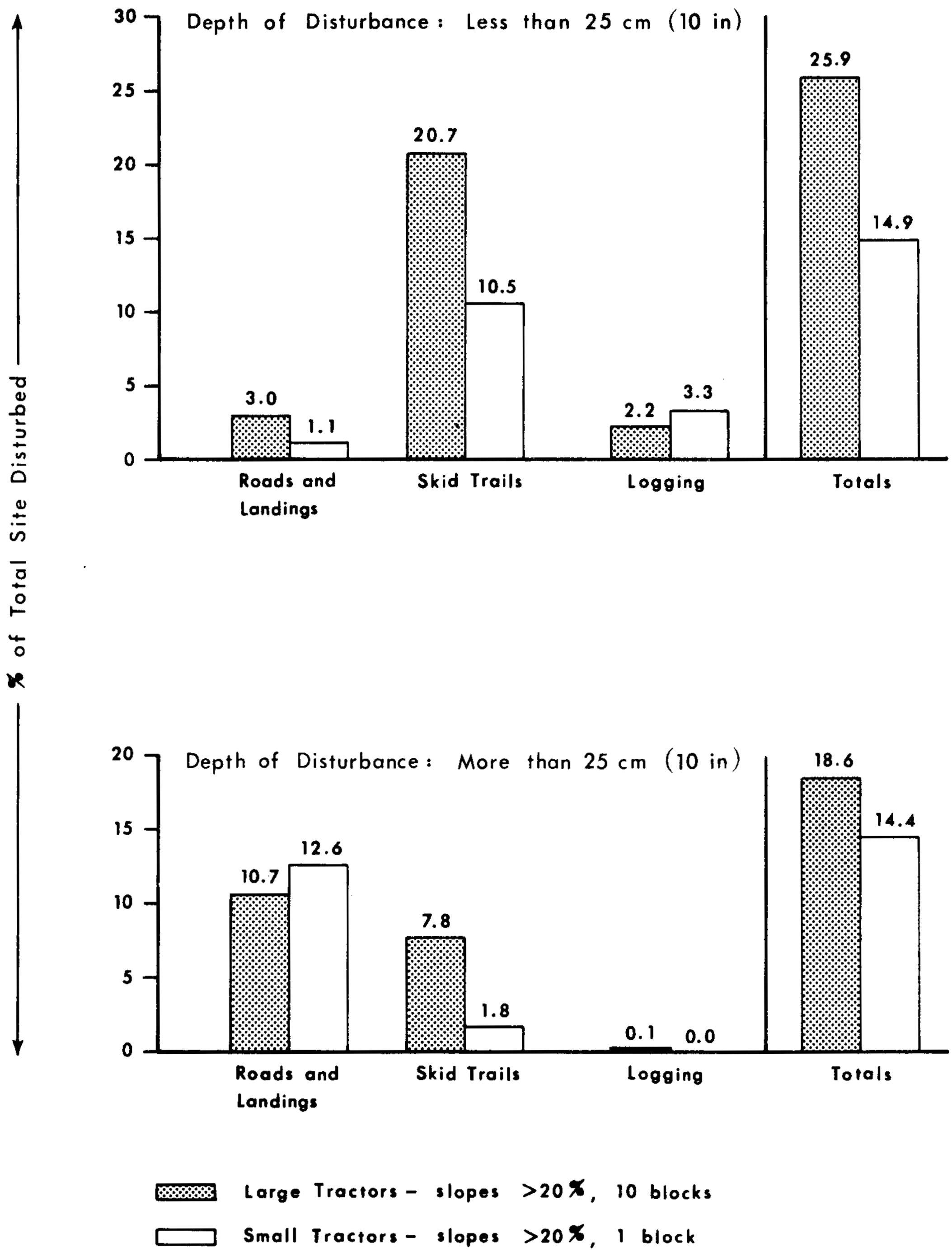


FIGURE G. Depth of disturbance - winter

Both source- and depth-of-disturbance results suggest that road and landing densities have neither increased nor decreased by changing to small tractors.

The distribution patterns for depth-of-disturbance levels related to skid trails show that small-tractor areas consistently had less disturbance than larger-tractor areas in both depth classes, summer and winter. In the more-than-25-cm class, small-tractor summer operations caused more disturbance than winter operations. This is probably the result of skid trails cut into packed snow with less of the cut in the soil.

Skid-trail dimensions and spacing: Table 10 shows the observed widths of skid trails built by small and large tractors for different slope classes. Surface widths do not increase materially with increasing slope for machines of either size. On trails built by small tractors, cutbank and sidecast widths increase gradually with ground steepness but on trails built by larger machines both cutbank and sidecast widths nearly double as slope increases from 20% to 60%. This probably results from more sluffing of the deeper cut and sidecast material during construction as a larger volume of material is moved.

On average, the total width of a trail built by a small tractor is 4.5 m (14.8 ft) or only 56% of the total width of a trail built by a larger tractor (8.1 m or 26.6 ft). This reduction in trail width means that for a given slope and trail spacing, site disturbance generated by skid trails can be halved by using smaller trailbuilding machines. Site disturbance can be further reduced if the spacing between trails is increased.

The average skid-trail spacing on the sites logged by small tractors is 32.1 m (105 ft), compared to an average of 27.0 m (86 ft) for areas prepared by large tractors. No relationship was evident between trail-spacing and timber type.

Analysis of these survey data indicates that the observed difference of trail-related disturbance between small and large tractor blocks is due to a combination of smaller trail widths and wider trail spacings.

TABLE 10. Comparison of Skid-Trail Widths

Slope Class %	m/ft	Small Tractors				Large Tractors				* % of Larger Trail
		Cutbank Width	Surface Width	Sidecast Width	Total Width	Cutbank Width	Surface Width	Sidecast Width	Total Width	
21-30	m	0.5	2.0	1.8	4.3	0.7	3.1	2.1	5.9	72
	ft	1.6	6.6	5.9	14.1	2.3	10.2	6.9	19.4	
31-40	m	0.5	1.9	**1.6	**4.0	1.0	3.3	2.2	6.5	62
	ft	1.6	6.2	**5.3	**13.1	3.3	10.8	7.2	21.3	
41-50	m	0.7	1.9	1.9	4.5	1.4	3.0	3.7	8.1	56
	ft	2.3	6.2	6.2	14.8	4.6	9.8	12.1	26.6	
51-60	m	**0.6	1.9	2.4	4.9	1.6	3.3	4.0	8.9	55
	ft	**2.0	6.2	7.9	16.1	5.3	10.8	13.1	29.2	

*Width of skid trail built by small crawler-tractor as a % of skid-trail width built by larger crawler-tractor.

**These values do not follow exactly the general trend of increased size with increased slope. However, no evidence was observed that would indicate construction technique as the cause.

It is important for each reader to realize that while depth-of-disturbance measurements are objective, the interpretation of those numbers is still highly subjective. There is little agreement on what is acceptable and what is not acceptable except in extreme situations. FERIC cannot state that soil disturbance caused by small tractors is acceptable but can only quantify the amount and compare that to results with some other logging method. Further work and discussion is necessary before specialists can agree on the severity of depth-of-disturbance problems.

TRAILBUILDER MACHINE

Assuming that a company has chosen small tractors to reduce site disturbance, then the trailbuilder machine becomes the key piece of equipment in meeting this objective. Improper control of the trailbuilding function may partially negate the advantages of a small-tractor system. It is important to understand the use of the machine to improve cost and production and decrease site disturbance.

The following presentations summarize shift time, productive time and delay categories and are followed by a brief discussion which includes photographs of some trail networks built by this machine.

Shift time summary: Table 11 contains the shift time summary for the trailbuilder and covers the period between June 9, 1977, and March 23, 1978. At the end of the study this tractor had been in use for 15 months, less than half the average fleet age. Mechanical Availability is 5% lower than the skidding fleet average. This difference can be expected to become even more pronounced with increased usage and probably results from performing the more difficult work of building trails instead of skidding. The higher level of mechanical downtime for the trailbuilder is also reflected by the MNA value of 19.4 hours. Compared to the fleet, the trailbuilder requires an additional 7.2 hours of repair and service per 100 productive machine hours. Machine Utilization during the study averaged 68 percent. This value is 11% lower than that for the skidding fleet. The lower Availability and Utilization values indicate the trailbuilder is faced with more serious delays than the skidders.

TABLE 11. Shift Time Categories - Trailbuilder
Based on 197 Scheduled Shifts

	Total Hours	Average Hr/Shift	% of Scheduled Time
Productive Machine Hours (PMH)			
Skidding	102.6	.5	6.4
Trailbuilding	564.8	2.9	35.5
Other work	412.5	2.1	25.9
Σ	1,079.9	5.5	67.9
Delays			
Repair	141.3	.7	8.9
Service	68.0	.3	4.3
Wait mechanic	9.0	<.1	.5
Wait parts	17.5	.1	1.1
Change landings	50.3	.3	3.2
Other non-mechanical	225.1	1.1	14.1
Total: Scheduled Machine Hours (SMH)	1,591.1	8.1	100%

CPPA Mechanical Availability = 85%
CPPA Utilization = 68%
MNA (Mechanical Non-Availability) = 19.4 hours

Further breakdowns of these time elements are given in Tables 12, 13 and 14.

Productive machine functions: Table 12 contains additional detail about the productive functions of this machine. Although the name "trailbuilder" is used to describe this tractor, skid-trail construction accounted for only 35% of scheduled time. Trails were built for small tractors and wheeled skidders. During the logging season the company encouraged skidder owners to trade in their machines for small tractors. By the end of the study the trailbuilder was servicing 2 skidders, 11 small tractors full-time and 2 small tractors part-time. The trailbuilder serviced the 2 small tractors part-time because the owners were constructing most of their own trails.

The activities listed in Table 12 illustrate the versatility of the trailbuilder. The machine was not restricted to skid-trail construction. It also performed other non-skidding functions (road construction or maintenance), as well as skidding trees and post-skidding activities (landing cleanup and slash disposal). In winter conditions the tractor plowed roads and landings. The trailbuilder also assisted logging trucks in poor weather conditions.

Delays: The mechanical downtime summary for this machine is shown in Table 13. Repairs are both more frequent and more time-consuming than for the skidding fleet. Average repair time is 149 minutes for the trailbuilder or 0.3 repairs at 43 minutes/shift. In comparison, average repair time for the skidding fleet is 100 minutes, or 0.2 repairs at 22 minutes/shift. Aside from repair rates, the distribution of repairs is also altered. The fleet averages show that 60% of the repair time was spent on the basic machine. The trailbuilder shows that 85% of its repair time was on the basic machine and that 90% of those hours were concerned with the drive-train and hydraulics systems. The undercarriage on the trailbuilder was extensively overhauled during the 1979 spring breakup (one year after study completion). This tractor had been in operation for approximately 3,800 hours.

Non-mechanical downtime categories are shown in Table 14. The average delay time was 44 minutes. This differs little from the skidding fleet average of 42 minutes. The trailbuilder, however, had a much higher frequency of 1.9 delays/shift, compared to 1.3 for the fleet. The two largest categories for the fleet (personnel delays and weather closures) are the smallest categories for the trailbuilder.

