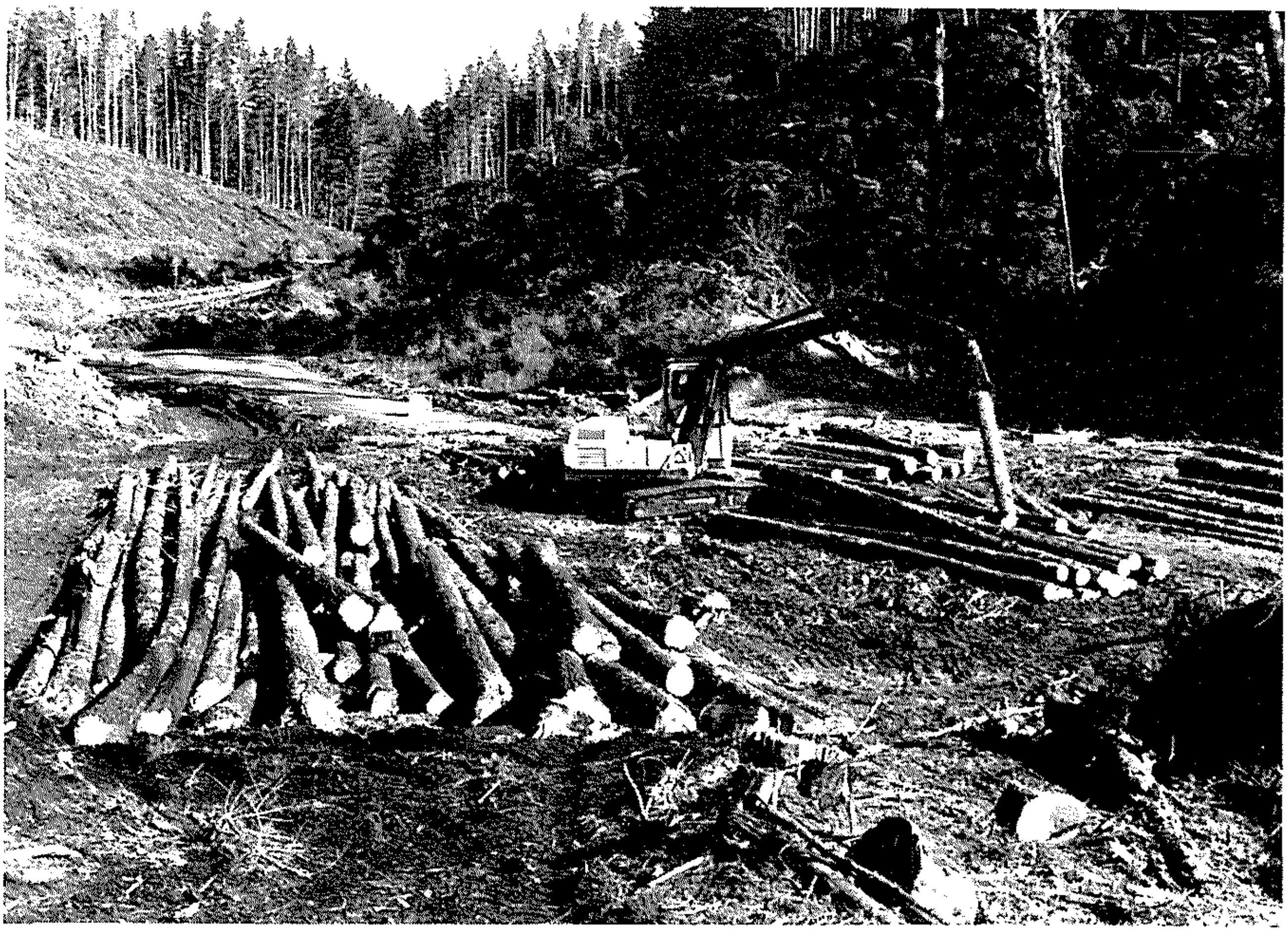
LOGGING INDUSTRY RESEARCH ASSOCIATION

NEW ZEALAND

PROJECT REPORT

An Evaluation of a Hydraulic Knuckleboom Loader in a High Production/Multiple Log Sort Operation

Myron Williams



Project Report

P.R. 47

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An Evaluation of a Hydraulic Knuckleboom Loader in a High Production/Multiple Log Sort Operation

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ABSTRACT

A detailed work study of a Mitsubishi MS230 hydraulic knuckleboom loader working with a tractor clearfell gang, was undertaken.

The loader showed the capacity to sort, stack and load up to nine separate log sorts at production levels up to 443 tonnes per 11 hour day. At this level the loader still had additional capacity and on one day loaded out a further 80 tonnes from stockpiles.

Truck scheduling has a major effect on loader utilisation and therefore on overall loader productivity. A regular flow of trucks through the day is essential. A scheduling regime is suggested and further study on the effects of truck scheduling on logging system productivity and profitability is recommended.

The 0.2 to 0.26 ha landings used were generally larger than required, but layout of the different work zones on the landing is important for efficient use of the space. Also a heelboom loader configuration would reduce required landing area.

The level of interference between the loader and the skiddies and tractors was minimal.

Truck loading time averaged 0.55 minutes per tonne, with pulp logs taking 50% longer to load than quality logs. Short quality logs took 30% longer to load than long quality logs.

The potential to produce at higher production levels, if other logging system factors are not limiting, was indicated.

ACKNOWLEDGEMENTS

The assistance and cooperation of Terry Faulkner, the owner/operator of the loader studied, the logging contractor involved, Alan Sinton and his crew members and the logging, wood supply and industrial engineering staff of NZFP Forests Ltd, Kinleith, is gratefully acknowledged.

1. INTRODUCTION

As part of the ongoing 'Work on Landings' LIRA project area, and to fill a gap in information collected to date, a trial looking at the use of a hydraulic knuckleboom loader, working with high production and multiple log sorts, was proposed.

To date most of the work undertaken by LIRA in the knuckleboom loader/multiple log sort area has been descriptive of existing operations (LIRA 1979, Hemphill 1987 and 1988, Raymond 1988). A limited amount of experimental trial work has been completed in the log processing field, which also looked at the flow on effects on the landing (Donovan 1989, Kellogg 1987, Prebble 1988). Multiple log sorting with a hydraulic knuckleboom loader has been investigated in New Zealand but only in relatively low producing operations - around 200 tonne/day or less (Raymond 1987, Raymond 1988).

When the maturing forests of Northland, East Coast North Island, Nelson/ Marlborough and Otago/Southland in particular, reach full production potential, and when New Zealand's hauler operations reach full productive capacity, it is almost inevitable that there will be a need to sort large numbers of log sorts (up to 12 and more) and large volumes (300 tonne/day plus) through relatively small, restricted landings (Galbraith 1987).

Overseas experience (Hemphill 1987, Hemphill 1988) would suggest that hydraulic knuckleboom loaders have the potential and capacity to meet the projected future demands, where more traditional New Zealand rubber tyred front end and rope crane loaders are likely to be limited by ground conditions, space or operating cost.

Truck scheduling is an important factor that must be considered in the overall log production system. To quote Kellogg (1987) "The logging operation should be viewed as a whole system with the individual elements such as hauling, loading and cartage working together."

To enable a smooth running extraction system to operate as well as maintain loadout production, trucks must be scheduled at a consistent interval throughout the day that is related to the rate of production of the extraction machines (Kellogg 1987).

The importance of the truck scheduling factor in the log production system is reiterated in various log loader and logging system studies including; Harper (1971), Clair (1977), Raymond (1987) and Prebble (1988). Also, Raymond (1988) in his "Multiple Log Sorting With a Hydraulic Knuckleboom Loader" report stated: "This study showed that the scheduling of trucks is the critical factor affecting the productivity of the whole operation."

This study was aimed to provide information that could be added to existing 'Work on Landings' and hydraulic knuckleboom loader/multiple log sort research results.

With the likely increase in numbers of hydraulic knuckleboom loaders operating in New Zealand, coupled with the projected move to more difficult logging and roading conditions, it is timely to attempt to bring together the information required to set up a harvesting system predictive model for New Zealand operating conditions. It is envisaged that this model should be able to predict optimum harvesting systems and layout given a particular set of extraction, loading, log sort, landing size, production and transport parameters. The information gathered during this trial will provide some of the inputs required to construct such a model.

2. PROJECT DESCRIPTION

2.1 OBJECTIVES

The primary objective of the trial was to identify and investigate factors that influence the efficiency of sorting, stacking and loading at high production levels with a hydraulic knuckleboom loader. In particular:-

(a) The influence of different numbers of log sorts and different truck scheduling methods on:

- the productive capacity of the loader, and
- the size of landing required.

(b) The interaction between extraction, processing, sorting, stacking and loading operations in a high production setting.

(c) Truck loading time for different log and truck types.

The secondary objective was to assess the suitability of hydraulic knuckleboom loaders for use in high production/multiple log sort operations.

2.2 THE LOADER AND OPERATOR

The loader studied during this trial was a 1980 model Mitsubishi MS230 hydraulic excavator base machine and boom with a standard length dipperstick as outlined in the machine specifications attached as Appendix Ia. General specifications of the machine are given in Appendix Ia but some modifications were carried out during conversion to a log loader. These modifications included: the fitting of a two-tonne counter weight, bringing the operating weight to approximately 25,000 kg; the cab was raised 0.5 metres and a cab guard was fitted; hydraulic modifications to enable grapple rotation were carried out and a Prentice model 848-W log bypass grapple was fitted. Grapple specifications are shown in the attached Appendix Ib.

The loader was operated competently and efficiently by an operator who has had many years experience in loading and logging operations, but only two years experience on the machine studied.

Conversion to a log loader was completed in early 1987 when the machine was between six and seven years old and had completed approximately six thousand operational hours as a digger. This trial was completed in February 1989 after approximately four thousand hours use as a log loader.

Apart from normal hydraulic hose replacements and minor breakdowns, no major unscheduled maintenance work has been necessary since the machine has been employed as a log loader. Generally mechanical availability has been high for a machine of its age and operational hours.

A machine costing on an equivalent new machine is outlined in Appendix II. The base machine used in the costing was a Sumitomo LS3400 with a standard excavator boom and a Prentice C-848-W continuous rotation log bypass grapple. The following modifications are included in the delivered price of $252,800:

(i) Raise cab and construct cab guard.

(ii) Install belly plates.

(iii) Run required extra hydraulic lines and set up controls.

The costing is based on an average scheduled machine hours (SMH) of 9.86 hours per day adjusted to observed productive machine hours (PMH) of 71% of SMH i.e. 7.00 PMH per day.

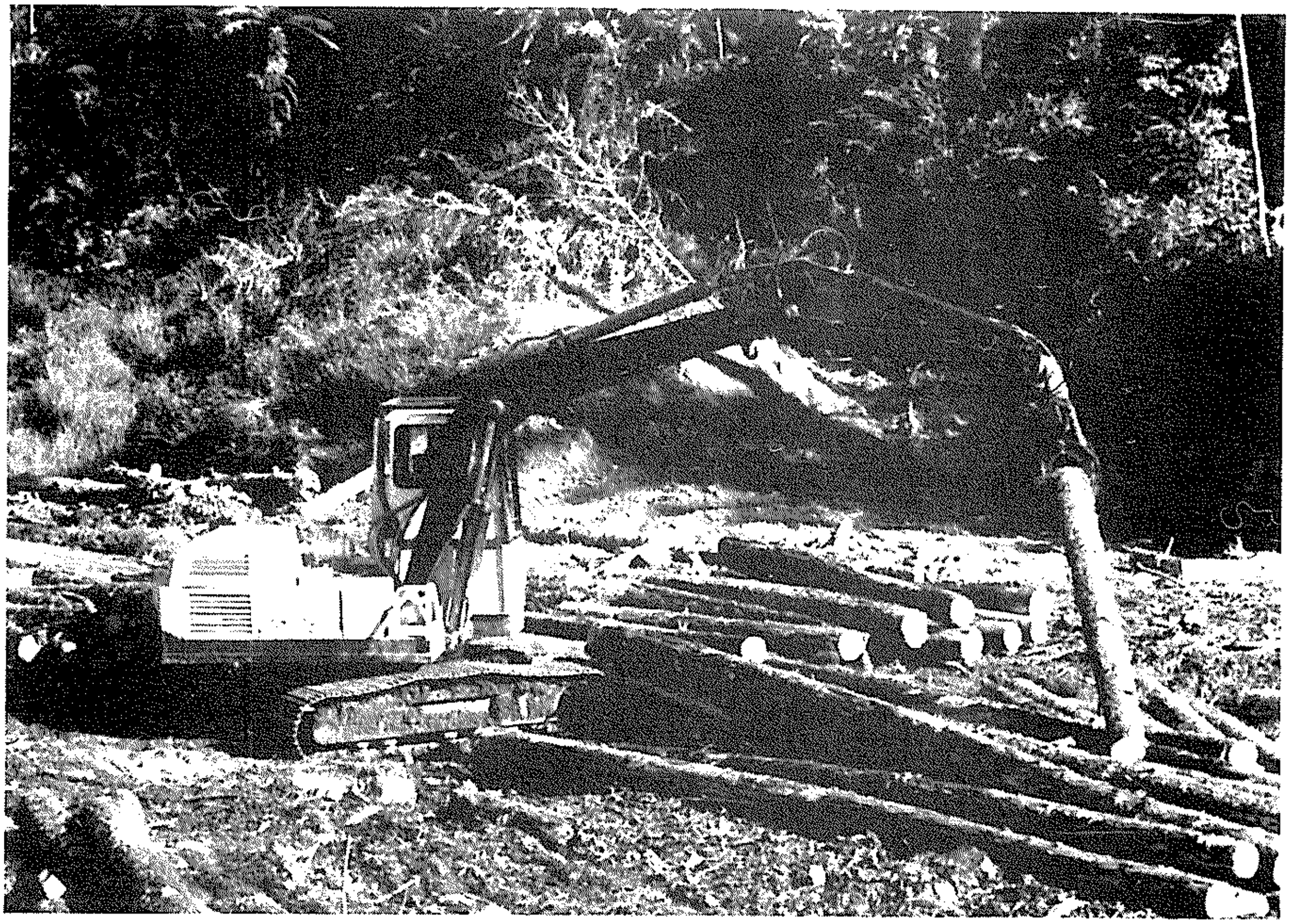

Figure (i) : The Mitsubishi MS230 Log Loader

2.3 STUDY SITE

The trial was conducted on four separate landings within one logging area in the Kinleith forest. One of the landings was at the end of a dead end road, the other three had a road running through them. In the latter cases the truck stood on the road for loading (Figure ii).

Four different landings were used during the trial. Figure (ii) shows the landing locations. All of the landings are described in more detail in the following sections.

Landing construction size and location were as per NZFP Forests Ltd policy and prescription. Weather conditions during the trial were dry and surface conditions were not limiting to the landing operations.

Extracted mean volume per piece, based on a 534 piece measured sample, was 1.79m^3, with a maximum of 7.32m^3 and a minimum of 0.06m^3. Mean extracted length per piece was 22.4 metres (maximum of 42.5 metres), mean large end diameter per piece was 44.3 centimetres and mean small end diameter per piece was 21.6 centimetres.

2.4 OPERATION DESCRIPTION

Trees were felled, trimmed and topped for extraction in tree length. The extraction machinery consisted of two tractors, a D65 Komatsu with towed arch and a D45E Komatsu. The small tractor was used as a cleanup machine and was used for extraction on a part time basis. The D65 was responsible for most of the production achieved.

