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PROJECT REPORT

SYSTEM EVALUATION — WARATAH PROCESSOR IN STEEP COUNTRY THINNINGS

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Project Report

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SYSTEM EVALUATION — WARATAH PROCESSOR IN STEEP COUNTRY THINNINGS

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ABSTRACT

A steep country thinning operation was evaluated to establish the potential productivity of the system and to determine the optimum balance between each phase of the operation.

The trees were extracted untrimmed headfirst by a Komatsu D37 tractor and a John Deere 440D skidder.

Processing on the landing was undertaken by a prototype Waratah Grapple Processor. An hydraulic knuckleboom loader mounted on an agricultural tractor was used for loading out.

In 0.3 m³ piece size Radiata thinnings, the system was found to have a potential productivity of 183 tonnes per day before the processor became limiting. To achieve that level of output either the addition of a further tractor unit or the continuous use of the hauler was required.

ACKNOWLEDGEMENT

LIRA acknowledges the cooperation of K S & E J Travers Limited, Rotorua; NZFP Forests Limited and Waratah General Engineering Limited, Tokoroa.

INTRODUCTION

Prior to the introduction of the Waratah processor, the standard work method for this steep country thinning operation involved the trimming of each drag in the bush. Difficulty in keeping experienced workers in the arduous task of trimming on steep country prompted the contractor to consider mechanised processing.

The objectives of the study were to assess the productive capacity of each phase of the operation and then to determine the optimum balance between each phase of the operation.

These objectives were achieved by:

1. Studying two systems of falling and breaking-out
2. Studying the John Deere 440D skidder and D37 Komatsu to identify cycle times and haul volumes
3. Collect productivity data on the Waratah processor working under a range of conditions
4. Establish productivity of the agricultural tractor-mounted knuckleboom loader.
5. Based on the results of the above, recommend the optimum system in terms of :
   (a) Manpower
   (b) Number of extraction units to supply the processor
   (c) Wood layout for processing and loading

PROJECT DESCRIPTION

Study Area

The system evaluation was undertaken during February 1988 in a thinning operation in Kinleith Forest.

The study area comprised 17 year old Radiata pine on moderate to steep slopes (Table 1).

Details of the stand data were obtained from a prethinning assessment by NZFP Forests Limited.

TABLE 1 : STAND DETAILS

Stand Age	*17 years*
Total Stocking	*886 s/ha*
Thinnings Stocking	*511 s/ha*
- Mean DBH	*24 cm*
- Mean Volume	*0.3 m^3*

Logging Equipment and Procedure

Conventional System

Conventional ground based production thinning systems use rubber tyred skidders on flatter country and small crawler tractors on the steeper faces. Depending on piece-size, either single or double drum winches are used on the rubber tyred skidders.

Various modifications to crawler tractors will improve utilisation and productivity, some of which are detailed in Evans (1984) and Pritchard (1986). Travers (1986) provided a general discussion on tractor performance in steep country thinning operations.

Felling and delimbing is carried out motor manually with the machine operator assisting the faller in breakout. Generally seven to eight chain strops are used.

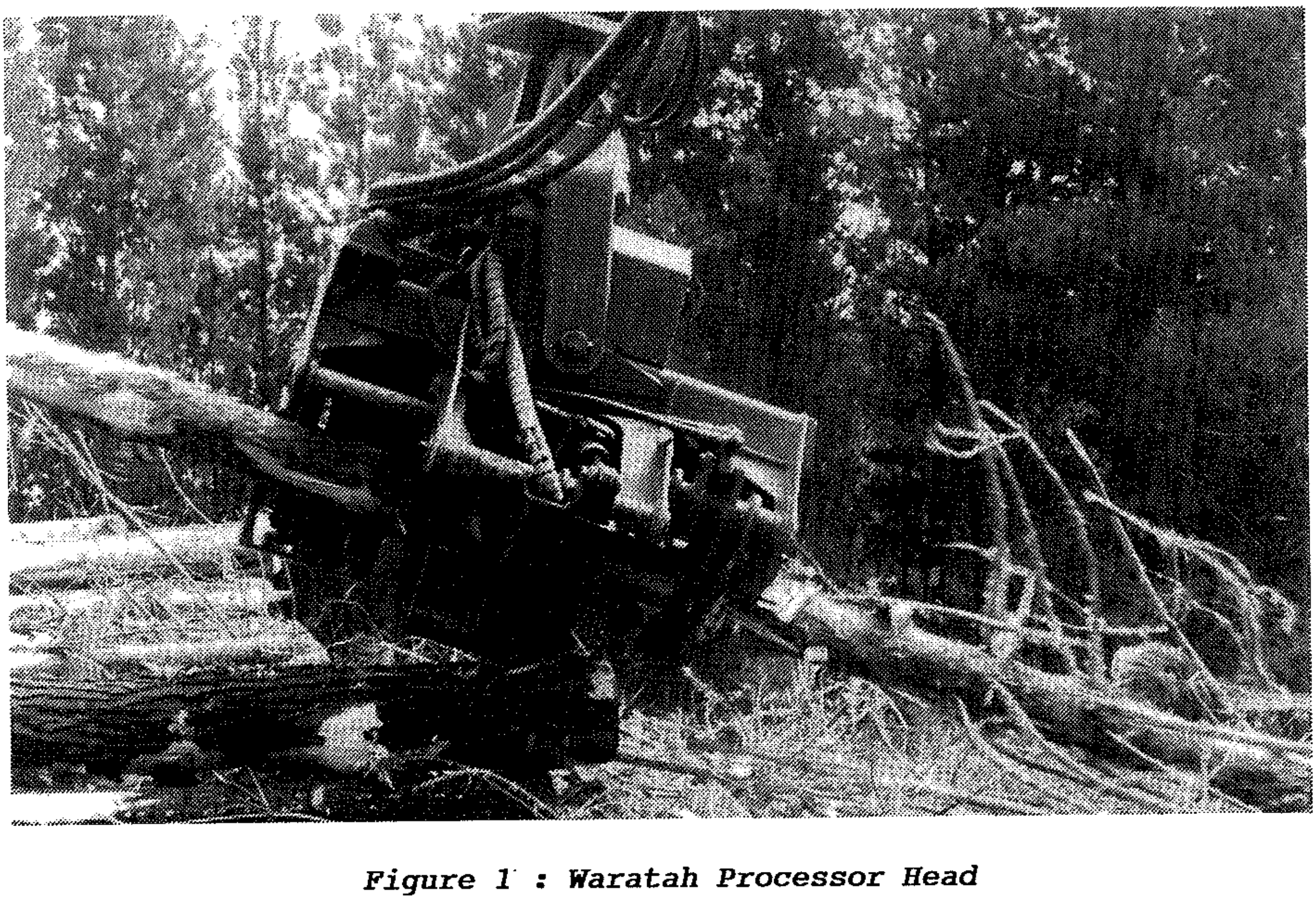


Figure 1 : Waratah Processor Head

The conventional work method for felling and delimbing on steep country for ground based extraction involves:

(i) directional felling (usually downhill)

(ii) delimbing from the butt to the head

(iii) cutting off the head at a 10 cm diameter

(iv) breakout, with the machine operator assisting the faller. Generally no prestropping is undertaken.

As the slope increases delimbing becomes increasingly arduous.

Mechanised System

To overcome the problem of retaining workers to trim wood on steep slopes a Waratah mechanised processor was introduced.

The Machine

The prototype Waratah Heavy Duty Grapple Processor was developed from experience with a Finnish grapple harvester and modified to achieve the robustness required when delimbing New Zealand radiata pine.

Delimbing is achieved by two wraparound knife arms and one fixed knife. The maximum tree diameter able to be delimbed is 50 cm, with a minimum of 7.5 cm.

Two spiked feed rollers and one spiked chain drive the tree through the processor with a feed speed of up to 3.5 m/s. An integral hydraulic chainsaw cuts to length with an option of an automatic length measuring device.