TABLE 12. Summary of Productive Activities - Trailbuilder

Category	Description	Time (hr)	% of Scheduled Time
Trailbuilding	For 13 small tractors	466.6	
	For rubber-tired skidders	98.2	
		564.8	35.5
Other Work	Road Construction or Maintenance		
	Culvert installation	39.0	
	Spread gravel on haul roads	36.4	
	Bridge construction	33.8	
	Construct water bars on roads/trails	23.4	
	Clean out gravel pits, ditches, creek channels	15.6	
	Grade, clean or repair truck roads	10.9	
		159.1	10.0
	Post-Skidding Activities		
	Clean landings, pile debris	91.2	
	Assist loader--clean and bunch log decks	48.2	
	Forwarding; repiling; bucking log decks	7.3	
	Build fire guard	3.4	
		150.1	9.4
	Weather-Related Activities		
	Plow snow--roads and landings	93.3	
	Pull logging trucks through mud or snow	10.0	
		103.3	6.5
	Subtotal: Other Work	412.5	25.9
Skidding	Assist small-tractor owners	79.9	
	Behind company feller-buncher (experimental)	22.7	
		102.6	6.4
	Total Productive Machine Hours (PMH)	1,079.9	67.9
	Average PMH/Shift	5.5	

TABLE 13. Mechanical Downtime Categories - Trailbuilder

Downtime Description		Assembly or Category	No. of Repairs or Occurrences	Time (hr)	% of all Mechanical Downtime
REPAIR Average time: 149 min Averages per shift No. of repairs: 0.3 Repair time : 43 min	BASIC MACHINE	Drive Train and Controls	9	58.2	24.7
		Hydraulics	28	47.6	20.2
		Undercarriage	8	8.8	3.7
		Cab and Canopy	3	3.0	1.3
		Electrical	1	.6	.3
		Frame	1	.4	.1
	Subtotal: Basic Machine		50	118.6	50.3
	ATTACHMENTS	Blade	4	20.5	8.7
		Winch and Controls	1	1.4	.6
		Lines	2	.8	.3
		Fairlead	Nil	Nil	Nil
		Miscellaneous	Nil	Nil	Nil
	Subtotal: Attachments		7	22.7	9.6
Total Repair			57	141.3	59.9
SERVICE		Fuel up, clean or grease tractor Machine warmup Other	109 99 16 224	31.6 26.6 9.8 68.0	28.8
WAIT PARTS			5	17.5	7.4
WAIT MECHANIC			5	9.0	3.8
		Total Mechanical Downtime	291	235.8	100%
		Average Mechanical Delay/Shift	1.5	1.2	

TABLE 14. Non-Mechanical Downtime Categories - Trailbuilder

Delay Category	Examples of Delay Types	No. of Delays	Time (hr)	% of all Non-Mechanical Downtime
Idle Time	Wait for trucks or loader (tractor assisting these machines - pull through mud, spread gravel, clean log decks)	150	72.5	26.3
Operator Assisting Other Equipment	Transport fuel, move machines, repair or start other equipment	55	58.9	21.4
Other	Planning, burn slash, build bridge, buck windfalls, construct culverts	50	56.7	20.6
Moves	Major landing changes	37	50.3	18.3
Personnel	Visitors, illness, coffee	74	32.6	11.8
Weather Closure	Extreme cold	6	4.4	1.6
	Total Non-Mechanical Downtime	372	275.4	100%
	Average Non-Mechanical Delay/Shift	1.9	1.4	
	Average Delay Time: 44 min			

The delay summaries illustrate that the trailbuilding machine loses more time-per-day and that the lost-time reasons are different from those experienced by the skidding machines.

Discussion: The operator of the trailbuilding machine attempts to follow three general concepts. First, trails are to be located 100 ft (30 m) apart. Second, trails should be kept parallel to the ground contours. Third, trails should be brought in at the ends of a landing and not the middle. Construction techniques and specific placement are at the operator's discretion.

Figure H shows what can happen where there is a communication mixup between the contractor, trailbuilder and foreman. The photograph shows one of the early areas logged by small tractors. After the trailbuilder had finished, changes were made to the network, with most taking place on the access to the main downhill trail from the branch trails. Figure I exemplifies a problem that occurs for all ground-skidding machines. The landing is serviced by an excessive length of trail.

Neither photograph is representative of the trailbuilder's normal performance. These pictures were chosen to illustrate the type of problem that will occur if loggers and logging planners think of small tractors only as log producers. The effect will be to submerge the needs and priorities of the trailbuilder in those of the skidding machines. A small tractor can build trail or skid wood but the problems associated with either activity are varied. The trailbuilder requires its own plan and budget. Planning procedures that reduce delays for skidding machines may not benefit the trailbuilder because of the different problems it must face.

Time spent planning the control and conduct of the trailbuilder is worthwhile. It results in reduced site disturbance and increased operational efficiency.

FIGURE H. Skid-trail network modified by contractor. Changes are indicated by the white arrowheads. Better and more frequent communication has reduced the amount of trail additions made by contractors.

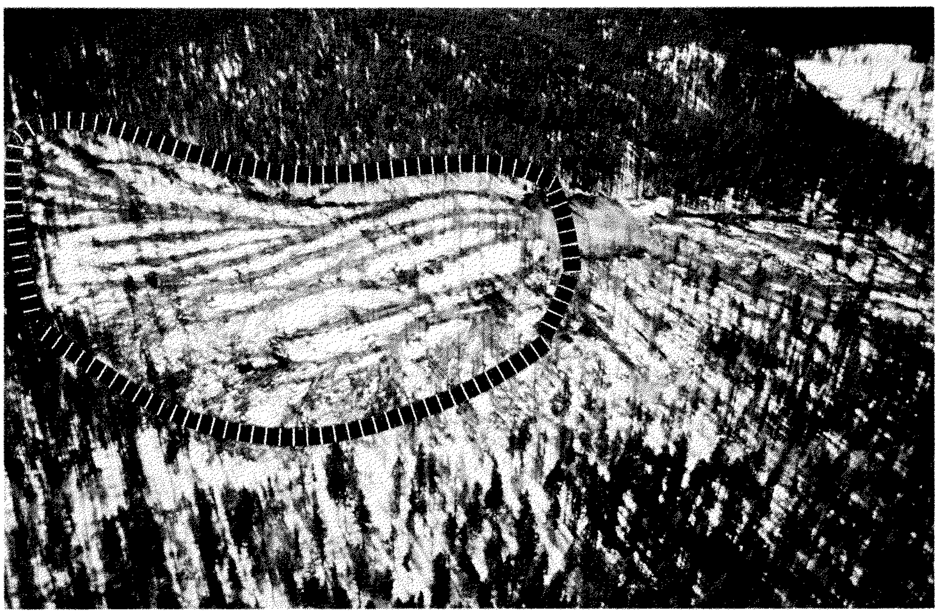


FIGURE I. High-density skid-trail network. The amount of trail within the encircled area could have been reduced by additional planning. The photograph also illustrates the effect of the pine-beetle attack. The characteristic reddish-grey areas in the background are prevalent throughout the valley. Machines in this study were generally conducting salvage operations for this timber.

DISCUSSION: THE APPLICATION OF SMALL TRACTORS

SMALL TRACTORS COMPARED TO OTHER LOGGING EQUIPMENT

This section uses cost comparisons to identify the relative performance levels of different log-skidding machines operated by the same company. The machines compared are a small tractor, a rubber-tired articulated choker-skidder, an FMC bunk-grapple skidder and a cable-yarding system.

Table 15 contains comparative cost estimates for decked wood on a landing or at roadside. Company records were used to obtain the cost/unit volume for the tractor and wheeled skidder. Stand and terrain conditions were similar and the machines worked from prepared skid trails. A company allowance for transportation and overhead has been included and we used the same allowance for the FMC and the cable machine to standardize the cost headings.

FERIC Technical Report No. TR-28 (Powell, 1978) provided most of the FMC information. The costs presented in that report have been updated for 1979. Felling, limbing and bucking costs were obtained from the company. Operating conditions for the FMC study can be classed as favourable for the machine. The grapple skidder worked mainly on flat ground behind a feller-buncher.

Information for the cable yarder was obtained from another FERIC study (McDonald, 1979). Costs from that report have also been updated for this comparison. As with the FMC, stand and terrain factors do not match those of the other ground-skidding systems. The FMC and cable-yarder studies represent the best information obtainable.

The small tractor shows the lowest cost while the cable system shows the highest. Certain variables have been deliberately ignored in this comparison--crew motivation, piece size and skid distance, for example. The same equipment working on other operations may show substantially different production rates. Although the comparisons are not ideal Table 15 does illustrate that a small tractor can be cost-competitive with other logging methods.

TABLE 15. Production and Cost Estimates for Ground- and Cable-Logging Systems

	Small Tractor		Rubber-Tired Skidder		FMC Bunk Grapple		3-Drum Cable Yarder	
Slope - %	40-50				flat		55	
Cunits/acre (m^3/hectare)	45 (315)				not available		60 (413)	
Species	pine				not available		larch, D.fir	
Daily Costs - 1979 ($)								
Machine and crew	274.00		246.00		497.76		688.20	
Transportation and overhead	62.28		62.28		62.28		62.28	
Total: daily skidding cost	336.28		308.28		560.04		750.48	
Production/8-hr scheduled day - cunits (m^3)	20 (56.6)		19 (53.8)		29 (82)		15.3 (43.2)	
	$/cunit	$/$m^3$	$/cunit	$/$m^3$	$/cunit	$/$m^3$	$/cunit	$/$m^3$
Skidding cost/unit volume	16.81	5.94	16.23	5.73	19.31	6.83	49.05	17.37
Additional costs								
Felling, bucking, limbing	5.21	1.84	5.49	1.94	8.21	2.90	9.90	3.50
Trails	.80	.29	2.63	.93	Nil	Nil	Nil	Nil
Swamper tractor on landing for tops, snags and chunks	Nil	Nil	.75	.26	Nil	Nil	Nil	Nil
Cost of decked logs	22.82	8.07	25.10	8.86	27.52	9.73	58.95	20.87

Advantages of Small Tractors

Skidding with small tractors is not a new concept. The machines are not prototypes but are proven and simple, and have been used for logging for many years. They are in the price range of wheeled skidders but have the versatility of crawlers.

Small tractors have the following additional benefits:

1) Tractors are more versatile than wheeled skidders or cable machines. Tractors, both large and small, have relatively good terrain capability in all seasons. They can also move earth or snow and assist other equipment. Some tractors can be converted into loaders.

2) Tractors can usually completely log a cutblock. Skidders often require tractor assistance, either to log a portion of the block or to assist the skidder itself. Three problems that often confront cable machinery (lack of landing space, poor deflection and a lack of solid tailhold or guyline stumps) are less severe or are absent with tractors.

3) Small-tractors cause less site disturbance than large-tractors, but their requirement for trails results in higher disturbance levels than those measured for cable yarders.

4) Small tractors are cheaper to operate than cable systems. The conceptual change to small tractors from other ground-skidding machines is less than from ground skidding to cable logging. Small tractors are easier to operate and their planning requirements much easier to understand.

5) Small tractors may be the only machines that can log certain areas. On steep hillsides with heavy rock outcrops a cable system which uses uphill yarding and a slackpulling carriage might function (assuming careful engineering planning) but a truck road would have to be built up the mountainside. Skidders require wide trails which may have to be drilled and blasted. Large tractors also require a wide running surface and cannot manoeuvre as well as small tractors on broken terrain with rock outcrops. Crestbrook has successfully used their small tractors in such an area.

Introduction of the Concept

Introduction of small tractors to employees and contractors requires planning. Two items are of special importance. First, the concept of "Bigger is Better" may require redefining to read "Bigger is Worse," particularly when site disturbance is considered. Second, a contractor may be concerned with job security and income protection. In the introductory stages a company may find it necessary to provide some level of guarantee to contractors.

