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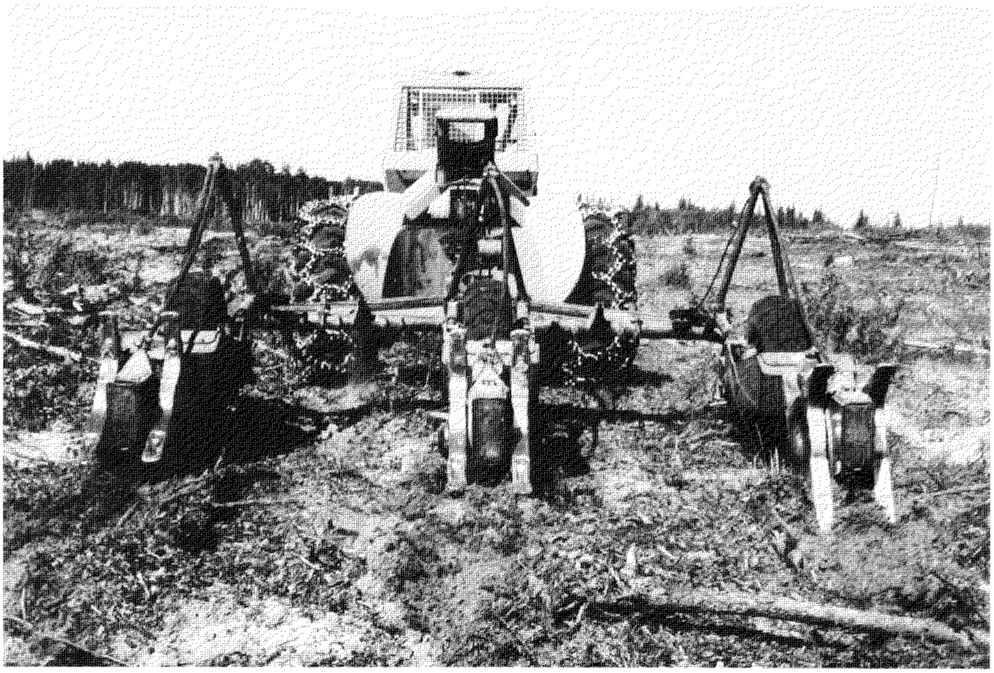
EVALUATION OF THE BRÄCKE BADGER PATCH SCARIFIER

M. Ryans, R.P.F.

May 1986



Technical Report

TR–65

TECHNICAL REPORT NO. TR-65

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Ce rapport technique est disponible en français

 ISSN 0318-7063

PREFACE

FERIC's evaluations are designed to assist future users in appraising the current status and prospective value of specific equipment. This report describes a field study of the technical and operating characteristics of the Bracke Badger patch scarifier. Biological studies are outside FERIC's mandate within the program of mechanization of silviculture. The effectiveness of a treatment is measured against the prescription provided by the co-operating forester, industry or government. Longer-term biological evaluations may be included in co-operative studies with other agencies.

The machine was the subject of both short-term and long-term studies. Short-term evaluations describe potential productivity under measured, but limited, operating and environmental conditions. Since both the range of conditions and the period of observation were limited, this study cannot be expected to predict performance under all circumstances. The results presented in this report should be considered only as a guide to realistic expectations of machine performance. The longer-term study gives information on long-term productivity, mechanical availability and causes of downtime.

Details of study procedures and analysis, plus results of limited interest, have been omitted for sake of brevity. Further details of the study will be supplied upon request.

All quantitative data throughout the report are given in "SI" (Système International d'Unités) units. A table for conversion to Imperial units is provided in Appendix D.

Grateful appreciation for help and cooperation during the study is extended to Roman Orynik of Prince Albert Pulpwood, Rahman Ali of Abitibi-Price Inc., and Herb Bax of KBM Forestry Consultants Inc.

Technical assistance was provided by FERIC employee E. Vajda.

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SUMMARY

Bräcke patch scarifiers of the 2-row Cultivator model were first built in Sweden in 1968 and have been in use in Canada since the early 70's. The Bräcke Badger incorporates most of the design features of the Cultivator but has greater versatility because of the ability to vary the number of rows and the spacing between rows.

The purpose of the study was to evaluate the Badger in the 3-row with 2-metre spacing configuration to determine any advantages or disadvantages the Badger may offer over the Cultivator, primarily in terms of production and cost per hectare. In other words, is the potential 50% production increase of a 3-row scarifier obtainable, and is this enough to offset the higher capital and operating costs of the larger prime mover that is required?

One study consisted of a 2-week short-term evaluation to assess the productivity and performance of the Badger under measured but limited cutover conditions. A shift-level study was made on operations in 1982 and 1983 to determine longer-term productivity, mechanical availability, and utilization. Both of these studies were done with the prototype model and performed on Prince Albert Pulpwood's limits north of Prince Albert, Saskatchewan. As well, a short study was made to examine the Badger in a 3-row configuration with 1-metre spacing on Domtar's Red Rock FMA limits north of Nipigon, Ontario. In 1984, a long-term evaluation of a new Badger was done at the request of Abitibi-Price at their White River operation.

The Badger demonstrated high productivity in the short-term study, averaging 2.2 and 1.8 hectares per Productive Machine Hour (PMH) for the two test sites. The C.P.P.A. terrain classification for the two sites was 1.1.1. and 1.2.1. and thus, the areas were generally easy to treat with few residuals. The high productivity can be attributed to a combination of skilled operator, fast average forward speed, concentric-circle treatment pattern and a 3-row machine.

The mineral soil area per patch was large, averaging 62 and 50 dm^2 and yielding a "gross" mineral soil exposure of 13 and 11% for the two sites, respectively. The rows of patches appeared as an almost continuous exposure of mineral soil because of the 15-tooth gear, light slash conditions and thin organic layer.

In the long-term studies, the mechanical availability of the Badger was 79% and 84% for the Prince Albert and White River studies. Mechanical availability of the Badger should be slightly lower than the Bräcke Cultivator because of the additional machine frame and more complex mounting system on the extended drawbar.

The main advantage of the Badger is its versatility. The scarifier can be matched with various silvicultural prescriptions and sites. The Badger can be used for subsequent planting, direct seeding and natural regeneration because of the ability to vary spacing and the number of rows. The scarifier can be further adapted to various sites and slash loadings, and to produce more or fewer patches by changing the gearing on the intermediate sprocket and by modifications to reduce slippage of the rubber tires.

The Badger will incur higher hourly costs primarily because of the capital cost of the larger prime mover. Companies, such as Prince Albert Pulpwood that already possess a larger prime mover, can take economic advantage of the additional power by using the Badger and increasing productivity over 2-row scarifiers. Costs on a per hectare basis can be lower, similar or higher with the Badger over the Bräcke Cultivator depending upon the productivity difference and the number of hours and uses that can be made with the prime movers.

A 3-row scarifier will offer a theoretical productivity increase of 50% over a 2-row model. Whether this can be achieved will depend primarily upon the forward speed. On a 3-row machine, the operator may perceive that he is more productive and have a tendency to slow down, thereby negating any potential productivity increase. With this in mind, it should be pointed out that travel speed is controlled not only by the drawbar pull requirements of the scarifier and the available power of the prime mover but also by factors such as ground conditions and slope. Moreover, the ground roughness is important because it affects the ride of the operator, who then adjusts the speed to an acceptable comfort level. What should not be overlooked, as it is of major importance, is that the quality of the microsite is affected by scarifying speed. Therefore, there are limits to the travel speed which can be accepted when one considers the objective of the optimum production of quality microsites. The Badger can offer a productivity increase while travelling at the optimum travel speed providing improved scarifier effectiveness and operator comfort compared to a 2-row machine.

INTRODUCTION

Bräcke patch scarifiers of the 2-row Cultivator model were first built in Sweden in 1968 and have been in use in Canada since the early 70's. The Bräcke Badger incorporates most of the design features of the Cultivator but has greater versatility because of the ability to vary the number of rows and the spacing between rows.

The purpose of the study was to evaluate the Badger in the 3-row with 2-metre spacing configuration to determine any advantages or disadvantages the Badger may offer over the Cultivator, primarily in terms of production and cost per hectare. In other words, is the potential 50% production increase of a 3-row scarifier obtainable, and is this enough to offset the higher capital and operating costs of the larger prime mover that is required?

One study consisted of a 2-week short-term evaluation to assess the productivity and performance of the Badger under measured but limited cutover conditions. A shift-level study was made on operations in 1982 and 1983 to determine longer-term productivty, mechanical availability, and utilization. Both of these studies were performed on Prince Albert Pulpwood's limits north of Prince Albert, Saskatchewan. As well, a short study was made to examine the Badger in a 3-row configuration with 1-metre spacing on Domtar's Red Rock FMA limits north of Nipigon, Ontario. In 1984, a long-term evaluation of a new Badger was done at the request of Abitibi-Price at their White River operation.

MACHINE DESCRIPTION

The Bräcke Badger is similar to the Bräcke Cultivator in both configuration and mode of operation. However, the Badger has a modified drawbar for the mounting of the scarifying machine frames. Trunnions, spaced at 0.93 metres across the drawbar, permit the following number of row and spacing combinations: 5 rows - 1 metre, 3 rows - 1 metre, 3 rows - 2 metre, 2 rows - 2 metre, 2 rows - 4 metre.

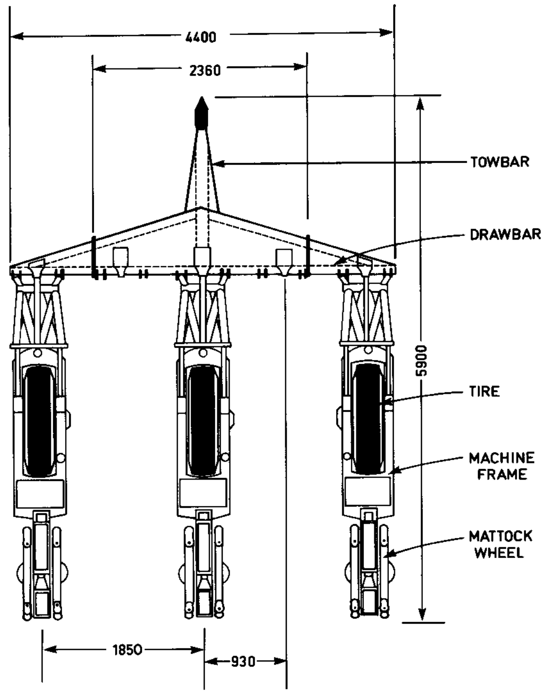


Figure 1. Schematic of the Bräcke Badger in 3 rows and 2-metre spacing configuration. Dimensions are in millimetres.