The processor head can be fitted to most excavators of 75 kW (or greater) engine output. The hydraulic requirement is 200 litres/min flow at 26 MPa. Grapple specifications are included in Appendix II. In this operation, the Waratah was fitted to a wheeled Hitachi 073 excavator base. The excavator is fitted with a blade to clear slash and also to act as a stabiliser in conjunction with two hydraulic outriggers. The excavator is capable of travel speeds up to 30 kph between skids.

Work Method

As delimbing and cutting to length was to be performed on the skid the conventional work method had to be modified.

As with all steep country thinning operations the direction of felling is predominantly downhill. Extraction also tends to be downhill. Downhill felling and head first extraction usually results in a tangle of heads which make the trees both difficult to locate and breakout. The tree heads also frequently break off unless the strops are attached at a minimum diameter of 8 to 10 cm.

To overcome these problems the contractor adapted the work method used for his hauler operation, whereby the trees are felled, headed off at 10 cm (sed) and the first metre of the stem was trimmed. This allowed for faster tree location and strop setting times and also allowed the processor to get a clean grasp of the tree to start delimbing. Removing tree heads in the bush resulted in a cleaner skid and fewer saw cuts per tree for the processor.

Initially it was proposed that three falling and breakout systems be studied.

A. Faller fells the tree and walks to the head which is cut off at 10 cm diameter. The first top one metre of the stem is then delimbed. Breaking out is a separate operation with a breaker out prestropping each drag for the extraction machine.

B. Faller operates as in system A but also breaks out each drag with the assistance of the machine operator. This system uses two fallers, with the extraction machine servicing each faller alternatively.

C. Faller fells only. The breaker-out cuts off the heads and trims the top metre, before prestropping for extraction.

As the study evolved, it became apparent that the breakerout would have insufficient time for system C and this system was therefore not implemented.

RESULTS AND DISCUSSION

Falling

An initial study of 230 trees was carried out to determine if a relationship existed between felling time and tree diameter.

No significant relationship between felling time and tree diameter was found. This may be attributed to a large degree to the high potential for hang ups when felling small "yield" trees among crop trees. This is especially the case when thinning to a high residual stocking of 375 s/ha.

As tree diameter was eliminated as a factor affecting felling time, the remainder of the study was based on the average extracted piece size and an average fell time per piece.

TABLE 2 : FELLING TIME VS TREE DIAMETER

Dependent Variable	*Independent Variable*	R^2
Fell element	*Tree Diameter*	*0.15*
Total Fell Time	*Tree Diameter*	*0.02*

Faller Productivity

The productivity of three fallers was recorded when felling for the mechanical processor on three different slopes, all with medium levels of hindrance. Because of the limited nature of the study, no delays were included in the felling times.

Fallers 1 and 2 worked on slopes of 25° and 15° respectively, both felling downhill for head first extraction. Faller 3 worked principally on flat country (0-5°) in slightly smaller trees and felled for both headfirst and buttfirst extraction, depending on the lean of the trees.

To provide a comparison, the time each of the fallers spent heading off and trimming the heads was standardised to the 85% level achieved by Faller 2. Results of the productivity study are given in Table 3.

The work method varied considerably between the fallers. Faller 2, working on moderate slopes, felled and headed off after sufficient trees for each drag had been felled, usually seven to eight trees. This method resulted in a high (85%) proportion of the heads being found, headed off and then trimmed.

The major trend which emerged was the increase in heading off and trim time (and hence an increase in total cycle time) as the slope

TABLE 3 : FELLING TIMES PER TREE (Minutes)

ELEMENT	FALLER 1	FALLER 2	FALLER 3
Walk & Select	0.23	0.23	0.20
Clean Stump and Limb Butt	0.06	0.11	0.19
Fell	0.61	0.72	0.50
Head off and Top Trim (85%)	1.03	0.73	0.69
Cut Slash	0.26	0.26	0.16
Total	**2.19**	**2.05**	**1.74**
Number of Trees	70	52	108
Mean dbh (cm)	25	26	22
Slope (degrees)	25	10-15	0-5
Trees/hr	27.4	29.3	34.5

TABLE 4 : VARIATION IN TREE PREPARATION TIME WITH SLOPE

Slope (degrees)	No. trees prepared (trees/hr)	Productivity decrease with slope (%)
0- 5	34	-
10-15	29	15
25	27	20

increased (Table 4). At 95% confidence limits, the difference in productivity of each of the three fallers was statistically significant.

Breakout

Two breakout methods were compared:

a) The fallers breakout the trees felled on a "drag for drag" basis

b) The fallers work ahead of a separate breaker out who prestrops each drag.

The comparison of breakout times is summarised in Table 5. (More detailed results of breakout and falling times are contained in Appendix I.)

The higher breakout time for the tractor reflected the more difficult terrain encountered when

TABLE 5 : BREAKOUT TIMES - PRESTROPPING AGAINST NO PRESTROPPING

	Prestropping (min/tree)	No. Obs	No Prestropping (min/tree)	No. Obs	% Difference
Tractor	0.69	24	0.92	25	+33%
Skidder	0.63	22	0.79	21	+25%

extracting with a tractor. Most gains from prestropping were achieved with the tractor, with a 33% decrease in the time the machine was involved in the breakout phase.

An analysis of the effect of prestropping on machine productivity was undertaken. Based on the breakout times from the extraction study of the skidder and tractor, the total daily productivity and cost/tonne were calculated to quantify the effect of prestropping against no prestropping (Tables 6 and 7).

Prestropping with a separate breakerout decreased breakout time by an average of 29% (25% for the skidder and 33% for the tractor). This had the effect of reducing total cycle time by an average of 10%. The cost benefit of prestropping was only readily apparent with tractor extraction when the haul distance approached 200 m.

TABLE 6 : PRODUCTIVITY AND COST OF TRACTOR EXTRACTION WITH AND WITHOUT PRESTROPPING

Haul distance (m)	*Prestropping*		*No Prestropping*	
	tonne/day	*$/tonne*	*tonne/day*	*$/tonne*
100	*69*	*13.56(b)*	*61*	*13.38(a)*
150	*58*	*16.14(b)*	*52*	*15.69(a)*
200	*50*	*15.86(c)*	*46*	*17.74(a)*

(a) daily cost of tractor with 2 fallers = $816
(b) daily cost of tractor with 2 fallers + 1 Breakerout = $936
(c) daily cost of tractor with 1 faller + 1 Breakerout = $793
(see Appendix IIb for details)

TABLE 7 : PRODUCTIVITY AND COST OF SKIDDER EXTRACTION WITH AND WITHOUT PRESTROPPING

Haul distance (m)	*Prestropping*		*No Prestropping*	
	tonne/day	*$/tonne*	*tonne/day*	*$/tonne*
100	*88*	*10.64(b)*	*79*	*10.33(a)*
150	*77*	*12.16(b)*	*68*	*12.00(a)*
200	*66*	*14.18(c)*	*60*	*13.60(a)*

(a) daily cost of skidder with 2 fallers = $ 816
(b) daily cost of skidder with 2 fallers + 1 Breakerout = $ 936
(see Appendix IIb for details)

This distance corresponded to where only one faller was required to meet the productive capacity of the tractor. Over the range of remaining haul distances for both the tractor and skidder an extra man must be employed solely for prestropping. The cost of employing the extra person increases the cost of felling and extraction only marginally - 2% for the tractor and 3% for the skidder.

Both the skidder and the tractor were equipped with 35 m of 19 mm mainline and eight chain strops per machine. The chain strops featured the "O" ring which allowed for fast attachment/ detachment from the mainline.

Chain strops, being able to be wrapped around the 10 cm diameter heads twice, resulted in negligible tree loss during extraction. The use of chains also allowed for "doubling up" enabling two trees to be extracted with the one strop.