Some re-training may be necessary for operators. Even operators with previous bulldozer experience operated the small tractor too quickly at first. Their logic was that since small tractors cannot carry as big a load as large tractors, they must go faster. This trend was even more pronounced for operators used to fast-moving skidder operations. It is important for the operator to determine the machine capability under different terrain and load conditions.

System Projecting, Planning And Control

PROJECTING AND PRODUCTION BUDGETING FOR SMALL TRACTORS

When Crestbrook began introducing small tractors, the company estimated that 8 tractors would replace 5 or 6 skidders. In fact, the changeover proved the opposite. Five or six tractors actually replaced 8 skidders over a one-to-two-year period.

The company attributes this difference to two basic causes. First, daily tractor production averaged 20 cunits (56 m^3) and supervisors considered this comparable to wheeled skidders. Part of this production rate is due to lower mechanical downtime for the tractors compared to that for skidders. A tractor can often work until the end of a shift but a skidder may not. (As an example--if a skidder tire is punctured the machine is down until the tire is replaced, but a tractor can lose a pad and still operate until the end of the day.) Second, tractors have extended the operating season. They are capable of working in weather and terrain conditions unsuitable for skidders.

An estimate of annual production is also necessary when projecting machine requirements for a logging year. Table 16 (16a for metric units) contains projected annual volumes for different fleet sizes and lengths of operating season. The average volume per shift is from our study. We found that 8½% of the scheduled shifts had no production. The "budgeted" length of season has been reduced by this amount. The reasons for these lost shifts are both mechanical and non-mechanical in nature and are representative of nearly a full logging season for the fleet.

The average volume used as the basis for the production ranges reflects the study conditions. The average is weighted more heavily to summer logging than winter. About 65% of the volume was logged from slopes greater than 25 percent. Depending on the area, average piece size ranged from 15 ft^3 to 22 ft^3 (0.42 m^3 to 0.62 m^3) and average skid distance ranged from 600 ft to 800 ft (183 m to 244 m). If this fleet, or future fleets, were to concentrate logging primarily in one extreme of the range--for example, on flat ground, large wood, and short skids--then this average would have to be modified.

PLANNING REQUIREMENTS

The small tractor is subject to the same principles that govern other ground-skidding equipment. Procedures are fully outlined in the joint industry-Forest Service manual entitled "Handbook for Ground Skidding and Road Building in British Columbia." The logging planner must be aware of additional factors specific to small-tractor operations.

Size Considerations. Small tractors cannot skid as large a turn as the bigger tractors. If the same area can be logged by either size of machine, then the small tractor will require additional time. If the time frame cannot be extended then the fleet size must be increased. A larger fleet requires additional landings, more equipment moving to and from the area, extra supervision, revised trucking and loading schedules, and additional personnel.

The smaller tractor also affects skid-trail width and spacing. Additional planning may be necessary to maximize the benefit obtained from increased spacing.

TABLE 16. Projected Annual Production for Varying Fleet Sizes and Lengths of Operating Season

Cunits/Year

Length of logging season - days		Fleet size - number of machines						
Budgeted	Projected no. of days worked	1	4	6	8	10		
150	137	2,730	10,910	16,360	21,810	27,260		
170	156	3,100	12,420	18,630	24,840	31,040		
190	174	3,460	13,850	20,780	27,700	34,630		
210	192	3,820	15,280	22,920	30,570	38,210		

TABLE 16a. m^3/Year

Length of logging season - days		Fleet size - number of machines						
Budgeted	Projected no. of days worked	1	4	6	8	10		
150	137	7 710	30 850	46 280	61 700	77 130		
170	156	8 780	35 130	52 700	70 260	87 830		
190	174	9 800	39 180	58 780	78 370	97 960		
210	192	10 810	43 240	64 860	86 480	108 100		

Notes

1. Blank spaces are for reader calculations.
2. Annual volume per machine = No. of days worked x 19.9 cunits (56.3 m^3) per day worked. (Average daily volume from this study.)
3. "Projected no. of days worked" = Budgeted days x 0.915.

   The factor 0.915 is derived from the study. 91.5% of the scheduled (budgeted) shifts had production.

   The ratio is $\frac{\text{1,016 shifts worked}}{\text{1,110 scheduled shifts}} = 0.915$

Landing size can also be determined by the size of skidding equipment and length of logs. Figure J shows a landing located at the end of a haul road that will accommodate two tree-length decks. Three trails will enter at each end. Because this landing is at the end of a haul road, the only congestion problems will be when loading occurs. Large machines cannot manoeuvre as easily as small machines on such a narrow landing. Figure K shows a comparable landing but this is located on the truck road instead of at the end. While this particular road was not heavily travelled, some of the study areas had active logging roads passing through small-tractor landings. From the contractor's viewpoint, production, efficiency, and landing procedures are affected. From the company's viewpoint, log decks must be loaded out once a day to keep the decks small enough so logging traffic may pass. Smaller landings are better with respect to site disturbance but may require additional planning to regulate loading schedules.

Travel Speeds. Both large and small tractors are slower-moving than skidders. Logging supervisors suggest that wheeled skidders often demonstrate cyclical production trends. Peak periods or flurries of activity can often be followed by lows where a much-reduced production level is attained. Downtime and operator motivation are two obvious factors which affect the peaks and lows. Tractors are not designed primarily for speed and cannot provide the same range of high-low periods. Tractor operations appear to be more consistent and predictable than skidder operations. This assists the supervisor when planning and scheduling equipment.

CONTROL AND RECORDS

Area records can provide extremely useful information. Acreage, slope, species, amount of logging equipment and personnel, days spent on the block, and cost can all be tied together once all wood has been hauled and scaled. Landing or block summaries can be easily obtained for those operations where monthly machine reports are used. For contractors without access to computerized records, hand-tabulated area summaries are not difficult to prepare. Factual, site-specific summaries help remove bias, opinion and inaccuracies from discussions about logging areas.

FIGURE J. Landing at end of truck road. Length = approx. 180 ft (55 m). Width varies between 40 to 65 ft (12 to 20 m). Sidehill slope is 68%. Small tractors are manoeuvrable on small landings. Larger machines are restricted.

FIGURE K. Landing on truck road. Size is similar to above photo, but on less steep terrain. Truck traffic can cause congestion and landing-organization problems when the road is active.

Contractors can benefit from keeping area-specific records, particularly when production levels and contract rates are under discussion. At the end of this study several of the contractors established or improved record-keeping systems that will assist with production planning and machine maintenance.

The amount or level of detail to be kept in a record-keeping system will vary depending on end use of the information. Generally speaking, the greater the amount of detail, the easier it becomes to identify problems.

EFFECT OF SKIDDING DISTANCE ON DAILY PRODUCTION

Figure L is a graph of daily production levels for different skid distances for both summer and winter. These results have been determined from the detailed time studies. Total time and volume for each turn were used to calculate hourly productivity, expressed as volume/PMH. Hourly productivity was then combined with an estimate of productive hours per shift. (Assumptions--80% utilization and an 8-hr day.) The resulting daily production value was plotted against the travel loaded distance for the turn. Sample size for the winter was 190 turns and for the summer 144 turns. Figure M contains the metric equivalents.

The graphs are aids for predicting production levels at different skid distances but they can also be used as a tool to help predict economical skid distance. The steps are briefly outlined below.

1. Calculate total daily cost for machine and crew. Example: $450.00.

2. Specify maximum permissible cost/unit volume. Example: $20.00/cunit ($7.06/m^3).

3. Divide these two numbers to obtain the average production level necessary for this situation. Example: 22.5 cunits/day (63.7 m^3/day).