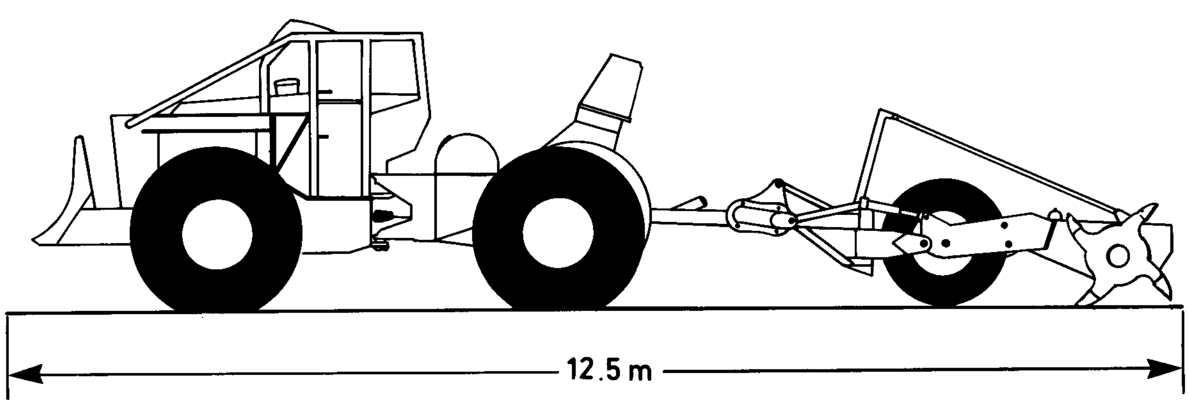


Figure 2. Bräcke Badger pulled by a Timberjack 550.

In the 3 rows - 1 metre, and 2 rows - 2 metre spacing combinations, the extension arms (see Figure 3) are removed from the drawbar to give a total width of 2.36 metres. The other combinations are mounted on the drawbar with the bolt-on wings giving a total width of 4.40 metres. Figures 1 and 2 show the Badger with 3 rows and a 2-metre spacing. The Badger is longer than the Cultivator owing to the more complex mounting system between the machine frames and drawbar. The weights of the Badger (3 rows - 2 metre) and Cultivator are 3640 kg and 3200 kg respectively.

Each machine frame consists of a rubber tire and mattock wheel scalping mechanism. A chain drive through an intermediate gearbox from the tire rotates the mattock wheel but at a slower rate to create the series of scarified patches. The four pairs of tines on the mattock wheel are equipped with replaceable scarifying teeth, as opposed to the welded claw and tooth system of older models of Bräcke Cultivators (Figure 3).

A B C D

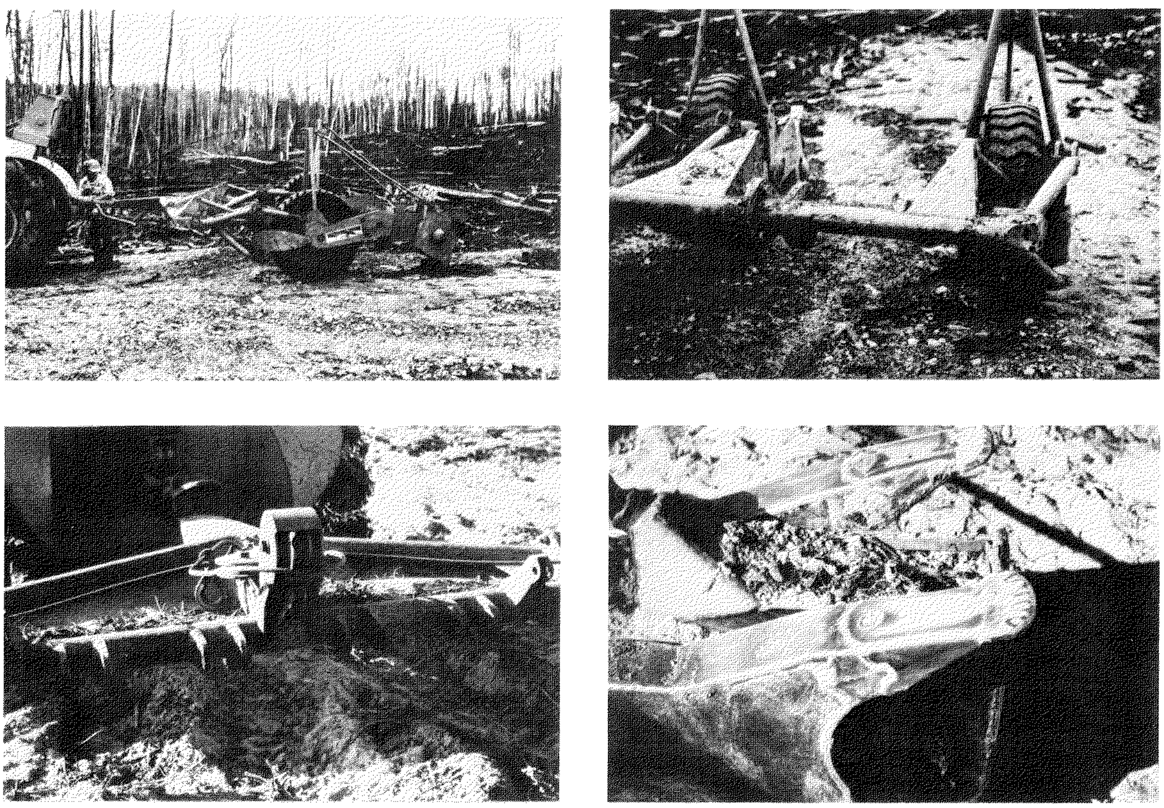


Figure 3. Main features of the Bräcke Badger:
- A. General view of Badger
- B. Bolt-on extension arms
- C. Mounting trunnions on the drawbar frame
- D. Replaceable teeth

The Badger is attached to the prime mover via a 'Bräcke' type quick disconnect hitch. This allows the Badger to be released from the prime mover by free-spooling the winch. The unit can then be winched in after the prime mover has climbed a steep slope or passed over a soft area.

The mattock wheels can be raised from the ground so that the Badger rides on its own wheels for transport between sites. The tow chain is pulled from the towbar and connected to a chain and pulley system to reach each liftbow. In contrast to the Cultivator, the liftbows are mounted on the machine frames rather than on part of the drawbar frame.

Pivot points that connect the major components of the Badger allow each part to move independently both horizontally and vertically. The mattock wheels can pivot over or slide sideways when passing an obstacle. The tire spins to take up the shock of striking an obstacle. As well, some of the shock is taken by the skidder's mainline rather than being transmitted directly to the hitch and prime mover.

The patch length and along-row spacing and thus, the subsequent number of patches per hectare can be changed to adapt to different site conditions. Four pairs of mattock tines are standard but a 5-pair mattock wheel can be used to decrease the patch length and increase the number of patches per hectare. Shifting the drive chain from 19 to 17 or 15 toothed gears along the intermediate axle results in a progressively longer patch length and lower number of patches per hectare. The lower gear reduction (15 teeth) is recommended by the manufacturer for heavier slash conditions.

At Prince Albert, the Bräcke Badger was pulled by a 140-kW Timberjack 550 cable skidder. The skidder was equipped with an enclosed cab and had studded chains on all of the 30.5 x 32 tires. A Timberjack 550 cable skidder with enclosed cab was also used at White River. Ring chains were installed on the front tires after 50 hours of operation because of excessive tire wear. Specifications on both the Badger and Timberjack 550 skidder can be found in Appendix A.

SHORT-TERM STUDY - PRINCE ALBERT

Background

Prince Albert Pulpwood owned a 140-kW Timberjack 550 skidder which they used to pull anchor chains in the winter to treat delicate, shallow-soiled sites. The experience of the company showed that the use of anchor chains in the summer produced natural regeneration of jack pine at too high a stocking, creating areas that would require future precommercial thinning. Patch scarification produced the quantity and quality of seedbed that resulted in a 60-65% stocking; a level that the company feels is optimal. The patch scarification had been done by a Bräcke Cultivator, used since 1973, and 2 Leno scarifiers, all pulled by modified Clark 667 grapple skidders. The Timberjack 550 was used on summer patch scarification but had a surplus of power for a 2-row Bräcke Cultivator.

The company evaluated the prototype Bräcke Badger in 1981 under a lease agreement, and was pleased with the performance of the machine in terms of production and the quality of the microsites produced with the new 15-tooth intermediate gear. The prototype was bought at the end of the trial. However, the Badger has been used in a 2-row configuration since the 1983 season because of the difficulty in preparing the original prototype for long-distance transport and the absence of large, relatively close cutovers that require scarification.

Site and Operation

The location of the short-term study was north of Prince Albert, Saskatchewan, and west of Lac La Ronge in Prince Albert Pulpwood's Camp 15 district. The area was flat to gently rolling with extensive jack pine stands on sandy soils. Aspen and white spruce appear in more upland lacustrine sites and black spruce can be found in poorly drained areas. The study area was within the Upper Churchill Section (B. 20) of the Boreal Forest Region (Rowe 1972).

The sites had been logged two years prior to scarification using a tree-length system. As a result, tops and branches were left by the stump but slash coverage and volume was light. Residual aspen were left standing in the cutover.

Method and Purpose of Treatment

The purpose of the scarification was to create a suitable seedbed for natural regeneration of jack pine. Although slash was light, the 15-tooth intermediate gear setting was used because it produces the number and size of patches per hectare that the company feels is best for natural regeneration. Spacing between passes was prescribed at 2 metres.

Figure 4. The Bräcke Badger working in Area 1 (left) and view of Area 2 prior to scarification. Note lack of debris on both sites.

Operation, Pattern and Sequence

The Badger and its prime mover were owned and operated by the company at the time of the short-term trial and it was their third season with the machine. The operator had a few months of experience with the scarifier. The operation was run on a one 8-hr shift per day and 5 days per week basis.

A concentric circle pattern was used because it minimizes the amount of turning between passes, and with natural regeneration, there is no need to keep parallel rows running from the road.

"Walking" between sites was done by simply raising the mattock wheels off the ground with the winch and driving the unit to the next area. Either a tractor and float or a self-loading straight truck (10-wheeler with Hiab crane) was used to transport the Bräcke over long distances between divisions or to major repair facilities (Figure 5).