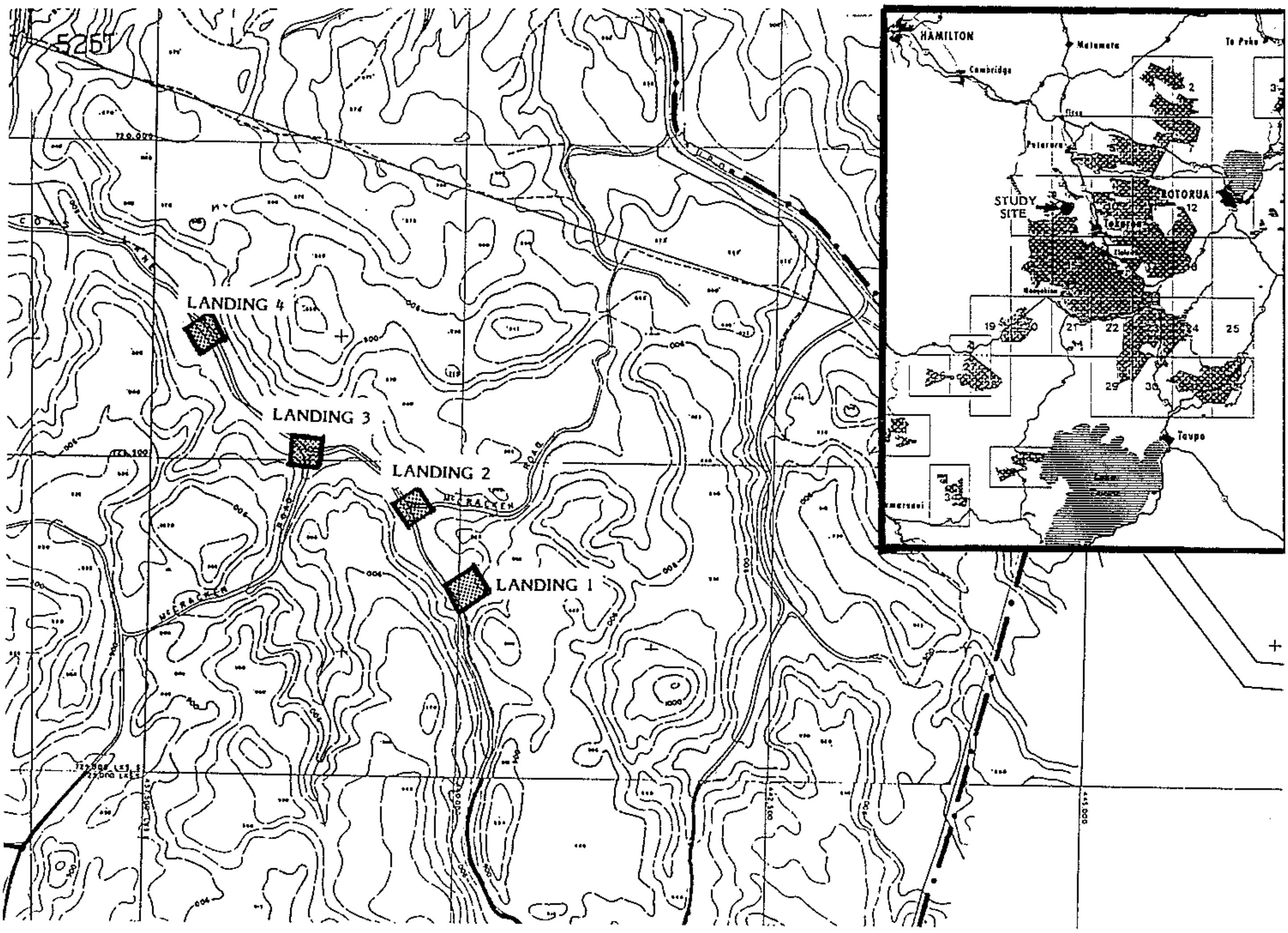

Figure (ii) : Landing Location Map (Wiltsdown area, Kinleith Forest)

Crew manpower during the study was steady at seven for all but one of the nine trial days, when six men were on the job. Landing manpower was planned at three, but the combination of work performed off the landing and one day worked with only two skiddies, resulted in a weighted average of between two and three effective skiddies for each treatment.

The MS230 Mitsubishi hydraulic knuckleboom loader was operated as a sorting, stacking and loading machine in a hot deck system. Generally the loader worked on the landing being worked by the extraction crew. However, on some of the early start days the loader loaded from landings other than those most recently worked by the extraction crew. On two days during treatments two and three the crew moved to a new landing while the loader finished sorting and stacking and/or loading from the previously worked landing.

Truck scheduling was controlled by the company truck controller on radio request from the loader driver. The truck controller was aware of the study and tried to despatch trucks immediately on receipt of a request from the loader driver. The effects of truck scheduling on the extraction/loading system are discussed in depth in the truck scheduling section.

The logging operation studied in this trial fits into a high production category with average daily production during the trial of 384 tonnes. The crew was under no production quota restrictions during the trial and the trial itself seemed to have no noticeable effect on crew production level.

In a trial such as this it is important to keep factors that are not specifically being investigated as constant as possible. Some variation in tree size and extracted log volumes did occur between landings and treatments. In the final analysis however, extraction cycle times and volumes within treatments were relatively constant. Some minor exceptions occurred where normal operational factors, such as the need for the extraction machine to do some tracking, had an effect on woodflow to the landing.

2.5 TRIAL DESCRIPTION AND METHODS

The trial data was collected using the following data collection and information gathering methods.

1. A continuous timing work study was carried out on the loader while it was employed in a hot loading situation where the job required sorting, stacking and loading of total crew production. A total of nine work days of data was collected, three days in each of the three treatments as outlined below:-

Treatment 1

Eight log sorts were processed during this treatment i.e.

1. 12 metre Japan export
2. 11 metre Korean export
3. 10 metre China export
4. SA short sawlogs
5. A short sawlogs
6. Pulp 1 longs
7. Pulp 1 shorts
8. Pulp 3 shorts

The 11 metre Korean export was produced for the first day of the treatment but was replaced by 10 metre China export for the last two days of the treatment.

The SA sawlogs and A sawlogs were generally not produced concurrently i.e. either one or the other being produced at any one time.

This meant six log sorts being cut at any one time.

Nine separate log types were loaded out during the three day period of Treatment 1. The extra log type resulted from loadout of existing stock produced outside the treatment period.

The loader started work two hours before the extraction crew and stayed on after the extraction crew had finished work to complete sorting and stacking, tidy up and load further trucks if they were available. Truck scheduling was on demand from the loader driver.

Treatment 2

Seven log sorts were processed during this treatment i.e.

1. 12 metre Japan export
2. 10 metre China export
3. A short sawlogs
4. Pulp 1 longs
5. Pulp 1 shorts
6. Pulp 3 longs
7. Pulp 3 shorts

Only one load of pulp 3 longs was loaded out during this treatment so effectively a total of six significant log sorts were processed.

Seven separate log types were loaded out during this treatment period.

The loader started work at the same time as the extraction crew but stayed on after the extraction crew had finished work to complete sorting and stacking, tidy up and load further trucks if they were available. Truck scheduling was as in Treatment 1 above.

Treatment (3)

Nine log sorts were processed during this treatment i.e.

1. 12 metre Japan export
2. 8 metre Japan export
3. 10 metre China export
4. 6 metre China export
5. SA short sawlogs
6. A short sawlogs
7. Pulp 1 longs
8. Pulp 1 shorts
9. Pulp 3 shorts

Nine separate log types were loaded out during this treatment period.

The loader work pattern and truck scheduling was as for Treatment 1 above.

2. An activity sampling study was undertaken to assess the production, processing, sorting and loading interactions and in particular to measure the interference between the extraction machines, the skiddies, and the loader.

3. The landing layout and effective landing area used for each treatment was described and measured.

The same basic layout was adopted for all landings with some minor modifications in Treatment 3, where more log sorts were made. Tree length logs were landed in the processing area on each landing where they were measured, marked, cut to length (bucked) and trimmed where necessary. The loader sorted and stacked the processed logs into four to five separate stockpiles, some with more than one log type. Loading took place from the sorted stockpiles with only the occasional log being loaded directly from the processing area to the truck. The log sorts producing the largest percentage of total volume were stacked closest to the processing area to minimise the amount of repositioning and restacking required to complete the sort and stack phase of the operation. The total area of each landing was separated into various areas of predominant use. The following definitions have been used in the analysis:-

Fleeting area - A working area for the extraction machines to fleet up processed logs. An area used for access to the landing and for manoeuvering the extraction machines. No logs were processed in this area.

Processing area - The area in which all log making activities were undertaken.

Loading area - The area used by the loader while loading trucks.

Stockpile area - The physical area taken up by sorted stockpiles.

Road area - The formed and metalled area generally used to locate trucks while loading. Only landings with through roads have this area defined.

Truck loading area - The area used for locating trucks while loading on non-through road landings. This area may be formed and metalled in parts.

Unused area - Total formed area minus the sum of all other defined areas.

Sorting and stacking area has not been specifically delineated but can overlap all areas, except the unused area.

4. Truck loading times were recorded, by truck and log type, during the continuous time study of the loader. In addition the number of logs and the number of grapple swings per load were recorded. Load weights were taken from weighbridge records.

   Data was collected on a total of 144 separate log type unit loads during the nine day trial period.

3. RESULTS AND DISCUSSION

3.1 LANDING LAYOUT

TREATMENT 1
(Six log sorts, loader early start)

Figure (iii) shows the basic landing layout of Landing 1 and Table 1 summarises its area utilisation.

Landing 1 was completely adequate in terms of size and shape to enable the volume of logs produced to be processed, sorted, stacked and loaded with a minimum of landing caused delays.

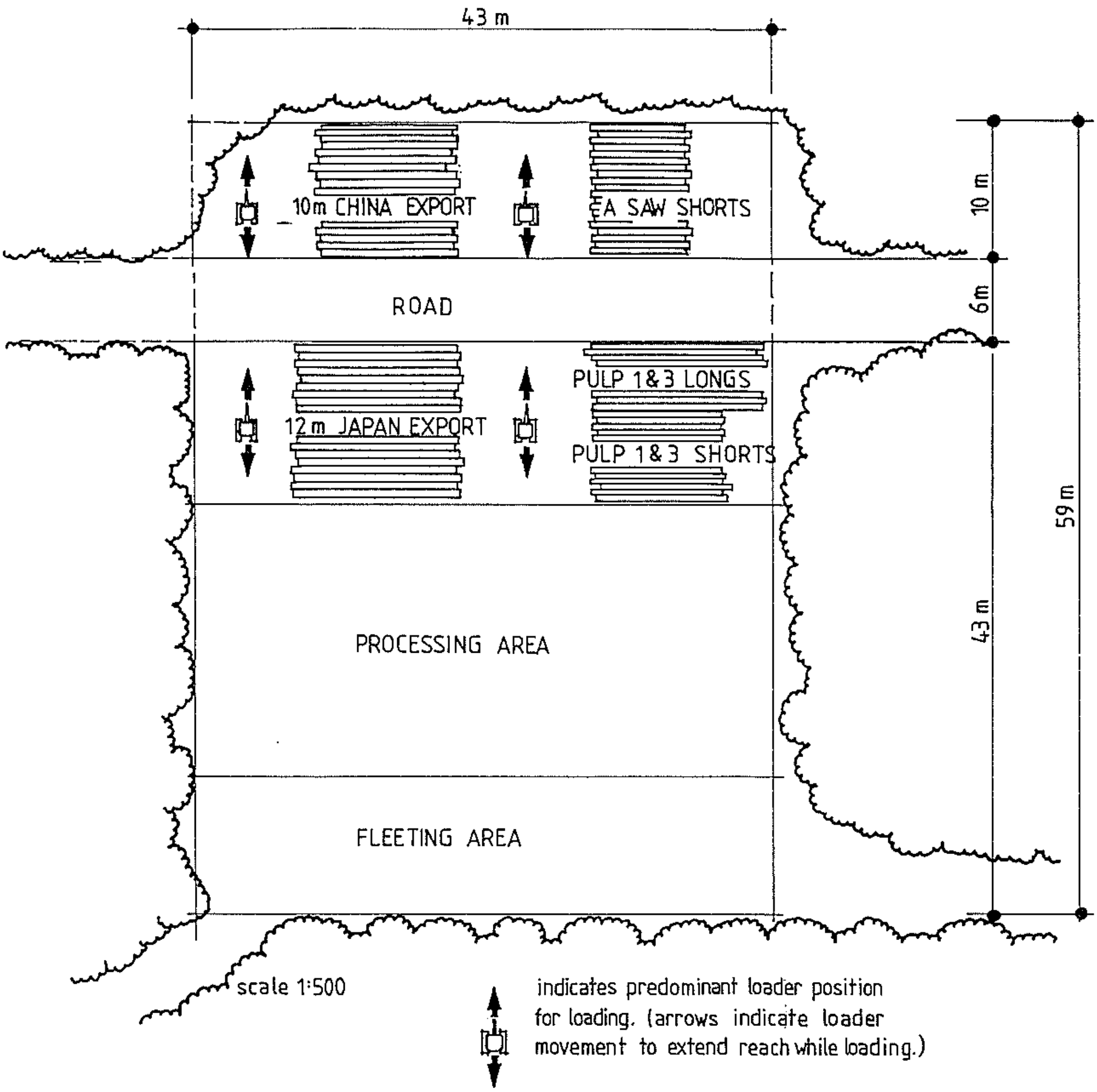

Figure (iii) : Plan of Landing 1, Treatment 1

Table 1 : Area utilisation - Landing 1, Treatment 1

Operation	Area Ha	% of Total Area
Fleeting	0.04	16
Processing	0.09	36
Loading	0.03	12
Stockpile	0.05	20
Road	0.03	12
Truck Loading	N/A	N/A
Sub Total-Used	0.23	96
Unused	0.01	4
Total	0.25	100

TREATMENT 2
(Six log sorts)

Two landings were used during this treatment: Landing 4 for two days and Landing 3 for one day. Figure (iv) shows the basic layout of Landing 4 and Table 2 summarizes its area utilisation.

Figure (v) shows the basic layout of Landing 3 and Table 3 summarises its area utilisation.

The layout, size and shape of Landing 4 was not limiting to the overall extraction/ processing/loading system at the level of production achieved during days one and two of Treatment 2.

Landing 3 became limiting to the system productivity towards the end of day three. The combination of very high production, (the highest observed during the trial), a small truck scheduling problem and the shape of the landing, contributed to a build up of unsorted logs in the processing area. To avoid the resulting interference to the tractor haul cycle, the tractors were moved to produce onto Landing 2 for the last forty-five minutes of the day. In hindsight the tractors could have stayed on Landing 3 and although some degree of interference would have resulted, production for the day would not have been significantly less than was actually achieved.

The size and shape of the fleeting area and the resulting size of the processing area contributed to the landing problems observed. The location of the road resulted in a significant unused area on the landing. (See Figure (v) towards the top of the diagram.) This contributed to the size and shape of the processing area. However, the landing operation limiting factors should be kept in context and truck scheduling and production were part of the overall equation as well. The two latter mentioned factors will be further discussed in their respective sections below.