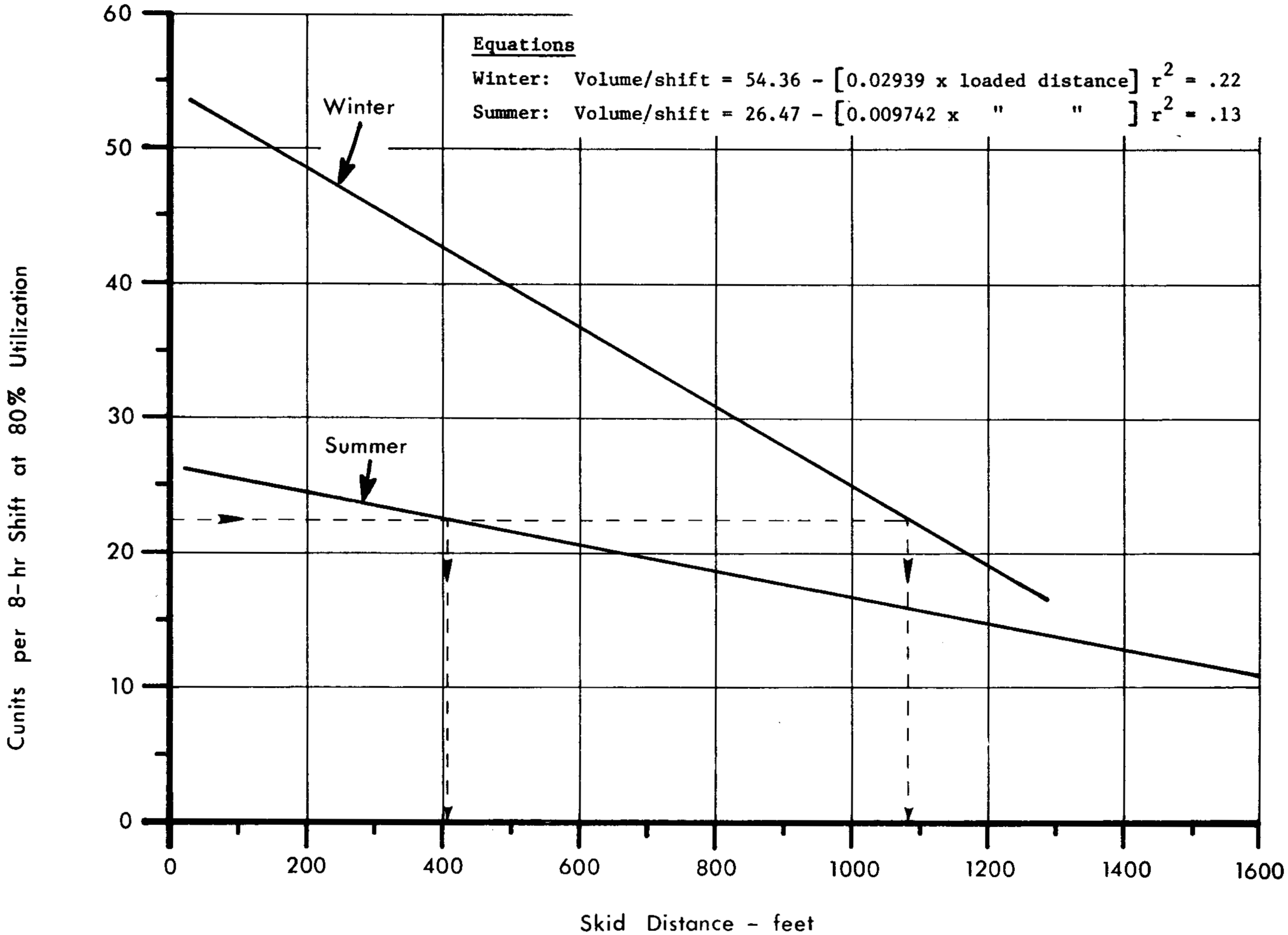


FIGURE L. Cunits/shift for different skid distances

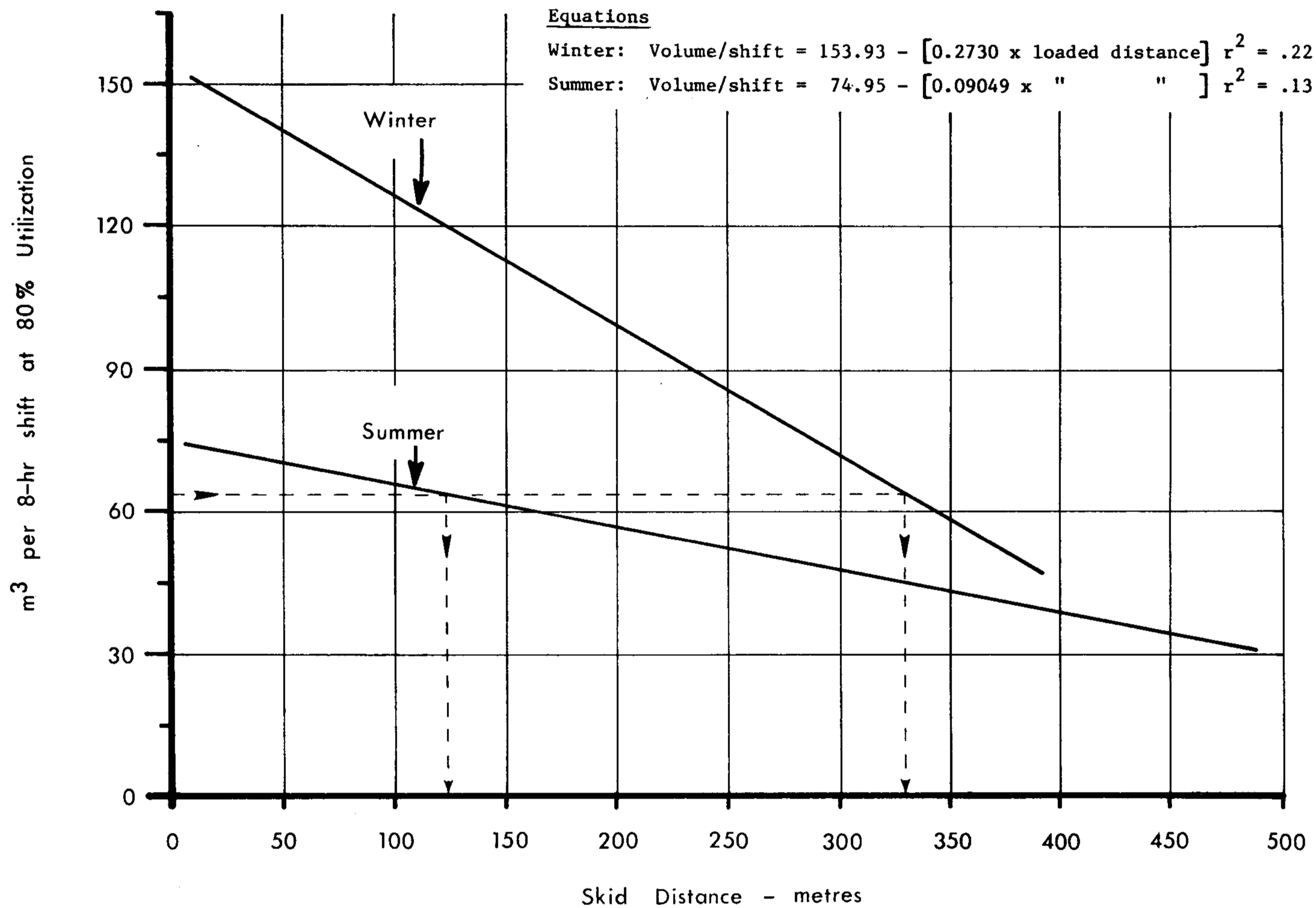


FIGURE M. m^3/shift for different skid distances

4. Determine skid distance at that production level from the graph. Example: Winter average skid distance at 22.5 cunits (67.3 m^3) per day is 1,084 ft (330 m). This example is illustrated by the dashed lines on the graph. For summer, average skid distance is 408 ft (124 m).

These graphs are based on the specific conditions encountered during the study. Projections made from these graphs must be modified for other conditions.

The winter graph shows figures which are artificially high because the machine operators were noticeably more competitive during that period. It is unlikely that level could be maintained over the course of a logging season.

Effective Techniques Used By Contractors

This section is divided into two parts and is directed mainly to operating personnel and contractors. The first deals with equipment modifications that have been made to the tractors and the second describes some of the operational procedures that were used by the operators. Interviews on this subject were conducted in July, 1979 with six of the contractors.

EQUIPMENT MODIFICATIONS

All contractors agreed that two modifications were necessary for their tractors. The first, shown in Figure N, provides added protection for the blade hydraulics. The second modification is shown in Figure O and prevents chokers from tangling while the machine travels empty. One contractor has also modified the blade on his tractor by drilling a quantity of different sizes of holes through the spill plate (see Figure P). When the blade is in the raised position (usually for decking), debris and dust particles exiting from the radiator rebound back into the cab. Most of this debris now passes through the holes and this contractor is able to wear his contact lenses full-time.

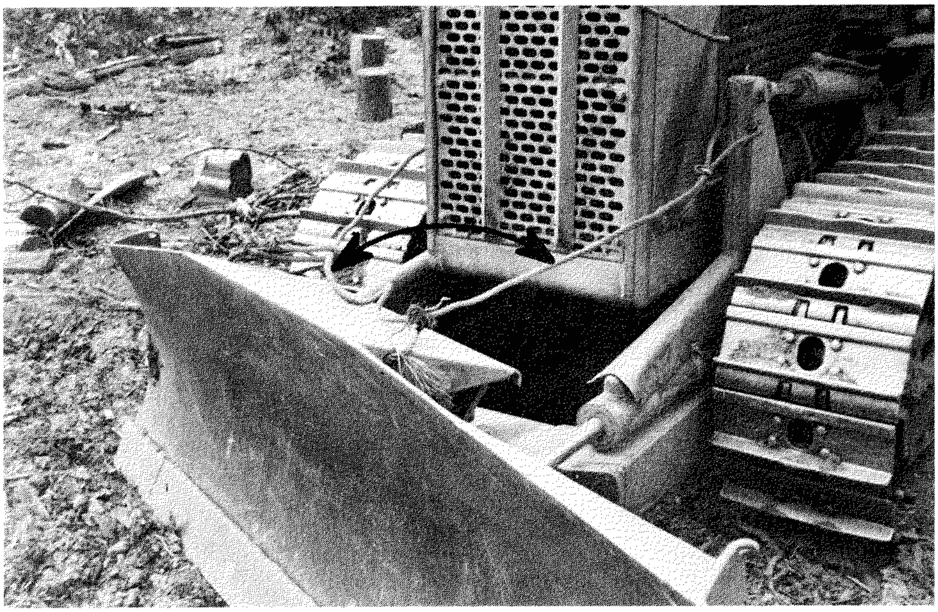


FIGURE N. Blade-hydraulics protection. Wire rope cable stretches from the cylinder mount arms to the blade. On TD-8's a single cable runs from the top of the radiator down to the blade.

FIGURE O. Choker hook to transport empty chokers--can be welded to the frame or hung from the wire mesh.

FIGURE P. Modified spill plate on TD-8 blade--holes prevent debris from the radiator from rebounding into the cab.

Three of the six operators interviewed stated they did not make any modifications, only necessary repairs. Two other contractors made some changes while the last operator made extensive alterations to his machine. The modifications are more related to operator preference than machine make or design.

The changes made by the contractors are as follows:

1. front screens added
2. front canopy guards extended
3. belly-pan reinforced
4. steel hydraulic line from pump replaced with flex hose to keep it from vibrating loose
5. blade cylinder mounts reinforced
6. cylinder mount arms on C-frame reinforced
7. fuel-tank supports reinforced
8. blade rebuilt and reinforced
9. additional rock-guards installed on undercarriage
10. fairlead angle and height from ground has been increased. (This has increased mainline life from 4-6 weeks to 6-8 weeks.)
11. hydraulic pump rebuilt to give slightly increased volume (hose size increased also). This provides faster blade reaction for the decking phase.
12. engine pre-breather has been added - approx. 2 weeks extra air-filter life
13. three dirt seals removed from the winch in winter. In cold conditions the mainline required 2 men to pull out. The winch now spools easily.

One item of interest, although not an equipment modification, is a maintenance truck obtained by one of the contractors. The truck houses an oxyacetylene torch, generator and welder, tools, spare parts and a stove. In bad weather the crew can change to dry clothing and warm up at lunch.

OPERATIONAL PROCEDURES

The six contractors were asked to discuss their log-skidding procedures. The following paragraphs are an attempt to summarize the ideas and comments of these operators.

Skidding on flat ground. All contractors agreed that flat ground (0-20%) provides the easiest, safest and fastest skidding. Four of the six operators interviewed preferred butt-skidding, stating that logs were easier to hookup in the bush and unhook at the landing. Three of these contractors will prebunch logs at the bush site if the timber is scattered. The fourth contractor considers prebunching a loss of productive time. Figures Q and R show an additional benefit when butt-skidding, particularly if each turn must be bucked and decked as it arrives on the landing.

The remaining two contractors prefer top-skidding and state several reasons for their choice. During butt-skidding, butts often catch on rough ground because of the low winch and fairlead height. Another reason is that if the faller places several tops together, the hookup phase requires fewer load points and fewer move times. This results in some time savings and less wear and tear on the tractor. Both operators often prebunch tops with the tractor blade while moving in either travel direction.

Skidding on sidehills. All contractors agreed on the sequence of events necessary to open a new area. Once roads, landings and trails are in place, the following events occur.

1. Pushover trees from the trail-construction phase are skidded to the landing, usually butt first.

2. Pushovers are used to develop deck locations and landing setup.

3. The area between the landing and the low side of the first trail is felled and skidded. Trees are usually felled towards the landing and top-skidded directly to it, but occasionally, depending on terrain, some portion of the timber may be felled away from the landing and top-skidded along the first trail.

4. Felling and skidding activities then proceed up the hillside.

Point No.4 may be classed as the stage where contractors spend most of their time. It is also the stage where methodology differences begin.

Five of the six operators start skidding at the landing edge and progress outward. The sixth contractor often starts at the trail end and works toward the landing. This procedure has two prerequisites: trees must be felled close to the

FIGURE Q. Butt-skidded turn at the landing--the turn can be stopped at the landing edge and topped.