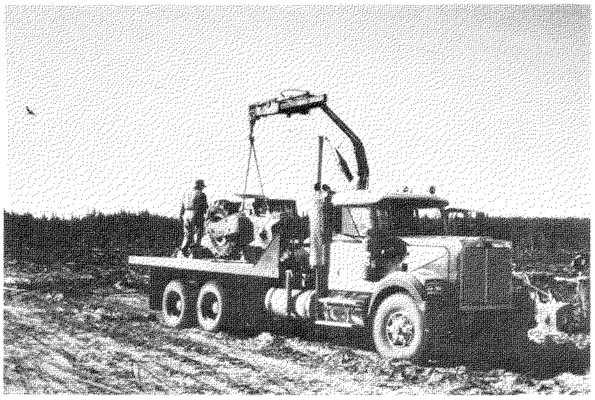


Figure 5. A machine frame is lifted onto a straight truck for transport to town for repairs.

ASSESSMENTS

The site conditions which may affect the passage of the machine and the subsequent quality of the scarification were assessed prior to the treatment. Circular plots (100 m^2) were laid out randomly in the various sites. Slash measurements were made using the line-intersect method as described by van Wagner (1968).

Continuous time studies were carried out to evaluate the productivity, performance and operational problems of the Badger. Fuel consumption was recorded during the study. Travel speeds were measured for 20-metre runs within the normal operation. A closed traverse was run around each scarified block to obtain an accurate figure of the scarified area.

Post-treatment measurements were done on 50-m^2 circular plots to evaluate the quality of scarification. The method used was similar to the Ontario Ministry of Natural Resources procedure as outlined in Anon. (1979). Measurements of mineral soil exposure and plantable spots included only those created by the scarifier. Although the purpose of the treatment was for natural regeneration, a survey of plantable spots was made. Each patch within the plot boundary was tallied on a plantable, marginally plantable, and non-plantable basis. The planting location chosen for each patch was on the upslope between the scalped patch and the inverted section. The dimensions of the mineral soil and inverted or mixed humus-mineral soil sections were measured for each patch in the plot.

RESULTS

Pre-Treatment Assessment

The results of the pre-treatment assessments are given in Tables 1 to 4.

Table 1. Residuals and brush assessments.

Location	Residuals (d.b.h. >10 cm)					Brush (d.b.h. <10 cm, height >1m)		
	Jack Pine (no/ha)	Trembling Aspen (no/ha)	Total Density (no/ha)	Avg. Diam. (cm)	Diam. Range (cm)	Density (no/ha)	Avg. Height (m)	Height Range (m)
Area 1	6	-	6	18	-	567	1.2	1.1-2.0
Area 2	13	125	138	19	12-25	238	2.4	1.1-3.0

Table 2. Stump assessment.

Location	Density (no/ha)	Avg. Height (cm)	Height Range (cm)	Avg. Diam. (cm)	Diam. Range (cm)	Percent of Density (%)	
Area 1	900	10	5-28	22	10-40	Jack Pine	92
						Black Spruce	8
Area 2	475	14	5-28	27	14-44	Jack Pine	61
						Black Spruce	39

Table 3. Slash assessment.

Location	Pieces per 20m of lineal tally		Avg. Diam. (cm)	Diam. Range (cm)	Volume (m^3/ha) by Species					Volume Range (m^3/ha)	Height (cm)	Coverage (%)
	<5 cm diam.	>5 cm diam.			Jack Pine	Black Spruce	Trembling Aspen	White Birch	Total			
Area 1	12	6	8.8	5-20	28	1	4	-	33	0-88	10	12
Area 2	17	6	8.1	5-20	11	3	13	1	28	0-50	12	12

Table 4. Slope, soil and terrain assessments.

Location	Slope to 5% (% of tally)	Avg. Slope (%)	Max. Slope (%)	Slope Class	Humus Depth (cm)	Soil Texture	Soil Depth (cm)	Soil Moisture	Ground Condition Class	Ground Roughness Class	CPPA Terrain Class	Stoniness (%)
Area 1	72	4.9	15	1	4.6	loamy sand	>30	dry	1	1	1.1.1	1%
Area 2	50	7.5	18	1(2)*	6.0	silty sand	>30	dry-fresh	2	1(2)*	1.2.1	10%

* Numbers in brackets indicate over 10% of sample.

Table 1 indicates that there were no residuals to be found on Area 1 except a few dead jack pine. On Area 2, the cutover was generally free of residuals except for a few clumps of aspen. Aspen, willow and alder brush were moderate in density on Area 1 and around one metre in height. High densities were found on only a couple of the plots. On Area 2, the brush was over 2 metres in height but relatively thin.

Stumps (Table 2) averaged a fairly high 900 per hectare on Area 1 but were cut low to the ground. The stumps on Area 2 were only slightly higher and larger in diameter but were at a much lower density.

The slash conditions on both areas were very light as indicated in Table 3. On a 20-m lineal tally basis, the slash ranged from 0 to 88 m^3/ha on Area 1 and from 0-50 m^3/ha on Area 2 for pieces over 5 cm in diameter. The slash was brittle and approximately two years old on both areas.

The two areas were gently rolling. Slopes up to 5% comprised 72% and 50% of Area 1 and Area 2 respectively. There was a maximum slope of 18% on Area 2 (Table 4).

The L-F-H layer was very thin on Area 1 and slightly thicker on Area 2. The dry, loamy sand gives a ground condition of 1 on Area 1. The fresh, silty sand of Area 2 yields a ground condition of 2 according to the Swedish terrain classification (Anon. 1969). Ground roughness was classed as 1 and 1(2) on Areas 1 and 2 respectively according to Anon. (1969), which can be described as somewhat uneven surface to very smooth. The soil on both sites was relatively stone free with some boulders found on Area 2. The C.P.P.A. terrain classification is therefore 1.1.1 for Area 1 and 1.2.1 for Area 2 (Mellgren 1980).

Time Studies

A summary of the continuous time studies is presented in Table 5. The summary presents a breakdown of elemental times within Productive Machine Hours (PMH) and the number of minutes per hectare for each time element. The time elements are defined in Appendix B.

Table 5. Summary of time elements.

TIME ELEMENT	OBSERVED PRODUCTIVE TIME			
	AREA 1		AREA 2	
	%	min/ha	%	min/ha
Effective Productive Time (Scarify only)	86.3	23.65	84.8	28.12
Manoeuvre (Turn)	5.5	1.51	3.0	1.00
Obstacle				
- Implement	0.3	0.09	0.1	0.03
- Prime Mover	-	-	1.0	0.34
Travel	2.5	0.68	2.5	0.82
Subtotal	94.6	25.93	91.4	30.31
Delay*	5.4	1.47	8.6	2.85
TOTAL	100	27.40	100	33.16

* Delay only includes those between 0.05 min. and 15 min. Delays less than 0.05 min. were included in the element in which they occurred, while those over 15 min. were not considered productive time and thus excluded from the sample.

There were no major differences between the elemental times of Areas 1 and 2. Effective Productive Time (EPT) comprised a high of 86% on Area 1 and 85% on Area 2. As none of the EPT was comprised of winching-in the implement, all of this element occurs when the implement is engaged in the soil and both the prime mover and implement are moving forward.

"Manoeuvre" time or turning between passes was very low because of the concentric circle pattern of operation.

A further breakdown of manoeuvre time is given in Table 6. All turns were of a broken pattern type when it became too tight to make a curve in the concentric circle near the end of treatment of a block.

Table 6. Breakdown of manoeuvre times.

	Area 1	Area 2
Turns per Hectare (no/ha)	2.0	1.5
Time per Turn (cmin)	76	66
Average Duration of Effective Productive Time Between Turns (cmin)	1184	1860

'Obstacle' times were a minor element in the total PMH (Table 5). 'Obstacle' time is the time between having to stop because of an obstruction until scarification resumes. With the Badger, this time includes the stuck time, moving forward while free-spooling the winch, and possible reversing after free-spooling. The obstacle time ends when the implement begins to be winched in. The winching time may be included if it is not producing effective scarification. The obstacle time is charged against the implement or prime mover depending upon the cause. Obstacle times in terms of frequency per hectare and total time per hectare were insignificant (Table 7).

Table 7. Summary of obstacle time.
('Delay' times of cleaning debris from implement are included to show total lost time because of site conditions).

CAUSE / LOCATION	IMPLEMENT				PRIME MOVER	
	STUMP	DEBRIS	CLEAN IMPLEMENT	TOTAL	SOFT GROUND	TOTAL
AREA 1						
no/ha	0.1	0.1	0.2	0.4	-	-
cmin/ha	4	5	11	20		
AREA 2						
no/ha	-	0.1	-	0.1	0.1	0.1
cmin/ha		3		3	34	34

"Delay" times that were less than 15 minutes and included in productive time comprised 5.4% and 8.6% of the total time on Areas 1 and 2 respectively (Table 5). The main difference between the two sites was because of greater personal delay time on Area 2 (see Table 8).

The productivity in terms of area treated per hour is presented in Table 9. On a Productive Machine Hour basis, the productivity was high on both areas. The productivity is higher on Area 1 on both a PMH and EPT basis. Expressing productivity on an EPT basis removes the effect of a difference in the time element breakdown within the PMH since only the time actually scarifying is used. The spacing between passes was prescribed at 2 metres and there was no major difference between that and the measured pass distances on the post-treatment survey. Therefore, the difference in productivity on a EPT basis reflects a difference in travel speed.

Table 8. Breakdown of delays.

DELAY	AREA 1		AREA 2	
	%	cmin/ha	%	cmin/ha
Personal	8.8	13	46.7	133
Supervision and Operator Reconnaissance	4.1	6	3.1	9
Prepare Implement for Scarification	11.6	17	7.7	22
Remove Debris from Implement	7.5	11	-	-
Warm-Up	50.3	74	26.7	76
Fuel	17.7	26	15.8	45
TOTAL	100	147	100	285

Table 9. Productivity summary.

	AREA 1	AREA 2
Total PMH (h)	6.17	5.12
Area (ha)	13.52	9.26
Productivity per PMH (ha/h)	2.19	1.81
Productivity per PMH minus delay time (ha/h)	2.31	1.98
Productivity per Effective Productive Time (ha/h)	2.54	2.13
Travel Speed (m/min)	72	62
Fuel Consumption (L/engine hour) (L/ha)	 25.1 11.9	 25.0 14.2

The travel speeds given in Table 9 are calculated from the following formula:

$$\text{Speed (m/min)} = \frac{10{,}000\ \text{m}^2/\text{ha}}{\text{working width (m)}} \; / \; \text{EPT (min/ha)}$$

The working width is calculated by adding the width of the machine (centre-to-centre between outside machine frames is 3.7 m) plus the average distance between passes from Table 12. Therefore, these speeds represent an average travel speed for the entire block.