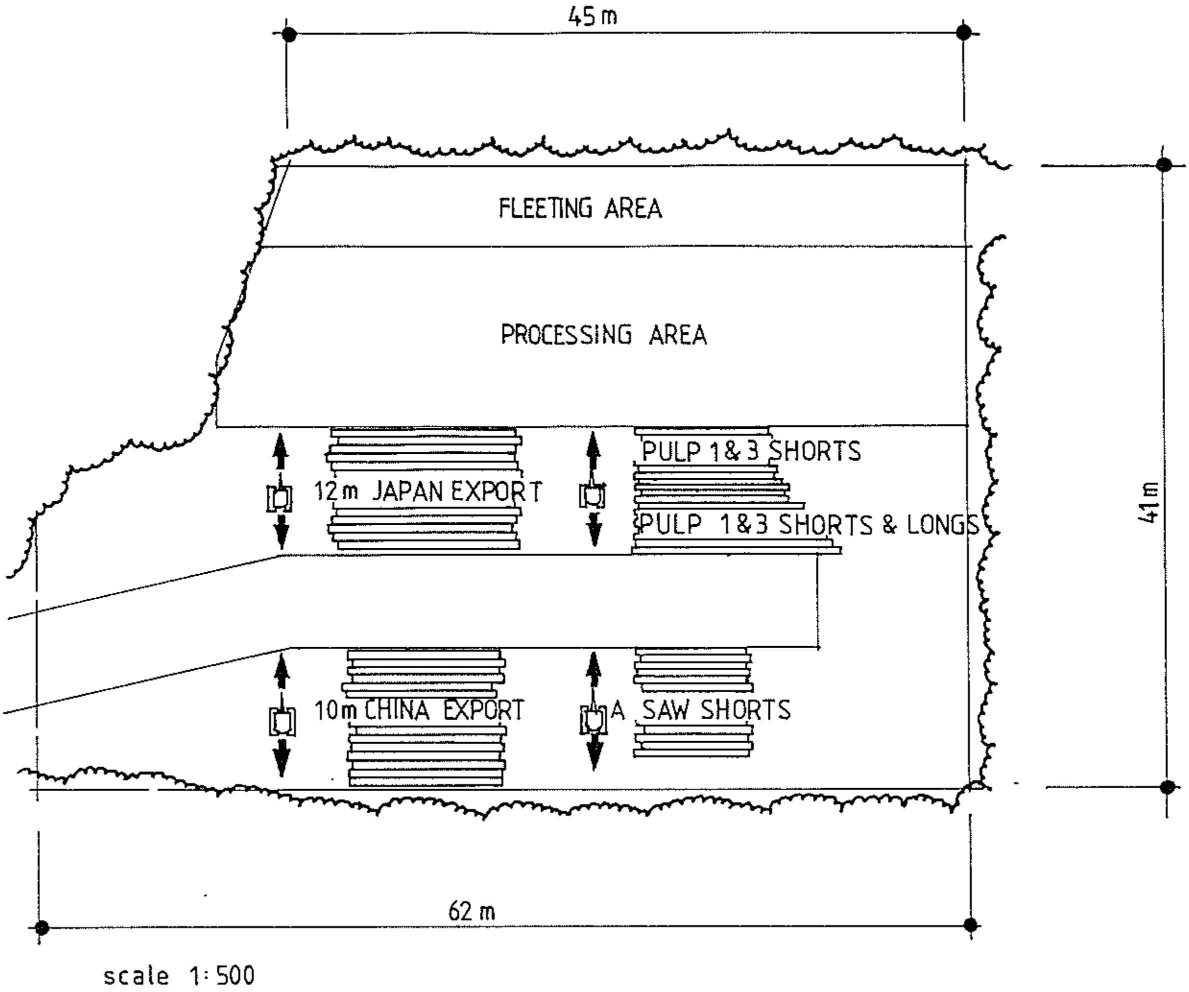

Figure (iv) : Plan of Landing 4, Treatment (2)

Table 2 : Area utilisation - Landing 4, Treatment 2

Operation	Area Ha	% of Total Area
Fleeting	0.03	12
Processing	0.06	23
Loading	0.02	8
Stockpile	0.04	17
Road	N/A	N/A
Truck loading	0.04	15
Sub Total Used	0.18	75
Unused	0.06	25
Total	0.24	100

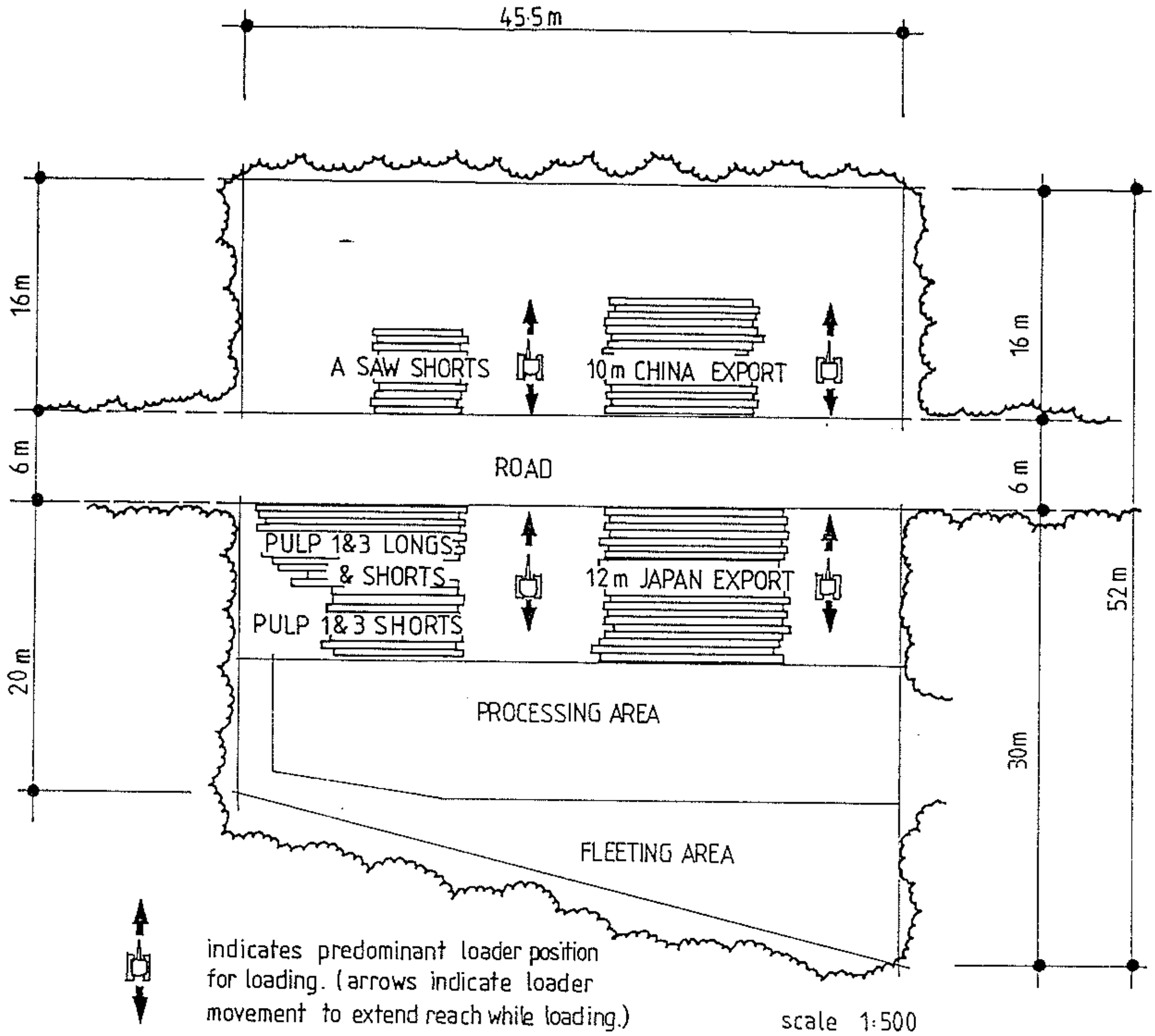

Figure (v) : Plan of Landing 3, Treatment 2

Table 3 : Area utilisation - Landing 3, Treatment 2

Operation	Area Ha	% of Total Area
Fleeting	0.02	9
Processing	0.05	23
Loading	0.03	14
Stockpile	0.04	18
Road	0.03	14
Truck loading	N/A	N/A
Sub Total Used	0.17	78
Unused	0.05	22
Total	0.22	100

TREATMENT 3
(Nine log sorts, loader early start)

Three landings were used during this treatment: Landing 3 for day one, Landing 4 for day two and Landing 2 for day three. Landing 3 layout is illustrated in Figure (vi) and a summary of area utilisation on Landing 3 is shown in Table 4.

Landing 4 layout is shown in Figure (vii) and an area utilisation summary is given in Table 5.

Landing 2 layout is illustrated in Figure (viii) and area utilisation data is summarised in Table 6.

The layout, size and shape of the landings used during Treatment 3 had no major effect on overall system production at the level of production achieved.

The extra log sorts were accommodated on the landings with relative ease and stockpile space never became system limiting on any of the three landings observed in this treatment.

The landing layout chosen on Landing 4 on day two of this treatment (Figure vii) illustrated an important factor that must be taken into account when operating a loader of the type studied in this trial. The requirement to move the loader to stack or restack of the type studied in this trial.

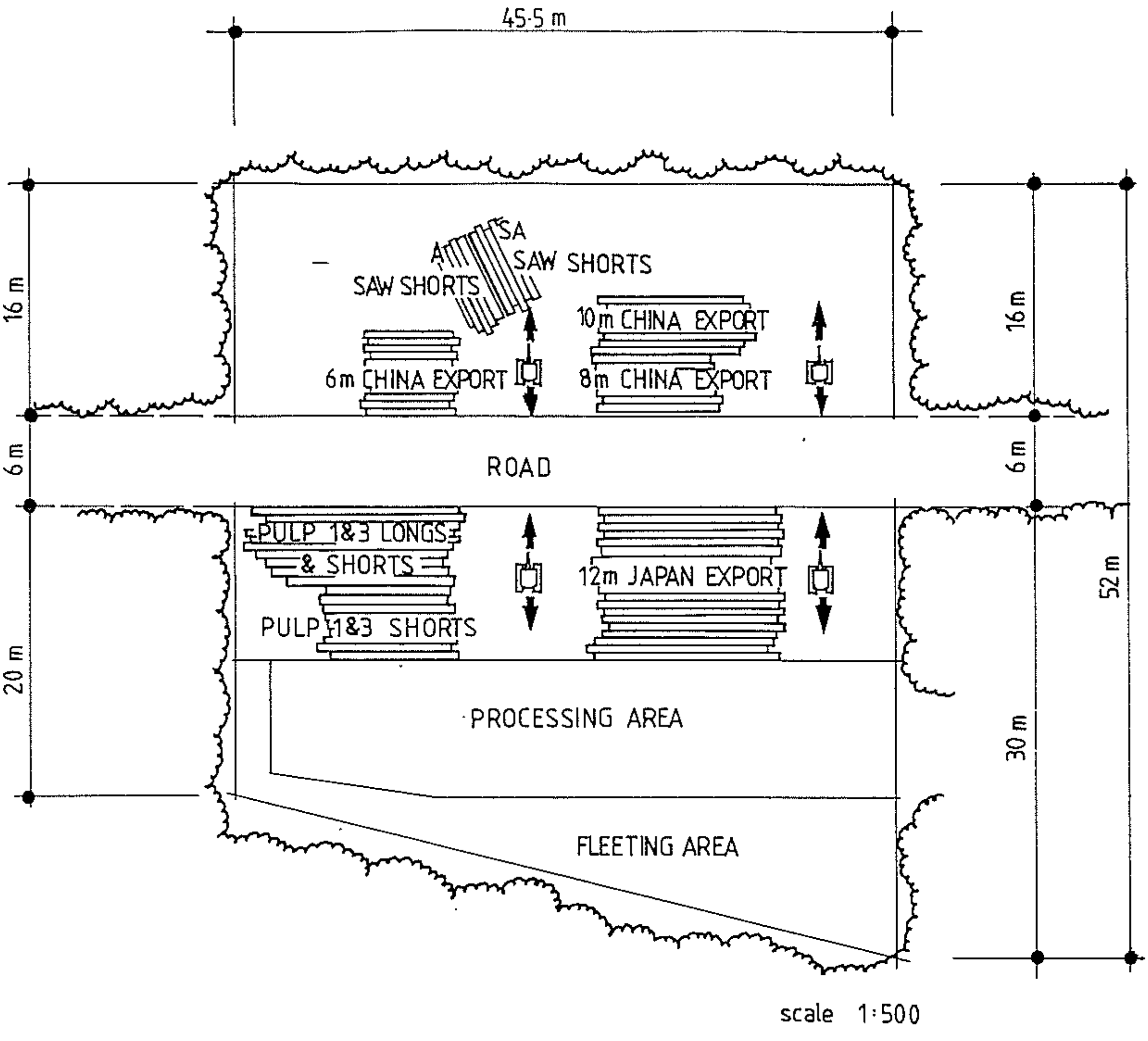

Figure (vi) : Plan of Landing 3, Treatment 3

Table 4 : Area utilisation - Landing 3, Treatment 3

Area Description	Area Ha	% of Total Area
Fleeting	0.02	09
Processing	0.05	23
Loading	0.03	14
Stockpile	0.042	18
Road	0.03	14
Truck loading	N/A	N/A
Sub Total Used	0.172	
Unused	0.048	22
Total	0.22	100

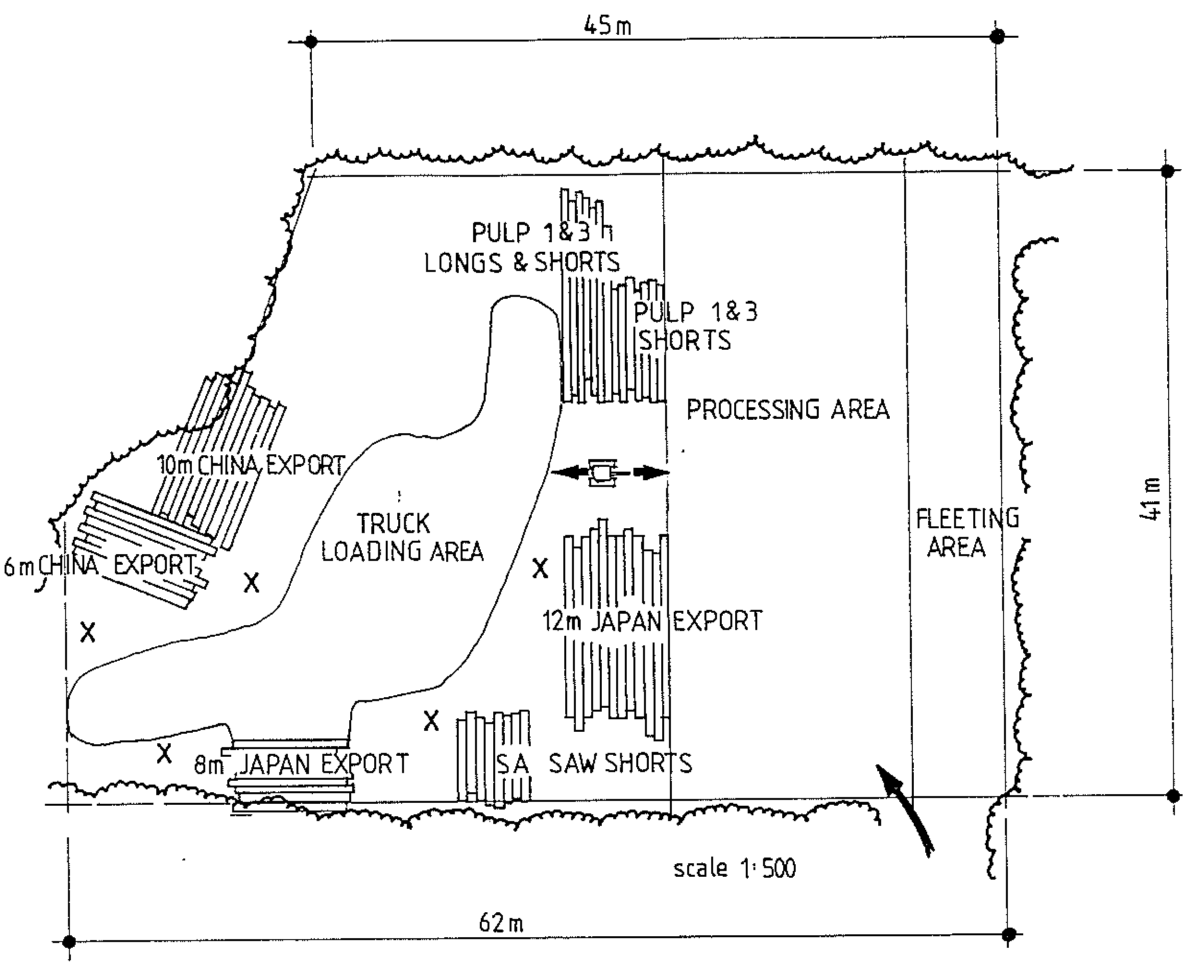

Figure (vii) : Plan of Landing 4, Treatment 3

Table 5 : Area Utilisation - Landing 4, Treatment 3

Area Description	Area Ha	% of Total Area
Fleeting	0.03	12
Processing	0.07	27
Loading	0.03	12
Stockpile	0.04	17
Road	N/A	N/A
Truck loading	0.04	15
Sub Total Used	0.21	83
Unused	0.04	17
Total	0.25	100

