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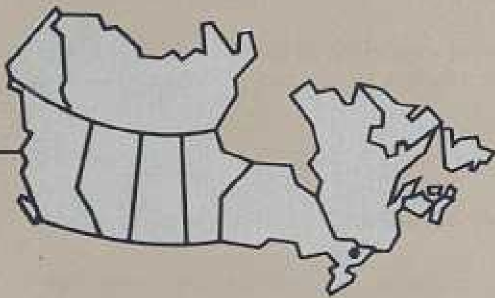
Canadian Forestry Service
Service canadien des forêts

Low-ground-pressure tires for skidders

B.J. Sauder



Information Report DPC-X-20
Research and Technical Services

THE CANADIAN FORESTRY SERVICE
GOVERNMENT OF CANADA

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The following are the main functions of the CFS:

1. Coordination of federal policies, for the promotion of better resource management and forest industry development.
2. Provision of scientific and technological leadership in forestry through research and development.
3. Provision and analysis of national and international statistics and information as a basis for policy formulation.
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Low-ground-pressure tires for skidders

B.J. Sauder
MacMillan Bloedel Limited

Scientific authority
D.V. Myles
Canadian Forestry Service

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D.V. Myles
Canadian Forestry Service
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Cette publication est aussi disponible en français sous le titre *Pneus à basse pression pour débusqueurs.*

SUMMARY

This report, prepared under contract to the Canadian Forestry Service (CFS), presents the results of a one-year trial of a skidder equipped with high-flotation tires. Experience with high-flotation (HF) tires in eastern Canada has already demonstrated their benefits compared with conventional tires. The intent of this trial was to evaluate the feasibility of yarding coastal sites with skidders equipped with HF tires. A concurrent study funded by the British Columbia Ministry of Forests and the CFS evaluated the site impact of the HF skidder.

Initially the performance of one skidder, a John Deere 640 line skidder equipped with 66 x 43 - 25 tires, was to be evaluated. During the latter part of the trial Firestone Canada Inc. made two sets of tires (66 x 43 - 26 and 66 x 50 - 26) available for testing. The trial was then expanded to allow evaluation of the various tire designs, and the performance of a John Deere 540 line skidder.

The overall average production level of 71 m^3 per 8-hour shift for the trial was lower than expected. Production levels varied from 48 to 166 m^3 per 8-hour shift over the five test sites. A sustainable average shift production approaching 125 m^3 appears a realistic goal, with greater experience.

Analysis of the site impact caused by the HF-tired skidder indicated that, on an overall harvesting area basis and for the soil types studied (sands to silt loams), there was no statistically significant difference between soil bulk density levels before and after logging.

Further research is required to document the impact of HF tires on other soil types. Effective methods of post-logging treatment of skid roads also need development. Scheduling of operations, prelogging location of major skid roads, adequate supervision, and operator training should minimize the environmental impact.

The tires survived a full year of operation and experienced approximately 50% tread wear after 1100 hours. The tires are considered by many contractors to be a feasible alternative to conventional skidder tires and increase the applicability of skidder systems on coastal sites.

Key words

skidders
high-flotation tires
soil compaction
site effects
steep slope harvesting

RÉSUMÉ

Dans ce rapport, préparé à contrat pour le Service canadien des forêts (SCF), sont présentés les résultats de l'essai pendant un an d'un débusqueur muni de pneus à basse pression. Les avantages de ces pneus par rapport aux pneus ordinaires ont déjà été démontrés dans l'est du Canada. Le but de l'essai était d'évaluer la faisabilité d'utiliser des débusqueurs munis de tels pneus sur les terrains côtiers. Les effets sur le sol ont été évalués dans une étude parallèle cofinancée par le ministère des Forêts de la Colombie-Britannique et le SCF.

Au début, on devait évaluer un seul débusqueur, le John Deere 640, qui devait être équipé de pneus de dimensions 66 x 43 - 25. Toutefois, au moment où l'essai se trouvait dans sa dernière partie, Firestone Canada Inc. a offert deux trains de pneus (66 x 43 - 16 et 66 x 50 - 26) pour des essais. Il a donc été décidé d'élargir l'étude pour l'évaluation de ces pneus ainsi que du débusqueur John Deere 540.

La production moyenne globale pour l'essai , soit 71 m^3 par période de 8 heures de travail, est plus faible que prévue. La production a varié de 48 à 166 m^3 par période de 8 heures aux 5 emplacements d'essai. Avec une plus grande expérience, une production moyenne soutenue de près de 125 m^3 par période de travail semble un objectif réaliste.

L'analyse des effets sur le sol a indiqué, pour l'ensemble du territoire coupé et pour les types de sol étudiés (du sable au loam limoneux), aucune différence statistiquement significative entre les densités apparentes du sol avant et après l'exploitation.

Les effets des pneus à basse pression sur d'autres types de sol devront être étudiés. Il faudrait également mettre au point des méthodes efficaces pour le traitement des chemins de débusquage après l'exploitation. L'établissement d'un calendrier pour les opérations, la détermination de l'emplacement des principaux chemins de débusquage avant l'exploitation, une supervision appropriée et la formation des opérateurs devraient réduire au minimum les effets sur l'environnement.

Les pneus ont survécu à une année entière d'utilisation et après 1 100 heures montraient une usure de la bande de roulement d'approximativement 50 %. De nombreux entrepreneurs estiment que ces pneus peuvent remplacer les pneus dont sont pourvus habituellement les débusqueurs et qu'ils augmentent les possibilités des systèmes de débusquage sur les terrains côtiers.

Mots clés

débusqueurs
pneus à basse pression
tassement du sol
effets sur le sol
exploitation sur terrain fortement en pente

TABLE OF CONTENTS

Note

The exclusion of certain manufactured products or equipment does not necessarily imply disapproval, nor does the mention of other products necessarily imply endorsement by the Canadian Forestry Service.

in eastern Canada has identified several advantages (Mellgren and Heidersdorf 1984) over conventionally tired skidders, including:

- increased productivity
- reduced fuel consumption
- reduced ground disturbance
- reduced soil compaction
- improved operator comfort
- improved machine stability.

These results indicated that there was an opportunity to increase the coastal forest area suitable for skidder operation by using HF tires.

OBJECTIVES

This report presents the results of a one-year trial, funded by the Canadian Forestry Service (CFS) to determine whether an HF-tired skidder is a feasible alternative to cable systems for yarding coastal sites with slopes less than 35%.

Specific trial objectives included:

- to describe the technical and operating characteristics of a line skidder equipped with HF tires
- to record productivity under measured conditions
- to obtain production levels, mechanical availability, machine utilization, and causes of delay over the trial period
- to compare the logging performance of an HF-tired skidder with conventional cable systems.