Extraction

As the study was undertaken during the summer, conditions for extraction were ideal. The topography consisted of even, medium to steep slopes of medium length. Hindrance was minimal with no wet guts or old stumps. Some extraction tracks from previous logging operations persisted. Both the John Deere 440D cable skidder and the Komatsu D37 tractor were studied and the productivity recorded.

Extraction was almost exclusively downhill. The skidder was restricted to the unthinned, flat country out to the gently sloping gully bottoms (<10°). The tractor worked the steeper areas (up to 35° in some cases), often tracking up a ridge to drive down over the wood on the steeper faces.

The work method varied slightly from the conventional extraction system in that :

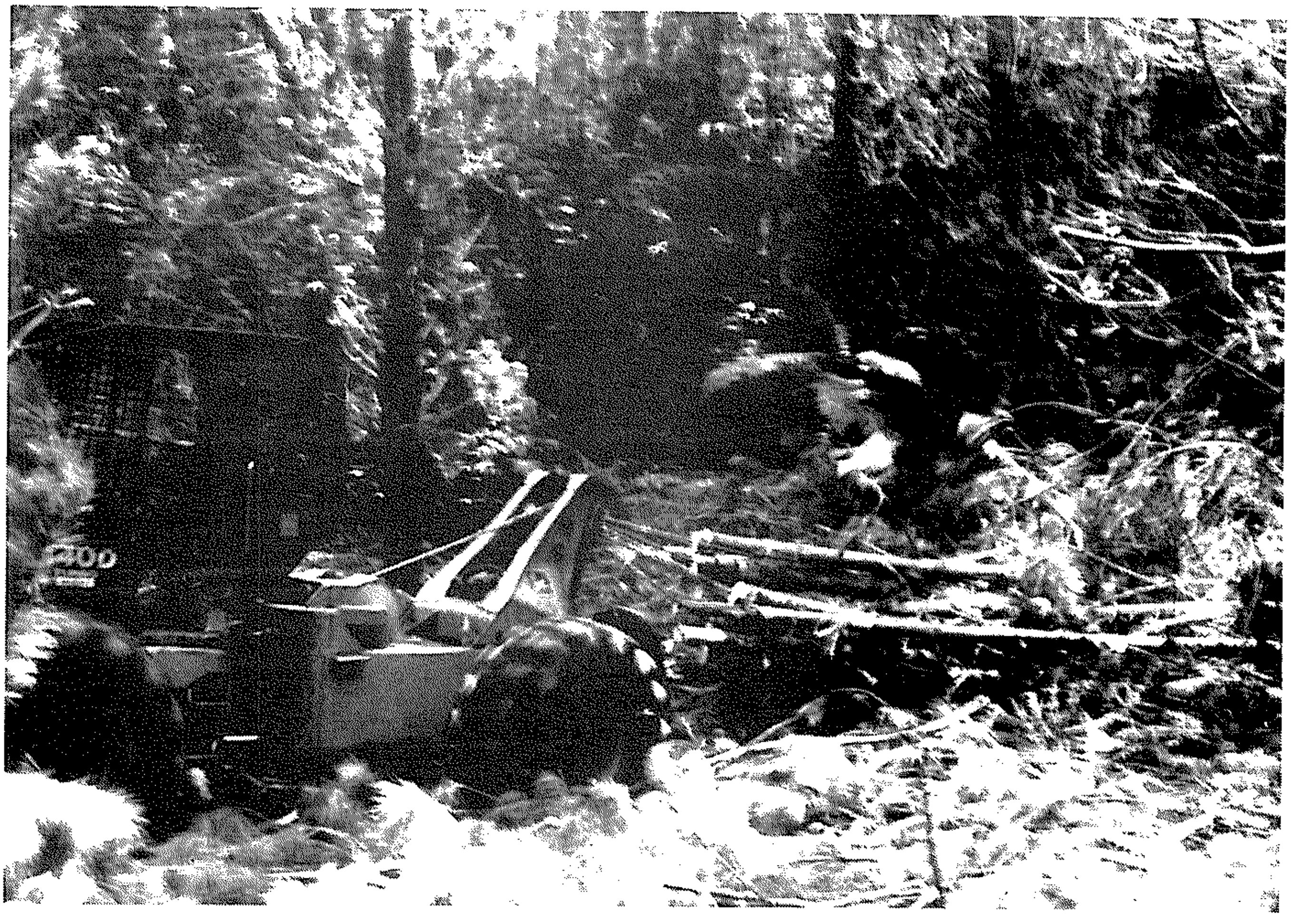


Figure 2 : John Deere 440 Extracting Untrimmed Trees

(i) The unhooking on the skid tends to be faster with the untrimmed trees due to the heads being separated by the branches

(ii) There is no requirement to fleet up the butt ends for the processing as is necessary when extracting already trimmed wood.

During the study period, the skidder was found to have a 10% faster cycle time and extract 0.34 tonnes more per cycle than the tractor. While the slightly smaller piece size accounts for 20% of the variation in haul volume, the remaining 80% is due to lower number of pieces per drag, 5.8 for the tractor versus 6.6 for the skidder. This was attributed primarily to the inexperience of the tractors' breakerout which resulted in a higher proportion of broken trees and broken strops, than would otherwise be expected.

The breakout component of the tractor and skidder cycles were 39% and 43% respectively. When the reduction in breakout times due to prestropping (Table 7) were applied to the extraction cycles, the tractor cycle time is reduced by 8% and the skidder cycle time by 12%. However as noted in the Breakout section, the benefits of the increased productivity, when offset against the cost of employing a breakerout, do not result in lower wood cost.

As it was not feasible to have the fallers convert to the conventional falling and delimbing system (which would result in the processor being idle), a "side by side" comparison of the conventional and mechanised extraction productivity was not possible. However, when comparing the production target of the tractor working the conventional system (ie. extracting trimmed trees) with tractor productivity in the mechanised system, an 18% increase of productivity was noted (44 tonnes/day conventional system and 52 tonne/day mechanised system).

TABLE 8 : EXTRACTION MACHINE CYCLE TIMES - KOMATSU D37 TRACTOR EXTRACTING UNTRIMMED TREES

Element time per cycle (min)	*Time/cycle (150 m) (min)*
Travel empty	*2.53*
Blade in Bush	*0.49*
Position in Bush	*0.76*
Breakout	*5.34*
Travel Loaded	*2.19*
Unhook	*1.36*
Operational Delays	*1.11*
Total	*13.78*
95% Confidence limits (min)	*± 5.10*

Number of cycles 49
Average haul distance 150 m
Average piece size 0.32 tonnes
Pieces per drag 5.8
Productivity 8.1 tonnes per productive machine hour
52 tonnes per 6.5 PMH day

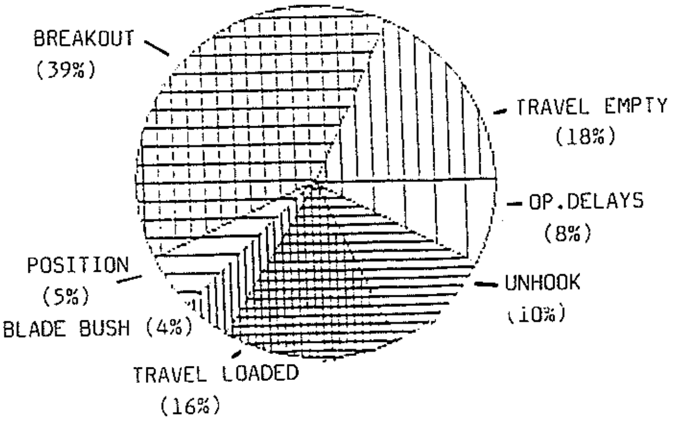


Figure 3 : Breakdown of Tractor Cycle Time Extracting Untrimmed Trees

The variation in productivity reflects :

a) The faster skid turnaround time achievable when extracting for the mechanised system, and

b) no secondary or "clean up" trimming being required in the mechanised extraction system after the logs have been broken out.