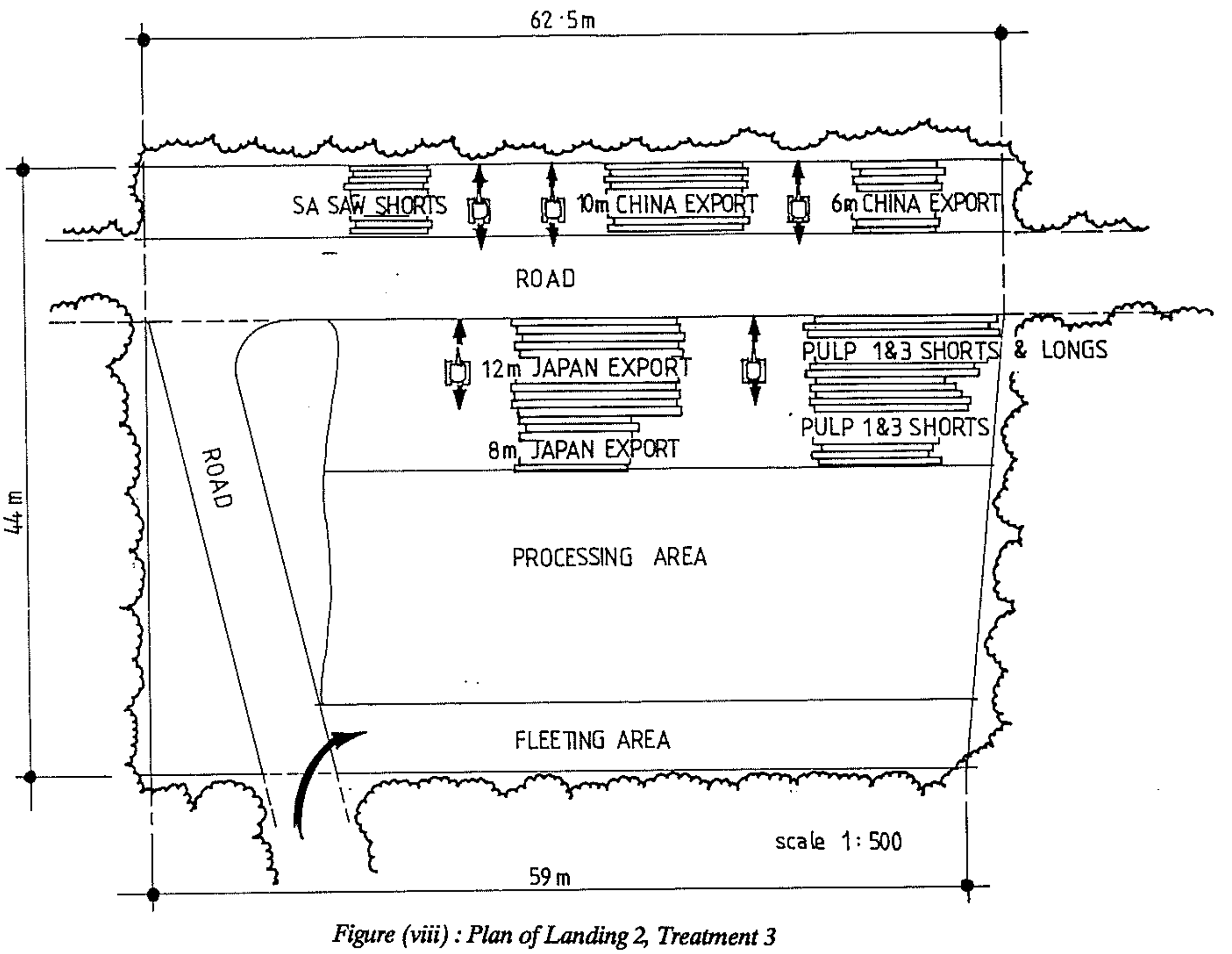

Figure (viii) : Plan of Landing 2, Treatment 3

Table 6 : Area utilisation - Landing 2, Treatment 3

Area Description	Area Ha	% of Total Area
Fleeting	0.03	12
Processing	0.07	27
Loading	0.03	12
Stockpile	0.04	15
Road	0.05	19
Truck loading	N/A	N/A
Sub Total-Used	0.22	85
Unused	0.04	15
Total	0.26	100

The requirement to move the loader to stack or restack the sorted log types, must be kept to a minimum by locating stockpiles as close as possible to the processing area or locating the processing area close to the potential stockpile areas. As shown in Figure (vii), three of the six stockpiles were located a considerable distance from the processing area and hence several boom swings and repositions of the loader were required to move the logs from the processing area to the sorted stockpiles. This type of landing layout with widespread stockpiles also tends to lead to an increased amount of reposition to load time. Loadout production was low from Landing 4 in this treatment but truck scheduling rather than landing layout seemed to contribute most to that situation. (Refer to the truck scheduling section).

Given a higher logging production level than that observed and more optimum truck scheduling, the landing layout as shown in Figure (vii) could well have become limiting to the overall logging system productivity. By locating the 12 metre Japan export and pulp stockpiles closer to the China export stockpiles, reposition and restack time could have been reduced. The available processing area would have also increased in size.

3.2 LANDING INTERACTIONS

Loader

The proportions of scheduled machine time that the loader spent doing each work activity, by treatment, is shown in Table 7.

Table 7 data was collected by continuous time study. Activity definitions are attached in Appendix IIIa.

No significant difference at the 95% confidence level was detected within most activities, between treatments. There was significantly more mechanical delay in Treatment 2 due to one breakdown on day two that could not be attributed to treatment. Skiddy interference in Treatment 2 was significantly higher than in the other treatments. This could not be attributed to treatment but related more to logging production level, with the very high

Table 7 : Loader Work Content

Activity		Proportion Of Total Worktime (%) Treatment 1	2	3
Sort & Stack		21	23	24
Restack		11	8	9
Reposition		7	8	7
Loadout	- loading	31	32	31
	- truck preparation	2	2	2
	- truck despatch	4	2	3
Delays	- operational	6	6	8
	- personal	4	4	3
	- mechanical	4	7	3
Wait	- Skiddies	3	4	2
	- Tractor	0	0	0
Idle (No Work)		7	3	8
Total		100	100	100
Sample Size (hours)		37	30	37

production on day three of Treatment 2 contributing most to the difference.

Figures (ix), (x) and (xi) show the loader activity charts for Treatments 1, 2 and 3 respectively.

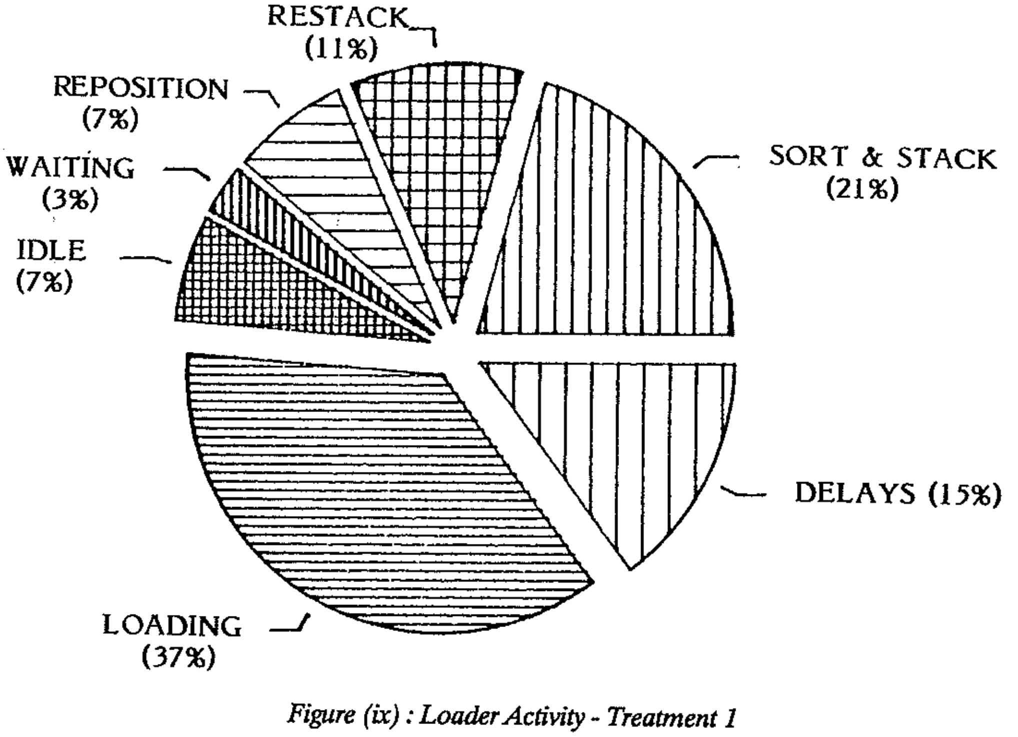

Figure (ix) : Loader Activity - Treatment 1

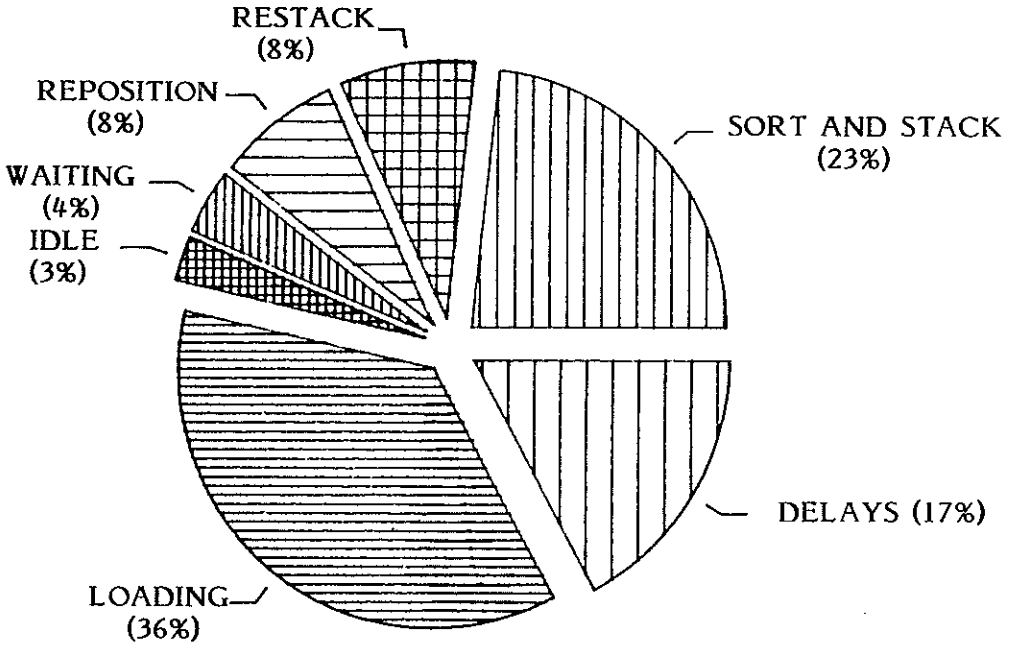

Figure (x) : Loader Activity - Treatment 2

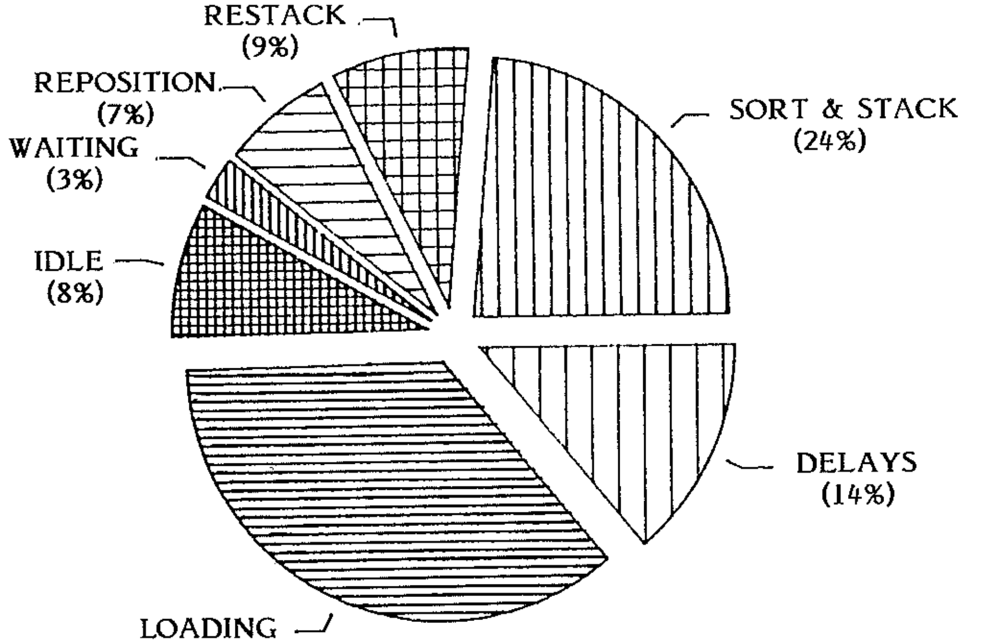

Figure (xi) : Loader Activity - Treatment 3

The only significant difference that could be attributed to treatment effects was the low percentage of idle time experienced during Treatment 2. This was a result of:

- the better spread of trucks through each day of Treatment 2

- the absence of the early period of the day, where low loader utilisation occurred due to insufficient numbers of trucks and no sorting and stacking work, in the other treatments.

Interference to the loader work cycle from the skiddies and tractors was very low. A trend of increased skiddy interference with increased log volume production, and possibly with higher proportions of quality log volumes, was indicated.

Skiddies

The proportion of scheduled work time spent doing skiddy activities on the landing is shown in Table 8.

Table 8 data was collected by activity sampling at 20-second time intervals.

Activity definitions are attached in Appendix IIIb.

Figures (xii), (xiii) and (xiv) show the skiddy activity charts for Treatments 1, 2 and 3 respectively.

The number of skiddies varied between two and three with small amounts of time where extra people were involved helping with skid activities. The weighted average number of skiddies for each of the treatments 1, 2 and 3 were 2.6, 3 and 2.6 respectively.

The main points of comparison within skiddy activities is between Treatments 1 and 3 i.e. 6 log sorts versus 9 log sorts being cut, respectively. It is important to note here that logging production levels were lower in Treatment 3 than in Treatment 1 and the percentage of quality log volume cut in Treatment 1 was higher than in Treatment 3. Both of these factors could be attributed to different tree sizes between treatments and not to the different number of log sorts.

Most of the significant differences between treatments within activities could not be attributed to different treatments.

The only significant difference between treatments within activities that could, at least in part, be attributed to the different number of log sorts processed in each treatment, was the mark and measure proportions lower in Treatment 1 than in Treatment 3.