Soil data were collected (Figure 2) as part of a study funded by the British Columbia Ministry of Forests and the CFS to determine the site impact of the HF-tired skidder.

Figure 2. Soil and site impact data were collected at three of the test sites.

Initially the performance of one skidder, a John Deere 640 line skidder (Figure 3) equipped with Goodyear 66 x 43 - 25[1] tires (168 x 109 - 64 cm) was to be evaluated. During the latter part of the trial Firestone Canada Inc. made two sets of tires available for testing, 66 x 43 - 26 and 66 x 50 - 26 (168 x 109 - 66 cm and 168 x 127 - 66 cm). The trials were then expanded to allow evaluation of the various tires.

Figure 3. HF tires were installed on a JD640 skidder equipped with winch and mainline.

PERFORMANCE EVALUATION

Test sites

The HF-tired skidder operated at five locations on eastern Vancouver Island (Figure 4; Table 1) from 1 September 1983 until 31 May 1984. Weather during the period (rain and snow) produced the most severe operating conditions to be expected in the area. The timber stands ranged from low-elevation alder (*Alnus rubra* Bong.) to high-elevation cypress [*Chamaecyparis nootkatensis* (D. Don) Spach] and hemlock [*Tsuga heterophylla* (Raf.) Sarg.]. Average piece sizes ranged from 0.69 to 2.2 m^3.

Method

Operational performance

Three levels of data collection were employed to evaluate the performance of the HF-tired skidder (Cottell et al. 1976; McMorland 1977; Powell 1978).

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[1]Three-number code identifies tire diameter in inches x tire width in inches - diameter of the bead opening in inches.

Detailed timing data – Measure and record:

- productive time elements of each work cycle (turn)
- delays
- number of pieces per turn
- sample log volumes
- terrain and skid road use

Shift level data – Record:

- delay times and categories (causes)
- scheduled machine operating hours

Figure 4. HF-tired skidder operated at five locations on eastern Vancouver Island.

Table 1. Site descriptions

Factor	Site				
	1	2	3	4	5
Topography	Flat terraces, one major side hill with slopes up to 40%	Undulating terrain, slopes reaching 35%	Flat	Flat	Undulating terrain, slopes reaching 35%
Timber type	Red alder/conifer	Cypress/hemlock	Douglas-fir	Cedar/hemlock	Hemlock/amabilis fir
(percent species mix)	(73/27)	(55/45)	(100)	(93/7)	(77/23)
Stand volume, m³/ha	150	560	350	400	753

- production (pieces/shift)
- operating conditions
- operator comments

Operational data – Record:

- stand species composition
- volume per hectare
- topography (e.g. slope, obstacles)
- soil characteristics

The detailed timing data were collected on site by a technician using standard stopwatch procedures. The work cycle was broken down into seven work elements. Shift level information was recorded daily by the machine operator on shift report forms (Appendix I).

Traction testing

To evaluate the traction efficiencies of various tires and the effect of varying tire inflation pressure, a test of pull versus tire slip was performed. A test track of 52.4 m (10 times the tire circumference) was marked out on a loosely compacted gravel parking area. The skidder was connected to a crawler tractor via a wire rope strap attached to a 222-kN capacity load cell (Figure 5). A digital readout was located in the crawler operator's cab; the load on the skidder was achieved by application of the crawler tractor's brakes. Load ranges of 19.75–30, 44-46, and 51–53 kN were applied. The tires were marked with a single radial line and each test was recorded on video tape. Tire revolutions were counted during slow-motion playback of the video tape. The HF tires were tested at 103 and 69 kPa, whereas the standard 23.1 - 26 (58 - 66 cm) tires were inflated to 152 kPa. Each combination of tire type, load, and tire inflation was tested three times with the skidder in second gear.

Figure 5. A load cell was used to measure and control the load applied to the skidder during traction tests.

Tires

During the trial, three sets of HF tires were tested (Table 2). The tires normally supplied with the JD640 line skidder are 23.1 - 26 inflated at 152 kPa. These standard tires were mounted only for the pull versus slip test and were not used during the logging trials. The major difference between the HF tires was their lug angles, 45° for Goodyear and 23° for Firestone.

Table 2. Low inflation pressures of high-flotation tires

Manufacturer	Tire Size, inches (cm)						Ply	Inflation Pressure		Lug	
	Dia		Width		Rim Dia			kPa	(psi)	Angle, °	Depth, cm
Goodyear	63	(160)	23.1	(59)	26	(66)	10	152	(22)	23	5.1
Goodyear	66	(168)	43	(109)	25	(64)	12	83	(12)	45	5.1
Firestone	66	(168)	43	(109)	26	(66)	10	83	(12)	23	5.1
Firestone	66	(168)	50	(127)	26	(66)	10	83	(12)	23	3.2

The HF tires operated at significantly lower inflation pressures than standard tires. If the effect of the tire wall is ignored, the contact pressure between the tire and ground must be equal to the tire pressure (Yoder and Witczak 1975). The HF tires reduce the ground loading by approximately 50%. The lower inflation pressure, increased tire width, and flexible sidewalls make these tires unique in their ability to produce a large footprint area (low ground loading), reduced rolling resistance, and softer ride. The ability of the HF tires to survive in west coast operating conditions (heavy slash, large stumps, exposed rock) is critical, however, to their acceptability.

With the 109-cm (43-inch) wide tires installed, total machine width was increased from 2.4 m to approximately 3.6 m. The wider stance improved machine stability on sidehills and reduced the machine's angular roll (Mellgren and Heidersdorf 1984).

All the HF tires tested were tubeless. Several modified rim designs were used to maintain the seal between the tire bead and the wheel rim. Firestone incorporated an inner ridge with a one-piece rim (Figure 6) to prevent separation of the tire and rim; Goodyear utilized a retainer outside ring (Figure 7) and a two-piece rim.

Four 109-cm-wide tires equipped with rims cost $15 000-$20 000 Canadian (1984 prices) depending on tire manufacturer and rim design.

Machine

The tires were mounted on a standard John Deere 640 line skidder. The machine was equipped with an 82-kW six-cylinder turbocharged diesel engine and weighed 9027 kg. No modifications to the standard machine were necessary to accommodate the wider tires, and full manufacturer's warranty applied.

At site 4 the contractor installed the HF tires on his 67.1-kW JD540 line skidder. The contractor did not modify his machine; however, John Deere recommends equipping the 540 model with 640-sized axles when using HF tires.

