LOGGING INDUSTRY RESEARCH ASSOCIATION

NEW ZEALAND

PROJECT REPORT

SMALL LANDING OPERATION: A STUDY WITH A MOBILE HAULER & HYDRAULIC KNUCKLEBOOM LOADER

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Project Report

P.R.32

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SMALL LANDING OPERATIONS : A STUDY WITH A MOBILE HAULER AND HYDRAULIC KNUCKLEBOOM LOADER

P.R. 32 1987

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AUGUST 1987

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ABSTRACT

A detailed study of work methods on a small cable landing area operation was completed. The smallest utilised landing area was 0.07 hectares (25 metres by 28 metres). Logs were sorted and stacked in a radial pattern around the hauler and loader. Truck scheduling was co-ordinated between the loader operator and mill yard dispatcher. Truck loading times averaged 19 minutes and 13 minutes for shorts and longs log trucks, respectively. Interferences to the hauling operation by the loader or skiddies were less than 1 percent. The effect on landing operations was compared between two different levels of log preparation completed in the bush. Both options helped toward achieving a smooth flow of wood on a restricted working area.

ACKNOWLEDGEMENT

LIRA wishes to acknowledge the co-operation from J. Dudson and the gang members of Skyline Logging Ltd for their enthusiastic support in trying new ideas.

INTRODUCTION

Much of the logging in the Central North Island is characterised by relatively gentle terrain and stable volcanic soils. Also, remnants of the original crop are being harvested and future second rotation stands are coming on stream. The proportion of future harvest from the Central North Island is projected to decrease with an increasing proportion from other regions such as the East Coast, Hawkes Bay, Taranaki and Wanganui-Manawatu (Galbraith and Liley, 1986). These areas are characterised by more difficult and less stable soils and a higher proportion of steep terrain. Thus many of the past logging methods and management practises will need to be re-evaluated in view of new constraints.

One such area is the landing. Most current cable and skidder landings generally involve a relatively large area. Smaller landings may be more appropriate in many future operations because of :

- high construction cost;
- difficulty of constructing large landings on some steep terrain conditions (e.g. midslope roads);
- the use of more mobile logging equipment (e.g. Washington 88 or Madill 071 mobile hauler) for smaller second crop forests.
- land taken out of tree growing production;

Operations on small landing areas have been common practice in the Pacific Northwest Region of the U.S. (PNW). However the wood flow structure from the stump to the mill is generally different between the U.S. and New Zealand. Thus it is not appropriate to modify one part of the whole system (landing size) without considering the effects on other parts.

In the PNW, the use of hydraulic knuckleboom loaders with cable hauling systems is one factor that makes the use of small landings feasible. In addition, most of the log preparation is completed in the bush and relatively small log inventories are stored at the landing. There are typically less than five log sorts on the landing. However, there are cases when up to around eight sorts are made. Log trucks usually haul several different log types to a mill where further sorting is completed.

The purpose of this study was to evaluate the use of an hydraulic knuckleboom loader working on a relatively small landing with a cable hauling system. We were particularly interested in identifying interferences and delays between hauling, log preparation, sorting and loading in a restricted work area. A comparison of landing operations with two different levels of log preparation in the bush was also completed.

The research results reported here are part of a larger LIRA work programme concerned with landings and cable hauling systems. Survey results of landing operations and factors influencing landing size have been reported by Raymond (1987).

PROJECT DESCRIPTION

Study Site

The study was conducted on a steep section of the Kaingaroa Forest, Compartment 1128, in a 62 year old stand of Douglas fir that had been previously production thinned. Other crop details are summarised below (from Kaingaroa Forest records) :

Stocking	217 stems/ha
Total Stem Volume	794 m^3/ha
Merchantable Volume	741 m^3/ha
Average Height	43 m
Mean DBH	58 cm
Mean Merchantable Tree	3.4 m^3

The stand was clearfelled during this trial.

Two log preparation treatments were laid out and the effect on landing operations were studied.[1]

1. Partial log preparation - where one long log was cut from the butt section of the tree after felling. The remainder of the tree was crosscut into logs on the landing. Most long logs were 12.3 metres in length; some were 9.8 metres.