Overall then the higher number of log sorts cut in Treatment 3 did not have a significant effect on skiddy work content.

Table 8 : Skiddy Work Content

Activity	Proportion of Total Worktime (%) Treatment 1	2	3
Unhook	3	3	5
Measure and Mark	15	15	18
Buck	27	25	24
Trim	13	18	15
Saw Maintenance	16	18	11
Wait Tractor	8	3	5
Wait Loader	0	1	0
Idle - No Work	12	9	13
Personal Delay	6	7	8
Operational Delay	0	1	1
Total	100	100	100
Sample Size	9993	12547	9890

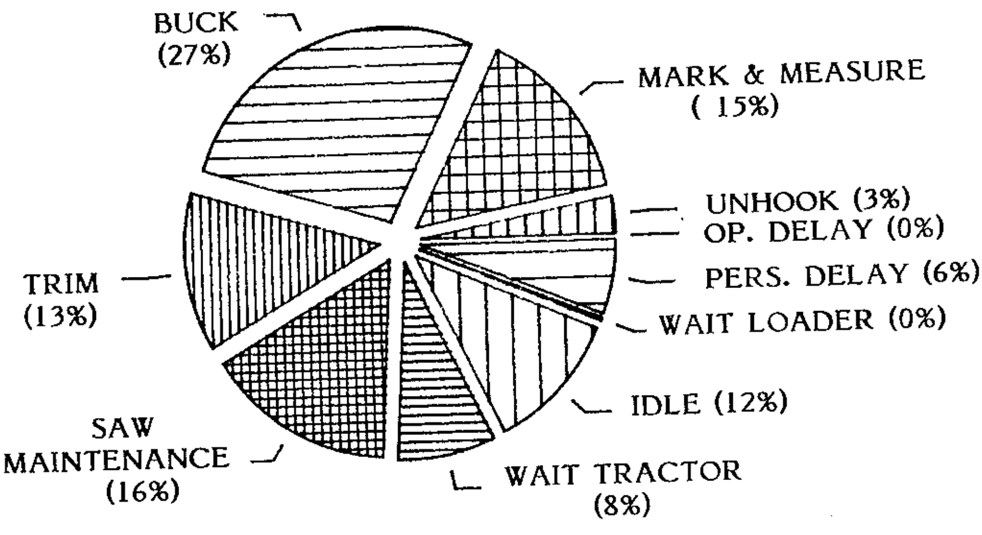

Figure (xii) : Skiddy Activity - Treatment 1

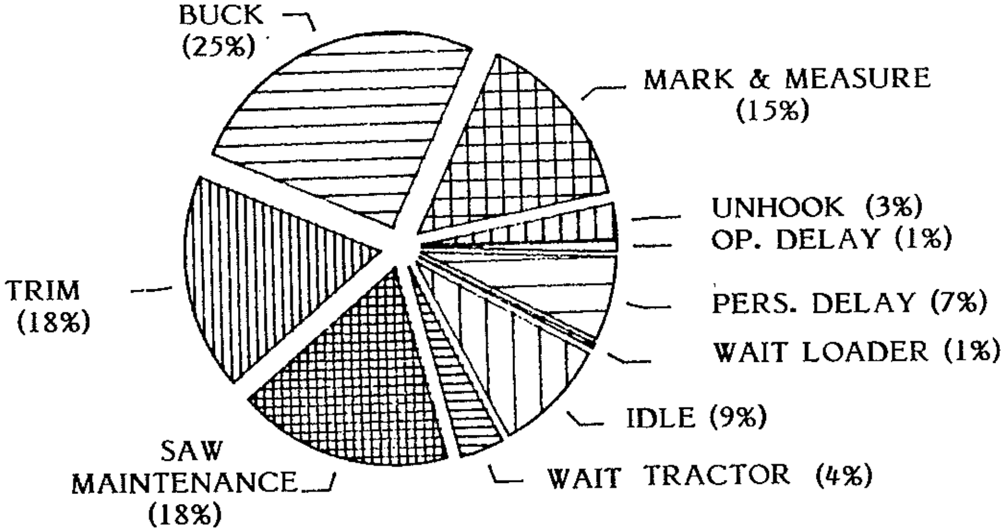

Figure (xiii) : Skiddy Activity - Treatment 2

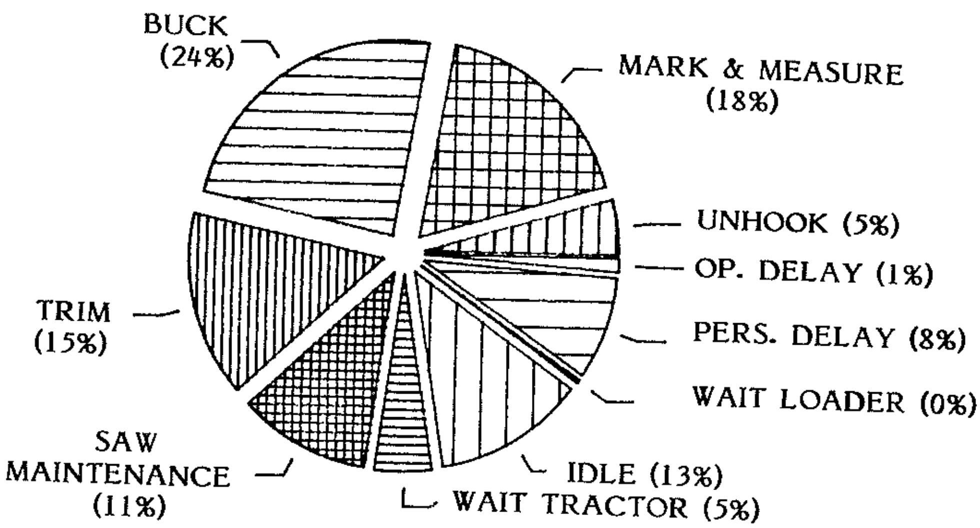

Figure (xiv) : Skiddy Activity - Treatment 3

Interference to the skiddy work cycle from the loader was negligible. Some appreciable tractor interference was observed and was related to the frequency of haul cycles and the volume of logs produced to the landing i.e. tractor interference increased in proportion to the amount of time the tractors were on the landing.

The average number of skiddies required to process the log types and volumes produced during the trial is between two and three. If three skiddies were employed full time on the landing there is some potential for more than nine log sorts to be handled at the same average production levels that were measured during the trial.

3.3 LOADER UTILISATION

Table 9 summarises the loader utilisation.

Loader availability and utilisation were relatively constant across all treatments. A nine day sample period is obviously not long enough to gather accurate utilisation figures, but the data presented in Table 9 is indicative of what could be expected from the loader in terms of utilisation.

Some variation in machine utilisation did occur on a daily basis. The high figure for Treatment 2, day three resulted from a much reduced idle time component due to good truck scheduling in balance with log production. The low figure in Treatment 1, day three and Treatment 2, day two resulted from mechanical breakdowns (hydraulic hose and system leaks).

It can be seen from the data presented in Table 9 that to keep net machine utilisation high, delays to the work cycle must be minimised. Operational delays such as idle time and interference can have a major influence on the productive capacity and therefore the efficiency of the loader operation.

The highest machine utilisation was achieved in Treatment 2 at 73%. If we refer to Figures (x), (xi) and (xii) we can see that idle time was significantly lower in Treatment 2 than in the other treatments. It was effectively the decrease in idle time that resulted in the higher net utilisation in Treatment 2.

Table 9 : Loader Utilisation

Treatment	Day	SMH	AMH	PMH	Availability	Utilisation
1	1	11.91	11.15	8.59	94%	72%
	2	11.96	11.46	8.68	96%	73%
	3	13.01	12.68	8.62	97%	66%
Treatment Mean		12.19	11.78	8.68	96%	70%
2	1	9.29	8.94	6.82	96%	73%
	2	9.75	8.42	6.23	86%	64%
	3	10.87	10.50	8.12	97%	75%
Treatment Mean		9.97	9.29	7.25	93%	73%
3	1	11.37	11.00	8.06	97%	71%
	2	12.72	12.42	8.95	98%	70%
	3	12.56	12.14	8.58	97%	68%
Treatment Mean		12.22	11.85	8.53	97%	70%
Overall Mean		11.49	10.97	8.14	95%	71%

*SMH = Scheduled Machine Hours
AMH = Available Machine Hours
PMH = Productive Machine Hours

(*See Appendix IV for standard definitions of abbreviations used.)

3.4 LOADER PRODUCTIVITY

Table 10 summarises the loading and sorting and stacking production for the trial period.

Table 10 shows that in Treatments 1 and 3 average loadout production exceeded average log production. In Treatment 2 average loadout and average production were in balance. The time worked by the loader to achieve the Treatment 2 result was much less than in Treatments 1 and 3.

Figures (xv), (xvi) and (xvii) illustrate the average loadout and log production trends for Treatments 1, 2 and 3 respectively. The average production rate is ahead of the average loadout rate in all treatments but by working the loader outside the production crew work hours, a net reduction in log stocks over the trial period occurred.

The loader has demonstrated its potential to loadout at the same rate as the logs are being produced, but only if trucks are scheduled at a similar rate.

Table 10 : Loading and Sorting and Stacking Production

Treatment	Day	Loadout (tonnes)	% Quality Logs	Sort & Stack	% Quality Logs
1	1	470	74	370	73
	2	463	72	363	73
	3	465	76	382	71
Treatment Mean		466	74	372	72
2	1	363	78	441	75
	2	366	80	384	80
	3	526	77	443	79
Treatment Mean		418	78	423	78
3	1	379	61	376	59
	2	341	62	382	77
	3	427	65	316	54
Treatment Mean		382	65	358	64
Overall Mean		422	72	384	71

In summary the loader is capable of achieving the balance at high production levels and with high numbers of log sorts but wood flow from the landing must be at a similar rate to wood flow onto the landing.

Table 11 summarises the loader productivity for the trial period.

As shown in Table 11 there are some differences in the loading productivity, and the sort and stack productivity, between treatments. Loading productivity was not expected to be strongly correlated to the number of log sorts processed and hence treatment differences are likely to be due to other factors.

There seems to be a relationship between loading productivity (per PMH), and the percentage of pulp quality logs produced. This could be expected, as the load time for pulp logs is greater than for quality logs, due to the pulp logs smaller and more variable piece size. It could also be expected that there may be some difference in sort and stack productivity between log sort treatments due to the larger number of physical log sorts and stockpiles. The effect of the smaller pulp material piece size could also be expected to influence sort and stack productivity, as it does loading productivity.