On timed 20-metre sections, travel speeds ranged from a low of 53 m/min travelling on a 7% upgrade and through light residuals and heavy aspen brush on Area 2, to a high of 82 m/min on a level, smooth section. It should be noted that the manufacturer recommends an average forward travel speed of between 50-60 m/min to maintain a good quality microsite.

Fuel consumption was similar for the two areas, averaging 25 litres per engine hour.

Post-Treatment Assessment

The assessment of mineral soil exposure (MSE) is presented in Table 10. 'Net Mineral Soil Exposure' reflects the ability of the scarifier to expose mineral soil in the area it has passed over (i.e. within the confines of the row). 'Gross Mineral Soil Exposure' relates the exposed mineral soil to the total area. Therefore 'net' MSE is a measure of the effectiveness of the scarifier to handle a particular site while 'gross' MSE is a measure of both the effectiveness of the equipment and the operation. 'Net' MSE averaged 49% and 38% on Areas 1 and 2 respectively. 'Gross' MSE averaged 12.7% on Area 1 and 10.7% on Area 2. If the zone of inverted and/or mixed humus and mineral soil is included, the total disturbed area is 16.4% on Area 1 and 12.1% on Area 2.

Table 10. Mineral soil exposure assessment.

Location	"Net" MSE		"Gross" MSE		Inverted+ Mixed Zone		Total Disturbed: Gross MSE+Inverted+ Mixed Zone (%)
	Avg. (%)	Range (%)	Avg. (%)	Range (%)	Avg. (%)	Range (%)	
Area 1	49	19-80	12.7	7.8-20.9	3.7	0-8.1	16.4
Area 2	38	12-62	10.7	5.4-16.8	1.4	0-6.9	12.1

On Area 1, 98% of the patches had some mineral soil exposure while on Area 2 MSE occurred on 90% of the patches.

Table 11 gives average dimensions and area of mineral soil exposure per patch for the two areas. On Area 1, the area of mineral soil averaged 62.2 dm^2 while on Area 2 the area was slightly over 50 dm^2. The width of MSE was 50 cm for both areas. Thus, the area of mineral soil exposure per patch was larger on Area 1 because the patch was 22 cm longer. The maximum depth of the patch averaged 15 cm but occasionally it reached 20 cm.

The number of patches with a zone of inverted mineral soil on humus and/or a mix of humus and mineral soil was lower on Area 2. However, the average dimensions and area of this portion of the patch was similar on the two sites when it occurred.

Table 11. Patch* size assessment.

Location	MSE Area per Patch		MSE Dimensions/patch				Inverted+ Mixed Area (dm^2)	Inverted+Mixed Dimensions		Patches with Inverted or Mixed Zone (%)
			Length		Width					
	Avg. (dm^2)	Range (dm^2)	Avg. (cm)	Range (cm)	Avg. (cm)	Range (cm)		Length (cm)	Width (cm)	
Area 1	62.2	4-126	120	20-220	50	20-80	41.6	75	56	45
Area 2	50.3	4-102	98	20-190	50	20-90	40.3	77	52	14

* for patches with at least 100 cm^2 of mineral soil exposure.

Figure 6 shows relative frequency over patch area classes for the total number of measured patches on both areas. Figure 7 presents the percentage cumulative frequency for patch area. At the 50% mark, the patch area is approximately 63 dm^2 on Area 1 and 48 dm^2 on Area 2.

If a minimum area of 9 dm^2 (30 x 30 cm) is prescribed, such as in Sweden (Anon. 1978), then 4% and 9% are below this standard on Area's 1 and 2 respectively. At the preferred level of 36 dm^2 (60 x 60 cm), 85% of the patches are above this size on Area 1 and 72% on Area 2. These limits will differ from enterprise to enterprise but Figure 7 can be used to determine the number of acceptable patches as long as the limits are known and site conditions are similar.

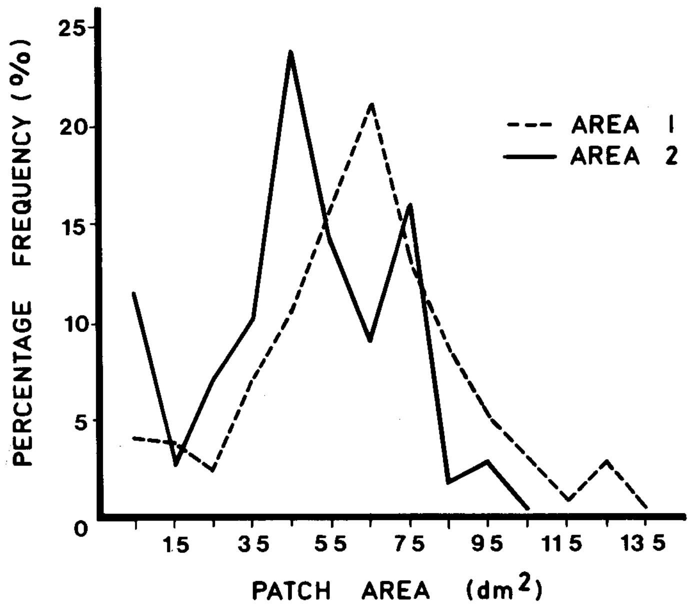


Figure 6. Percentage frequency over midpoint of patch area class.

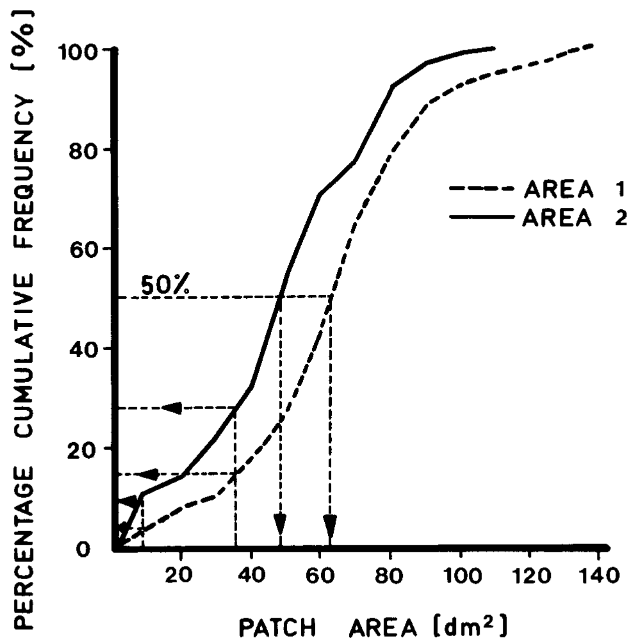


Figure 7. Ogive for the cumulative percent of patch area.

The assessment of plantable spots is given in Table 12. Eighty-eight percent of the patches were of the plantable class on Area 1 and 75% on Area 2. Marginally plantable spots and non-plantable spots were higher on Area 2.

Table 12. Patch assessment for planting.

Location	Plantable Spot Breakdown								Spacing Along Row (m)	Distance Between Passes (m)	Avg. Distance Between Rows (m)
	Plantable		Marginal		Non-Plantable		Total				
	no/ha	%	no/ha	%	no/ha	%	no/ha	%			
Area 1	1846	88	208	10	54	2	2108	100	2.62	2.16	1.95
Area 2	1590	75	370	18	150	7	2110	100	2.64	2.12	1.94

The intrinsic between-row spacing, set by the distance between machine frames is 1.85 metres. The distance between passes (extrinsic spacing) was 2.16 metres on Area 1. This produces an average distance between rows of 1.95 metres. The extrinsic spacing is dependent upon the operator and how well he follows the prescription. There are 2 intrinsic spaced rows to 1 extrinsic spaced row because of the 3-row machine.

On a flat, slash free landing, the distance between patches along a row was 2.8 metres. The actual distance between patches is less in the cutover because of slipping of the wheel. Figure 8 shows a view of Area 1 after scarification. The rows appear as an almost continuous exposure of mineral soil because of the 15-tooth gear, light slash conditions and thin organic layer.

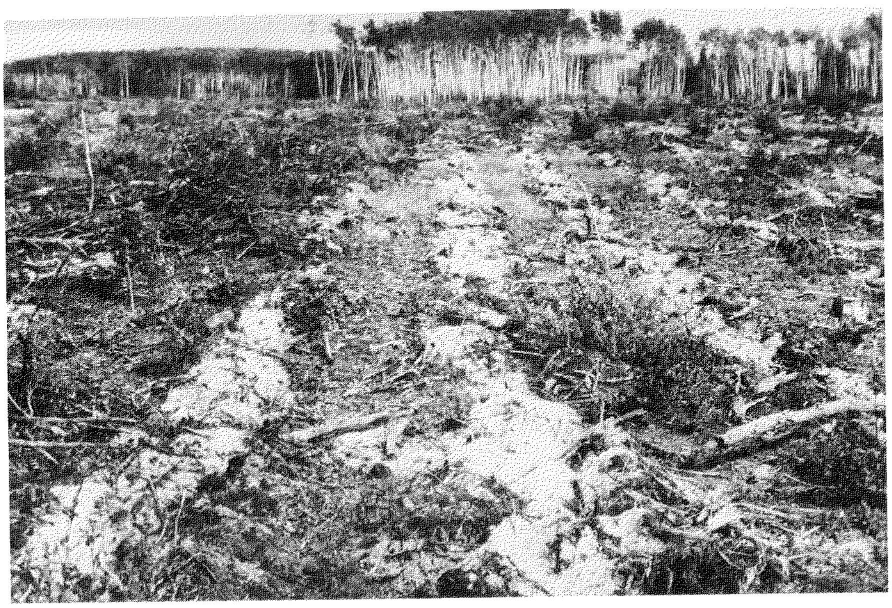


Figure 8. View of Area 1 after scarification.

SHIFT-LEVEL STUDIES

During periods from May 1982 to July 1983, FERIC monitored the Bräcke Badger at Prince Albert Pulpwood on a shift-level basis to gather information on long-term production and mechanical availability. At the request of Abitibi-Price at White River, Ontario, another long-term study was done in 1984.

Daily report forms were filled out by company personnel and accompanied by Servis Recorder charts at both locations. FERIC was responsible for the auditing, compilation and analysis of these data. The FERIC procedure for shift-level availability and productivity studies can be found in Folkema et al. (1981).

Prince Albert

The skidder and prototype Badger were the same units as previously described in the short-term study. Shutdowns of all woodland's operations because of summer vacations, poor market conditions and routine closures of the mill for maintenance resulted in a low number of reported days in both years.

Table 13 provides an operational summary of the results of the long-term study broken down into the 1982 and 1983 scarification seasons. Table 14 indicates some of the causes of non-productive time. Summaries are provided for the repair time and frequency under the various components of the prime mover and implement. Definitions of the time elements and machine formulas are given in Appendix B.