In the conventional system the extraction machine must both fleet the butts and push up the trimmed trees on the skid to provide a well formed stack for the load out phase. In the extraction phase of the mechanised system however, no fleeting of the butts and minimal pushing up is necessary.

The unhook time on the skid was also noticeably faster in the mechanised extraction system with the branches on the untrimmed trees tending to spread the heads apart when the drag is dropped on the skid. The flexible combination of the skidder, tractor and hauler in steep country thinning provide the contractor with a range of extraction capability which is able to efficiently production thin most conditions and terrain encountered.

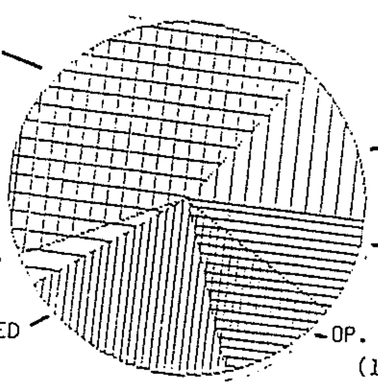


Figure 4 : Breakdown of Skidder Cycle Time Extracting Untrimmed Trees

TABLE 9 : JOHN DEERE 440D CABLE SKIDDER EXTRACTING UNTRIMMED TREES

Element time/cycle (min)	*Time/cycle (150 m) (min)*
Travel Empty	*1.86*
Blade in Bush	*0.02*
Position in Bush	*0.42*
Breakout	*5.21*
Travel loaded	*2.49*
Unhook	*1.08*
Operational Delays	*1.39*
Total	*12.47*
95% Confidence limits (min)	*±4.78*

Number of cycles 43
Average haul distance 150m
Average piece size 0.33 tonne/piece
Pieces per drag 6.6
Productivity: <u>*10.5 tonnes/PMH*</u>
<u>*68 tonnes per 6.5 PMH day*</u>

<u>**Processing**</u>

The processor usually worked out-of-phase with the extraction machines, ie. cold deck. However, trees could be extracted to an existing stack without causing interference to either the processor or extraction machine. Due to the high productivity of the processor, hot decking alone was not a viable option.

The operation sequence of the processor involved starting at one end of the untrimmed stack and reversing away, usually at 2-3 metres per move.

The processed trees were stacked in line with the untrimmed stack (if possible) or alternatively were turned by the processor.

Cutting-to-length was done either with the hydraulic chainsaw (resulting in a mixed length stack of both longs and shorts), or manually (resulting in separate long and short length stacks).

Figure 5 : The Waratah Grapple Processor working in NZFP Forests Limited, Kinleith Forest

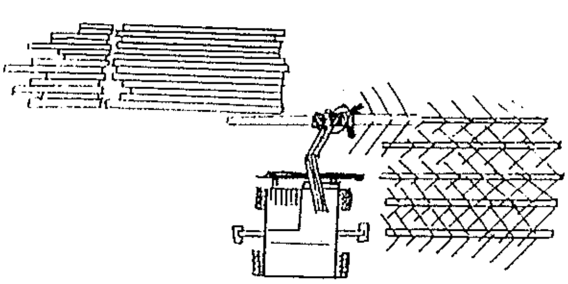


Figure 6 : Skid Layout for Waratah Processor

The slash that accumulated between the processed and unprocessed stacks was bladed away by either one of the extraction machines or by the processor.

Study Results

A preliminary study of 105 trees was undertaken to assess the effect of length, diameter and tree volume on processing time. Results are summarised in Table 10.

TABLE 10 : PROCESS TIME AGAINST PIECE SIZE

Dependent Variable	*Independent Variable*	R^2
Delimb time	*Tree length*	*.34*
Delimb time	*Tree diameter*	*.11*
Delimb time	*Tree volume*	*.29*
Total Process Time	*Tree volume*	*.19*

A weak relationship was found between delimbing time and tree length ($R^2 = 0.34$). This R^2 value was lower than expected and reflects :

(i) The effect of the "position head" component of the delimb element, (which was not able to be recorded separately);

(ii) The longer delimb times during occasions when the processor head reversed along the tree to gain sufficient momentum to overcome either a large internodal swelling or a heavy whorl of branches.

After this preliminary study, a further 380 trees were timed during processing to determine the effect of the following factors :

(i) Operator difference
(ii) Butt-first versus head-first processing
(iii) Stack orientation
(iv) Malformation and large branches.

A further study of the processor, undertaken in 0.2 m^3 piece size, confirmed that tree parameters (Table 11) were not a determining factor in the processing time of a tree. After the average piece size was reduced from 0.3 m^3 to 0.2 m^3, no significant difference (at 95% confidence limits) was found in the number of trees able to be processed per machine hour. This suggests that while piece size does not affect the number of trees processed per machine hour, piece size is the major factor determining the total volume processed per machine hour.

(i) Effect of Operator Difference

An analysis of the work cycle for two different operators was undertaken (Table 11).

(ii) Tree Orientation

The 15% difference in productivity between the two operators was not a function of experience. Raymond (1986) noted productivity

TABLE 11 : PROCESSOR CYCLE TIMES AND PRODUCTIVITY

Cycle Element	*Operator 1*	*Mean Time Per Cycle (min)* %	*Operator 2*	%	*Mean*
Accumulate	*0.05*	*7.5*	*0.09*	*11.5*	
Pick Up and Return	*0.14*	*20.9*	*0.15*	*19.2*	
Position and Delimb	*0.27*	*40.3*	*0.30*	*38.5*	
Cut to Length	*0.07*	*10.5*	*0.07*	*9.0*	
Move Along Stack	*0.01*	*1.5*	*0.03*	*3.8*	
Move Along Road	*0.04*	*5.9*	*0.04*	*5.1*	
Restack	*0.01*	*1.5*	*0.02*	*2.6*	
Blade Skid	*0.08*	*11.9*	*0.08*	*10.3*	
TOTAL CYCLE	*0.67*	*100.0*	*0.78*	*100.0*	*0.73*
95% Confidence limits (min)	*(± 0.018)*		*(± 0.017)*		
C L (as % of mean)	*3%*		*2%*		
Productivity					
Cycles observed	*248*		*220*		*-*
Trees processed per PMH	*90*		*77*		*84.5*
Trees processed/6.5 PMH day	*585*		*500*		*549*
Tonnes/6.5 PMH day	*195*		*167*		*183*

1 - Standardised for comparison
2 - Based on 4 km per day @ 10 kph
3 - Piece size 0.3 m^3, conversion factor 0.9 m /tonne

differences of up to 30% for two operators on similar machines in the same stand. The difference between operators 1 and 2 is attributed to the smoother operating technique of Operator 2, who spent less time accumulating the trees and appeared to have a greater skill in the operation of the grapple knives.

Steep country thinning generally involves head-first extraction. There are occasions however, usually on flatter country or when pulling over a ridge, when butt-first extraction is possible.

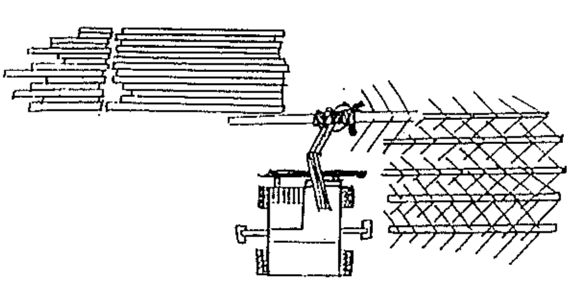
A comparison of head-first and butt-first processing was undertaken to determine the effect on processing speed and delimbing quality using Operator 1.

The difference in total processing time per tree between the two processing methods was not significant. Butt-first processing, while allowing for faster accumulation, required more frequent restacking of the processed trees. This time consuming restacking was due to the reduced ability of the processor to control direction of the processed stem with the small end in the grapple.

Because radiata pine has a typical average branch angle of 60° (Gleason, 1985), the quality of delimbing head-first was noticeably superior. The quality of both processing options however was acceptable to local mill standards.