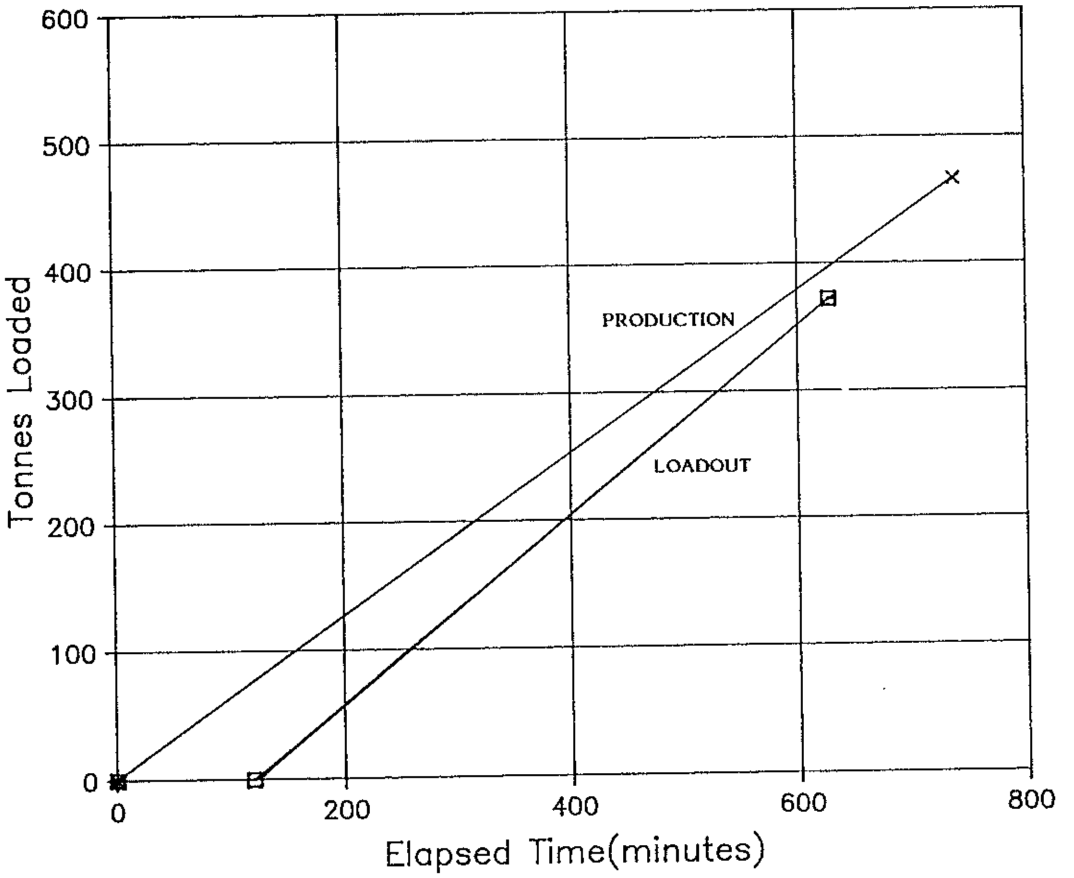

Figure (xv) : Log Production and Loadout Trends - Treatment 1

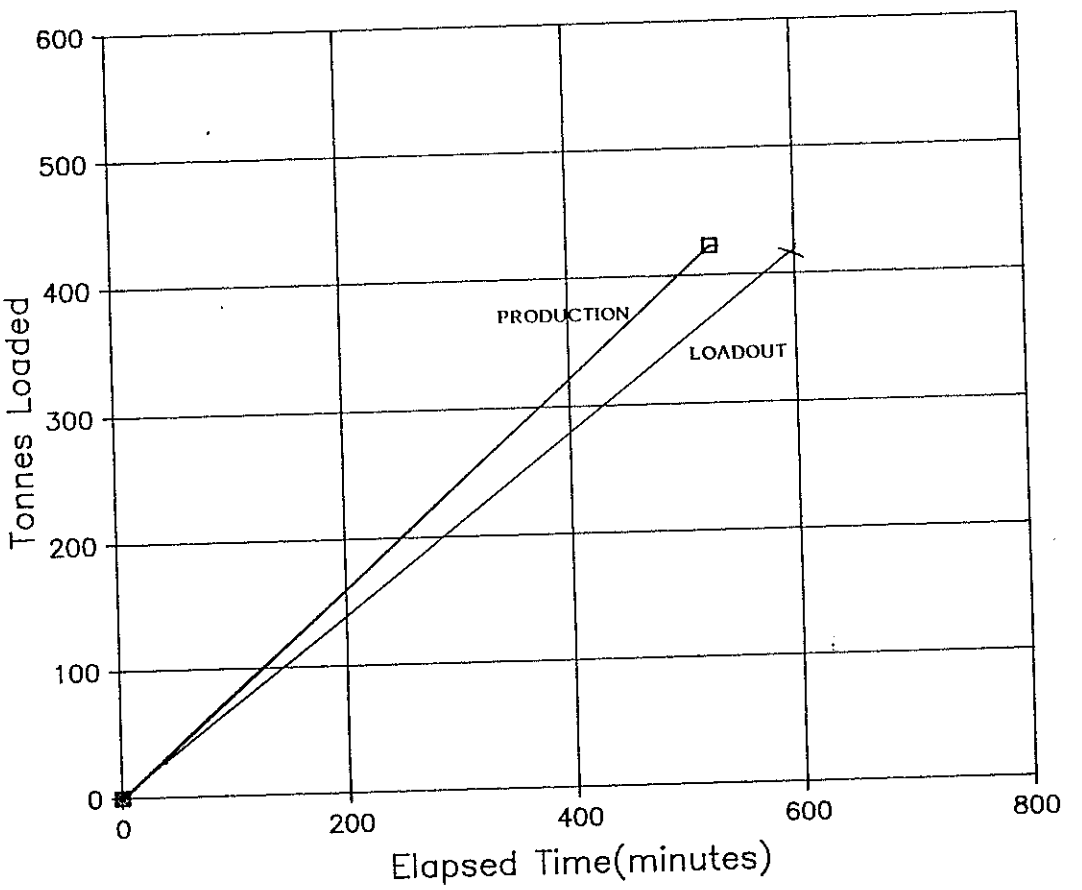

Figure (xvi) : Log Production and Loadout Trends - Treatment 2

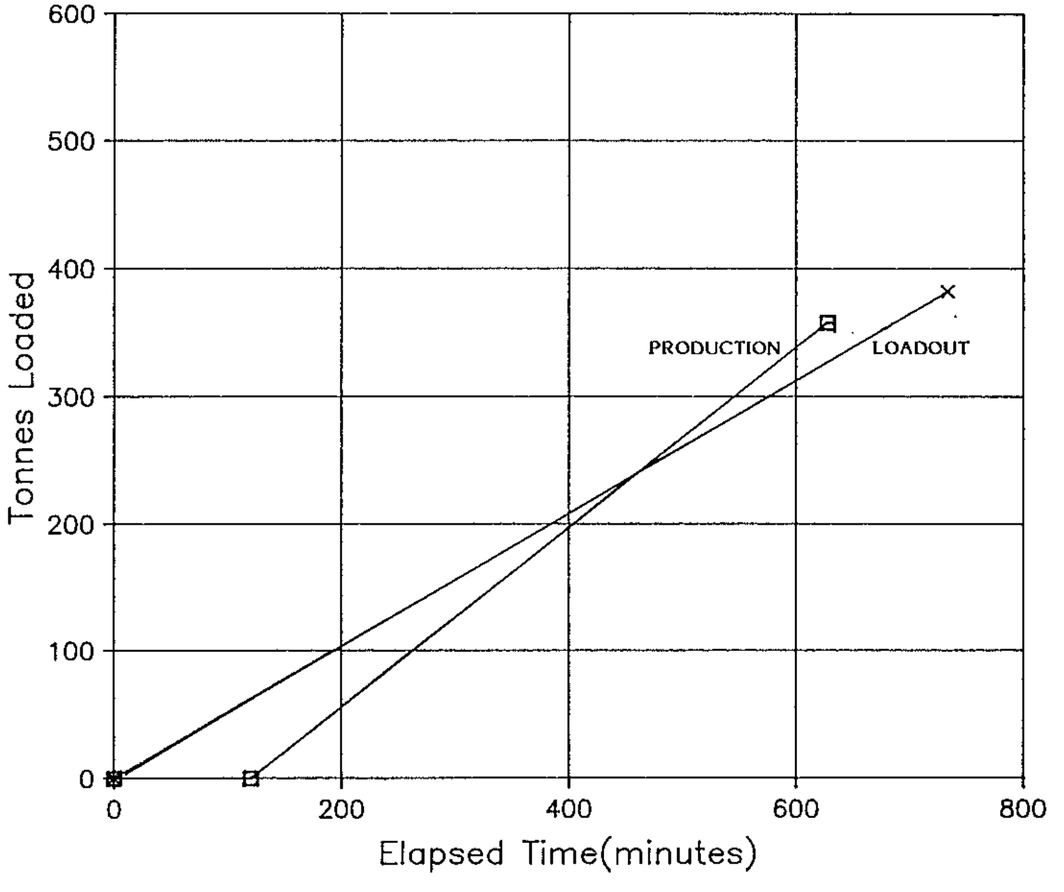

Figure (xvii) : Log Production and Loadout Trends - Treatment 3

Table 11 : Loader Productivity

Treatment	Activity	Productivity (tonne/hour) /SMH	/AMH	/PMH
1	load	91	102	121
	sort & stack	52	52	77
2	load	97	97	129
	sort & stack	75	85	105
3	load	74	75	102
	sort & stack	51	53	75
Overall	load			117
	sort & stack			85

The results of the trial would suggest that on a PMH basis, loading productivity has been affected by the percentage of pulp material produced in each of the treatments i.e. a high proportion of pulp produced gives a lower PMH productivity result. In comparing Treatments 1 and 3 it would seem that the difference between sorting and stacking productivity could be attributed to a combination of the increased number of log sorts and a higher percentage of pulp produced in Treatment 3.

The high sort and stack productivity in Treatment 2 could be attributed to the lower percentage of pulp produced but it would seem that in PMH terms the efficiency of the sort and stack phase was better during Treatment 2 anyway. It is likely that the Treatment 2 days one and three log production situation pushed the loader towards its limit, and contributed to the higher sort and stack productivity result.

Table 12 shows an example of achievable, balanced, loadout/log production given a standard PMH per day of seven hours and the loader utilisation data shown in Table 9.

The effect of reducing operational delays to the loader operation is highlighted in Table 12 where total daily SMH's in Treatment 2 have been reduced for the same PMH as in the other standardised treatments. Also in Treatment 2 where loader productivity was high, the potential to produce at high levels given similar PMH's is illustrated.

If the situation as exemplified in the Treatment 2 standardised PMH example above could be achieved on a long term basis, it would have a major impact on the efficiency and therefore the cost of the log sorting and loading portion of the log production system. However, it is clear that the other parts of the log production system must be in balance if this indicated level of efficiency is to be sustained.

Table 12 : Standardised PMH Productivity
(Based on 7 PMH and Overall Productivity from Table 9)

Treatment	Activity	PMH	SMH	Production Tonnes
1	load	2.72		
	sort & stack	4.28		
	total	7.00	10.00	329
2	load	3.14		
	sort & stack	3.86		
	total	7.00	9.59	405
3	load	2.96		
	sort & stack	4.04		
	total	7.00	10.00	302
Overall	load	2.93		
	sort & stack	4.07		
	total	7.00	9.86	343

3.5 TRUCK LOADING

The loading of a total of 144 unit loads was timed over the nine days of the study and these times were analysed by log type and length. Table 13 gives a summary of the truck loading cycle by log and truck types.

Pulp logs took nearly 60% longer per tonne to load than quality logs. Although more pulp logs were handled in each swing, their much smaller size reduced loading productivity.

Due to the dry weather conditions during the study period, a high percentage of trucks towed their trailers empty and therefore truck preparation time was lower than would normally have been the case. Truck preparation times included in Table 13 are averages from the 40 percent of trucks that required some truck preparation time from the loader.

Table 13 : Loading Times by Log Type

	Quality Logs[2]	Pulp Logs	All Logs
Unit loads[1] observed	94	50	144
Net Loading time (min)	12.68	15.13	13.53
Truck preparation and despatch (min)	2.58	1.43	2.18
Delay time[3] (min)	2.49	2.66	2.55
Total load time (min)	17.75	19.22	18.26
Load size (tonnes)	29.4	20.8	26.4
Number logs	26.2	54.8	36.1
Boom swings	19.4	27.1	22.1
Logs per swing	1.35	2.02	1.57
Net Loading Productivity (min/tonne)	0.46 (±0.03)[4]	0.73 (±0.04)	0.55 (±0.03)
Total Loading Productivity (min/tonne)	0.60	0.92	0.69

1. Unit loads : a truck and trailer, or Bailey bridge trailer of short logs, is two unit loads.

2. All log types except pulp, i.e. saw, export, peeler.

3. All personal, mechanical and operational delays to the loading cycle, including any sort and stack, restack or reposition that occurred during loading.

4. 95% confidence limits.

Figure (xviii) : Truck Loading

Table 14 : Loading Times by Log Length

	Quality Logs		Pulp Logs	
	Long	Short	Long	Short
Unit loads observed	70	24	7	43
Net Loading time (min)	14.03	8.75	22.25	13.97
Truck preparation and despatch time (mins)	2.79	1.94	2.66	1.23
Delay time (mins)	2.25	3.16	4.27	2.40
Total load time (mins)	19.07	13.85	29.18	17.60
Load size (tonnes)	33.9	16.2	29.9	19.3
Number logs	25.5	27.9	71.0	52.2
Boom swings	19.9	18.0	35.1	25.8
Logs per swing	1.28	1.58	2.04	2.01
Net Loading Productivity (min/tonne)	0.42 (±0.02)	0.56 (±0.10)	0.75 (±0.54)	0.73 (±0.05)
Total Loading Productivity (min/tonne)	0.56	0.85	0.98	0.91

Short quality logs took 33% longer to load than long, a function of both their smaller size and the smaller unit loads.

Average net productivity across all truck and log types was 0.55 minutes per tonne.

The number of pieces loaded per grapple swing averaged 2.01 for pulp material, while an average of 1.35 pieces was achieved for the quality material. The number of pieces per grapple swing is a factor that can affect loading time (Twaddle 1979, Raymond 1988). The shape of the grapple jaws and the type of logs being loaded obviously affects the number of pieces that can be loaded per boom swing. The majority of logs handled by the loader are smaller in diameter than those that the grapple, as fitted to the loader studied, was designed to handle. Given the proportion of pulp and small diameter quality material produced from second crop stands, it is possible that a multi-purpose pulp/log grapple would give increased loading productivity by increasing the average number of pieces loaded per boom swing.

As outlined by Twaddle (1979) in a study of rubber tyred front end log loaders, and by Raymond (1988) in a study of an hydraulic knuckleboom loader, three main variables affect loading time given a particular average log size. These are:

- the number of logs loaded
- the volume of logs loaded
- the number of grapple swings taken to load the unit.

The number and volume of logs loaded are easily measured variables and the linear regression equations relating these variables to net load time were calculated from loading data collected during the study.

The calculated equations are as follows:

Truck /Log Type	*Regression Equation*	*r2*
Short Logs	*Net Load Time (mins) = 5.75 + 0.088 (no. of logs/load) + 0.093 (load volume, tonnes)*	*(0.71)*
Total Shorts	*Net Load Time (mins) = 6.11 + 0.14 (no. of logs/load)*	*(0.57)*
Total all	*Net Load Time (mins) = 2.59 + 0.13 (no. of logs/load) + 0.23 (load volume, tonnes)*	*(0.59)*
Quality Longs	*Net Load Time (mins) = 4.31 + 0.25 (no. of logs/load) + 0.095 (load volume, tonnes)*	*(0.61)*
Quality Shorts	*Net Load Time (mins) = 4.57 + 0.15 (no. of logs/load)*	*(0.55)*
Quality All	*Net Load Time (mins) = 1.38 + 0.16 (no. of logs/load) + 0.24 (load volume, tonnes)*	*(0.61)*
Pulp Longs	*Net Load Time (mins) = not valid, insufficient data*	
Pulp Shorts	*Net Load Time (mins) = 8.96 + 0.096 (no. of logs/load)*	*(0.38)*
Pulp All	*Net Load Time (mins) = 1.81 + 0.054 (no. of logs/load) + 0.50 (load volume, tonnes)*	*(0.58)*

The equations outlined above predict net load time. To calculate total load time, standardised truck preparation and truck despatch times and standardised total delays should be added to total load time. The following example illustrates the above procedure:

- To predict net load time , total load time and total load cycle time for an off highway load of 12 metre japan export given;

  i) total logs per load = 20

  ii) average log size = 1.85 tonnes

Solution

Net Load Time = 4.31 + 0.25 * (20 logs per load)

+ 0.095 * (1.85 tonnes*20 logs)

= 4.31 + 5 + 3.52

= 12.83 minutes

Total Load Time = 12.8 + truck prep and despatch + delays (from Table 13)

= 12.8 + 3.7 + 2.4

= 18.9 minutes

If loading time for mixed log type, shorts units are being calculated, each unit load time should be calculated and total truck load time will be the sum of each unit load time.

3.6 TRUCK SCHEDULING

To recap: Treatments 1 and 3 were the early loadout treatments with trucks scheduled from 5.00am through to approximately 5.00pm; Treatment 2 trucks were scheduled from 7.00am through to approximately 5.00pm.

A measure of the effect of truck scheduling on the loader productivity was achieved by analysis of the loadout data collected during this study. By plotting tonnes loaded against elapsed work time, on a daily basis, illustrations of the actual truck schedules were produced. Figures (xix), (xx) and (xxi) show the truck schedule for each of the Treatments 1, 2 and 3 respectively. Each box, cross or triangle on the truck scheduling graphs represents a point where loading of a truck or unit was completed.

Some variation within treatments occurred but on average Treatment 2 displayed the 'best' or most consistent loadout flow. As outlined in section 3.4 above, Treatment 2 also showed the highest sort and stack productivity. To illustrate the extremes in terms of truck scheduling, the day three, Treatment 2 truck schedule representing the best and the day two, Treatment 3 representing the worst of the nine days sampled, are presented on the same graph (Figure (xxii)).

The day three, Treatment 2 situation shows a regular flow of loadout through the day. The loader carried on loading and stacking after the extraction crew had finished work but started at the same time as the extraction crew in the morning. The first truck arrived at the same time as the crew started work and on completion of loading, the first haul cycle had been loaded and processed and was ready for sorting and stacking by the loader. As can be seen on the graph (Figure (xxii), a period of 69 minutes elapsed between the