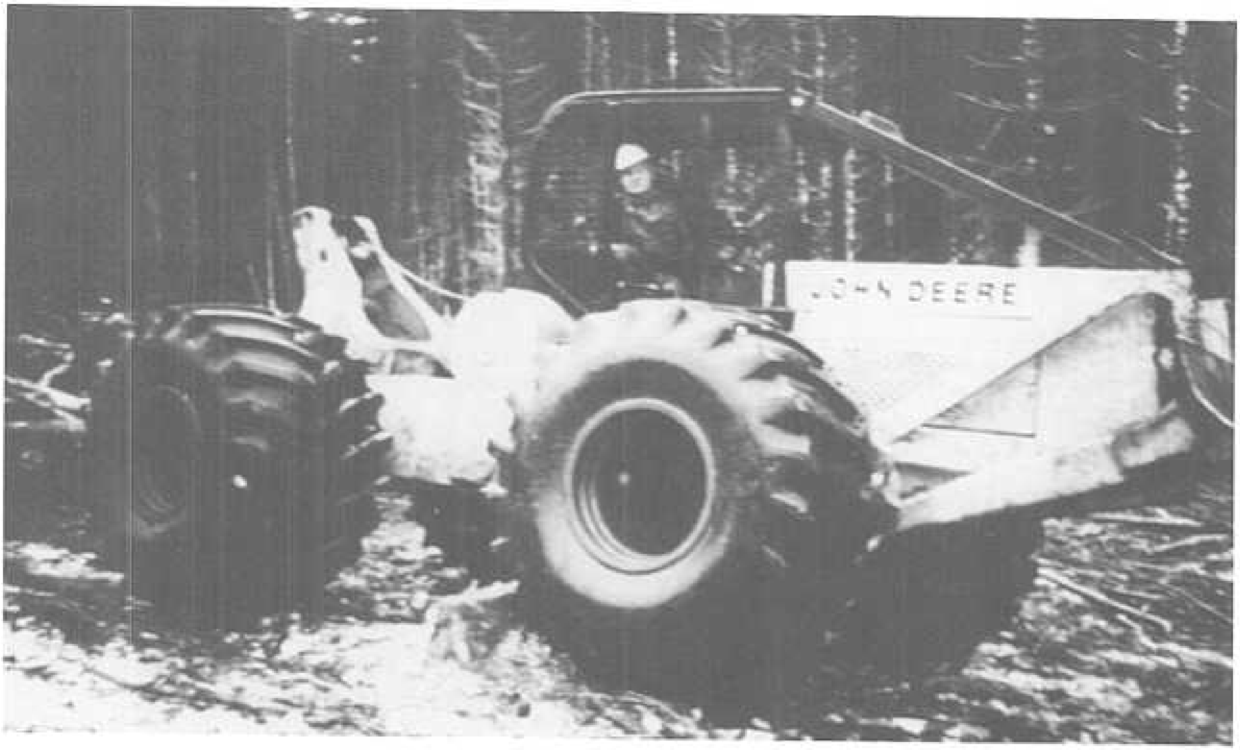

Figure 6. Firestone HF tires were mounted on a one-piece rim.

Figure 7. Goodyear HF tires were mounted on a two-piece rim with the continuous retainer outside ring.

Harvesting systems

All harvest areas were felled manually; in portions of sites 4 and 5 the "cut-and-skid" system was used, with trees felled one turn at a time (Table 3). At site 2 some large windfall material was removed with the skidder prior to clear-felling, to reduce the incidence of tree breakage.

Table 3. Harvesting system applied

Factor	Site				
	1	2	3	4	5
Felling	Manual felling, clear fell	Manual felling and bucking, clear fell after removal of windfalls	Manual felling and bucking, clear fell	Manual felling, clear fell and cut and skid	Manual felling, clear fell and cut and skid
Yarding	Full tree, limb and top at landing	Log length	Log length	Full tree, limb and top at landing	Full tree, limb and top at landing
Average yarding distance, m	240	175	60	175	100
Crew level	1 and 2	1 and 2	2	1 and 2	1 and 2
Tire type	Goodyear 66 x 43 - 25 Firestone 66 x 43 - 26	Goodyear 66 x 43 - 25	Firestone 66 x 43 - 26	Goodyear 66 x 43 - 25	Firestone 66 x 43 - 26
Machine	JD640	JD640	JD640	JD540	JD640

RESULTS

Production

For the five sites, mechanical availability of the skidder exceeded 80% (Table 4). Overall, tire problems accounted for a 2.5% loss (0.2 hour delay per 8-hour operating shift) in mechanical availability. The relatively high tire-related delays experienced in site 3 were a result of seating the tire bead of the newly installed Firestone tires; this is considered a nonrecurring delay. Wire rope, mechanical problems, and service time contributed to the remaining 13.5% of time lost. None of the mechanical problems was attributable to use of the HF tires.

Table 4. Shift level (machine availability was 84% during the trial; machine utilization was 67%)

Factor	Site					Total and Weighted Average
	1	2	3	4	5	
No. of shifts	55	17	6	9	24	111
Scheduled machine-hours (SMH) per shift	8	8	8	8	8	8
Productive machine-hours (PMH) per shift	5.0	6.8	5.5	5.0	5.5	5.4
Delay, hours per shift						
Repair						
Machine	1.6	0.7	0.2	0.6	0.1	1.0
Tires	-	-	1.1	0.6	0.1	0.2
Service	0.1	-	-	-	0.4	0.1
Nonmechanical	1.3	0.5	1.1	1.8	1.7	1.3
Machine availability, %*	78	92	83	84	91	84
Machine utilization, %*	62	85	69	62	69	67
Mechanical nonavailability, %**	34	10	25	22	13	24

*Berard, J.A.; Dibblee, D.H.W.; Horncastle, D.C. 1968. Standard definitions for machine availability and utilization. WSI No. 2428 (B-1), Can. Pulp Paper Assoc., Montreal, 2 p.

**Mechanical nonavailability: repair and service time required to achieve 100 productive machine hours.

Machine utilization averaged 67% during the trial. The low utilization level reflected a combination of weather-related delays and, in the case of sites 4 and 5, interaction delays between the fallers and the skidders.

Productivity exceeded 100 m³ per 8-hour shift at sites 3 and 4 (Table 5). The small average piece size and a maximum of five chokers installed on the skidder resulted in a low level of productivity in site 1.