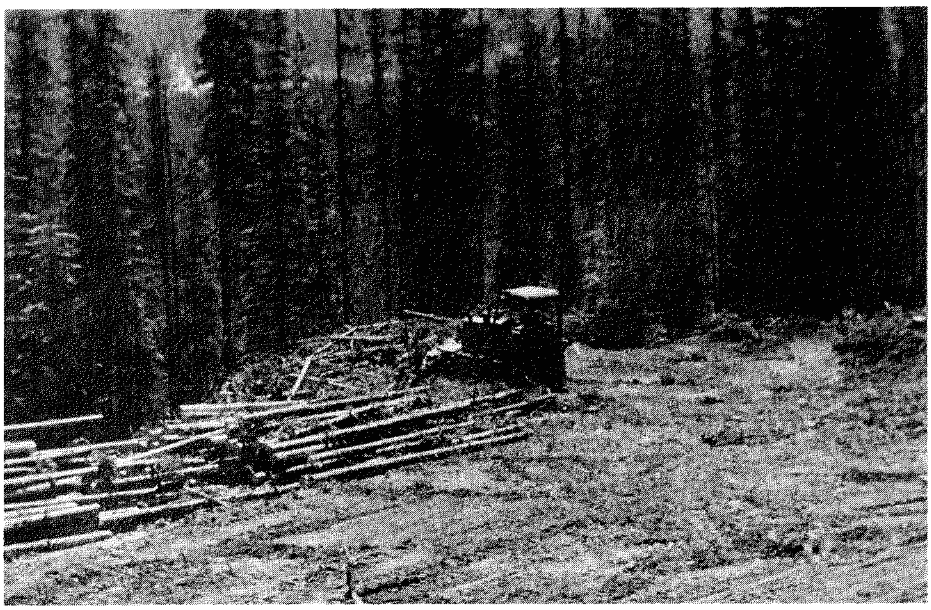


FIGURE R. Cleaning the landing--little additional time is required to move the debris to the nearby slash pile.

trail but not on it, and the operator on his way to the back end must use the mainline and chokers to prebunch tops at the trail edge so that hookup times for building turns are minimized.

Three contractors stated that when the tractor works from a prepared trail they will only skid to the uphill side. Trees between trails are always felled to the lower trail and are all top-skidded.

The remaining three contractors skid to both sides of the trail, top-skidding to the upper side and butt-skidding to the lower. Depending on the contractor, distance on the downhill side varies, ranging from 10 ft to 30 ft (3 m to 9 m). Two of the operators prefer to finish the low side of the trail before starting uphill. The third contractor follows the same procedures in high-volume stands but he indicated a preference for alternating top- and butt-skidding in 200-ft (60-m) stretches in low-volume stands.

It is difficult to choose the "most efficient system" for skidding. Each contractor felt comfortable with his system and he and his crew wanted to make it work. The choice is further complicated by financial incentive. During the study, each contractor was asked to state, on a confidential basis, the monthly payment he had arranged for his tractor. At the end of the study, the contractors were ranked by average daily production. Although the specific order differed, the highest producers had the highest monthly payments.

<u>Trail construction - company or contractor?</u> Contractors were evenly divided in their opinion on this subject. Three contractors wanted the company to continue with trailbuilding functions. The remaining three wanted to build their own trails. One did, in fact, do his own trailbuilding and was paid an hourly machine rate.

Most of the concern about trails appeared to center around two points: landing-entry location and landing-entry angle. The contractors' main suggestions were that more frequent communication and greater input into trail-placement decisions would be valuable. The faller's comments about tree lean and falling direction could also be incorporated into trail-placement decisions.

If a contractor builds his own trails he can place them for landing entry where necessary. He will either have to pay an inactive faller or work overtime to accomplish this.

Companies must control trailbuilding in order to reduce site disturbance levels. Contractors require input but if they must modify company-built trails, then site-disturbance levels may increase, not decrease.

Trail spacing. Contractors were asked to respond to the non-specific question, If you built your own trails, how far apart would you space them? The responses to the question are listed below. Two contractors who had similar opinions are grouped together. Responses are ranked in order of increasing complexity.

Reply #1 - On slopes greater than 30% all trails should be an 80-ft (24-m) maximum.
Slopes less than 30% do not require trails.

Reply #2 - "Steep slopes need narrower spacing." The greater the slope the greater the cutbank, which makes climbing difficult. More trails mean less climbing.
Winter - trees slide; trails can be farther apart. (This contractor was unwilling to assign slope or distance values.)

Reply #3 - On slopes greater than 50% - trees slide so trail spacing can be 150 ft (45 m).
On slopes less than 50% - spacing should be less than 100 ft (30 m).

Reply #4 - On "steep slopes," trail spacing should be "tree length + 20%."
On steep slopes with windfall, trees slide farther. Increase the spacing.
On "low" slopes trees are taller. Wider spacing can also be used.

Reply #5 - On slopes greater than 40%
Winter - spacing should be 80 ft to 85 ft (24 m to 26 m). Trees slide further in winter, so more trails increase the chances for stopping the tree.
Summer - 100-ft (30-m) spacing adequate. On slopes less than 40% little or no trail is required. Tractor can top-skid without trails.

Three distinct opinions are in evidence: a) as slope increases trails should be wider-spaced, b) the reverse of (a)--trails should have narrower spacing, and c) if trails are necessary, spacing should be constant regardless of slope.

The company has specified that trails should be spaced at 100-ft (30-m) intervals. The intent is to reduce site disturbance levels by reducing the total amount of trail construction. It is evident from the replies that the loggers are reluctantly accepting this decision.

Two-tractor operations. One contractor began this study with two machines. Another contractor bought a second tractor after the study was completed. Both company and contractor planning must be modified when an additional machine is added.

If both machines work out of the same landing the company must decide either to increase landing size or loading frequency. The tractors could be placed in separate areas but this complicates the contractor's supervision. During this study the company usually had two-tractor operations located on single larger landings.

Which trails will each tractor work? and In what order will they be skidded? These decisions will affect the faller, machine interaction, and general landing efficiency.

The decisions may also affect deck-positioning and truck-loading. The contractors in Figure S and Figure T were both top-skidding to these particular landings. On one landing the log decks point the same way. On the other, the log decks are pointed in opposite directions. One of these landings may cause difficulty for a loaderman.

Even with the best planning one machine interferes with the other. The tractors have interaction on the landing. The detailed time study shows that the fleet of small tractors averaged about 45% of their time on the landing in the summer and 37% in the winter. The probability that two tractors will be on a landing at the same time is 20% in summer and 14% in winter. These percentages represent 1.6 hr and 1.1 hr per 8-hr day of potential increase in delay.

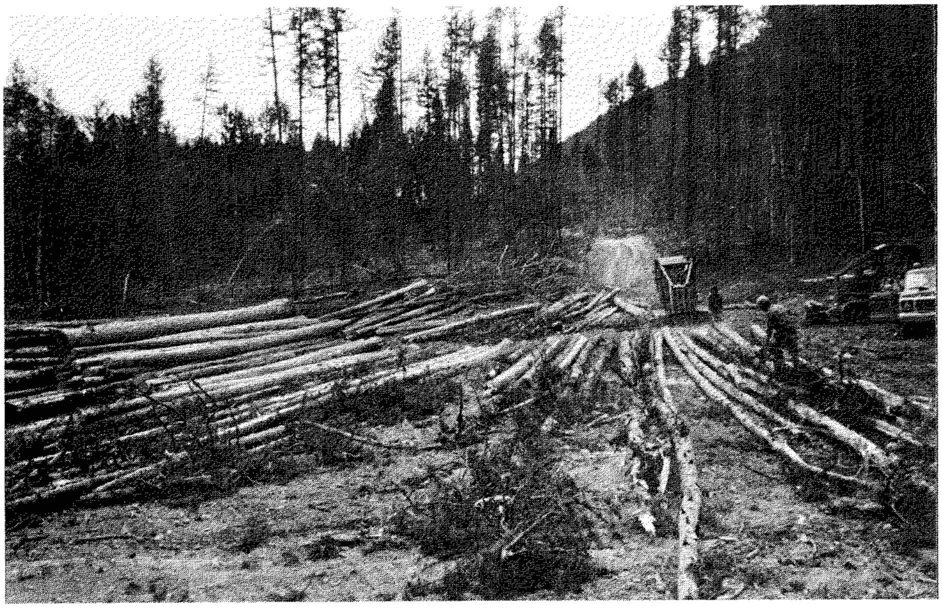


FIGURE S. Bucking for 550's. These tractors worked different trails. The trails entered the landing at the same end. Log decks both point in the same direction.

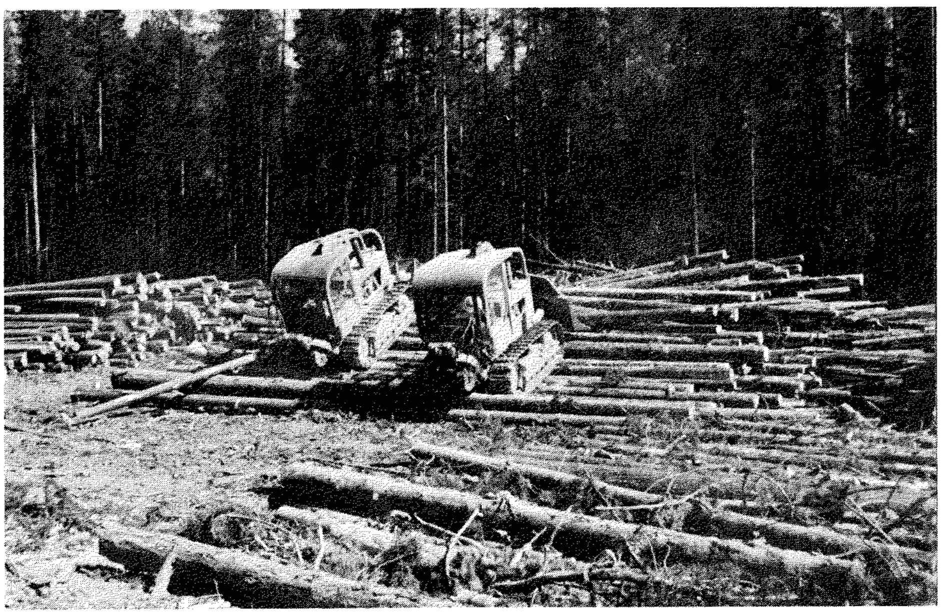


FIGURE T. TD-8's performing decking. These machines also worked separate trails, but the trails entered the landing at opposite ends. The machine paths crisscrossed at landing center, resulting in the two decks having their tops pointed in opposite directions.

When two machines work out of the same landing their cycles are even less random because they tend to leave the landing together. This occurs several times per day: at shift startup, after lunch, after coffee breaks, and after joint decking and landing-cleaning periods. The effect is further compounded if the machines return to the landing at the same time because of similar skidding distances.

There are several ways to help reduce machine interaction problems.

1. Stagger machine startup times. Have them leave the landing separately.

2. Schedule to avoid "togetherness." Maintenance and service periods can be separated. Joint landing work may not be necessary. If a repair job requires a helper, the bucker instead of the second operator can provide assistance.

3. Put the machines on separate trails, and if possible, at different distances without interfering with faller efficiency. If the tractors are on different sides of the block the faller must spend a higher portion of his time travelling.

4. Utilize two decks (three, if they will all fit on the landing). This helps in two ways. First, when both tractors do arrive at the same time, waiting time might be avoided. Second, it assists the landing man who must limb, top and buck, when both tractors are working under short-distance, high-production conditions.

CONCLUSIONS

1. This fleet of seven contractor-operated tractors averaged 19.9 cunits (56.3 m^3) per shift worked over a logging season. These shifts represent 91.5% of the scheduled or planned shifts during the study. The calculated cost for decked wood on a landing (using a daily cost of $461) was $23.16/cunit ($8.19/m^3).

2. The areas logged by small-tractors have approximately one-third less site disturbance, summer or winter than those logged by large tractors. Most of the reduction results from narrower skid trails and wider trail spacing.

3. The trailbuilder machine is the key to obtaining beneficial site disturbance results because control of trail placement is essential.

4. Over the long-term part of the study, little seasonal variation was observed in average production per shift. During the winter the contractors had fewer working hours/day but a larger piece size.