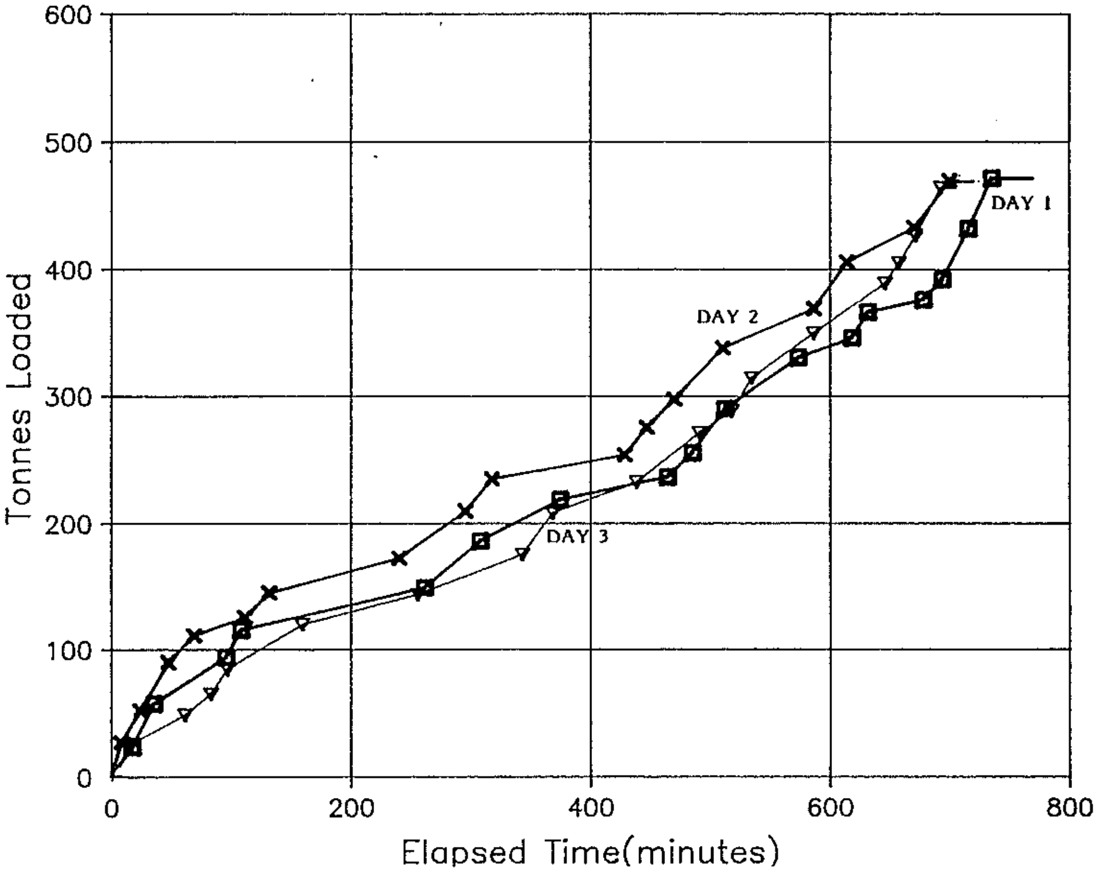

Figure (xix) : Truck Schedule - Treatment 1

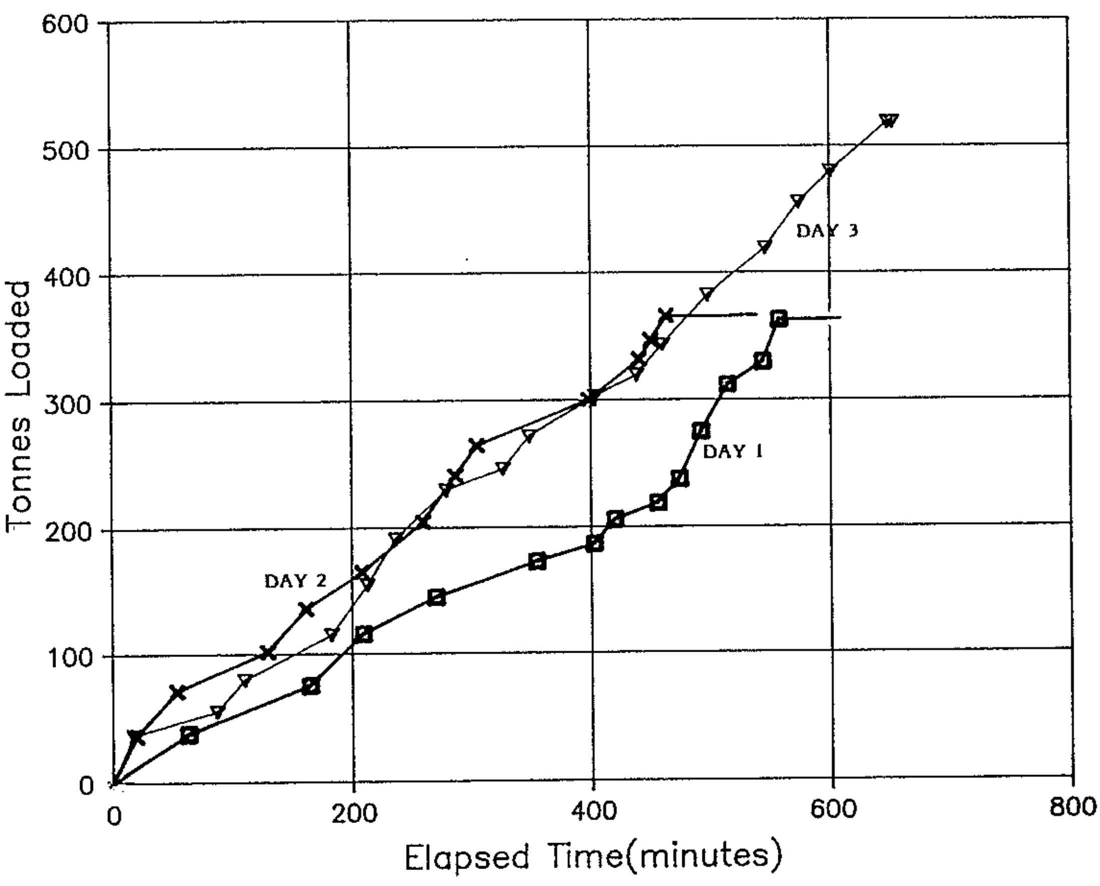

Figure (xx) : Truck Schedule - Treatment 2

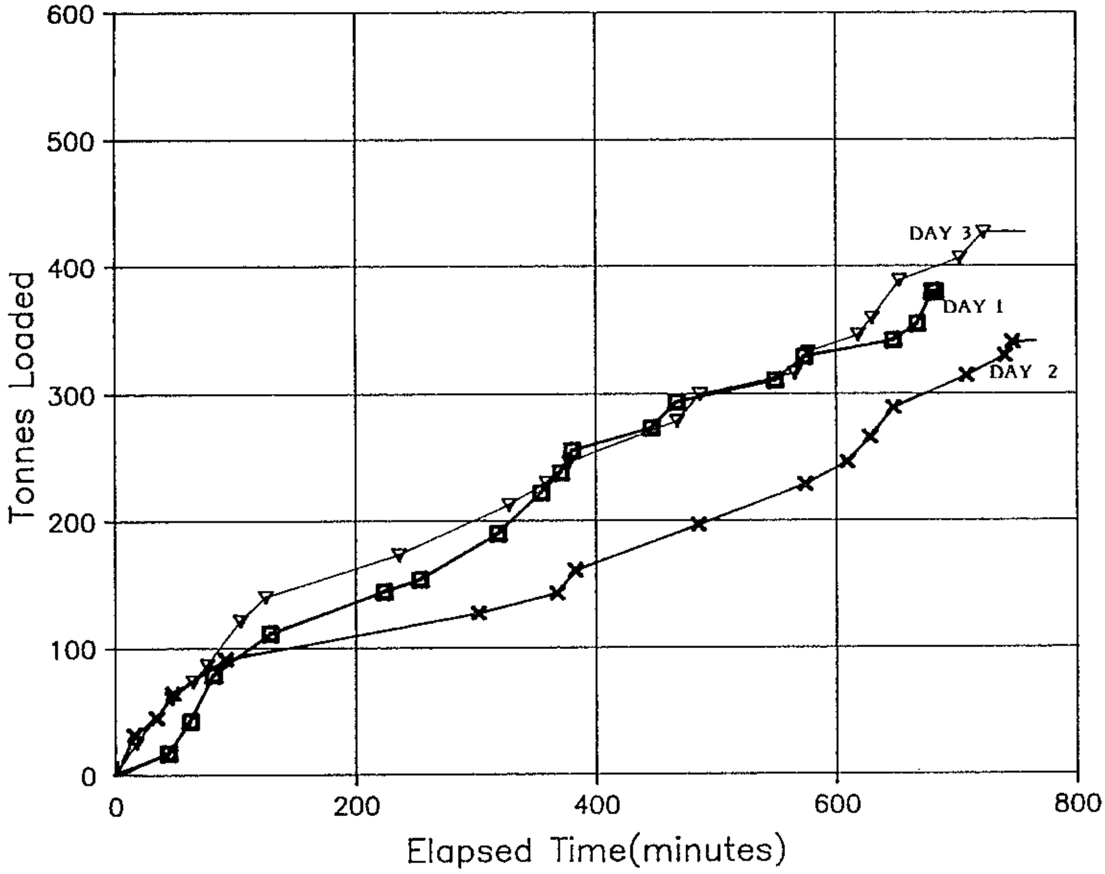

Figure (xxi) : Truck Schedule - Treatment 3

first and second units, and a period of 72 minutes elapsed between the third and fourth units. Both of these time periods saw the loader under utilised. However, the period from 350 through to 500 elapsed minutes, where two longs trucks and a shorts truck were loaded, saw the loader pushed slightly beyond its limits. Hence the situation as described in section 3.1 (Treatment 2) occurred. Generally the day three Treatment 2 example illustrates an operationally acceptable, high loader utilisation and subsequent high production.

The day two, Treatment 3 situation as shown in Figure (xxii) represents the worst truck schedule of those sampled. The loader started work two hours (120 minutes) before the extraction crew and continued stacking and loading for approximately two hours after the crew had finished work. On an elapsed time basis, day two, Treatment 3 loadout edged ahead of day three, Treatment 2 during the first 120 minutes of the loader day. This was due to the early start where only loadout work was available for the loader. Based on the average total load cycle time given in section 3.5, the loader had the capacity to load a total of 173 tonnes in the first 120 minutes of the day i.e. between 5.00am and 7.00am. From the graph it can be seen that the loader was under utilised during that period with only 91 tonnes or 53% of its capacity being achieved. A further period of 180 minutes elapsed before any more logs were loaded out. A burst of loadout production occurred late in the day after the extraction crew had finished work but the net effect was a full day of low loader utilisation and hence low loadout production.

Obviously not all of the differences in utilisation and production observed during the trial can be attributed to truck scheduling, but for the examples shown in Figure (xxii), a very high proportion of the differences between the two days could only be attributed to the difference in truck scheduling. If it is assumed a total scheduled work day of 652 minutes is worked by the loader, the difference in loadout production between the two examples would be approximately 225 tonnes. Other factors such as the lack of logs to load out may have restricted the potential production of the loader on day two of Treatment 3 but a loadout production of well over 400 tonnes was achievable on that day.

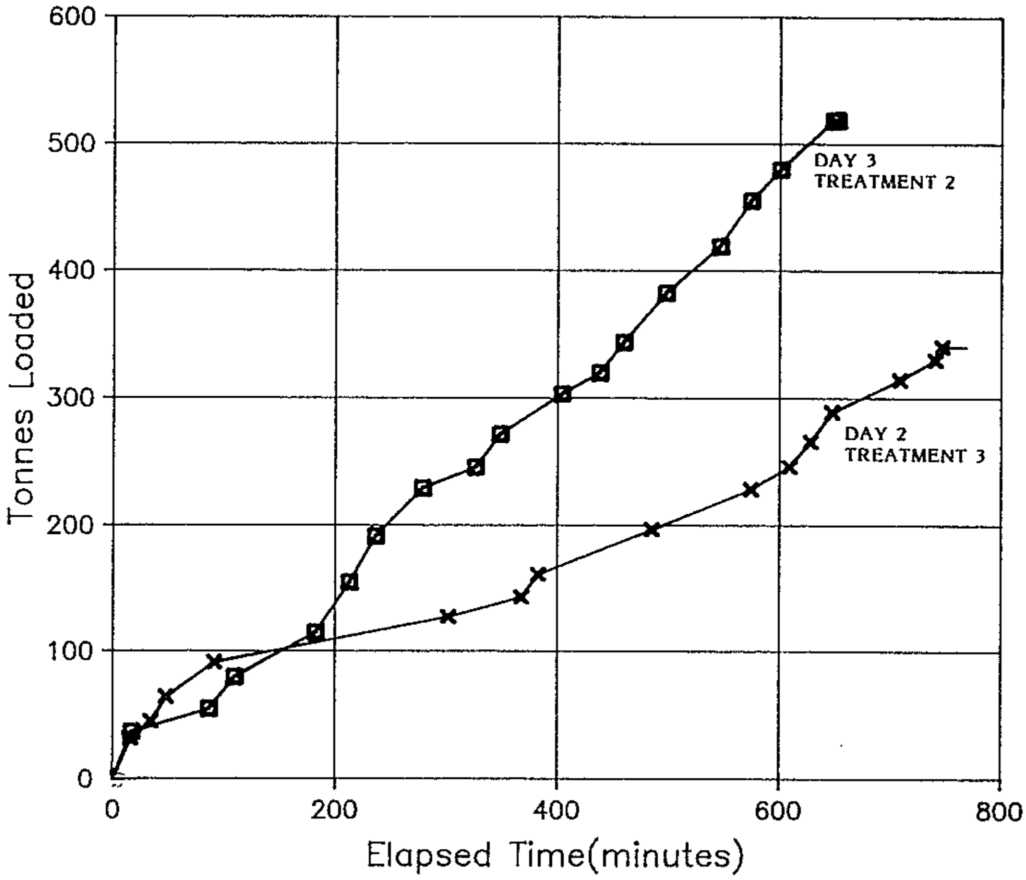

Figure (xxii) : Best and Worst Truck Schedule

4. CONCLUSIONS

1. The landing layout used on all four landings and three treatments adequately accommodated the needs of the extraction machines and the loader. Also the landing sizes were adequate in most cases to handle normal loads of production and loadout. In some instances the landing size became limiting to the system production when high production level coincided with poor truck scheduling.

Some significant areas of the (0.2 to 0.26 ha) landings were unused. On landings 3 and 4 22 to 25% of the total area wasn't required. Landing 1 was the only one where an insignificant proportion of total area remained unused. The average unused area for all landings was 12%.

The three factors most likely to affect landing area utilisation are, shape and size, loader configuration and whether it is a through road landing or a dead-end road landing. Landing shape could be optimised by looking at the requirements of each predominant use area. In different areas the optimum total landing size and shape required can be different. These differences could be caused by the direction of log flow onto the landing, whether the logs will be predominantly butt or head pulled, length of extracted logs, access of trucks for loading, ground conditions, number of log cuts etc. The logging planning process should take account of these factors and construction should be planned accordingly.

The loader configuration can have a major influence on the landing area required. The loader studied in this trial had a standard excavator boom and dipperstick and therefore no heeling device, either fixed or live. This type of set up requires centre swing loading and stacking and hence the requirement for loader access between stockpiles.

If a loader with a live heel was used to lift the logs from the end and heel them into stockpiles or onto trucks, the same production could be handled on a much smaller landing area. Taking Landing 3 as an example, if a heel boom loader had operated on the landing it would have been possible to position all stockpiles above the road (see Figure (vi)) using the road as the loading and stacking area for the loader. Two benefits would result from this set up. The area above the road would be better utilised and the loading and stockpile areas below the road in Figure (vi) would not be required. In that case the formed landing area required would be less. If it is assumed that the fleeting and processing areas remained the same size as in Figure (vi), the total formed area used by a heel boom loader would be 0.14 ha or 17% less than for the standard boom machine and 35% less than the total formed area.

Some minor modifications to the landing layout to reduce the amount of repositioning and restacking required, could have improved loader efficiency on Landing 4, Treatment 3.

The extra log sorts in Treatment 3 were accommodated on the existing landings without trouble. Some extra landing area was used in Treatment 3 but ample was available and landing area never became limiting to system production.

Generally the loader handled its tasks well, given the size, shape and layout of the landings worked.

2. The level of interference on the landing between the tractors, skiddies and the loader was low.

The loader was not significantly delayed by either of the other two landing operations. There was however, a trend of increased skiddy interference to the loader with increased log volume production and with higher proportions of quality log production.

A significant decrease in loader idle time occurred in Treatment 2. This could be attributed to the more regular spread of trucks, through the day.

The increased number of log sorts in Treatment 3 resulted in only minor differences in skiddy activity proportions.

Tractor interference to the skiddies increased with increasing log production.

A three man log making team has the potential, given the average volume of logs produced, to process a larger number of log sorts than tested in Treatment 3. The landing system did not reach its productive limits during the trial period.

There was indicated potential for the loader and the skiddies to handle more log sorts and more production but the ability to realise that potential is dependent on the relatively constant flow of wood onto the landing and onto trucks as loadout.

3. Loader availability was generally high during the trial, averaging 95%. Utilisation averaged 71%.

Good truck scheduling in Treatment 2 had the effect of reducing loader idle time significantly. The main periods of poor utilisation occurred between 5.00am and 7.00am in the early start treatments, where achieved loadout did not match the loader productivity potential.

Loader efficiency is directly related to the level of mechanical, personal and operational delays that occur. The Treatment 2 result of high utilisation was achieved by decreasing operational delays, including idle time.

4. The loader has shown the ability to sort and stack multiple log sorts at high production levels. Its full potential however, can only be achieved when all parts of the logging system approach a balanced production level.