Highest production (per shift) was achieved at site 3, which had the smallest total turn time (Table 6) and shortest average yarding distance. Trail building accounted for 14.5% of the total time per turn in site 4. The extremely swampy ground in this site required portions of the main skid road to be

Table 5. Productivity (average gross volume produced varied from 48 to 166 m³ per shift)*

Factor	Site					Total and Weighted Average
	1	2	3	4	5	
Machine	JD640	JD640	JD640	JD540	JD640	
Shifts recorded	55	17	6	9	24	111
Average no. of logs per 8-hr shift	69.1	38.6	166.0	66.0	54.9	66.3
Average piece size, m³	0.7	2.2	1.0	1.8	1.3	1.2
Average gross volume produced, m³ per 8-hr shift	48.4	84.9	166.0	118.8	71.4	71.0
Productivity per productive machine hour, m³/PMH	9.7	12.5	30.2	23.8	13.0	13.1
Productivity per scheduled machine hour, m³/SMH	6.0	10.6	20.7	14.9	8.9	8.9

*Based on shift level reports for the total study period.

Table 6. Productivity time*(Hookup time consumed the greatest proportion of productive time)**

Factor	Site					Total and Weighted Average
	1	2	3	4	5	
Turns recorded	461	66	216	198	418	1359
Travel empty	1.86	2.61	1.22	2.11	1.99	1.87
	(9.0)	(12.2)	(9.1)	(11.0)	(8.3)	(9.1)
Maneuver	0.07	0.04	0	0.01	0.01	0.03
	(0.3)	(0.2)	(0)	(0.1)	(0)	(0.1)
Hookup	5.40	7.73	3.01	3.98	5.65	5.00
	(25.8)	(36.3)	(22.6)	(20.7)	(23.5)	(24.4)
Move during loading	0.20	0.16	0.02	0.07	0	0.09
	(1.0)	(0.8)	(0.1)	(0.4)	(0)	(0.4)
Travel loaded	1.97	3.04	1.53	2.32	2.42	2.14
	(9.4)	(14.2)	(11.5)	(12.1)	(10.1)	(10.5)
Unload	1.06	0.88	1.23	0.69	0.72	0.92
	(5.0)	(4.1)	(9.2)	(3.6)	(3.0)	(4.5)
Deck	1.89	1.55	1.58	1.73	1.94	1.82
	(9.0)	(7.3)	(11.9)	(9.0)	(8.1)	(8.9)
Trail-build	0.67	1.68	0.58	2.79	2.45	1.56
	(3.2)	(7.9)	(4.4)	(14.5)	(10.2)	(7.6)
Delay	7.85	3.63	4.16	5.48	8.86	7.02
	(37.5)	(17.0)	(31.2)	(28.6)	(36.9)	(34.3)
Total time per turn	20.93	21.32	13.33	19.18	24.04	20.45
	(100)	(100)	(100)	(100)	(100)	(100)

*Measured in minutes; parentheses denote percentage.

**Based on detailed timing data.

corduroyed to allow skidder passage. Overall, hookup time was the largest single component of productive time. Delays, however, were the largest component of total turn time and represent an opportunity for significant improvement in productivity.

The key to maintaining machine productivity is the operator's ability to maximize payload per turn. Table 7 shows that for sites 2 and 4 the average gross volume per turn achieved was 5.4 m^3, or 1.74 times the average turn size for site 1. Mechanical bunching or increasing the number of chokers on the machine would increase payload in low-density, small-piece-sized timber. In deciduous stands such as site 1, the "cut-and-skid" system would be attractive because the problems of interlocking crowns after clear felling would be minimized.

Table 7. Gross volume per turn (varied from 3.1 to 5.4 m^3)*

Factor	Site					Total and Weighted Average
	1	2	3	4	5	
Turns recorded	461	66	216	198	418	1359
Average no. of logs per turn	4	2	5	3	3	3.6
Average gross vol. per turn, m^3	3.1	5.4	4.6	5.4	4.1	4.1
Average no. turns per shift	20	22	36	22	18	22
Average production per shift, m^3	62	119	166	119	74	93

*Based on sample scaling of skidded logs and performance data recorded during detailed timing of approximately 62 shifts.

Tire pull versus slip

In all cases the HF tires were more efficient (pulled harder and experienced less slippage) than the standard 23.1 - 26 skidder tires (Figure 8; Appendix II). The 23.1 - 26 tires spun out twice and only completed one turn at the 35.6 kN loading. The test results supported Mellgren's hypothesis that traction efficiency improves with lower inflation pressures (Mellgren and Heidersdorf 1984); all HF tires performed better at 69 than 103 pKa (Figure 9).

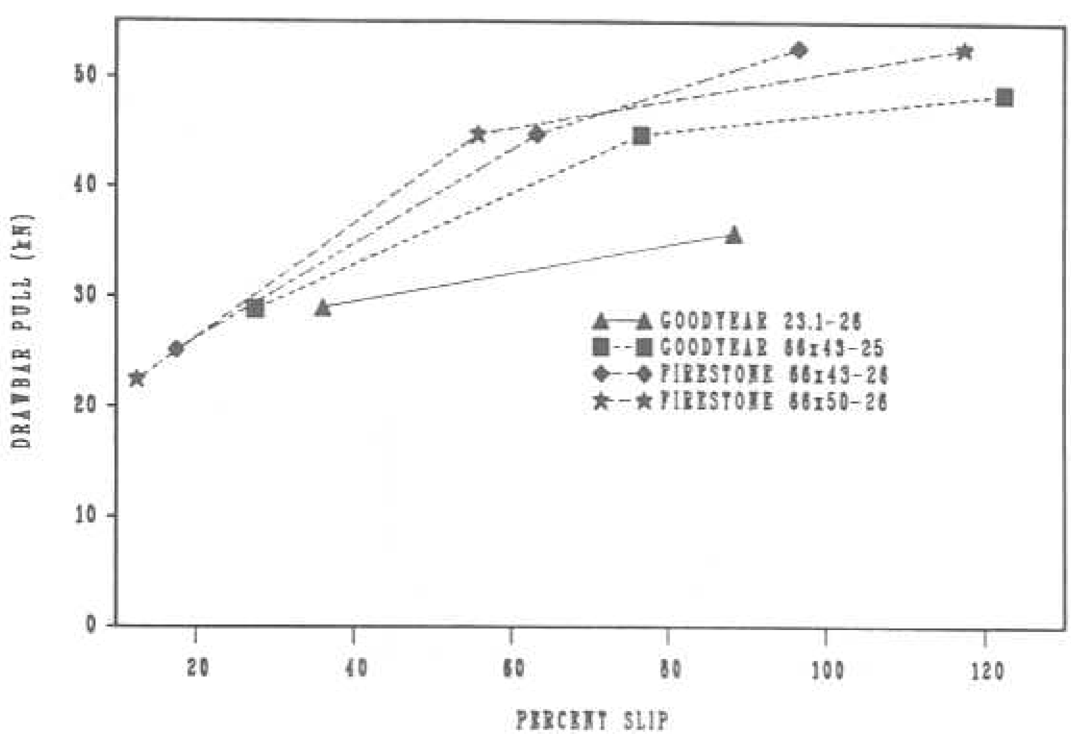

Figure 8. All HF tires (inflated to 103 kPa) were more efficient than standard tires.