Mechanical Availability was poor in 1982 because of a long repair to strengthen the drawbar frame at the trunnions and extension arms. As well, there were a number of repairs to the prime mover. The Badger owned by Prince Albert Pulpwood was the original prototype unit and thus more modifications and repair time were to be expected. The manufacturer has since strengthened the drawbar frame on its production models. If the two long repairs to the drawbar frame and mattock wheel shaft are removed, the mechanical availability of the Badger itself is 92% for both years combined. Service on the Badger was a minor part of the total service time and is estimated at 10% of the total Active Service Time.

Mechanical Availability was much better in 1983. The skidder was almost free of repairs except for one to a tire chain. The Badger had a lower repair time as well. One long repair of the mattock wheel shaft assembly was caused by a broken keyway.

Non-productive operating time consisted primarily of "walking" between sites. On one occasion, the skidder was used to pull another skidder that was stuck. Miscellaneous delays were personal delays, talking to foreman, helping another skidder operator, or moving the skidder and Bräcke on a lowbed.

The difference in productivity between 1982 and 1983 could be interpreted as an anomaly but it is probably caused by a difference in the reporting of area. Occasionally small areas which have not been scarified are reported as treated.

Long-term fuel consumption was slightly higher than for the short-term study. A more difficult terrain may account for the higher consumption since the sites in the short-term trial were very easy to traverse. Fuel consumption on a per shift basis was not monitored in 1982. On days with a high proportion of walking time, the fuel consumption was as low as 16 L/engine hour.

The total days reported was somewhat limited during the two seasons. However, there is no indication that the mechanical availability of the Badger will be lower than for a Bräcke Cultivator.

White River

At Abitibi-Price's operation in White River, Ontario, the Bräcke Badger was a production model, used in the 3-row and 2-metre spacing configuration. Both the Timberjack 550 skidder and Badger were new at the start of the study.

The cutover conditions were more difficult than those at Prince Albert. Boulders and bedrock outcrops were numerous on most of the cutovers and heavy aspen residuals were common. The topography was rough to rugged. The high ground roughness class (2 and 3) and slopes necessitated frequent use of the quick-release hitch and winch. A combination of concentric circle and run-by-run patterns was used.

An operational summary of the White River study is given in Table 13 and the repair statistics are presented in Table 14. Utilization was only 59% because of numerous repairs and miscellaneous delays. A breakdown of the 124.5 hours of miscellaneous delays is as follows: 69% were personal delays and operator being sick or late, 11% supervision, 9% stuck, 5% rain delay or not enough time at the end of the day to begin a new site, 1% removing logs and mainline from mattock wheel and machine frame, 1% travel between sites and prepare for travel, and 4% in other various minor delays. If operator sick delays did not occur, the utilization would be increased to 64%.

Non-productive operating time consisted of 59% "walking" between sites and travel for repairs, 32% warm-up and 9% stuck with engine running.

Mechanical Availability was 82% for the prime mover, 84% for the Badger and 71% combined. As shown in Table 14, there were frequent repairs to the skidder and implement. Wear and damage to the belly pan inspection plates and differential housing by bedrock and boulders accounted for 25 hours of the repair time to the skidder. Tire chain slippage and breakage was the most frequent problem with the prime mover.

There were two areas of major repair to the Badger. The longest repair was caused by the bolts coming loose on the mattock wheel sprocket, which resulted in a bent mattock sprocket and shaft, broken drive chain and damaged chain stretcher. On another occasion, the same bolts came loose on a different machine frame causing the drive chain to snap. The other major repair involved welding cracks on the extention arms of the drawbar frame near the stabilizer bar attachment points. In 1985 (not monitored by FERIC), the company has used the machine in a 2-row configuration without the extention arms when in rough terrain because of reoccurring cracks on the extention arms.

Frequent short delays were required to repair the liftbows that became bent from falling residuals. As well, the frequent use of the quick-release hitch resulted in 7 repairs to the mainline. In 5 of these the mainline was replaced.

Despite the very difficult site conditions, the productivity averaged 1.6 ha/h. In the last half of the study (225 PMH and 449.6 ha) the productivity averaged 2.0 ha/h. The terrain was as difficult as in the first part of the year. However, the operator had more experience and the size of the blocks was larger. Fuel consumption averaged 16.8 L/PMH over the entire season.

Table 13. Shift level operational summaries.

PERIOD		Prince Albert 1982	Prince Albert 1983	White River 1984
Scheduling				
Days Reported	d	17	25	95
Scheduled Time	h	154.5	187.5	756.0
Out-of-Shift Time	h	-	-	35.0
Total Time	h	154.5	187.5	791.0
Shifts/Day	d	1	1	1
Machine				
Repair In-Shift	h	44.5	18.0	93.0
Repair Out-of-Shift	h	-	-	35.0
Service In-Shift	h	9.5	12.0	50.5
Service Out-of-Shift	h	-	-	-
Operations				
Non-Productive Operating Time	h	8.0	11.5	17.0
Wait Parts	h	-	-	22.5
Wait Mechanic	h	-	2.5	5.0
Miscellaneous Delays	h	15.5	6.0	124.5
Machine and Operations				
PMH In-Shift	h	77.0	137.5	443.5
PMH Out-of-Shift	h	-	-	-
CPPA Availability	%	65	83	77
Mechanical Availability	%	59	82	71
Utilization	%	50	73	59
Total Time Utilization	%	50	73	56
Production				
Area Treated (ha)		191.5*	211*	701.1
Productivity (ha/PMH)		3.36*	2.23*	1.62
Operators to Date		1	3	3
Fuel Consumption	L/PMH	NA	27.9	16.8

* These totals or averages do not correspond with the total PMH because some areas at Prince Albert were treated with both a Cultivator and Badger at the same time.

Table 14. Repair summaries.

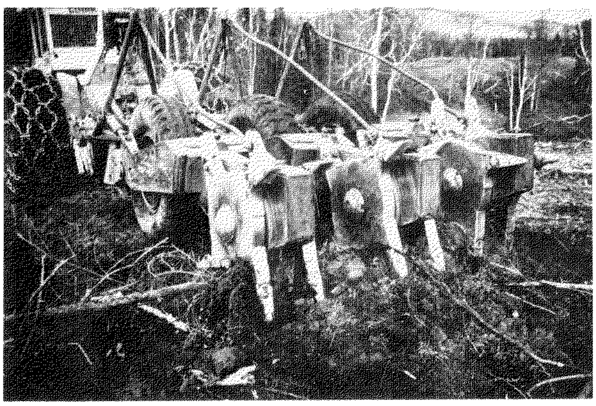
Reasons for Repair (Components)	Active Repair Time (h) Prince Albert		White River
	1982	1983	1984
TJ550 SKIDDER			
Power Plant			
Basic Engine			
Fuel System			3.5(2)
Cooling System			
Radiator & Fan	1.5(1)*		1.0(1)
Oil Filter			1.5(3)
Power Train			
Transmission Powershift			1.0(1)
Differential & Housing			4.5(1)
Drive Shafts			
Universal Joints	7.5(2)		4.0(1)
Planetaries			0.5(1)
Tires & Rims	4.5(1)		8.0(1)
Tire Chains		2.0(1)	11.0(8)
Controls			
Brake System	0.5(1)		
Hydraulics			
Pumps			2.5(2)
Valves			0.5(1)
Fittings			2.0(2)
Blade Cylinder			0.5(1)
Chassis/Supporting Structure			
Engine Cowling			1.0(1)
Belly Pan Insp. Plates			18.5(5)
Door Latch			0.5(1)
Steps			1.5(1)
Guards, Sheet Metal			0.5(1)
Brackets & Mounts			1.0(1)
TOTAL Prime Mover	14.0(5)	2.0(1)	63.5(35)

Reasons for Repair (Components)	Active Repair Time (h) Prince Albert		White River
	1982	1983	1984
BRÄCKE BADGER			
Cable	1.0(2)	2.0(1)	4.0(7)
Hitch			
Tow Chain & Connecting Link			1.5(2)
Tow Tube			
Drawbar Frame & Extention Arms	26.0(3)		10.0(4)
Liftbow		1.0(1)	
Liftstay	2.0(1)	3.0(3)	5.5(5)
Curtailer	1.5(2)		2.5(1)
Spindle Section			
Wheel Fork			
Rubber Wheel		1.5(1)	
Machine Frame			
Mattock Teeth			
Mattock Wheel			
Mattock Wheel Shaft		7.5(1)	
Driving Chain & Stretcher			2.5(4)
Gear Drive & Sprockets			38.0(3)
Bearings			
Seeder Compartment Lid			0.5(1)
Other (Not identified)		1.0(1)	
TOTAL Scarifier	30.5(8)	16.0(8)	65.0(27)

* Numbers in brackets denotes frequency.

NIPIGON OPERATION

A visit was made to Domtar's limits north of Nipigon, Ontario to view the Bräcke Badger in a 3-row and 1-metre spacing configuration. A 141-kW Clark 668 cable skidder was used to pull the scarifier. Both skidder and Badger were owned and operated by KBM Forestry Consultants (see Figure 9).



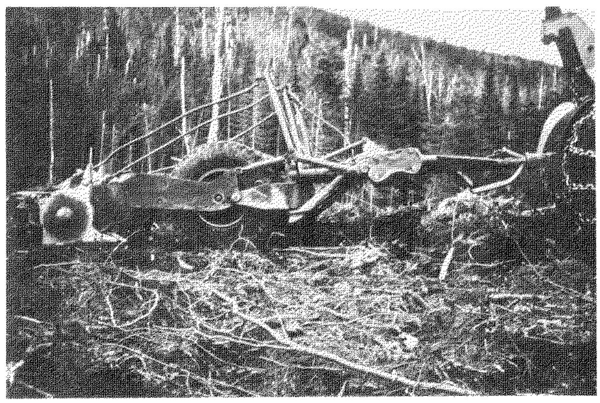


Figure 9. Clark 668 pulling the Bräcke Badger in a 3-row and 1-m spacing configuration. Note that extention arms are removed.

The objective of the treatment was to make the area suitable for subsequent planting of bare-root jack pine. Machine frames were spaced at 1 metre to insure a sufficient number and selection of microsites for the planters. Since the area was under a Forest Management Agreement, the company wanted to plant a high number of seedlings (3500/ha) to insure that there was adequate stocking at the assessment year.

The site was logged in the spring of the same year using feller bunchers and both the hardwood and softwood were skidded as full trees to roadside. The trees were chipped at roadside. As a result, the site was relatively free of slash, brush, and residual trees. The average number of stumps was 1520 per hectare. The site was a class 2.1.1 under the C.P.P.A. terrain classification system.