5. The detailed time studies suggest that for an average daily production of 22.5 cunits (63.7 m^3), skid distance can range up to 820 ft (250 m) in the summer (average skid 410 ft (125 m)) and 2,170 ft (661 m) in the winter (average skid 1,085 ft (331 m)). Conditions during the winter study were very favourable and it is unlikely that this level of production could be maintained over the course of a logging season.

6. Mechanical Availability for the fleet of tractors was 90% and can be considered satisfactory for machines with an average age of 3 years. Machine Utilization for the fleet averaged 79 percent. Availability and Utilization for the trailbuilder averaged 85% and 68% respectively, indicating that trailbuilding is mechanically more difficult and operationally more complex than skidding.

7. Based on this study, a projected annual volume for a fleet of 10 small tractors over a 190-day budgeted season would be approximately 34,600 cunits (98 000 m^3).

8. Small tractors are more versatile than either wheeled skidders or cable machines and can extend the operating season.

9. The contractors in this study had developed individual equipment modifications and detailed operating procedures. Some would have preferred to construct their own skid trails while others were satisfied to let the company accept this responsibility.

10. Small tractors appear most suited to logging on steeper-than-30% sidehill slopes. Slopes less than 30% can usually be logged without trails and the faster rubber-tired skidder should out-produce the slower tractor. On slopes greater than 30%, low ground-pressure track machines may also be attractive if they can operate without skid trails. Skid trails for wheeled skidders and large crawler-tractors must be wider and have deeper cuts than trails for the small tractors. Skidding with small tractors is a practical and economical logging method which may reduce environmental impact to acceptable levels on some sensitive forest sites. Operators logging in areas where site disturbance is of concern should consider small tractors as an alternative to other ground skidding machines or to cable logging.

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APPENDIX I

Study Results for Machine No.1

Machine Statistics

Tractor make: John Deere

Model: 550

Year manufactured: 1976

Machine age at study completion: 2 years

Contractor Background

Current job: tractor operator

Age at end of study: 50 years

Previous logging experience: logging truck driver; chokerman behind tractor; bulldozer operator for road building and skidding; faller and bucker

Current employees: one faller

Study Information

Period covered: June 15, 1977 to February 27, 1978

Number of scheduled shifts: 186

Number of shifts worked (shifts with piece count): 174

TABLE 1. Shift Time Categories
Based on 186 Scheduled Shifts

	Total Hours	Average Hr/Shift	% of Scheduled Time
Productive Machine Hours (PMH)			
Skidding	1,192.9	6.4	81.3
Trailbuilding	38.1	.2	2.6
Other work	14.9	.1	1.0
Σ	1,245.9	6.7	84.9
Delays			
Repair	30.9	.2	2.1
Service	75.1	.4	5.1
Wait mechanic	0	0	0
Wait parts	5.8	<.1	.4
Change landings	8.2	<.1	.6
Other non-mechanical	102.2	.5	7.0
Total: Scheduled Machine Hours (SMH)	1,468.1	7.9	100%

CPPA Mechanical Availability = 92%
CPPA Utilization = 85%
MNA (Mechanical Non-Availability) = 8.5 hours

TABLE 2. Production and Productivity
Based on 174 Shifts Worked

Study Production Totals			
Volume produced, cunits (m^3)	4,059		(11 494)
Pieces skidded		24,503	
Turns		2,999	
Study Averages			
Overall average piece size, ft^3 (m^3)	16.6		(0.47)
Volume/shift worked, cunits (m^3)	23.3		(66.1)
Pieces/shift worked		140.8	
Turns/shift worked		17.2	
Volume/turn, cunits (m^3)	1.4		(3.8)
Pieces/turn		8.2	
Productivity			
Volume/PMH, cunits (m^3)	3.3		(9.2)
Trees/PMH		19.7	

TABLE 3. Detailed Time Results by Season
Turn Averages and Descriptive Factors

		Summer		Winter	
TIME SUMMARY		minutes	%	minutes	%
Loading Phase	Manoeuvre Hookup Prebunch Move during load	.91 3.55 .56 .62	28.6	.48 2.97 .77 .50	31.4
Unloading Phase	Unhook Limb, top Align butts Decking Clean landing	2.14 1.77 .19 1.63 1.38	36.0	1.26 1.03 .38 2.13 .60	35.9
TERMINAL TIME (load + unload)		12.75	64.6	10.12	67.3
Travel Phase	Empty Loaded Winching	1.63 2.43 .16	21.4	1.47 1.83 .30	23.9
TURN TIME (terminal + travel)		16.97	86.0	13.72	91.2
Delay Time		2.76	14.0	1.32	8.8
TOTAL TURN TIME		19.73	100%	15.04	100%
STAND AND OPERATING FACTORS					
Distance, ft (m)	Empty Loaded	374 (114) 377 (115)		353 (108) 405 (123)	
Slope - % Loaded, on trails - range - average Sidehill - range - average		 0 to +8 3 0 to 10 3		 -15 to +16 -4 0 to 63 18	
No. prebunch points No. loading points No. times load was winched		.1 2.5 .4		.5 2.6 .9	
PRODUCTION AND PRODUCTIVITY					
Piece count per turn Turn volume, ft^3 (m^3) Piece volume, ft^3 (m^3)		8.1 113 (3.20) 14.0 (0.40)		4.8 137 (3.88) 28.5 (0.81)	
Potential Productivity	Cunits (m^3)/PMH Trees/PMH	3.4 (9.7) 24.6		5.5 (15.5) 19.1	
SAMPLE SIZE - no. of turns in study		33		30	

APPENDIX II

Study Results for Machine No.2

Machine Statistics

Tractor make: John Deere

Model: 550

Year manufactured: 1976

Machine age at study completion: 1½ years

Contractor Background

Current job: tractor operator

Age at end of study: 39 years

Previous logging experience: bulldozer operator; faller and bucker; rubber-tired skidder operator

Current employees: one faller

Study Information

Period covered: June 16, 1977 to March 6, 1978

Number of scheduled shifts: 152

Number of shifts worked (shifts with piece count): 139

TABLE 1. Shift Time Categories
Based on 152 Scheduled Shifts

	Total Hours	Average Hr/Shift	% of Scheduled Time
Productive Machine Hours (PMH)			
Skidding	1,015.8	6.7	79.4
Trailbuilding	29.0	.2	2.3
Other work	15.0	.1	1.2
Σ	1,059.8	7.0	82.9
Delays			
Repair	41.3	.3	3.2
Service	45.5	.3	3.6
Wait mechanic	0	0	0
Wait parts	15.3	.1	1.2
Change landings	7.2	<.1	.6
Other non-mechanical	109.5	.7	8.6
Total: Scheduled Machine Hours (SMH)	1,278.6	8.4	100%

CPPA Mechanical Availability = 92%
CPPA Utilization = 83%
MNA (Mechanical Non-Availability) = 8.2 hours

TABLE 2. Production and Productivity
Based on 139 Shifts Worked

Study Production Totals			
Volume produced, cunits (m^3)	3,404		(9 639)
Pieces skidded		16,609	
Turns	Turn count not supplied to FERIC		
Study Averages			
Overall average piece size, ft^3 (m^3)	20.5		(0.58)
Volume/shift worked, cunits (m^3)	24.5		(69.3)
Pieces/shift worked		119.5	
Productivity			
Volume/PMH, cunits (m^3)	3.2		(9.1)
Trees/PMH		15.7	

TABLE 3. Detailed Time Results by Season
Turn Averages and Descriptive Factors

		Summer minutes	Summer %	Winter minutes	Winter %
TIME SUMMARY		minutes	%	minutes	%
Loading Phase	Manoeuvre Hookup Prebunch Move during load	.38 4.67 .18 .71	32.4	.38 3.33 .14 .80	26.8
Unloading Phase	Unhook Limb, top Align butts Decking Clean landing	3.29 1.17 1.29 .59 1.65	43.5	1.75 .26 .82 2.25 1.65	38.8
TERMINAL TIME (load + unload)		13.93	75.9	11.38	65.6
Travel Phase	Empty Loaded Winching	1.07 1.66 .02	15.0	1.48 1.93 .26	21.2
TURN TIME (terminal + travel)		16.68	90.8	15.05	86.7
	Delay Time	1.68	9.2	2.30	13.3
TOTAL TURN TIME		18.36	100%	17.35	100%
STAND AND OPERATING FACTORS					
Distance, ft (m)	Empty Loaded	117 (36) 239 (73)		349 (106) 292 (89)	
Slope - %					
Loaded, on trails - range - average		-25 to +7 -2		-11 to +4 -5	
Sidehill - range - average		2 to 25 8		0 to 25 3	
No. prebunch points No. loading points No. times load was winched		.3 2.6 .1		.2 3.4 1.2	
PRODUCTION AND PRODUCTIVITY					
Piece count per turn Turn volume, ft^3 (m^3) Piece volume, ft^3 (m^3)		9.6 116 (3.28) 12.1 (0.34)		5.7 175 (4.96) 30.7 (0.87)	
Potential Productivity	Cunits (m^3)/PMH Trees/PMH	3.8 (10.7) 31.4		6.1 (17.2) 19.7	
SAMPLE SIZE - no. of turns in study		30		30	

APPENDIX III

STUDY RESULTS FOR MACHINE No.3

Machine Statistics

Tractor make: John Deere

Model: 450

Year manufactured: 1974

Machine age at study completion: 4 years

Contractor Background

Current job: faller-bucker

Age at end of study: 50 years

Previous logging experience: cable-yarder operator; faller and bucker; rubber-tired skidder operator; chokerman; logging truck driver; horse-logging experience

Current employees: one tractor operator

Study Information

Period covered: June 15, 1977 to November 30, 1977

Number of scheduled shifts: 119

Number of shifts worked (shifts with piece count): 105

TABLE 1. Shift Time Categories
Based on 119 Scheduled Shifts

	Total Hours	Average Hr/Shift	% of Scheduled Time
Productive Machine Hours (PMH)			
Skidding	739.4	6.2	76.1
Trailbuilding	0	0	0
Other work	1.2	<.1	.1
Σ	740.6	6.2	76.2
Delays			
Repair	43.5	.4	4.5
Service	18.8	.2	1.9
Wait mechanic	0	0	0
Wait parts	21.5	.2	2.2
Change landings	2.6	<.1	.3
Other non-mechanical	144.6	1.2	14.9
Total: Scheduled Machine Hours (SMH)	971.6	8.2	100%

CPPA Mechanical Availability = 91%
CPPA Utilization = 76%
MNA (Mechanical Non-Availability) = 8.4 hours

TABLE 2. Production and Productivity
Based on 105 Shifts Worked

Study Production Totals			
Volume produced, cunits (m^3)	1,611		(4 562)
Pieces skidded		9,191	
Turns		1,340	
Study Averages			
Overall average piece size, ft^3 (m^3)	17.5		(0.50)
Volume/shift worked, cunits (m^3)	15.3		(43.4)
Pieces/shift worked		87.5	
Turns/shift worked		12.8	
Volume/turn, cunits (m^3)	1.2		(3.4)
Pieces/turn		6.9	
Productivity			
Volume/PMH, cunits (m^3)	2.2		(6.2)
Trees/PMH		12.4	