Head First vs Butt-First Processing

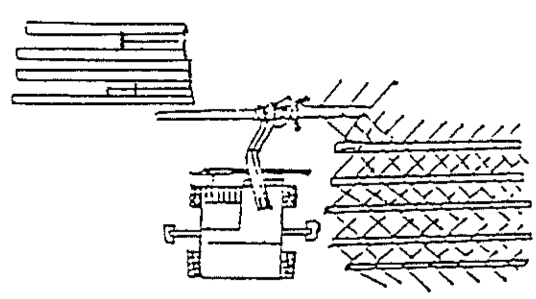
Head-first Processing



Mean cycle time : 0.65 min/tree

Cutting-to-length is done manually with a chainsaw by the processor operator at intervals (usually 15-20 heads at one time). The processor chainsaw is not used. A tree of less than 11 m is stacked among the long lengths.

Butt-first Processing

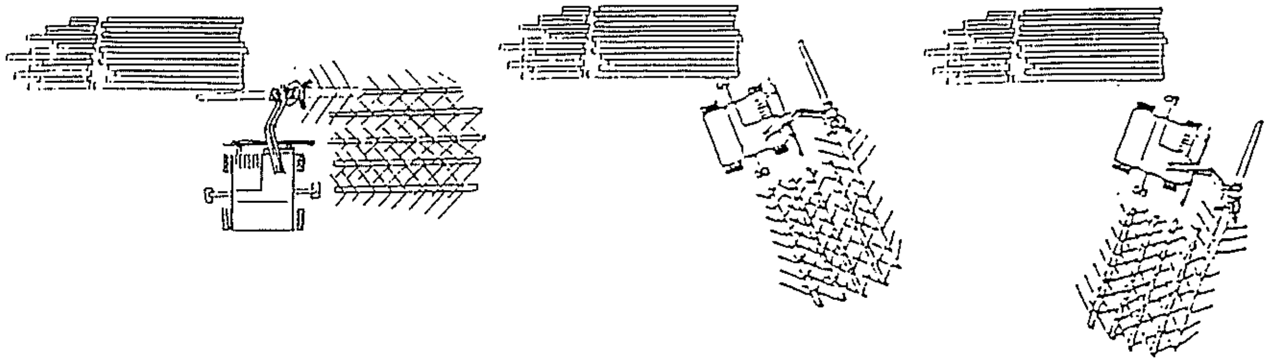


0.64 min/tree

Alignment of the butts at the far end of the processed stack is more difficult. Trees exceeding 11 m in length are cut-to-length using the processor and the short lengths are stacked among the long lengths.

Figure 7 : Work Methods

(a) 0° (b) 60° (c) 110°



Mean Cycle Time :

0.78 min/tree | 0.79 min/tree | 1.09 min/tree

Figure 8 : Effect of Stack Orientation

(iii) Effect of Stack Orientation

Because of the ability of the processor to delimb while slewing the tree, there was no significant difference (at 95% level) in delimbing time between layout (a) and (b) (Figure 8). Layout (c) however was significantly slower than the other layouts.

(iv) Effects of Malformation and Large Branches

As the work method required the removal of large branches and double leaders in the bush, the frequency of malformed trees and large branches was low (6.5%). Large branch size and malformations were noted if problems in processing arose. Delimbing problems occurred only where branch diameters exceeded 4 to 5 cm. Overall, trees with large branches and malformation required 43% more processing time (1.12 min per tree).

It must be stressed that grapple processors are primarily designed to delimb small branches only. It is considered that grapple type processors would not be suitable for the delimbing of branches encountered on (windthrown) crop trees grown at low (250 stems/ha) stockings.

(v) Processing Productivity and Cost

During the study, Operator 1 averaged 90 trees per productive machine hour (PMH) and Operator 2, 79 trees per PMH, to give a weighted mean productivity of 85 trees per PMH (refer Table 11).

Because of the difficulty in predicting the machine utilisation of a prototype, the standard estimate of 6.5 PMH/day was used.

85 trees/PMH x 6.5 x 0.3 m^3 (average tree size) = 166 m^3 /day at 0.9 m^3 /tonne Production = 183 tonne/day.

Costing the machine using the LIRA format (Wells, 1981) gives a total daily rate for the Waratah and operator of $873 per day and a delimbing cost of <u>$4.77 per tonne</u>. This compares well with other mechanised processors working in radiata pine thinnings (Raymond, 1988).

<u>Comparison of Conventional vs Mechanised Processing</u>

Conventional System

The conventional steep country thinning operation typically consisted of 3 fallers, who also trimmed and assisted the machine operator in the breakout phase. The extraction machine was usually a small tractor (50-60 kW range) which carried 7 to 8 strops.

	$/Day
1 extraction machine	*$325*
3 fallers, 1 machine operator @ $120/day	*$480*
Operating supplies (chainsaws, transport etc)	*$154*
Daily Cost	*$959*

- Target of 44 tonnes/day
Unit Cost <u>$21.80/tonne</u>

Mechanised System

The mechanised system required three extraction units, with one faller less in the crew. The two fallers trimmed the top metre of the tree and assisted the machine operator during the breakout phase. The 15% increase in daily production for the tractor reflected both the faster skid turnaround in the mechanised system, where the fleeting requirement was minimal, and the lack of "clean up" trimming in the bush after breakout was completed.

The mechanised processing system therefore compares well in terms of cost, with conventional steep country thinning operations. The fallers greatly preferred the mechanised processing work method.

Although the mechanised system required the extraction units to work in close proximity, the processor has the advantage of being able to be double shifted. This advantage will hasten the move toward mechanised processing and harvesting in New Zealand, through reducing machine costs.

Figure 9 : Processed Trees ready for Loadout

1 Waratah processor
+ Operator
*+ Saw** — *$ 873*
3 conventional extraction units (each less one faller + saw)
- 2 tractors (52 tonne/day) @ $816/day — *$1,632*
- 1 skidder (68 tonne/day) @ $816/day — *$ 816*

Daily Cost — *$3,321*
- Daily Production 172 tonne/day

Unit Cost *<u>$19.30/tonne</u>*

** See Appendix IIa for details*

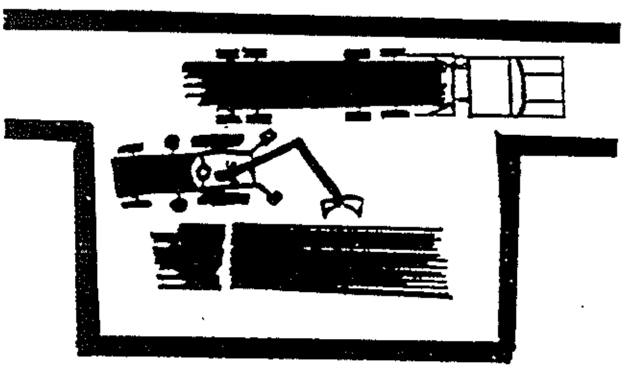


Figure 11 : Landing Layout for Knuckleboom Loader

<u>Loading</u>

The load out phase utilised a hydraulic knuckleboom loader mounted on an agricultural tractor.

<u>The Machine</u>

The Hiab 1300 Knuckleboom loader is mounted on an International 786 rubber tyred agricultural tractor. Major modifications to the tractor were required, including the addition of four stabilizer rams. The Hiab Knuckleboom is a 12 year old unit, previously used as a loading crane on a self-loading truck. The use of the crane is however, restricted to use with trucks which do not require the trailer to be off loaded.