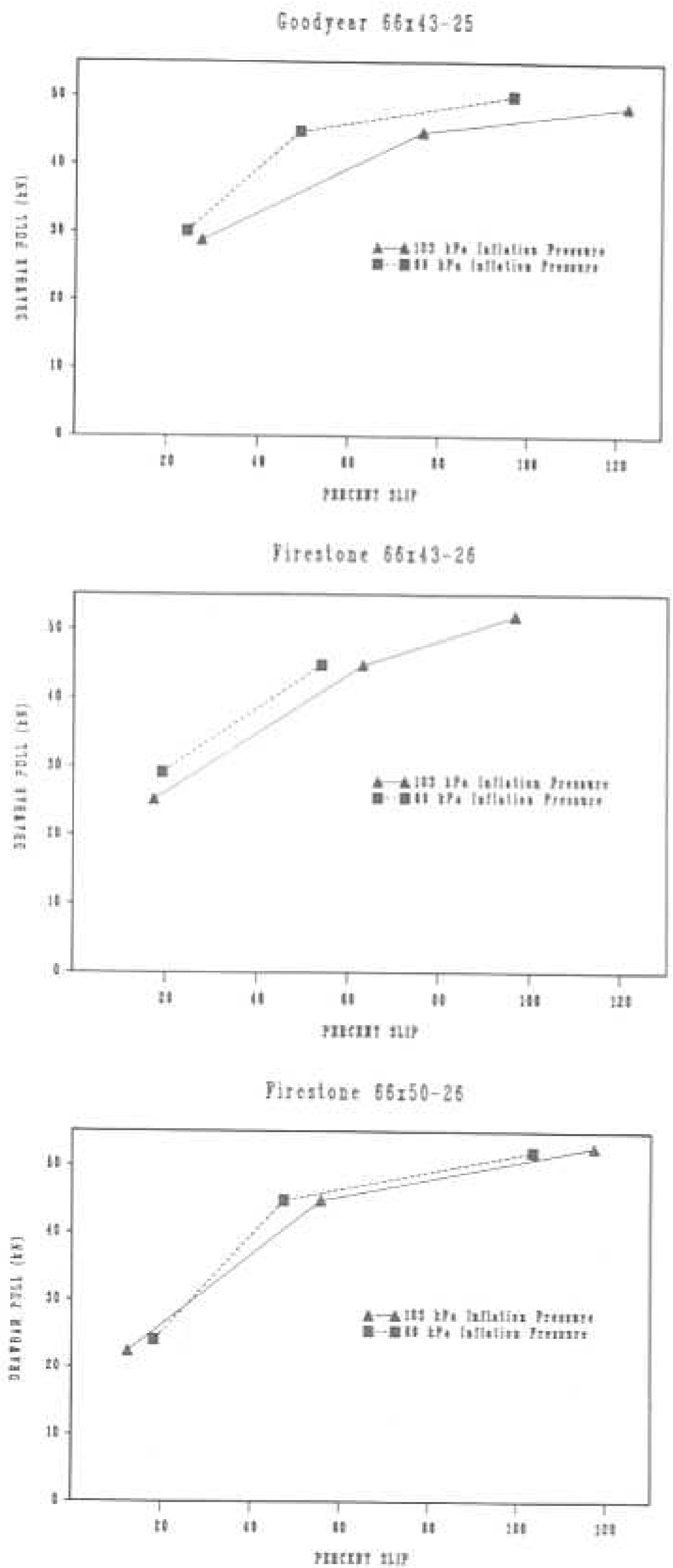

Figure 9. HF tires provided higher drawbar pull at lower inflation pressures.

Fuel consumption levels were not measured during the trial but, by inference, reduced slippage should result in more effective use of horsepower applied or fuel consumed.

The Firestone 66 x 50 - 26 tires experienced some bouncing during the pull tests (excessive bouncing preceded spinout). The bouncing may be a result of the shallow lug design of this tire. The Firestone 66 x 43 - 26 tires inflated at 69 and 103 kPa did not spin out, but stalled the machine. Maximum drawbar pull recorded just prior to stall was 62.4 and 65.0 kN for 69 and 103 kPa, respectively. For the test ground conditions the 23° lug angle of the Firestone tires appeared to give better traction. However, these tires were almost new, with little tread wear; they are not directly comparable with the Goodyear HF tires which had approximately 40% wear.

DISCUSSION

Operational results

The HF tires have survived a year of operation under west coast logging conditions and are considered to be a feasible alternative to conventional skidder tires. The Goodyear 66 x 43 - 25 tires originally installed for the trial operated for approximately 1100 hours and experienced 50% tread wear. Sidewalls were in good condition after the trial; retreading or relugging of these tires is considered feasible.[1]

The trials have demonstrated that a tire width of approximately 1 m is adequate for flotation and does not prevent the skidder from maneuvering between the stumps. The operators noted even greater flotation with the Firestone 66 x 50 - 26 tires, but thought that the marginal flotation improvement did not warrant the increased cost and operational difficulties presented by the wider tire.

Some contractors are considering HF tires of larger diameter (73 x 44 - 32; 185 x 112 - 81 cm) to improve ground clearance and flotation. These larger diameter tires may be necessary to accommodate the greater wheel loadings experienced on skidders equipped with larger cables and heavier chokers. Operators felt that the Firestone 23° lug angle gave better traction in slippery conditions (confirmed in pull tests) than the Goodyear's 45°, but the opportunity for site disturbance was increased. The newly available Goodyear 73 x 44 - 32 tires have a modified lug design with lug angles approaching 23°.

Operator comments on the HF tires included:

Advantages

Stability

- The machine could safely turn around on a 35% side slope.
- On steep slopes the larger wheel base improved stability while winching.

Softer ride

- On established skid trails and areas relatively free from debris, the wide axle beam resulted in a smooth ride.
- Lower ground pressure reduced compaction of soil around stumps; stumps did not protrude farther from the ground with time as they do with standard tires.
- Softer ride contributed to less operator fatigue.

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[1]MacKenzie, B. 1984. Personal correspondence. Contract Tire Ltd., Port McNeill, B.C.