A couple of concentric circle passes were made around the 3-hectare site prior to a run-by-run pattern. Productivity was calculated at 0.92 hectares/PMH. Approximately 4200 patches per hectare were made, of which 94% were assessed as plantable. The average length of the mineral soil and inverted + mixed sections of a patch were 148 and 84 cm respectively. Average patch width was 48 cm. This resulted in a gross MSE of 28% and an additional 13% if the inverted section is included.

DISCUSSION

Effect of Site Conditions on the Scarifier

There was little effect of site obstacles on the scarifier or prime mover in the short-term trial at Prince Albert Pulpwood.

The slopes found on both sites did not slow down the scarifier to any great extent. As well, the operator did not have to release the scarifier with the winch on any of the slopes.

The stumps were small and did not pose any problems. The ground conditions were excellent for both scarifier mobility and exposure of mineral soil. Boulders found on Area 2 resulted in a smaller patch size but they were few in number and presented no major obstacle.

Residuals were almost nonexistant. On Area 2, the skidder pushed over the sparse aspen or left the dense clumps standing. The manoeuvrability in heavy residuals was therefore not assessed but may be lower than that of the Cultivator because of its greater width.

The slash loading was very light in spite of a tree-length logging system. Only the occasional windfall presented an impediment to the scarifier.

Productivity and Operational Considerations

The productivity of the Bräcke on a hectare per hour basis was excellent because of the easy site conditions, concentric circle pattern, ample power of the prime mover and a skilled operator.

There were very few stops caused by obstacles on either sites. There was a high average scarifying speed on both areas. However, Area 2 had a lower speed because of more residuals, a higher ground roughness and a lower ground condition class. Gradeability should be similar to the Cultivator because of the quick-disconnect hitch.

The concentric circle pattern meant that there was a low percent of productive time in manoeuvres. Few samples of turn-around times were taken, but the average time per turn was low during the trial. In a run-by-run pattern or in small, irregular blocks, the Badger may be less manoeuvrable because of the greater width and length but the quick disconnect hitch helps to reduce the time taken during such turns.

Although the skill of the operator is not as important on concentric pattern operations and in large, easy blocks, the operator demonstrated good intuition and ability to drive a skidder on a scarification operation.

The Badger demonstrated that it was as easy to "walk" between blocks as the Bräcke Cultivator because of the ability to raise the mattock wheels and ride on its own wheels. The extra width of the 3-row Badger is somewhat of a problem for long distance transport. The extra extension arms must be removed before being carried on a float. To ready the Badger for long distance transport when set at the 2-m spacing, the outside machine frames are pushed with the skidder blade back into the 1-m spacing. The extention arms are then unbolted. Therefore, travel between sites will be more expensive because of the extra time to dismantle the machine unless the Badger can be "walked" in the 2-m spacing.

Effectiveness of Scarification

The Bräcke Badger produces adequate type and number of microsites for natural regeneration of jack pine on Prince Albert Pulpwood's limits according to Smith (1981). The combination of low gear reduction (15-tooth sprocket) and replaceable teeth produced a consistantly long patch with a large area of mineral soil exposure under the easy site conditions in the study. As a result, there was a higher gross mineral soil exposure produced in comparison with other reported figures on Bräcke Cultivators (Armson 1978, Smith *et al*. 1984). The manufacturer claims that the low gear reduction and more aggressive, replaceable teeth provide better slash penetration. This claim was untested owing to the light slash conditions in the study area.

In terms of plantable spots, there were less than 2000 per hectare of an acceptable quality in spite of a high percentage of plantable to non-plantable patches. The main reason for not achieving a large number of planting sites lies in the low gear reduction. The along-row spacing averaged over 2.6 metres and on flat ground with no obstacles the distance is up to 2.8 metres. An unacceptable, between-pass distance of 0.9 metres is required to meet 2500 plantable spots/ha with 2.6 metres along-row spacing at 100% effectiveness (i.e. 100% of the patches are plantable). Therefore, when site preparing for planting with a Badger, the 17- or 19-tooth gear setting should be used if a 2 m x 2 m spacing is to be obtained (2500 plantable spots/ha). An alternative method is a 1-metre setting on the Badger and the use of a 15-tooth gear for better patch quality, such as in the Nipigon study.

Table 15 compares the effect of the Bräcke Badger sprocket settings with the number of patches produced from other studies. This table is presented as an indication of the effect of the sprocket. It does not give the range of patch densities that may be expected because of the limited range of site conditions.

Table 15. Number of Patches per Hectare with the Badger at Two Locations with Various Intermediate Gear Setting.

	Sprocket Setting		
Location	15	17	19
A[1] 2-metre spacing	2190	-	2772
B[2] 1-metre spacing (plantable)	4272 (2982)	4423 (2831)	-

[1] Source: Internal memo, Prince Albert Pulpwood, 1981.

[2] Source: KBM (1982).

On Prince Albert's limits (Location A), the company found that the 19-tooth sprocket produced a larger number of patches in medium slash coverage, and moderately fine to moderately coarse soils under moist to wet conditions. An assessment of plantable spots was not made since the treatment was for natural regeneration. The gross mineral soil exposure was 8.6% with the 19-toothed sprocket and 7.1% with the 15-tooth. However, the percent of the ground surface suitable for germination (including duff disturbance) was 20% and 21% with the 19- and 15-toothed sprockets respectively.

At location B, near Nipigon, Ontario, a 1-metre spacing was used and the 15- and 17-tooth sprockets were compared under heavy slash conditions. There was a low percentage of useable microsites on both settings but the percent was higher with the 15-tooth sprocket, resulting in a higher number of useable patches per hectare.

In general, as the gear setting is increased (15 to 17 to 19), there is a greater number of patches per hectare produced but at a loss of patch size. However, the percent of plantable patches may be reduced since a lower drag time reduces the chance of penetrating the debris. Therefore, increasing the number of teeth on the intermediate gear may not necessarily increase the actual number of plantable spots especially when slash conditions become more difficult. A lower gear setting increases the distance between patches along the row. It also produces a larger patch which increases the distance from the seedling to the surrounding competition.

An increased patch length also can be achieved by adding weight to the tires, choosing a more aggressive tire tread, and by reducing travel speed. These methods reduce the slippage of the tire and help reduce bouncing of the scarifier.

Table 16 can be used as an aid to determine the prescribed distance between passes to achieve a desired density. A number of inputs are required before using the table:

1. the required number of plantable patches per hectare.

2. minimum and maximum allowable spacing (e.g. ± 0.5 m).

3. prescription of a plantable patch for local sites in terms of:

   - minimum MSE area and/or mixed humus-mineral soil area per patch.
   - acceptable patch profiles.

4. surveys or practical experience on the percent plantable patches in terms of total produced per hectare for each gear setting on local sites.

5. average along-row spacing between patches for each gear setting on local sites.

For example, it is known that 80% of the patches produced are plantable on a particular site and that the along-row spacing averages 2.2 metres with the 17-tooth gear setting. The planting prescription calls for 2 x 2 metre spacing but a ± 0.5 m deviation is acceptable. Two thousand plantable patches are required. At the 80% plantable rate, this requires a total of 2500 patches to be produced. Going down the 2500 column until the along-row spacing of 2.2 m is met indicates a required distance of 1.8 metres between passes. Note that every third row will have a 1.8-m spacing, the other two rows have an intrinsic spacing of 1.85 metres.

Table 16. Required distance between passes for a given patch density and along-row spacing.

Range for Intermediate Gear Setting	Along Row Spacing (m)	PATCHES PER HECTARE (no/ha) 1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200
	1.6	6.2	5.7	5.2	4.8	4.5	4.0	3.8	3.5	3.2	3.0	2.8	2.6	2.3	2.2
	1.7	5.6	5.1	4.7	4.3	4.0	3.7	3.4	3.1	2.8	2.6	2.4	2.2	2.0	1.8
19	1.8	5.1	4.6	4.0	3.9	3.6	3.2	3.0	2.7	2.5	2.3	2.0	1.9	1.7	1.5
	1.9	4.6	4.0	3.8	3.5	3.2	2.9	2.6	2.4	2.1	1.9	1.7	1.6	1.4	1.2
	2.0	4.0	3.8	3.4	3.1	2.8	2.6	2.3	2.1	1.9	1.7	1.5	1.3	1.1	<1.0
	2.1	3.8	3.4	3.1	2.8	2.5	2.3	2.0	1.8	1.6	1.4	1.2	<1.0		
17	2.2	3.5	3.1	2.8	2.5	2.2	2.0	1.8	1.5	1.4	1.2	<1.0			
	2.3	3.2	2.8	2.5	2.2	2.0	1.7	1.5	1.3	1.1	<1.0				
	2.4	2.9	2.6	2.3	2.0	1.8	1.5	1.3	1.1	<1.0					
	2.5	2.6	2.3	2.0	1.8	1.5	1.3	1.1	<1.0						
15	2.6	2.4	2.1	1.8	1.5	1.3	1.1	<1.0							
	2.7	2.2	1.9	1.6	1.4	1.1	<1.0								
	2.8	1.9	1.7	1.4	1.2	<1.0									

- Shaded area delineates region of 2 metre planting with allowable range ± 0.5 m

- Dotted line example: 80% of patches are useable for planting,
  thus, 2000 plantable patches/ha requires 2500 total patches/ha.

Economic Analysis

Table 17 shows the total cost per PMH (assuming 85% utilization for both machines) for a Bräcke Cultivator pulled by a Timberjack 380 skidder and a Badger mounted on a Timberjack 550 skidder. This includes fixed (owning), variable (operating), and labour costs. The Cultivator costs approximately $14.20 per PMH while the Badger costs $21.84/PMH. The cost difference between the machines is given to indicate the productivity increase required using the Badger for similar costs per hectare. The assumptions, formulas and a further breakdown of costs are provided in Appendix C.

In Case 1, the skidders are used for both summer scarification and winter logging. The assumption is made that there is a need for a large skidder to pull wood in the winter. This will usually not be the case in eastern Canada. However, both the TJ380 and TJ550 are larger skidders than those of most company fleets. The harvesting side must put up with a higher internal rental rate to use these prime movers in skidding wood or the extra cost could be placed on the scarification operation. The extra cost of the latter has not been included in the Case 1 figures.

In Case 2, the prime movers and scarifiers are only used in the summer for scarification.

The Timberjack 550 skidder has the capacity to pull anchor chains in the winter. The added scheduled hours for winter scarification are used as Case 3 for the TJ550 only. In all cases, it is assumed that the user buys the prime mover and the scarifier new.

Table 17. Comparison of cost per PMH between the Badger and Cultivator. Cost difference expressed as a percent of the Badger over the Cultivator.