The proportion of pulp log production had an inverse effect on loading and sorting and stacking productivity. This is a function of the smaller average piece size of the pulp material and the subsequent larger number of logs to be handled per tonne of production.

The standardised productivity Table 12, clearly shows the effect of good loader utilisation on productive potential. The potential balanced production level, at seven PMH, for Treatment 2 was 23% higher than Treatment 1 and 34% higher than Treatment 3.

The efficiency of the loader operation in Treatment 2 was much better than in the other two treatments as a result of higher productivity and better utilisation.

5. The loader was able to load trucks to the specifications required, at high loadout production levels. There was a marked difference in truck loading productivity measured between pulp and quality log types. The average net loading time for all pulp was 0.73 minutes per tonne, while the average loading time for all quality logs was 0.46 minutes per tonne. The average for all truck and log types was 0.55 minutes per tonne. Therefore the observed pulp loading times were 60% longer per tonne, than the quality log loading times.

A change to a grapple more able to accumulate larger numbers of logs could increase the pulp loading productivity and also the smaller dimension, quality log loading productivity of the loader studied. If the right grapple was selected larger logs could be loaded at the same productivity levels.

6. The effect of truck scheduling on loader productivity has been graphically demonstrated in this trial. Although the loader has shown its ability to sort, stack and load out multiple log sorts at high production levels, it didn't reach its full productive capacity during the trial. In terms of numbers of log sorts, Treatment 3 didn't push the loader to the limits of its capacity. Treatment 2 results hinted at the loader's potential given good truck scheduling and utilisation. Better utilisation in Treatments 1 and 3 would have resulted in much less scheduled time worked for the same production output.

The primary reason why utilisation was lower in Treatments 1 and 3 was the out-of-balance nature of the wood flows onto, through and off the landing. From the study results, if less than 164 tonnes is loaded out in the two hour period when there is only loading work to do, the loader is under utilised. At no stage was that level of loadout achieved during the early loadout treatments, hence a significant proportion of the total under utilisation occurred in the early start, loadout only, portion of the day.

The loader production data collected during this trial suggests that the 384 tonne average log production could be sorted, stacked and loaded in something like 9.5 scheduled hours per day. This implies a loadout rate of 40 tonnes per scheduled hour. This would leave 32 minutes per hour, or 53% of total scheduled time, for sorting and stacking. The loader work content analysis suggests that sort and stack, reposition, restack, and a percentage of total delays, could be accommodated in the available 53% of scheduled time.

The balanced production situation could be achieved in this operation if, (i) the loader started work at the same time as the extraction crew and, (ii) one truck was scheduled per hour as a matter of course. The remaining 0.5 of a truck per hour required could be made up on a non-regular basis provided no more than two trucks required loading concurrently. Three trucks loaded concurrently resulted in three unsorted drags being present in the processing area. It is at that point that bottlenecks in the sort and stack operation occurred and the loader became limiting to system production.

7. The productive capacity of the loader was affected very little by the addition of three extra log sorts to the system at the production levels observed. The potential to handle more than nine sorts was indicated but the level at which a significant influence on production would occur cannot be accurately forecast from the trial results.

   The extra landing area required to handle the nine log sorts was only marginally more than for six sorts, as most of the extra sorts were accommodated in existing stacks i.e. two log types were stacked adjacent to each other.

   The productive capacity of the loader was significantly higher in Treatment 2 where a better average flow of trucks was achieved.

   No measurable difference in the landing area used between the two truck scheduling treatments was observed.

   The Mitsubishi MS230 hydraulic knuckleboom loader, as studied in this trial, was entirely suitable as a sort, stack and load machine, at the production levels and maximum log sort numbers that were tested.

   Productivity potential above the levels measured during the trial were indicated, given some log production system modifications.

5. RECOMMENDATIONS

1. A summary of existing information on rubber tyred front end loaders working at similar production levels as observed during this trial, should be undertaken. This would enable a back to back comparison between a rubber tyred front end and an hydraulic knuckleboom loader to be made. If no good existing information is available a trial should be set up to provide this comparative information.

2. Many loader and landing investigations, both in New Zealand and overseas, have indicated the importance of truck scheduling in maintaining or attaining efficient, logging system production. There is little incentive to explore potential productivity gains in log extraction or loading if the transportation system is the limiting factor in the overall logging system. An attempt should be made to quantify the effect of truck scheduling on logging system productivity and profitability. This would help to enable objective decisions on extraction, loading and transport system selections, to be made.

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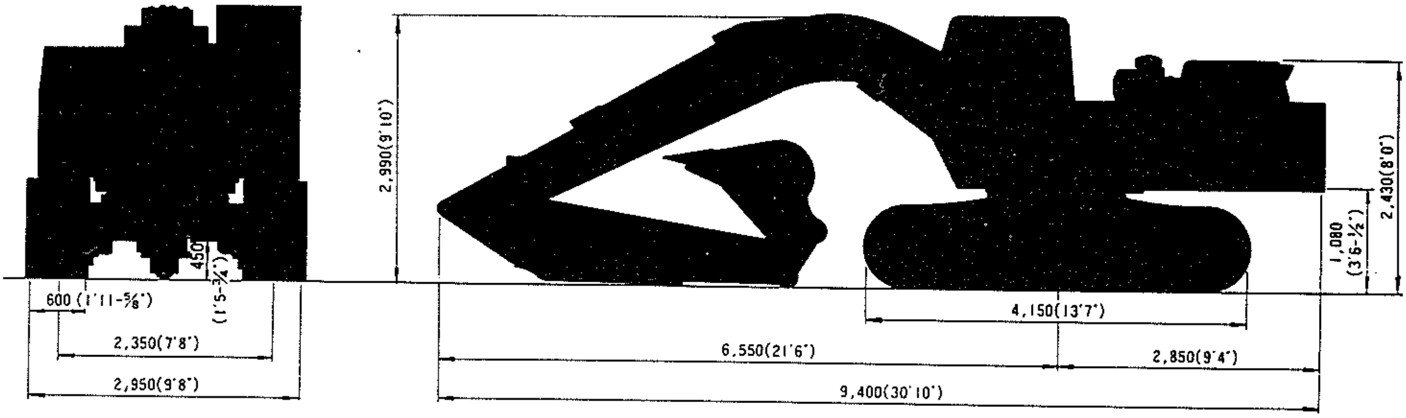
APPENDIX Ia

Loader Base Machine Specifications

MITSUBISHI HYDRAULIC EXCAVATOR MS230-3

Main Dimensions



Dimensions are in mm (ft. in)

SPECIFICATIONS

Operating weight		23,000kg(50,600lbs.)
Transport Dimensions	Overall length	9,400mm (30'10")
Transport Dimensions	Overall width	2,950mm (9'8") with 600mm (1'11-5/8") shoe 3,150mm (10'4") with 800mm (2'7-1/2") shoe
Transport Dimensions	Overall height	2,990mm (9'10")
Engine	Model	MITSUBISHI DIESEL ENGINE 6D20C
Engine	Output/rpm	SAE NET 131 HP/1,600rpm
Engine	Max. torque/rpm	62kg·m (SAE NET 434ft·lbs.)/1,400rpm
Hydraulic System	Pumps: Type	Variable displacement, axial plunger
Hydraulic System	Pumps: Pressure Delivery Number of pumps	250kg/cm² (3,550psi) 220ℓ/min (58.1 Imp. gal./min)/one pump 2
Hydraulic System	Swing motor	Fixed displacement, axial plunger
Hydraulic System	Travel motor	Fixed displacement, axial plunger
Track	Type drive	Assembled link type
Track	Overall length	4,150mm (13'7")
Track	Shoe width	600mm (1'11-5/8") — Triple grouser 800mm (2'7-1/2") — Triple grouser
Track	Ground pressure	0.58kg/cm² (8.2psi) with 600mm (1'11-5/8") shoe 0.45kg/cm² (6.3psi) with 800mm(2'7-1/2") shoe

Bucket	Heaped capacity range	0.7~1.1m³ (7/8~1-1/2cu.yd.) SAE 0.75~1.21m³ (1~1-5/8cu.yd.)
Bucket	Heaped capacity for general purpose bucket	0.9m³ (1-1/8cu.yd.) SAE 0.98m³ (1-1/4cu.yd.)
Cycle time		15~19sec.
Digging force at bucket cylinder		12,000kg (26,400lbs.)
Gradeability		70% (35°)
Travel speed		3.2km/h (2.0mph)
Swing speed		10rpm
Rear end radius		2,950mm (9'8")
Fuel tank capacity		310ℓ (81.8 Imp. gal.)
Hydraulic oil tank capacity		260ℓ (68.6 Imp. gal.)
Working Range	Max. digging depth	6,590mm(21'7") [7,580mm(24'10")]
Working Range	Max. vertical wall digging depth	4,920mm(16'2") [5,780mm(19'0")]
Working Range	Max. cutting height	8,950mm(29'4") [9,190mm(30'2")]
Working Range	Max. digging radius	9,640mm(31'8") [10,520mm(34'6")]
Working Range	Max. dumping height	6,150mm(20'2") [6,410mm(21'0")]
Working Range	Max. depth of cut for 8' level bottom	6,350mm(20'10") [7,300mm(23'11")]

[ ] is for long dipperstick

Specifications and design may be changed without notice.

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APPENDIX Ib

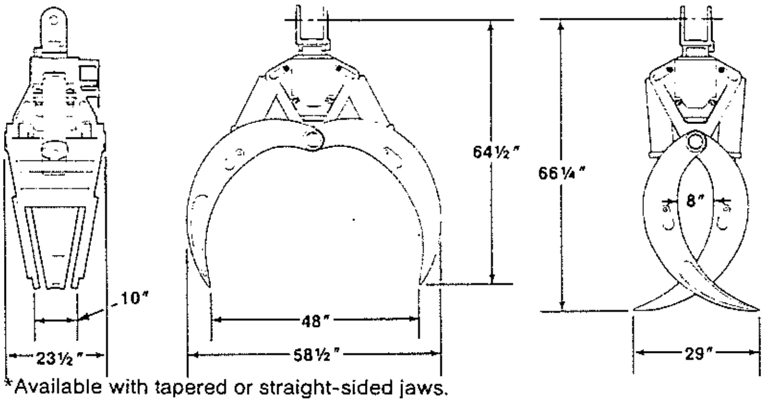
Grapple Specifications

PRENTICE MODEL 848-W Log Bypass Grapple

· *Also available with continuous rotation*

Weight: 1426 lbs.
Jaws: $1\frac{1}{2}$-inch hi-tensile steel plate
Head: High-strength steel casting
Cylinders: Bolt-on head, Prentice Built
4-inch Bore, 12-inch Stroke
$2\frac{1}{2}$-inch Rod
Rotor: Prentice Built, Heavy Duty,
270° rotation with external stops
Mounting: Cast Steel Yoke and 7-inch Knuckle
$2\frac{1}{16}$-inch hi-tensile steel pins

Recommended for use with Prentice 410 & 610 Loaders



*Available with tapered or straight-sided jaws.

APPENDIX II

Loader Operation Costing

1. Ownership Costs

Input Description	Input Value LOADER	VEHICLE
Delivered machine cost	$229,850	$25,000
Minus track/tyre replacement	$30,000	$1,000
" Residual value	$70,000	$9,000
Life of equipment (yrs)	7	5
No. of days worked/year	235	235
No. of hours worked/day	7.00	9.86
Interest expense	17%	17%
Insurance (% of annual investment)	1.75%	1.75%

Output Description	Output Value LOADER	VEHICLE
Depreciable value	$129,850	$15,000
Depreciation	$18,550.00	$3,000
Average annual investment	$161,342.86	$18,600
Interest expense	$27,428.29	$3,162
Insurance	$2,823.50	$325.50
Annual ownership costs	$54,539.29	$6487.50
Annual utilisation (PMH per year)	1645	2317.10
Total ownership cost ($ per PMH)	(A)$29.67	(B)$2.80

2. Equipment Running Costs

Input Description	Input Value LOADER	VEHICLE
% of machine depreciation for repairs & maintenance	100%	80%
Fuel consumption (litres/hour)	15	0.78
Fuel cost ($/litre)	0.69	0.89
% of fuel consumption for lubricants	15	3
Cost of lubricants (per litre)	$3.00	$2.14
Cost of tracks/tyres	$30,000	$1,000
Estimated life of tracks/tyres (hours)	10,000	5,200

Output Description	Output Value LOADER	VEHICLE
Repairs & maintenance	$11.28	$1.04
Fuel	$10.35	$0.69
Oil & lubricants	$6.75	$0.05
Tracks or tyres	$3.00	$0.19
Equipment operating cost ($ per PMH)	(C)$31.38	(D)$1.97
Total labour cost ($ per SMH)	(E)$20.00	

3. Summary

Daily Loader Rate	= ((A) + (C)* 7.0 hrs)	(F) = $427.35
Daily Labour Rate	= (E)* 9.86 hrs	(G) = $197.20
Daily Vehicle Rate	= ((B) + (D)* 9.86 hrs)	(H) = $47.03
Total Daily Rate	= (F) + (G) + (H)	(I) = $671.58

Achievable balanced loadout/production level = 343 tonne per day

Sort, Stack and Load Rate = (I)/ 343 = $1.96 per tonne

NB: The above costing is based on the standard LIRA costing format and the resulting rate is valid only for the input parameters specified.

APPENDIX (IIIa)

Loader Activity Definitions

1. **Sort and stack** is the moving of logs from the processing area to sorted stockpiles by log type or to temporary stockpiles for future restacking beyond the one swing reach of the loader.

2. **Restack** is the stacking of logs to sorted stockpiles by log type from temporary stockpiles established during sort and stack.

3. **Reposition** is the physical moving of the base of the loader while either, stacking, loading or preparing to restack, stack or load.

4. **Operational delay** occurs when the loader is potentially productive but is temporarily delayed i.e loader operator marking logs or talking to truck driver etc.

5. **Personal delay** includes smoko, rest etc.

6. **Mechanical delay** includes refueling, greasing etc as well as mechanical breakdown.

7. **Skiddy interference** occurs when the loader has work to do but cannot because the skiddies are in the way.

8. **Tractor interference** occurs when the loader has work to do but cannot because the tractor is in the way.

9. **Idle time** occurs when there is no work to do.

10. **Despatch** is the time taken to write the load docket.

11. **Net load time** is the time taken to select logs, swing loaded, adjust logs and swing unloaded.

12. **Truck prep.** includes the time to unload trailers, hook up trailers and adjust trailer pins etc.

APPENDIX (IIIb)

Skiddy Activity Definitions

1. **Unhook** = unhook logs on landing.

2. **Mark and Measure** = mark and measure logs on landing.

3. **Buck** = cut logs to length and dock slovens.

4. **Trim** = trim logs that reach the landing with branches still attached. Tidy up logs to meet quality specifications.

5. **Saw Maintenance** = refuel, sharpen and general maintenance to saw.

6. **Wait Loader** = loader interference i.e. wait for loader to leave the skiddy work area or until it is safe to proceed with skid work.

7. **Idle-No Work** = no work to do.

8. **Wait Tractor** = as for loader above.

9. **Personal Delay** = smoko rest etc.

10. **Operational Delay** = talk to loader/truck/tractor operator or supervisor etc.

APPENDIX (IV)

Loader Utilisation Definitions

SMH = Scheduled Machine Hours = Total Worktime - Travel Time

AMH = Available Machine Hours = SMH - Mechanical Delays

PMH = Productive Machine Hours = AMH - Personal Delays
- Operational Delays*

*Operational Delays include idle time, interference, truck despatch and preparation, etc i.e. all non-mechanical and non-personal delays.

MACHINE AVAILABILITY = (AMH/SMH) * 100

MACHINE UTILISATION = (PMH/SMH) * 100