TABLE 3. Detailed Time Results by Season
Turn Averages and Descriptive Factors

		Summer		Winter	
TIME SUMMARY		minutes	%	minutes	%
Loading Phase	Manoeuvre Hookup Prebunch Move during load	1.91 8.28 3.96 1.38	31.5	.41 3.72 .56 .42	30.1
Unloading Phase	Unhook Limb, top Align butts Decking Clean landing	4.05 .90 .44 .01 .98	13.0	1.14 .29 .80 .54 .48	19.2
TERMINAL TIME (load + unload)		21.91	44.5	8.36	49.3
Travel Phase	Empty Loaded Winching	6.86 8.03 1.04	32.3	3.59 3.33 .02	40.9
TURN TIME (terminal + travel)		37.84	76.8	15.30	90.3
Delay Time		11.42	23.2	1.65	9.7
TOTAL TURN TIME		49.26	100%	16.95	100%
STAND AND OPERATING FACTORS					
Distance, ft (m)	Empty Loaded	1,051 (320) 1,104 (336)		870 (265) 875 (267)	
Slope - %					
Loaded, on trails - range		-54 to +8		-14 to -12	
- average		-23		-12	
Sidehill - range		35 to 80		50 to 70	
- average		60		57	
No. prebunch points		.5		.3	
No. loading points		3.5		2.1	
No. times load was winched		2.2		.1	
PRODUCTION AND PRODUCTIVITY					
Piece count per turn		7.5		5.3	
Turn volume, ft^3 (m^3)		156 (4.42)		119 (3.37)	
Piece volume, ft^3 (m^3)		20.8 (0.60)		22.5 (0.64)	
Potential Productivity	Cunits (m^3)/PMH Trees/PMH	1.9 (5.4) 9.1		4.2 (11.9) 18.8	
SAMPLE SIZE - no. of turns in study		23		30	

APPENDIX IV

Study Results for Machine No.4

Machine Statistics

Tractor make: International

Model: TD-8E

Year manufactured: 1976

Machine age at study completion: 1 year usage

Contractor Background

Current job: tractor operator

Age at end of study: 36 years

Previous logging experience: none

Current employees: one faller

Study Information

Period covered: June 9, 1977 to March 7, 1978

Number of scheduled shifts: 191

Number of shifts worked (shifts with piece count): 184

TABLE 1. Shift Time Categories
Based on 191 Scheduled Shifts

	Total Hours	Average Hr/Shift	% of Scheduled Time
Productive Machine Hours (PMH)			
Skidding	1,180.5	6.2	73.2
Trailbuilding	4.5	<.1	.3
Other work	179.1	.9	11.1
Σ	1,364.1	7.1	84.6
Delays			
Repair	51.5	.3	3.2
Service	79.8	.4	5.0
Wait mechanic	0	0	0
Wait parts	16.3	.1	1.0
Change landings	8.0	<.1	.5
Other non-mechanical	92.5	.5	5.7
Total: Scheduled Machine Hours (SMH)	1,612.2	8.4	100%

CPPA Mechanical Availability = 91%
CPPA Utilization = 85%
MNA (Mechanical Non-Availability) = 9.6 hours

TABLE 2. Production and Productivity
Based on 184 Shifts Worked

Study Production Totals			
Volume produced, cunits (m^3)	4,515		(12 785)
Pieces skidded		24,781	
Turns		3,291	
Study Averages			
Overall average piece size, ft^3 (m^3)	18.2		(0.52)
Volume/shift worked, cunits (m^3)	24.5		(69.5)
Pieces/shift worked		134.7	
Turns/shift worked		17.9	
Volume/turn, cunits (m^3)	1.4		(3.9)
Pieces/turn		7.5	
Productivity			
Volume/PMH, cunits (m^3)	3.3		(9.4)
Trees/PMH		18.2	

TABLE 3. Detailed Time Results by Season
Turn Averages and Descriptive Factors

		Summer		Winter	
TIME SUMMARY		minutes	%	minutes	%
Loading Phase	Manoeuvre Hookup Prebunch Move during load	.53 6.03 .05 .49	30.3	.46 5.41 0 .33	34.5
Unloading Phase	Unhook Limb, top Align butts Decking Clean landing	3.41 3.11 1.28 1.35 1.91	47.3	1.67 .72 .68 1.82 1.05	33.1
TERMINAL TIME (load + unload)		18.16	77.6	12.14	67.6
Travel Phase	Empty Loaded Winching	1.21 1.33 .13	11.4	2.56 2.11 .16	26.9
TURN TIME (terminal + travel)		20.83	89.0	16.97	94.5
Delay Time		2.56	11.0	.99	5.5
TOTAL TURN TIME		23.39	100%	17.96	100%
STAND AND OPERATING FACTORS					
Distance, ft (m)	Empty Loaded	200 (61) 165 (50)		565 (172) 611 (186)	
Slope - %					
Loaded, on trails - range		-11 to 0		-19 to -6	
- average		-6		-16	
Sidehill - range		0 to 10		62 to 80	
- average		8		74	
No. prebunch points		.1		0	
No. loading points		2.0		1.7	
No. times load was winched		.4		.6	
PRODUCTION AND PRODUCTIVITY					
Piece count per turn		8.4		7.0	
Turn volume, ft^3 (m^3)		109 (3.09)		142 (4.02)	
Piece volume, ft^3 (m^3)		13.0 (0.37)		20.3 (0.57)	
Potential Productivity	Cunits (m^3)/PMH Trees/PMH	2.8 (7.9) 21.5		4.7 (13.4) 23.4	
SAMPLE SIZE - no. of turns in study		30		30	

APPENDIX V

Study Results for Machine No.5

Machine Statistics

Tractor make: International

Model: TD-8E

Year manufactured: 1976

Machine age at study completion: 1 year usage

Contractor Background

Current job: falling and bucking

Age at end of study: 38 years

Previous logging experience: faller and bucker; rubber-tired skidder operator; loaderman; bulldozer operator for road construction and skidding

Current employees: one tractor operator

Study Information

Period covered: August 9, 1977 to March 21, 1978

Number of scheduled shifts: 144

Number of shifts worked (shifts with piece count): 132

TABLE 1. Shift Time Categories
Based on 144 Scheduled Shifts

	Total Hours	Average Hr/Shift	% of Scheduled Time
Productive Machine Hours (PMH)			
Skidding	866.1	6.0	77.4
Trailbuilding	16.9	.1	1.5
Other work	5.6	<.1	.5
Σ	888.6	6.2	79.4
Delays			
Repair	42.4	.3	3.8
Service	54.3	.4	4.9
Wait mechanic	0	0	0
Wait parts	5.8	<.1	.5
Change landings	5.9	<.1	.5
Other non-mechanical	121.8	.9	10.9
Total: Scheduled Machine Hours (SMH)	1,118.8	7.8	100%

CPPA Mechanical Availability = 91%
CPPA Utilization = 79%
MNA (Mechanical Non-Availability) = 10.9 hours

TABLE 2. Production and Productivity
Based on 132 Shifts Worked

Study Production Totals			
Volume produced, cunits (m^3)	2,639		(7 473)
Pieces skidded		16,191	
Turns		2,933	
Study Averages			
Overall average piece size, ft^3 (m^3)	16.3		(0.46)
Volume/shift worked, cunits (m^3)	20.0		(56.6)
Pieces/shift worked		122.7	
Turns/shift worked		22.2	
Volume/turn, cunits (m^3)	0.9		(2.5)
Pieces/turn		5.5	
Productivity			
Volume/PMH, cunits (m^3)	3.0		(8.4)
Trees/PMH		18.2	

TABLE 3. Detailed Time Results by Season
Turn Averages and Descriptive Factors

		Summer	Winter	
TIME SUMMARY			minutes	%
Loading Phase	Manoeuvre Hookup Prebunch Move during load	No summer study	.04 5.84 0 .15	44.2
Unloading Phase	Unhook Limb, top Align butts Decking Clean landing		.98 .14 .54 1.82 1.00	32.8
TERMINAL TIME (load + unload)			10.51	77.0
Travel Phase	Empty Loaded Winching		1.25 1.60 .04	21.2
TURN TIME (terminal + travel)			13.40	98.2
Delay Time			.25	1.8
TOTAL TURN TIME			13.65	100%
STAND AND OPERATING FACTORS				
Distance, ft (m)	Empty Loaded		300 (91) 314 (96)	
<u>Slope - %</u> Loaded, on trails - range - average Sidehill - range - average			 -12 to +4 -4 52 to 76 61	
No. prebunch points No. loading points No. times load was winched			0 1.3 .3	
PRODUCTION AND PRODUCTIVITY				
Piece count per turn Turn volume, ft^3 (m^3) Piece volume, ft^3 (m^3)			4.4 148 (4.19) 33.6 (0.95)	
Potential Productivity	Cunits (m^3)/PMH Trees/PMH		6.5 (18.4) 19.3	
SAMPLE SIZE - no. of turns in study			30	

APPENDIX VI

STUDY RESULTS FOR MACHINE No.6

Machine Statistics

Tractor make: International

Model: TD-8C

Year manufactured: 1972

Machine age at study completion: 6 years

Operator Background

Current job: tractor operator

Age at end of study: 41 years

Previous logging experience: feller-buncher operator; faller and bucker; rubber-tired skidder operator; gravel-truck driver; bulldozer operator for road construction and skidding

Current employees: none

Study Information

Period covered: June 15, 1977 to March 9, 1978

Number of scheduled shifts: 179

Number of shifts worked (shifts with piece count): 161

TABLE 1. Shift Time Categories
Based on 179 Scheduled Shifts

	Total Hours	Average Hr/Shift	% of Scheduled Time
Productive Machine Hours (PMH)			
Skidding	979.0	5.5	68.3
Trailbuilding	80.6	.5	5.6
Other work	2.5	<.1	.2
Σ	1,062.1	5.9	74.1
Delays			
Repair	107.3	.6	7.5
Service	61.4	.3	4.3
Wait mechanic	0	0	0
Wait parts	4.6	<.1	.3
Change landings	4.8	<.1	.3
Other non-mechanical	193.2	1.1	13.5
Total: Scheduled Machine Hours (SMH)	1,433.4	8.0	100%

CPPA Mechanical Availability = 88%
CPPA Utilization = 74%
MNA (Mechanical Non-Availability) = 15.9 hours

TABLE 2. Production and Productivity
Based on 161 Shifts Worked

Study Production Totals			
Volume produced, cunits (m^3)	2,473		(7 003)
Pieces skidded		15,037	
Turns		2,116	
Study Averages			
Overall average piece size, ft^3 (m^3)	16.4		(0.47)
Volume/shift worked, cunits (m^3)	15.4		(43.5)
Pieces/shift worked		93.4	
Turns/shift worked		13.1	
Volume/turn, cunits (m^3)	1.2		(3.3)
Pieces/turn		7.1	
Productivity			
Volume/PMH, cunits (m^3)	2.3		(6.6)
Trees/PMH		14.2	