Cultivator & TJ 380 / Badger & TJ 550	Case 1 $70.99/PMH	Case 2 $85.19/PMH
Case 1 $ 94.16/PMH	33%	11%
Case 2 $113.05/PMH	59%	33%
Case 3 $107.49/PMH	51%	26%

Table 17 shows the cost difference per PMH, expressed as a percent, of the Badger over the Cultivator when all cases are compared. If it is assumed that a 50% productivity increase can be achieved with the Badger in a 3-row and 2-metre spacing configuration, then the cost per hectare can be less or more expensive with the Badger depending upon the comparison. In all three cases of the Badger against Cultivator Case 2 (summer scarification only) and in Case 1 Badger vs Case 1 Cultivator, the cost per hectare would be cheaper with the Badger. Similar costs occur when comparing Case 3 Badger and Case 1 Cultivator. The Badger would prove more expensive in Case 2 Badger vs Case 1 Cultivator. The actual productivity difference under local conditions may change the final costs per hectare and, therefore the choice of machine.

The following factors, which are difficult to quantify, must also be examined before a choice of scarifier is made:

- more machines are required to treat an equivalent total area with a 2-row scarifier and thus, supervision and other overhead charges may be greater.

- the Badger has the flexibility to go to 1-metre spacing. This may be an advantage where different sites require different prescriptions and treatments.

- if the prime mover is contractor supplied, the rental rate may be higher or lower than the figures calculated in the analysis and thus, the Badger will be less or more attractive.

- the Badger could be used as a 2-row scarifier similar to the Cultivator when a larger prime mover is not available. This would increase the cost per PMH theoretically by approximately $6 (Badger fixed cost plus Cultivator operating cost vs Cultivator total cost).

- skidders that are cheaper to purchase than the two in the analysis may be used as long as they have sufficient power.

- other large prime movers may be available and fuller use of their available power can be achieved pulling a 3-row implement. For example, a modified large forwarder or shortwood harvester.

- the cost to transport a 3-row machine over long distances may be higher because of the extra time to make it ready for transport.

<u>Required Prime Mover</u>

The 140-kW Timberjack skidder displayed ample power to pull the Badger in a 3-row and 2-metre spacing configuration. However, the terrain conditions were excellent and the study team did not view the machine on slopes greater than 20% in the short-term study.

The drawbar pull requirement of the 2-row Cultivator at the 19-tooth gear setting was measured by Dalström (1974). The mean drawbar pull was 15-17 kN with a maximum of 30 kN. The ground roughness was class 3, and the stoniness was 13-75%. The driving speed was 69 m/min. The drawbar pull of the Badger has not been measured to date. However, the force will be higher than the Cultivator because of its additional weight.

The Badger with extension wings and 3 machine units has a weight of 3640 kg. The 15-tooth gear will also add to the required drawbar pull because of the longer drag time. The more aggressive interchangeable teeth may provide deeper penetration and require more pull as well.

At a net power rating of 140-kW, the Timberjack 550 was well above the manufacturer's specified minimum power rating of 108 kW. The available rimpull (tractive effort) is also an important criteria in prime mover selection. At speeds of 50 m/min, 70 m/min and 90 m/min, the Timberjack 550 generates 101, 78 and 53 kN of available rimpull respectively. Potential prime movers should also be judged on their tractive effort. Attempts to pull the Badger with a prime mover of lower tractive effort and weight than a Timberjack 550 have not been documented.

A Double Cultivator (4-row model)

In Sweden, a double Bräcke Cultivator (4 rows, 2-metre spacing) was developed and tested in 1974. A comparison of the single and double Cultivators indicated that the wider unit had economic potential in smooth and flat terrain when the size of the cutovers averaged 10-20 ha or more according to Dalström (1975).

The double unit was more sensitive to steep slopes and rough terrain in terms of reduced driving speed than the single Cultivator. However, this was primarily attributed to the design of the 1974 model which did not allow independent sideways movement of each unit thus restricting the ability of the machine to negotiate slopes and obstacles. As well, the early model was difficult to dismantle and set up for travel between sites.

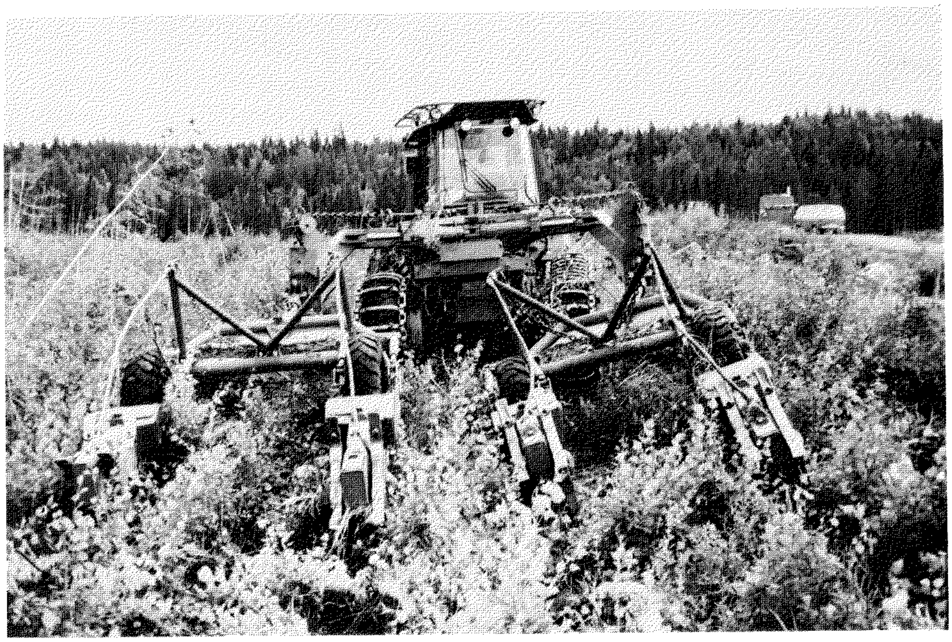


Figure 10. Double unit Cultivator in operation on SCA's limits in Sweden, 1984.

There may be potential for a 4-row machine in Canada because of the large average cutover size and less restriction with travel width on roads. However, a large prime mover would have to be extensively modified and equipped with a double-drum winch.

CONCLUSION

The Badger demonstrated high productivity in the short-term study. However, site conditions were limited and the areas were generally easy to treat. The Badger produced a consistently large patch of mineral soil, and a high gross mineral soil exposure for a patch scarifier. This occurred because of the easy site conditions and the use of the 15-tooth intermediate gear. The performance of the scarifier under difficult conditions was not tested in the short-term study but the Badger should be similar to the Bräcke Cultivator in terms of scarification effectiveness since the machine frames are identical.

Although the mechanical availability of the prototype Badger was not high, most of the repair time was caused by modification to the drawbar frame. This has been corrected in production models, and thus, mechanical availability of the Badger should be only slightly lower than the Bräcke Cultivator because of the additional machine frame required for 3-row configurations.

The main advantage of the Badger is its versatility. The scarifier can be matched with various silvicultural prescriptions and sites. The Badger can be used for subsequent planting, direct seeding and natural regeneration because of the ability to vary spacing and the number of rows. The scarifier can be further adapted to various sites and slash loadings, and to produce more or fewer patches by changing the gearing on the intermediate sprocket and by modification to reduce slippage of the rubber tires.

The Badger will incur higher hourly costs primarily because of the capital cost of the larger prime mover. Companies, such as Prince Albert Pulpwood that already possess a larger prime mover, can take economic advantage of the additional power by using the Badger and increasing productivity over 2-row scarifiers. Costs on a per hectare basis can be lower, similar or higher with the Badger over the Bräcke Cultivator depending upon the productivity difference and the number of hours and uses that can be made with the prime movers.

A 3-row scarifier will offer a theoretical productivity increase of 50% over a 2-row model. Whether this can be achieved will depend primarily upon the forward speed. On a 3-row machine, the operator may perceive that he is more productive and have a tendency to slow down, thereby negating any potential productivity increase. With this in mind, it should be pointed out that travel speed is controlled not only by the drawbar pull requirements of the scarifier and the available power of the prime mover but also by factors such as ground conditions and slope. Moreover, the ground roughness is important because it affects the ride of the operator, who then adjusts the speed to an acceptable comfort level. What should not be overlooked, as it is of major importance, is that the quality of the microsite is affected by scarifying speed. Therefore, there are limits to the travel speed which can be accepted when one considers the objective of the optimum production of quality microsites. The Badger can offer a productivity increase while travelling at the optimum travel speed providing improved scarifier effectiveness and operator comfort compared to a 2-row machine.

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APPENDIX A

TECHNICAL DATA ON THE MACHINE

Bräcke Badger

Mattock wheels	3 mattock wheels with 4 pairs of tines per wheel
Tine width	10 cm, replaceable teeth
Weight	3640 kg
Tires	30 x 60, 12-ply
Required prime mover	minimum 108 kW

Options - seeders

- 15- 17- and 19-tooth sprockets for changing patch length and number per hectare - available in gear pairs (15-17) (15-19) (17-19).
- mattock wheels with 5 pairs of tines.

Price: $56,000.00 F.O.B. Thunder Bay

Manufacturer

Robur Maskin AB
Gransgatan 42
S-840 60 Bräcke
Sweden

Distributor

KBM Forestry Consultants Inc.
360 Mooney St.
Thunder Bay, Ontario
P7B 5R4

Prime Mover

Timberjack 550 Cable Skidder

engine	make	model	net flywheel power
	GM	6V-53N	140 kW

power train - single stage torque converter
- 4 speed powershift transmission
- travel speeds (km/h) with 24.5-32 tires

1st	2nd	3rd	4th
6.9	14.1	24.8	34.4

Weight: 13,200 kg
Tires: 30.5 x 32
Chains: studded chains on all 4 wheels.

Further specifications available upon request from manufacturers or distributors.

APPENDIX B

DEFINITION OF TIME ELEMENTS AND TERMINOLOGY

LONG-TERM STUDY

DEFINITION OF MACHINE TIME ELEMENTS

SCHEDULED MACHINE HOURS (SMH): Nominal statement of intent for regular machine activity (e.g., 8-hour shift). It usually corresponds to operator's paid on-job time.

PRODUCTIVE MACHINE TIME or **PRODUCTIVE MACHINE HOURS (PMH):** That part of Total Machine Time during which the machine is performing its primary function.

ACTIVE REPAIR: Repair is mending or replacement of part(s) owing to failure or malfunction. It also includes modifications or improvements to the machine.