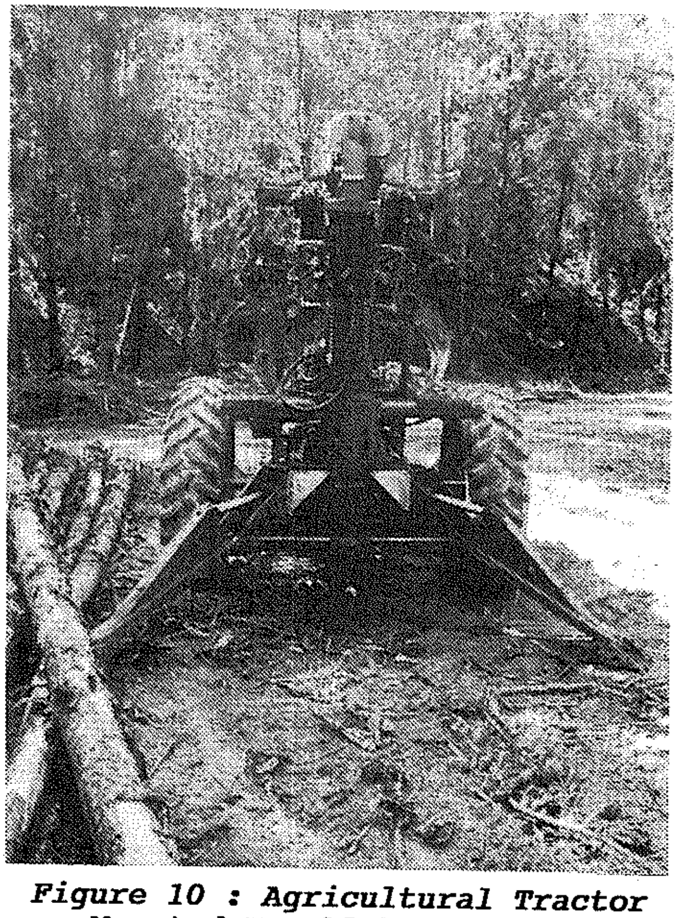


Figure 10 : Agricultural Tractor Mounted Knuckleboom Loader

<u>The Landing Layout</u>

The loader is generally positioned between the truck and log stack (see Figure 11).

Initially the logs are picked up in the centre and positioned to form a bed, into which the random short lengths are stacked. As the height of the load increased, the logs tended to be picked up at the near end and slewed up onto the trailer between the near bolsters. Although equipped with a dead heel on the main boom, the elevation of the crane when mounted on the agricultural tractor did not provide sufficient lift for the heel to be utilised.

<u>Productivity</u>

The work method involved loading both long (11-12 m) and random short length pulp on the one unit, and as a consequence, loading time varied depending on the proportion of long lengths to short lengths.

Of the six trucks loaded during the study random short length pulp logs accounted for 45% of all pieces and 14% of the volume.

The grapple was able to load twice as many shorts (7 pieces) as longs (3.5) per swing, with the time to load 1 m³ of long length pulp, being a third of the time to load 1 m³ of short length pulp.

When compared with larger purpose built loaders (Raymond, 1988b) the loading time of the tractor mounted knuckleboom was calculated to be 40% slower.

The slower load out times reflect the cumulative effect of the small grapple, lower lift capacity and slow slew time.

The loader took 26.2 minutes to load a truck with an average weight of 26.6 tonnes. The average loaded piece size was 0.23 m³ (Table 12).

The knuckleboom loader, mounted on an agricultural tractor, provides an alternative means of loading out smallwood in operations in which production does not exceed 250 m³ per day.

The loader however lacks the versatility of larger capacity machines, being unable to offload trailers and efficiently load sawlogs.

TABLE 12 : SUMMARY TABLE OF LOADER PRODUCTIVITY

	Piece Size m^3	*Pieces/ swing*	*Volume/ swing*	*Time/ swing (min)*	*Time/ m^3 (min)*
Shorts	*0.07*	*6.97*	*0.49*	*1.26*	*2.57*
Longs	*0.35*	*3.52*	*1.23*	*1.09*	*0.89*
Average	*0.23*	*4.50*	*1.04*	*1.14*	*1.10*

RECOMMENDED SYSTEM

The major change to the Present System currently operating (Figure 12) is the addition of a third extraction unit (Figure 13) to meet the productive capability of the Waratah processor.

The breakerout in the tractor crew, as presently used, was not found to be cost efficient. It is recommended that both the present tractor crew and the additional tractor crew be restricted to two workers in the bush. For haul distances less than 150m, two fallers were found to produce wood at the lowest cost. At distances approaching 200m and greater, when the tractors productivity capacity could be met by one faller, the second faller was best utilised by prestropping.

In the system recommended the processor is working to 94% of its capacity. As the operation is cold deck, the mechanical availability of the processor is not crucial.