Wet area traction

- The machine was able to skid through wet areas inaccessible to skidders equipped with conventional tires.
- Logging season could be extended into wet winter months.

Performance on slopes

- The machine operated on slopes measured up to 35%.
- On uphill grades the machine could push with greater force to clear debris (stumps were left in place wherever possible).

Disadvantages

Loss of traction

- HF tires prevented spinning out of tops and debris, which would have allowed the tires to make good ground contact; this hampered climbing ability (especially in reverse). Adverse-sloped skid trails had to be kept clear of debris.

Extra width

- Wider track resulted in increased tire contact with stumps, causing rougher ride and loss of traction when traveling off skid trails; skid trails had to be chosen carefully.

The lower inflation pressures and tubeless construction of the HF tires increases the possiblity of air leakage at the tire bead. Beads or side rings can be pushed away from the wheel rim if the skidder is run alongside log decks, or if debris is forced between the tire and rim. Clearing the tire bead area of debris should be considered a normal service activity. Tire sidewalls should incorporate a debris deflector at the bead. If a two-piece rim is used, the outside ring must be continuously retained. Neither the Goodyear nor Firestone tires required a "bead lock" type of rim. Tires were mounted dry without lubricant; no slippage between tire and rim occurred during the trial even with inflation pressures as low as 69 kPa.

The smoother ride produced by the HF tires was felt to reduce shock loading on mechanical components and whole body vibration experienced by the operator. Although no comparative data are available, the equipment supplier believed that the skidder equipped with HF tires experienced fewer of the maintenance problems normally associated with skidders using conventional tires.[1]

Expected production levels

Overall production levels for the trial were lower than expected, largely because half of the study shifts were spent in a deciduous stand with small trees. Experience with skidders in other regions indicates that significant productivity improvement should be expected as familiarity with the system increases.[2] A sustainable average production approaching 125 m^3 per 8-hour shift appears realistic. This would require machine utilization of 75% and productivity of 21 m^3 per productive machine-hour (a level exceeded in sites 3 and 4).

Comparison with grapple yarder

Grapple yarders equipped with mobile tailholds (bulldozers or backhoes equipped with short spars or masts to support tailblocks) are the current preferred logging equipment for the type of terrain to

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[1] Robinson, J. 1984. Personal correspondence. Coast Tractor and Equipment, Campbell River, B.C.

[2] Weinard, R.H. 1984. Personal correspondence. Northwood Pulp and Timber Ltd., Prince George, B.C.

which HF-tired skidders appear applicable (slopes up to 35%). To be a feasible alternative the HF-tired skidder must be able to yard logs at lower cost and achieve acceptable ground disturbance levels compared with this cable system. Although no long-term side-by-side comparison of HF skidder and grapple yarder occurred during the study, the following suggests the HF skidder's potential.

Costs

If the cost index of a grapple yarder equipped with a mobile tailhold and a two-man crew is assumed to be:

	Cost Index[1]
Capital	45
Operating	55
Total	100

Then the comparable cost index of an HF-tired skidder is:

	Cost Index	
	1-Man Crew	2-Man Crew
Capital	9	9
Operating	20	31
Total	29	40

Further, if the sustainable production level of the HF-tired skidder is assumed to be 45% that of a grapple yarder, then the comparative production cost index would be:

	Production Cost Index
Grapple yarder	100
HF skidder (1-man crew)	64
(2-man crew)	88

Figure 10 illustrates the sensitivity of yarding costs to changes in the base level of production. A grapple yarder operating at 100% of its base production level would achieve yarding costs of a two-man HF-tired skidder operation at 88% of its base production level.

Equipment scheduling and utilization are major concerns of a woods manager. The grapple yarder's high capital cost per hour represents the substantial investment required for purchase. Capital cost represents 45% of the total yarding cost for the grapple system, compared with 31% and 22% for the HF-tired skidder crewed by one or two persons respectively. The variable-cost proportion of the skidder system is an advantage when equipment must be replaced to maintain productivity during periods of capital scarcity, and when operational shutdowns are expected.

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[1]Cost index based on equipment costs developed using standard accounting formulas.

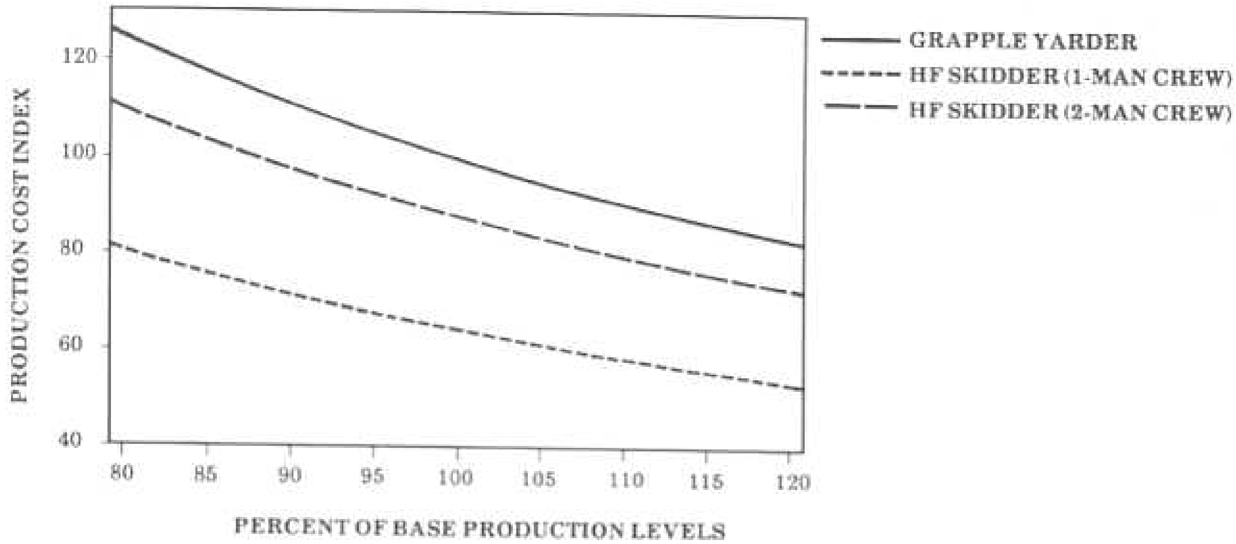
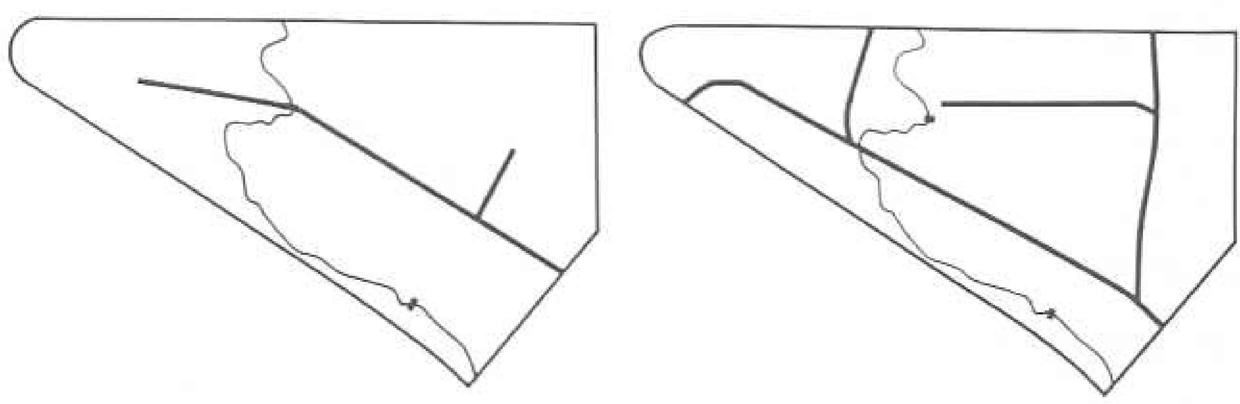