TABLE 3. Detailed Time Results by Season
Turn Averages and Descriptive Factors

		Summer		Winter	
TIME SUMMARY		minutes	%	minutes	%
Loading Phase	Manoeuvre Hookup Prebunch Move during load	.37 6.24 0 .16	26.9	.41 6.73 0 .23	33.5
Unloading Phase	Unhook Limb, top Align butts Decking Clean landing	1.73 .20 .64 1.85 .78	20.7	1.85 .40 .99 .84 .60	21.2
TERMINAL TIME (load + unload)		11.97	47.6	12.05	54.7
Travel Phase	Empty Loaded Winching	4.28 4.76 .21	36.8	4.10 5.11 .18	42.6
TURN TIME (terminal + travel)		21.22	84.3	21.44	97.3
Delay Time		3.94	15.7	.59	2.7
TOTAL TURN TIME		25.16	100%	22.03	100%
STAND AND OPERATING FACTORS					
Distance, ft (m)	Empty Loaded	814 (248) 865 (264)		1,100 (335) 1,160 (354)	
Slope - % Loaded, on trails - range - average Sidehill - range - average		 -26 to +4 -12 44 to 47 45		 -5 to -4 -4 38 to 51 45	
No. prebunch points No. loading points No. times load was winched		0 1.3 .8		0 1.6 .6	
PRODUCTION AND PRODUCTIVITY					
Piece count per turn Turn volume, ft^3 (m^3) Piece volume, ft^3 (m^3)		6.0 120 (3.39) 20.0 (0.57)		8.7 143 (4.05) 16.4 (0.47)	
Potential Productivity	Cunits (m^3)/PMH Trees/PMH	2.9 (8.1) 14.3		3.9 (11.0) 23.7	
SAMPLE SIZE - no. of turns in study		28		21	

APPENDIX VII

Study Results for Machine No.7

Machine Statistics

Tractor make: International

Model: TD-8C

Year manufactured: 1972

Machine age at study completion: 6 years

Contractor Background

Current job: tractor operator

Age at end of study: 38 years

Previous logging experience: bulldozer operator; rubber-tired skidder operator; logging truck driver; loader operator; faller and bucker

Current employees: one tractor operator, two fallers

Study Information

Period covered: August 22, 1977 to March 16, 1978

Number of scheduled shifts: 139

Number of shifts worked (shifts with piece count): 121

TABLE 1. Shift Time Categories
Based on 139 Scheduled Shifts

	Total Hours	Average Hr/Shift	% of Scheduled Time
Productive Machine Hours (PMH)			
Skidding	709.7	5.1	64.0
Trailbuilding	6.5	<.1	.6
Other work	4.8	<.1	.4
Σ	721.0	5.2	65.0
Delays			
Repair	89.0	.6	8.0
Service	48.9	.4	4.4
Wait mechanic	3.4	<.1	.3
Wait parts	36.0	.3	3.2
Change landings	4.4	<.1	.4
Other non-mechanical	207.2	1.5	18.7
Total: Scheduled Machine Hours (SMH)	1,109.9	8.0	100%

CPPA Mechanical Availability = 84%
CPPA Utilization = 65%
MNA (Mechanical Non-Availability) = 19.1 hours

TABLE 2. Production and Productivity
Based on 121 Shifts Worked

Study Production Totals			
Volume produced, cunits (m^3)	1,513		(4 284)
Pieces skidded		10,334	
Turns		1,369	
Study Averages			
Overall average piece size, ft^3 (m^3)	14.6		(0.41)
Volume/shift worked, cunits (m^3)	12.5		(35.4)
Pieces/shift worked		85.4	
Turns/shift worked		11.3	
Volume/turn, cunits (m^3)	1.1		(3.1)
Pieces/turn		7.5	
Productivity			
Volume/PMH, cunits (m^3)	2.1		(5.9)
Trees/PMH		14.3	

TABLE 3. Detailed Time Results by Season
Turn Averages and Descriptive Factors

		Summer	Winter	
TIME SUMMARY		No summer study	minutes	%
Loading Phase	Manoeuvre Hookup Prebunch Move during load		.46 7.24 0 .46	30.9
Unloading Phase	Unhook Limb, top Align butts Decking Clean landing		1.95 .34 1.24 1.97 2.12	28.9
TERMINAL TIME (load + unload)			15.78	59.8
Travel Phase	Empty Loaded Winching		4.18 3.75 .01	30.1
TURN TIME (terminal + travel)			23.72	90.0
Delay Time			2.65	10.0
TOTAL TURN TIME			26.37	100%
STAND AND OPERATING FACTORS				
Distance, ft (m)	Empty Loaded		894 (272) 899 (274)	
Slope - % Loaded, on trails - range - average Sidehill - range - average			 -12 to -7 -8 48 to 62 58	
No. prebunch points No. loading points No. times load was winched			0 1.9 <.1	
PRODUCTION AND PRODUCTIVITY				
Piece count per turn Turn volume, ft^3 (m^3) Piece volume, ft^3 (m^3)			11.7 130 (3.68) 11.1 (0.31)	
Potential Productivity	Cunits (m^3)/PMH Trees/PMH		3.0 (8.4) 26.6	
SAMPLE SIZE - no. of turns in study			19	

APPENDIX VIII

Study Forms

FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA

FERIC

SHIFT REPORT FORM

PROJECT 317: SMALL-TRACTOR SKIDDING

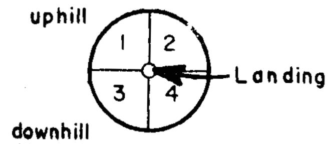
Identification

Date: ______________

Form completed by: ________________________

Block No: _______ Landing No: ______________

Quadrant No: ______________________________



Time Record

Start Shift Time ________ End Shift Time _________

Explain in more detail the delays that happened today. Identify both mechanical problems (repair, service, wait for mechanic or parts) and non-mechanical delays (machine stuck; visitors; no trees felled; lunch; coffee).

____

____

____

____

____

____

Scheduled machine operating hours: __________ hr (include coffee breaks, but do not include lunch)

Operating Conditions and Factors

No. of pieces skidded ____________________ No. of turns ____________________

Piece size: ☐ full tree ☐ tree length ☐ log length

Species: ____________________ Many limbs? (yes or no) ______________

No. of chokers: ____________

Skidding directions: ☐ uphill ☐ downhill ☐ cross-slope

Skidding pattern: ☐ top skidding ☐ butt skidding

Temperature (°F at start of shift) ☐ below 0 ☐ 0-31 ☐ 32-79 ☐ 80 or over

Precipitation ☐ rain ☐ snow duration __________ hr

General Comments

Mention any points that have affected your production: for example - plugged landing; skid trail too steep; very rough topography. Also note here if you do not plan to work tomorrow, and why.

____

____

____

____

FERIC

SHIFT REPORT FORM
PROJECT 317: SMALL-TRACTOR SKIDDING
ROAD BUILDING

Identification

Form completed by:______________________________ Date:____________________

Sale or Block No.:______________________________ Landing No.:______________

Time Record Start Shift Time_____ End Shift Time_____

Explain in more detail the delays that happened today. Identify both mechanical problems (repair, service, wait for mechanic or parts) and non-mechanical delays (machine stuck; visitors; aid other machines; lunch; coffee).

____

____

____

____

Scheduled machine operating hours:_____hr (include coffee breaks, but not lunch)

Operating Conditions and Description

I. Work performed today: check sections which apply.

If working for small tractors, explain: no. of trails completed today; any work on landings; any other work just for small tractors.

If not working for small tractors, explain: why; what you were doing - for instance, grading other roads or landings or snow removal; travel time between blocks (mark on Servis Recorder chart); other work.

If skidding trees, complete boxes below that section.

☐ In areas for other small tractors ☐ Not in areas for small tractors Explanation______________________ ________________________________ ________________________________ ________________________________	☐ Skidding Trees No. pieces____ No. turns____ Skid direction: ☐ uphill ☐ downhill ☐ cross slope No. of chokers__________

II. Temperature (^{o}F at start of shift) ☐ below 0 ☐ 0-31 ☐ 32-79 ☐ 80 or over

Precipitation ☐ rain ☐ snow duration__________hr

General Comments

Mention any points that have affected your production: for example - heavy mud or rock; steep hillsides; very rough topography; blowdown. Also note here if you do not plan to work tomorrow, and why.

____

____

____

____

FERIC PROJECT 317 - INTERIOR SMALL TRACTOR SKIDDING

Page ___ of ___

Recorder: __________

Date: ________________

Operator: ____________

Machine No: ____________

TIME AND DISTANCE FORM

Block: ________

Landing: ________

End time: __________

Start time: __________

Elapsed time: __________

Turn	Travel Empty			Manoe	Load	Move in	Top or Butt	Travel Loaded				Unhook	Limb	Align	Deck	Clean	Delay	
No.	%	time	dist.	-uvre	time	load	Skid	%	time	dist.	winch intravel		top	butts		ldg.		

APPENDIX IX

Machine Time Calculations

Mechanical Non-Availability (MNA)

= Total Repair + Service hours, in hr/100 PMH

Canadian Pulp and Paper Association (Bérard et al., 1968)

Mechanical Availability

$$= \frac{\text{Scheduled Machine Hours - Mechanical Delays}}{\text{Scheduled Machine Hours}} \times 100\%$$

(Mechanical Delays include Repair, Service, Wait Parts and Wait Mechanic)

Machine Utilization

$$= \frac{\text{Productive Machine Hours}}{\text{Scheduled Machine Hours}} \times 100\%$$

APPENDIX X

Machine Cost Calculations

A) Tractor

Machine price: \$70,000, July 1979 (range \$68,000 to \$72,000 depending on manufacturer and option packages) Cranbrook, B.C.

<u>Assumed values</u>

Depreciation period: 5 years
Resale value: 20% - \$14,000
Interest over depreciation period: \$29,900 - obtained from Vancouver banking institution July 1979. Conditions - \$70,000 principal, 5-year term; commercial loan regulations at 15% simple interest. (Interest charges will vary depending on specific arrangements made to repay the principal. Two other estimates that were obtained range from \$28,875 to \$31,115.)
Logging season: 180 days/year

<u>Calculations</u>		\$/day
Machine depreciation: $\dfrac{\$70{,}000 - \$14{,}000}{5 \text{ years} \times 180 \text{ days/year}}$	=	62.22
Interest: $\dfrac{\$29{,}900}{5 \text{ yr} \times 180 \text{ days/yr}}$	=	33.22
Insurance: $\dfrac{\$850/\text{yr}}{180 \text{ days}}$	=	4.72
Repair and maintenance: 80% of depreciation \$62.22 x .8	=	49.78
Operating supplies: 1 choker/wk @ \$8.40 = \$1.68/day 1 mainline/mth @ \$60.00 = 3.00 fuel: 20 gal/day x \$0.70/gal = 14.00 lube: ½ fuel cost = 7.00	=	25.68
Total daily cost	=	\$175.62

B) Pickup

Machine price: \$9,000, July 1979. 2-wheel drive pickup with heavy-duty, off-road option packages. Vancouver, B.C. \$500 mechanic's and maintenance tools

Assumed values

Depreciation period: 3 years
Resale value: 20% - \$1,800
Interest over depreciation period: \$2,092 - obtained from Vancouver banking institution July 1979. Conditions - \$9,500 principal, 3-year term; non-commercial loan regulations at 13.5% simple interest.
Logging season: 180 days/year

Calculations		\$/day
Depreciation: $\frac{\$9,500 - \$1,800}{3 \text{ years} \times 180 \text{ days/year}}$	=	14.26
Interest: $\frac{\$2,092}{3 \text{ yr} \times 180 \text{ days/yr}}$	=	3.87
Insurance: $\frac{\$500/\text{yr}}{180 \text{ days}}$	=	2.78
Repair and maintenance: 100% of machine price $\frac{\$9,000}{3 \text{ yr} \times 180 \text{ days/yr}}$	=	16.67
Operating supplies:		
fuel: $\frac{100 \text{ miles/day}}{10 \text{ miles/gal}} \times \$1.00/\text{gal}$ = \$10.00/day		
tires: 2 sets/yr @ \$250 each $\frac{\$500}{180 \text{ days}}$ = 2.78	=	12.78
Total daily cost	=	\$50.36