Present System

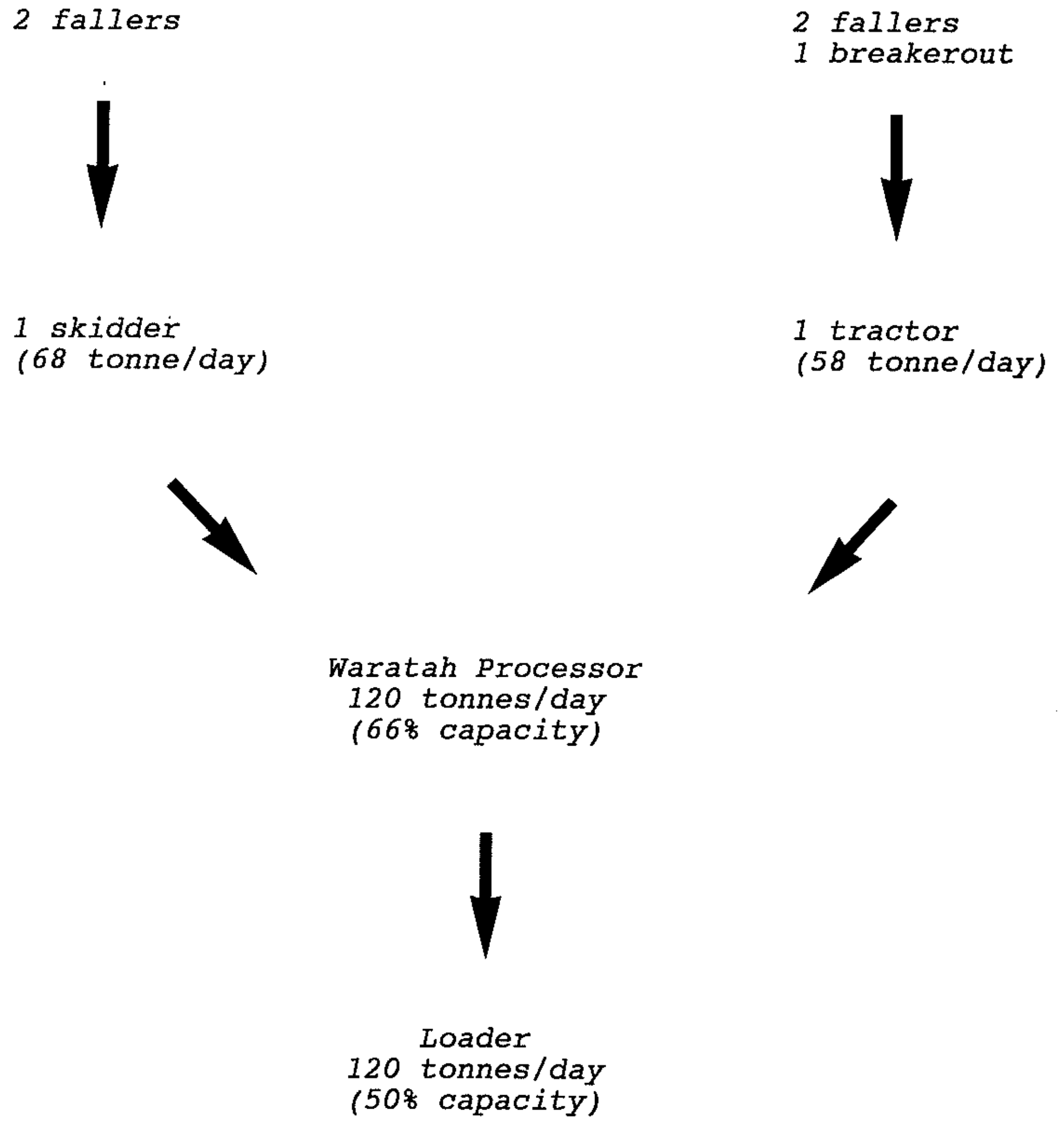


Figure 12 : Woodflow in Present Operation

Recommended System

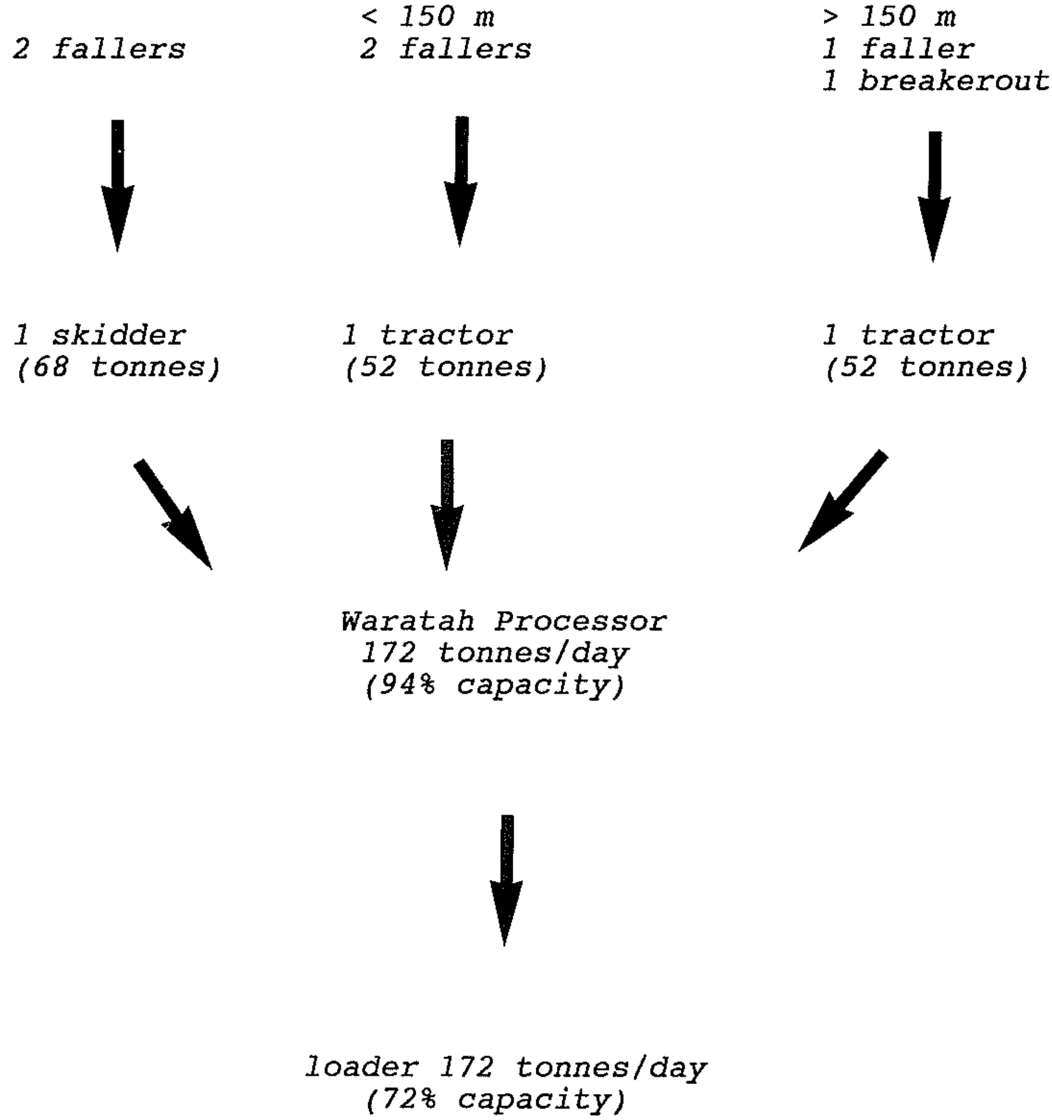


Figure 13 : Woodflow in Proposed Operation

CONCLUSIONS

FALLING

The work method, whereby the faller heads off, and trims up the first one metre of the head of the tree, worked well and allowed easy location and strop attachment during breakout. The alternative method, which involved a separate breakerout carrying out this operation as well as setting the strops, was not viable.

The felling of one drag at a time and then heading the trees off, was found to result in the highest proportion of heads cut off (85%).

BREAKOUT

Prestropping was not found to be cost effective for either the skidder or tractor extraction, although cost increases incurred by prestropping were minimal.

Only when the haul distance for the tractor approached 200m did it become viable for one of the fallers to prestrop on a full time basis.

Prestropping can however, at minimal cost, be an option to reduce the workload of the fallers, allowing them to become fully conversant with directional felling techniques required in steep country thinning.

EXTRACTION

The combined use of a tractor and skidder, with the option to use a hauler on particularly steep faces, provided the ideal mix to efficiently log the majority of areas encountered.

As the study was conducted during the summer period (with good ground conditions prevailing throughout) and the faces being thinned during the time study, it was not possible to estimate the time required to form extraction tracks. Forming tracks can severely affect the productive time available for extraction by the tractor involved.

To eliminate any interference at the landing, it is preferable that only one machine extract to a landing at one time.

An extraction machine could work to a stack being processed, without causing interference to either the processor or the extraction machine.

The observed machine productivities at 150 m in the mechanised extraction system, 52 tonnes/day for the tractor and 68 tonnes per day for the skidder, corresponded well with the long term productivity records (based on weighbridge dockets) of 120 tonne/day.

PROCESSING

The Waratah processor was found to be capable of high levels of production in radiata thinning operations. No significant relationship was found between piece size and processing time. The processor was able to process both head-first and butt-first without adversely affecting productivity. Stack orientation, while important, was not found to be limiting to production unless the angle of slew exceeded 90°. This slew capability was found to be particularly useful when processing wood pulled to the roadside, by both the hauler and the ground based machines.

With production levels of experienced operators varying by as much as 15%, selection of a good operator is essential to ensure contract viability.

As the stand was at a high stocking, branch size did not pose a significant problem. It is considered however that this processor would not be suitable to delimb the large branches encountered in stands thinned to ca 250 stems per hectare at an early age. The stroke type delimber is thought to be more suitable to process these types of stands.

The piece size processed (0.3 m average, with a range of 0.03 m to 0.57 m) was considered to be approaching the upper level of the processor's capabilities.

The wheeled excavator base allows the processor to move quickly (up to 30 kph) between landings and is central to the success of a system which requires the simultaneous extraction to up to three different landings.

As with any mechanised operation, the processor's ultimate acceptability will depend on the level of mechanical availability achieved and the back up service provided.

LOADING

The loader, presently operating at 50% capacity (120 tonne/day), is not limiting to the system. An increase in daily production to 172 tonnes/day would increase utilisation to 72%.

REFERENCES

Duggan, M J (1988) : "Colco2, An Update of LIRA's Logging Costing Program". LIRA Report Vol. 13 No. 22.

Evans, S (1984) : "Modifying Small Crawler Tractors for Thinning". LIRA Technical Release Vol 6(1).

Gleason, A P; Stulen, J A (1985) : "Radiata Branch Characteristics and Delimbing Forces", LIRA Report, Vol 10 No 4.

Pritchard, N C (1986) : "The Logquip Smart Arch for Small Crawler Tractors", LIRA Technical Release Vol. 8 No. 3.

Raymond, K A (1988) : "The Harricana Stroke Delimber in Radiata Thinnings", LIRA Report, Vol 13 No 1.