Figure 10. Sensitivity of production cost index to varying levels of production.

Development costs

Skidders, unlike cable systems, are not constrained by deflection requirements. Maintenance of efficient yarding distance and minimizing of environmental impact are the primary concerns of access. Figure 11 shows a hypothetical comparison of the road requirements of a flat site logged by a grapple yarder and by a skidder. Windrow piling of the wood by the grapple yarder requires that roads be extended to the site boundaries. The skidder requires 1184 m less road, a 51% saving in development cost. This saving does not include the elimination of backspar roads or the opportunity to construct lower-standard roads for the lighter-weight skidder.



HF skidder:
Total road length, 1128 m

Grapple yarder:
Total road length, 2312 m

Figure 11. For a flat site the HF skidder requires 1184 m less road than a grapple yarder.

Operators using HF-tired skidders may also be able to increase the timber volume accessible to existing road networks.[1] In areas with severely broken topography the grapple's maximum yarding distance may be reduced to less than 90 m, well below the machine's theoretical yarding distance capability (generally 240 m). The HF-tired skidder can yard areas that are isolated behind terrain breaks but are still within feasible skidding distance, as long as ground slope is not a limiting factor.

Fiber recovery

A skidder's production is relatively insensitive to changes in average piece size: chokers can be added or removed to maintain optimal turn size. Grapple yarders, however, are extremely sensitive to piece size because yarding generally proceeds one piece at a time. The lesser impact of piece size and lower operating costs for the skidder allow it to recover smaller logs that are marginally uneconomic for the grapple system. Mechanical bunching of small trees to produce larger turn sizes for the grapple yarder will improve this system's productivity. However, application of the same bunching techniques for the skidder will maintain the relative advantage of the skidder system.

The skidder's flexibility also contributes to higher fiber-volume recovery. At site 3, windfall material was removed prior to clear-felling, significantly reducing the breakage. Applying the cut-and-skid method also reduced breakage, and resulted in recovery of low-inventory-volume stands subject to degradation of value due to insect attack, as well as accumulating interest charges.

Applicability

It is feasible for HF skidders to operate successfully and at lower cost than grapple yarders on wet and moderately sloping sites. Acceptable productivity will be achieved with improved site layout, and provision of landing facilities adequate to accommodate that productivity. Experience indicates that cumulative advantages exist if more than one skidder is employed in the same general area (one skidder can retrieve another if a mechanical problem occurs in the woods; supervision and maintenance support can be more concentrated).

The use of HF tires may not be necessary during all seasons or for all sites. Operators should consider a set of both conventional and HF tires to achieve maximum operating flexibility. During periods of high rainfall, alternative areas should be available if high water table conditions exist. With planning and adequate supervision, year-round use of the skidder should be possible.

The highest production rates were achieved by a two-man company crew at site 3. The choice of crew levels and system configuration (cut and skid, or clearcut and skid) should be made after considering the production versus cost relationship. To achieve maximum efficiency, management must have the opportunity to vary crew levels depending on the site characteristics. Similarly, the decision to operate the units by company or contract crews should be made after considering labor availability, performance, and experience levels.

ENVIRONMENTAL IMPACT

As the terrain most conducive to skidder logging is generally the most productive coastal forest land, there is a recognized concern for the disturbance levels attributed to skidding. Soil compaction,

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[1]McDermid, G. 1984. Personal correspondence. Whonnock Industries Ltd., Vancouver, B.C.

causing reduced forest productivity and increased surface water flow on skid trails, has been identified as an impact of skidder logging (Dickerson 1976; Froehlich et al. 1981). However, one must evaluate these concerns carefully (Appendix III).

A study (Rollerson 1985), funded by the British Columbia Ministry of Forests and the CFS, to measure the ground compaction and mineral soil exposed during yarding with the HF-tired skidder was undertaken concurrently with the productivity study. The study report's summary states:

- A trend of increasing bulk density with increasing numbers of return trips with an HF skidder along skid trails is apparent; however, the increases are quite low and should not have a detrimental effect on seedling growth.

- Measurements of soil bulk density over the total site before and after logging show no significant increase in overall densities. In one case where the effect of the HF skidder is compared with that of a cable logging system, there is no difference between the two systems.

- Increasing HF skidder traffic along skid trails results in increasing exposure of mineral soil, especially on steeper slopes.

- Severe rutting can occur with excessive HF skidder traffic on medium textured soils under high soil moisture conditions, especially if surface slash and stumps are bladed away.

The study raises concerns regarding mineral soil exposure, rutting, and soil erosion. Further research is required, to determine the long-term impact of rutting, establish acceptable levels, and develop effective post-logging rehabilitation methods to alleviate the associated problems. The impact of HF skidder use on soil types not encountered during the trial should also be monitored. Attention to planning, including prelogging location of major skid trails, and scheduling, adequate supervision, operator training (Toews and Brownlee 1981), and provision of easily understandable reference material such as the FERIC skidding handbook (FERIC 1976) will keep site impact of skidding within acceptable limits.

CONCLUSIONS AND RECOMMENDATIONS

The trial of HF-tired skidders demonstrated that the tires can stand up to coastal logging conditions. High-flotation tires increase the forest area to which skidder systems are applicable. Savings in yarding and road development costs should result in reduced timber harvesting costs for these systems compared with grapple yarder systems.