SERVICE: Service is routine and preventive maintenance performed to retain the machine in satisfactory operational condition.

DELAY: That part of Scheduled Machine Time during which the machine is not performing its primary function for reasons other than active repair and service. Delay time is divided into:

> **NON-PRODUCTIVE OPERATING TIME:** Period of in-shift time during which the machine's engine is running but the machine is doing something other than its primary function.
>
> **WAITING FOR MECHANIC(S):** Period of in-shift time during which the machine is broken down and is not under repair because of the unavailability of mechanic(s).
>
> **WAITING FOR PART(S):** Period of in-shift time during which the machine is broken down and is not under repair owing to the unavailability of part(s).
>
> **MISCELLANEOUS DELAY:** Period of in-shift time during which the machine engine is not running for reasons other than active and/or waiting for repairs and service.

TOTAL MACHINE TIME MODEL

<table>
<tr><td rowspan="7">TOTAL MACHINE TIME (Normal Shift Length plus Overtime)</td><td colspan="2">Productive Machine Time*</td></tr>
<tr><td colspan="2">Active Repair</td></tr>
<tr><td colspan="2">Active Service</td></tr>
<tr><td rowspan="4">Delays</td><td>Non-Productive Operating Time</td></tr>
<tr><td>Wait For Mechanic(s)</td></tr>
<tr><td>Wait For Part(s)</td></tr>
<tr><td>Miscellaneous Delays</td></tr>
</table>

* Breakdown of time elements for short-term timing is given in Table 5.

MACHINE TIME FORMULAS

$$\text{Utilization} = \frac{\text{PMH (In-Shift)}}{\text{SMH}} \times 100$$

$$\text{Total Time Utilization} = \frac{\text{PMH (In-Shift and Out- of-Shift)}}{\text{SMH + Overtime}} \times 100$$

$$\text{Mechanical Availability} = \frac{\text{PMH}}{\text{PMH + Repairs + Service}} \times 100$$

(PMH, Repairs and Service include both in- and out-of-shift activities)

$$\text{CPPA Availability} = \frac{\text{SMH - (Repair + Service + Wait (Parts + Mechanic))}}{\text{SMH}} \times 100$$

(Repair and Service includes only in-shift)

PMH = Productive machine hours
SMH = Scheduled machine hours

CPPA Availability, by definition, is influenced not only by machine characteristics but also by operational factors (i.e. waiting for parts, or waiting for mechanic). Mechanical Availability, by definition, excludes these operational factors.

For details regarding definitions of machine time elements and data collection procedures, refer to Folkema et al. (1981).

SHORT-TERM STUDY

The Productive Machine Hours (PMH) recorded in the continuous timing were broken down into the following elements.

Effective Productive Time EPT (Scarify) - begins when the implement is in the soil and the prime mover begins forward travel. The EPT can be subdivided into winching if the implement is equipped with a quick disconnect hitch and there is effective scarification occurring while winching.

Manoeuvre (Turn) - occurs when the scarifier has finished a pass to begin a turn and until the scarifier begins the next pass. This element may include raising the implement off the ground, turning, and then lowering the implement. With the Badger, the implement is kept on the ground so that the element includes the time looping from when the pass is completed until the scarifier is aligned for the next pass. If the winch is used, the time free-spooling and winching is included especially if over previously scarified area and at a narrow angle.

Manoeuvre is broken down into the type of turn: run-by-run, operation in lands pattern, or broken pattern.

Obstacle - this time begins when the scarifier stops because of an obstruction until scarification resumes. Sub-elements are stuck, travelling forward while the implement is raised or being free-spooled and travelling in reverse. Subsequent winching is included in obstacle or EPT depending upon the effectiveness of the scarification while winching. Obstacle times are classified as prime mover caused or implement caused and the type of obstruction is noted.

Travel - is the time spent travelling in the block or to the roadside between breaks, and repairs. It also includes travelling between sites if less than 15 minutes.

Delay - includes those between 0.05 min. and 15 min. Delays over 15 min. were not considered part of productive time. Delay is any downtime and non-productive operating time.

APPENDIX C

COST ANALYSIS AND ASSUMPTIONS

The CPPA costing model has been used to analyze the combinations of a Badger mounted on a Timberjack 550 and a Bräcke Cultivator pulled by a Timberjack 380. Estimated machine costs are on a PMH basis. Costs per hectare are not given but can be calculated by dividing the various total machine costs by the productivity. For example, the Badger used in both summer and winter scarification (Case 3), and at a productivity of 1.81 ha/PMH (Area 2) would result in a cost of $59.39 per hectare.

Calculation of Machine Costs

Bräcke CULTIVATOR

Machine Life: 10 a
Scheduled Hours/a: 800

Purchase Price: (delivered) $39,000

Salvage Value: 0
Insurance: $390/a
Utilization: 85%

I. Fixed Costs:

Depreciation (straight line)
Interest Rate: 15%
Insurance: 1% (of purchase price)

Total Fixed Cost/PMH: $11.04

II. Variable Costs:
Repair + Maintenance: 50%
(% of purchase price over life of machine)
Tire Replacement Price: $1000
Tire Life : 4000 h

Total Variable Cost/PMH: $3.16

TOTAL COST/PMH: $14.20

Bräcke BADGER

Machine Life: 10 a
Scheduled Hours/a: 800

Purchase Price: (delivered) $60,000
Salvage Value: 0

I. Fixed Costs:
  Depreciation (straight line)
  Interest Rate: 15%
  Insurance: 1% (of purchase price)

Total Fixed Cost/PMH: $16.99

II. Variable Costs:
  Repair and Maintenance: 50%
  Tire Replacement Price: $1000
  Tire Life: 4000 h

Total Variable Cost/PMH: $4.85

TOTAL COST/PMH: $21.84

TJ 380 SKIDDER

Case 1. Summer Scarification and Winter Skidding

Machine Life: 5 a
Scheduled Hours/a: 800 scarification
960 skidding
1760

Case 2. Summer Scarification Only

Machine Life: 10 a
Scheduled Hours/a: 800

Purchase Price: $90,000 (incl. 30.5 x 32 tires, taxes, transport)

Salvage Value: $9000 (10% of purchase price)

Utilization: 85%

I. Fixed Costs:
  Depreciation (straight line)
  Interest Rate: 15%
  Insurance: 1% (of purchase price)

Total Fixed Cost/PMH Case 1: $17.21
Case 2: $25.05

II. Variable Costs:
  Repair and Maintenance: Case 1: 60%
  (% of purchase price over life of machine) Case 2: 75%

  Fuel Consumption (during scarification operations): 17 L/PMH
  Fuel Cost: 0.40 $/L
  Lubes and Oil: 30% of fuel cost/PMH
  Tire Replacement Price (per 30.5 x 32 tire with double-diamond chains): $5000.

Tire Life: Case 1 3000 h
Case 2 2000 h

Total Variable Cost/PMH Case 1: $21.23
Case 2: $27.59

III. Labour Cost:
($12.00/SMH plus 30% fringe) Total Labour Cost/PMH: $18.35

TOTAL COST/PMH Case 1: $56.79
Case 2: $70.99

TJ 550 SKIDDER

Case 1. Summer Scarification and Winter Skidding

Machine Life:	5 a	
Scheduled Hours/a	800	scarification
	960	skidding
	1760	

Case 2. Summer Scarification Only

Machine Life: 10 a
Scheduled Hours/a: 800

Case 3. Summer and Winter Scarification

Machine Life:	7 a	
Scheduled Hours/a:	800	summer
	350	winter
	1150	

Purchase Price: $130,000 (including 30.5 x 32 tires with double-diamond chains, taxes, transport).

Salvage Value: $13,000
Utilization: 85%

I. Fixed Costs:
Depreciation (straight line)
Interest Rate: 15%
Insurance: 1% (of purchase price)

Total Fixed Cost/PMH Case 1: $24.85
Case 2: $36.18
Case 3: $30.68

II. Variable Costs:

Repair and Maintenance: (% of purchase price over life of machine)	Case 1	60%
	Case 2 and 3	75%

Fuel Consumption (on scarification operation): 26 L/PMH
Fuel Price: 0.40 \$/L
Oil and Lubes: 30% of fuel cost/PMH
Tires Replacement Price (per 30.5 x 32 tire with double-diamond chains): \$5000.

Tire Life: Case 1: 3000 h
Case 2 and 3: 2000 h

Total Variable Cost/PMH	Case 1:	\$29.12
	Case 2:	\$36.68
	Case 3:	\$36.61

III. Labour Cost:
\$12.00 per SMH plus 30% fringe

Total Labour Cost/PMH: \$18.35

TOTAL COST/PMH	Case 1:	\$72.32
	Case 2:	\$91.21
	Case 3:	\$85.65

Equations for Cost Analysis:

Fixed Costs (FC) are calculated using the equation

$$FC = \frac{\frac{(PP - SV)}{ML} \times \left(1 + \frac{i\,(ML + 1)}{2}\right) + SV \times i + IC + LC}{SMHY \times U}$$

where:
- PP = purchase price (\$)
- SV = salvage value (\$)
- ML = machine life (years)
- SMHY = scheduled machine hours per year
- i = interest rate (.%)
- U = utilization (.%)
- IC = insurance cost per year (\$)
- LC = license cost per year (\$)

Variable costs (VC) are calculated using the equation

$$VC = \frac{\frac{N \times CC \times (ML \times SMHY - CL)}{CL} + RCL}{ML \times SMHY \times U} + FC \times FP + OLC$$

where:
- N = number of components per machine
- CC = component cost (\$)
- CL = component life (SMH)
- RCL = lifetime repair costs (\$)
- FC = fuel consumption (volume/hour)
- FP = fuel price (\$/volume)
- OLC = oil and lubricant costs (\$/hour)

Labour costs (LC) are calculated using the equation

$$LC = \frac{OW + H \times HW}{U}$$

where: OW = operator's wages ($/SMH)
H = number of helpers
HW = helper's wages ($/SMH).

Total costs (TC) are the sum of fixed, variable and labour costs.

$$TC = FC + VC + LC$$

APPENDIX D

CONVERSION TABLE

1 mm (millimetre)	=	0.039 inch
1 cm (centimetre)	=	0.39 inch
1 m (metre)	=	3.28 feet
1 km (kilometre)	=	0.62 mile
1 ha (hectare)	=	2.47 acres
1 L (litre)	=	0.22 Imperial gallon 0.26 US gallon
1 kg (kilogram)	=	2.20 pounds
1 kPa (kilopascal)	=	0.145 pounds per square inch (psi)
1 kW (kilowatt)	=	1.34 horse-power
1 kN (kilonewton)	=	0.2248 kips (1 kip = 1000 lbs force)