Raymond, K A (1988) : "Multiple Log Sorting with a Hydraulic Knuckleboom Loader". LIRA Report Vol 13 No 5.

Raymond, O (1986) : "Mechanised Felling and Delimbing", Evening Session, in "Ground-Based Logging" Seminar Proceedings LIRA.

Travers, K (1986) : "Versatility of Small Crawler Tractors in Thinnings". In: Proceedings of a LIRA Seminar on Ground Based Logging, held in June 1986. LIRA, Rotorua.

Wells, G C (1981) : "Costing Handbook for Logging Contractors", LIRA.

The costs stated in this Report have been derived using the procedure shown in the LIRA Costing Handbook for Logging Contractors. They are only an estimate and do not necessarily represent the actual costs for this operation.

APPENDIX I

FALLER BREAKING OUT FOR SKIDDER EXTRACTION (No Prestropping)

	Mean (min)
Fell drag	7.85
Trim heads	4.90
Breakout drag	5.40
Wait for skidder	0.43
Total cycle time	18.54
Pieces/cycle	6.81
Breakout time/cycle	0.79

SEPARATE BREAKEROUT (Prestropping)

Work time/cycle	7.74
Wait time/cycle	0.86
Machine Breakout time/cycle	4.03
Total Cycle Time	12.63
Pieces/cycle	6.4
Breakout time/piece	0.63

FALLER BREAKING OUT FOR TRACTOR EXTRACTION (No Prestropping)

Fell drag	7.70
Trim heads	5.13
Breakout drag	5.70
Wait for tractor	0.83
Total cycle time	19.36
Pieces/cycle	6.20
Breakout time/cycle	0.92

SEPARATE BREAKEROUT (Prestropping)

Work time/cycle	7.51
Wait time/cycle	3.87
Machine Breakout time/cycle	4.14
Total Cycle Time	15.52
Pieces/cycle	6.0
Breakout time/cycle	0.69

APPENDIX IIa

WARATAH PROCESSOR COSTS

<u>Machine Costs</u>	
Waratah Processor Head	217
Excavator Base	293
	505
<u>Labour Costs</u>	
	143
<u>Supplies</u>	
Transport	80
Chainsaw	46
Incidentals	4
	130
Overheads 2%	15.56
Profit 10%	79.00
	873.00

APPENDIX IIb

SKIDDER AND TRACTOR COSTS (Conventional)

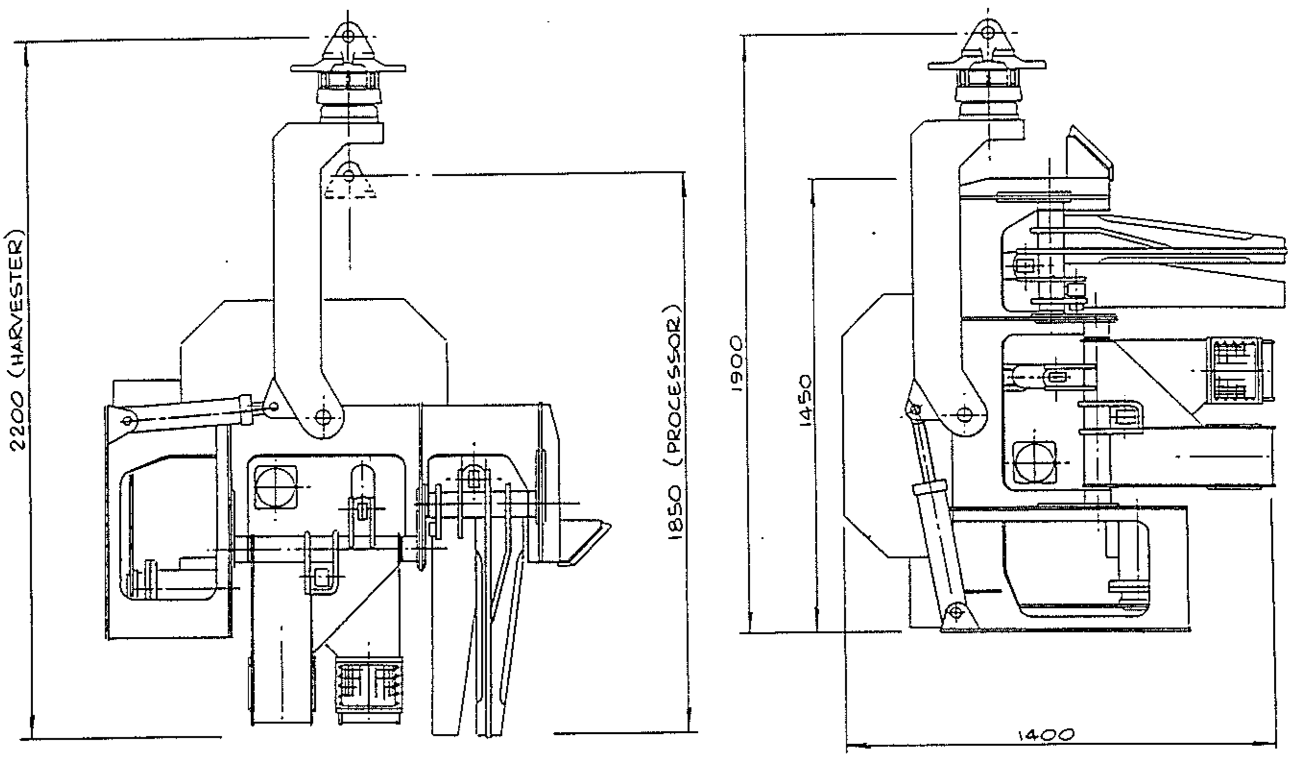
Summary of Machine Costs

Machine Purchase Price	136,000
Machine Life in Years	5
Machine Resale Value	35,000
Productive Hours Per Year	1,495
Machine Owning Costs : ($/hr)	
Depreciation	12.31
Cost of Capital	12.79
Insurance	1.60
Total Owning Costs	26.70
Machine Operating Costs : ($/hr)	
Fuel	5.50
Tyres	3.00
Rigging	2.45
Repair and Maintenance	12.31
Total Operating Costs	23.27
Total Hourly Costs	49.96
Total Daily Costs Based on 6.5 Prod. Hrs/Day	324.75
Labour	
3 fallers	120
1 machine operator	120
	480/day
Supplies	
Incidentals	6
Transport	80
Chainsaw 3 @ $23.00/day	69
	154
	$959

APPENDIX III

WARATAH FORESTRY EQUIPMENT

HEAVY DUTY GRAPPLE PROCESSOR/HARVESTER



TECHNICAL DATA

FELLING – CROSS CUTTING

Max Diameter	50cm	20"
Felling Power	40kw	54HP
Felling Saw	Hydraulic Driven	
Chain Dimension	½ inch or 404	
Shear (optional)	46cm	18"

FEED

Feed Type	2 Hydraulically Driven Steel Rollers and 1 Driven Chain. Option: 4 Hydraulically Driven Steel Rollers or 3 Rubber Drive Wheels.	
Feed Power	19kw @ 260 bar △ P Start	1.9 Ton
	28kw @ 260 bar △ P Run	2.8 Ton
Feed Speed	0-3.5m/s	0-11.5Ft/s
Clamping Power	Adjust to required pressure	

DELIMBING

Type	2 Moveable Delimbing knife arms Option: 2 additional delimbing arms 1 fixed knife	
Delimbing Diameter	min – 75mm – 500 max	3in – 20"

HYDRAULIC SYSTEM

Required Oil	From 200 L/min	44 Gals/min UK
Maximum Pressure	260 Bar	3770 p.s.i.
Minimum Power	75kw	100HP

Open, Closed, load sensing, or Pressure comp, Danfoss, Monsun Tison, GV 10 Rotator Indexators or Waratah Heavy Duty Gear Rotator.

WEIGHT

	1000kg Depending on options	2200 lbs

We reserve the right to alter the specifications without prior notice