Labor and management problems such as the setting of crew levels, the choice of company or contractor crews, and balancing of equipment utilization must be resolved before widespread use of HF-tired skidders is realized.

Although the HF tires generate a softer ride, research is still needed to improve operator comfort. The HF tires were tested at 83 kPa; perhaps even lower tire inflation pressures (55 kPa) are possible to improve traction and operator comfort and reduce mechanical shock loading.

Environmental concerns cannot be ignored, nor should they be overstated. Efforts must be made to minimize the opportunity for catastrophic site degradation. A learn-as-we-go approach should be adopted on the part of both government regulators and equipment users. Research should continue to evaluate the impact of various skidder and tire design combinations on sites of different soils and slopes. This research could encourage development of rational operating and planning guidelines. Effective methods for post-logging treatment of skid roads should also be developed.

A successful movement toward increasing use of mobile logging systems by the coastal forest industry is one key to regaining competitiveness. The advent of HF tires will allow skidders to assume their role as a primary yarding system for the British Columbia coast.

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APPENDIX I

DEFINITIONS AND STUDY FORM

Definition of Skidding Turn Time Categories (for Detailed Studies)

Time Element	Begins	Ends
Travel empty	When skidder starts to travel empty from the log deck at the landing to the stump area.	When forward motion stops so that maneuver or loading can begin.
Maneuver	At the end of travel empty.	When loading activities start or manual setting of chokers starts
Hookup	At the end of maneuver.	When skidder starts to move with a load.
Move during hookup (= move time between hookup points)	At the end of loading.	When forward motion stops and hookup recommences.
Travel loaded	At end of loading when a full load has been accumulated.	When skidder stops at landing.
Unhook	At end of travel loaded.	When skidder starts moving again so that travel empty or deck may begin.
Deck	At end of unhook.	When skidder proceeds past end of log deck so that travel empty may begin.
Trail building	When skidding activity is interrupted to clear trails.	When normal skidding activity recommences.
Delay	When production function is interrupted.	When the production function recommences.

General term	Definition
Turn	The total cycle of the skidder from stump area to landing and return to stump area.
Loading	The act of winching trees to the skidder until a full load has been accumulated.

SHIFT REPORT FORM

Division: ______________________ Date: ______________, 19___

I. Operator: ______________________

Landing No. ______________________ Total Pieces Skidded: ______________

Number of Turns: ______________________ Volume Skidded: ______ m^3 ______ cunit

Average Travel Distance: ______ m ______ ft

Travel is Mainly: ______ X-Country ______ Skid Roads ______ Up Hill ______ Down Hill

Timber Felled by: ______ Power Saw ______ Feller Buncher. Average Trial Slope: ______ %

II. Start Shift Time: ______________________ Scheduled Machine Time: ______ hours (include coffee, but not lunch)

End Shift Time: ______________________

III. Record: (ignore times less than 10 minutes)

Mechanical Delay Times: Explain Cause of Delays:

a. Repair ______ hours ______ minutes ______________________

b. ______ hours ______ minutes ______________________

c. Service ______ hours ______ minutes ______________________

d. Other ______ hours ______ minutes ______________________

Nonmechanical Delay Time (enter only total time for each category, e.g. moving between landings, stuck, personnel, wait for parts/service, etc):

Time (hours)	Explanation	Time (hours)	Explanation

Comments: ____

____

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____

____

APPENDIX II

RESULTS OF PULL VERSUS SLIP TEST

Tire	Inflation Pressure kPa	Runs		Average of Achieved Runs		Comments
		Attempted	Achieved	Pull, kN	Slip, %*	
Goodyear 23.1 - 26	152	3	3	28.8	36.0	
		4	1	35.6	88.5	Spun out
Goodyear 66 x 43 - 25	103	3	3	28.7	27.5	
		3	3	44.5	76.7	
		2	2	48.3	122.5	
	69	3	3	30.0	24.2	
		3	3	44.5	49.2	
		2	2	49.9	96.2	
Firestone 66 x 43 - 26	103	3	3	24.9	17.5	
		3	3	44.5	63.3	
		5	3	51.7	96.7	Stalled machine Maximum pull recorded 62.4 kN
	69	3	3	29.0	19.2	
		3	3	44.5	54.2	
		4	0	–	–	Stalled machine Maximum pull recorded 65.0 kN
Firestone 66 x 50 - 26	103	4	4	22.3	12.5	
		4	3	44.5	55.8	Spun out
		3	2	52.5	117.5	Spun out
	69	3	3	23.9	18.3	
		3	3	44.5	47.5	
		3	2	51.7	103.7	Spun out

*Derivation of percent slip:

L = length of test track (52.68 m)
D = diameter of tire (m)
R_V = tire revolutions - unloaded = $L/D\pi$ e.g. 52.68 m/1.68 m x π = 10
R_L = tire revolutions - loaded

Slip (%) = $R_L / R_V \times 100$

APPENDIX III

ECONOMIC IMPACT OF SOIL COMPACTION RESULTING FROM SKIDDER USE

Example[1]

Assume that using a conventional rubber-tired skidder to skid a clearcut coastal stand would reduce harvesting costs by $3.50/m^3 compared to cable yarding systems (Wellburn 1975).

In the worst case, there could be a 40% loss in volume yield (over a rotation) for the trees growing on the 12% of the total logged area compacted by skidding (Power 1974; Rollerson 1985).

Established skid trails would be reused in subsequent harvesting of the area.

Net revenues are after 50% corporate tax stated in constant 1985 Canadian dollars; discount rate (net of inflation) is 4%.

Therefore:

Case 1 - Cable Yarding

Year	0	80
Volume removed	725	725
Net revenue, \$/m^3	13	13

Case 2 - Skidder

Year	0	80
Volume removed	725	690
Net revenue, \$/m^3	14.75	14.75

The net present worth (NPW) for each harvesting alternative is:

Case	NPW, $/ha	
1	9 834	Cable yarding
2	11 125	Skidder

The skidder operation results in a $1301.00/ha increase in NPW even when a generous yield loss due to compaction is considered.

This example does not take into account the spatial distribution of the crop trees in the stand. Trees could be planted on noncompacted soil, beside the skid trails, or between wheel ruts without disrupting standing densities. Silvicultural practices such as thinning to waste and spacing would tend to concentrate the growth on trees not affected by the skid trails. The benefit of established access paths for stand management is also not considered. It is important to avoid projecting measurements of skid trail compaction over the whole harvest area.

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[1]Sauder, B.J. 1984. Skidders using high flotation tires. Proc. COFE/IUFRO, Maine, 11-18 August 1984.