2. "Complete" log preparation - where two long logs were cut from the tree in the bush. Broken portions of the tree above these two cuts were also hauled to the landing and cut into a random short length. Thus the total tree was not completely prepared in the bush.

Both treatments required crosscutting on steep slopes up to 70 percent (35°). Trees were felled across the slope for crosscutting and trimming (Figure 1).

Logging Equipment and Procedure

A Madill 071 mobile hauler was used for hauling. This machine is highly mobile with a tank track carrier, three guylines, 15 metre tower, and five operating drums that provide line capability for reaching approximately 500 metres. A variety of cable systems were used with the Madill for uphill hauling to one landing and downhill

Figure 1 - Cross slope felling and crosscutting completed in the bush

1. Partial and complete log preparation, as defined in this study, reflect a relative difference in the amount of log preparation completed in the bush.

hauling to a second landing. The study area had been previously laid out and large landings were constructed for "conventional hauling" with a big tower and front end loader. This study was limited to working with the existing layout. When set up on a large landing, the operation was restricted to the smallest area required and only a portion of the total landing area was used. Hauling terrain was highly variable with both concave and constant ground slopes. Ground clearance and deflection for hauling was generally not a problem. Slope hauling distances were approximately 230 metres maximum, with an average distance of 135 metres. Average cable hauling production rates were approximately 140 to 175 m3 per day.

A 30-tonne Sumitomo Link Belt 4300 hydraulic knuckleboom log loader was used in conjunction with the Madill 071. The Sumitomo was fitted with a Prentice 610 boom and Pierce-designed log grapple and heel rack. A lifting test conducted by LIRA with Tasman Forestry Limited showed a maximum capability of 12.6 tons at a radius of 4.35 metres (Table 1). At maximum reach (9.75 metres), the loader could lift 5.1 tonnes. Small increases in lifting capability over those reported would be possible through the addition of extra counter-weighting.

The loader worked close to the hauler and log sorting was completed from a central location (Figure 2). There were four landing sorts with the majority of wood fitting into three sorts; 12.3 metre long logs, random short logs and short pulp. The fourth sort was 9.8 metre long logs. Log trucks backed up to the loader and the trailer was taken off by the loader. Truck scheduling was completed by the loader operator and mill yard dispatcher through radio communication.

TABLE 1 : LOADER LIFTING CAPABILITY

Lifting Capacity, Over Side

Radius of load (metres)	4.35	6.00	6.35	7.45	8.25
Load (tonnes)	12.58	10.93	9.30	6.76	5.12
Failure mode[1]	Boom Creep	Track Lift	Track Lift	Track Lift	Track Lift

Lifting Capacity, Over End

Radius of load (metres)	6.85	7.25	8.85	9.75
Load (tonnes)	10.93	9.30	6.76	5.12
Failure mode[1]	Boom Creep and Track Lift	Track Lift	Track Lift	Track Lift

1. Failure Mode :

Track Lift is the load when outside track starts to lift.

Boom Creep is the load when boom just holds the load without creeping down.

Figure 2 - Madill 071 and Sumitomo loader working from a central location

Study Methods

A work sampling study was conducted on the landing activities for the skiddies, hauling and loading operations. Activities were recorded at a one minute interval. With this study method, the proportion of time spent in the various activities, along with interferences, delays and idle times, can be determined.

A detailed time and motion study was also conducted on the log loading operation to determine truck loading times. A total of 32 trucks were timed (10 shorts trucks and 22 longs trucks).

Loader availability, utilisation and fuel consumption were monitored for a 28 day period. The operator was provided with a form for recording this information daily. The landing layout was measured for each landing configuration; uphill and downhill hauling; partial and complete log preparation.

In addition to the landing organisation/ knuckleboom loader study reported here, a detailed time and motion study on the hauling operation was completed by the Forest Research Institute in co-operation with LIRA. These results are reported separately (Kellogg, 1987).

RESULTS AND DISCUSSION

Landing Layout

A typical layout of the landing organisation is shown in figure 3. There was a log preparation area between the hauler and loader where the skiddies could work without being under the hauling ropes. Partially prepared trees were repositioned from the landing chute to this work area as much as possible. After trimming and crosscutting, logs were then fleeted to stacks in a radial pattern around the loader. Logs trimmed and crosscut in the bush could be directly fleeted from the landing chute.

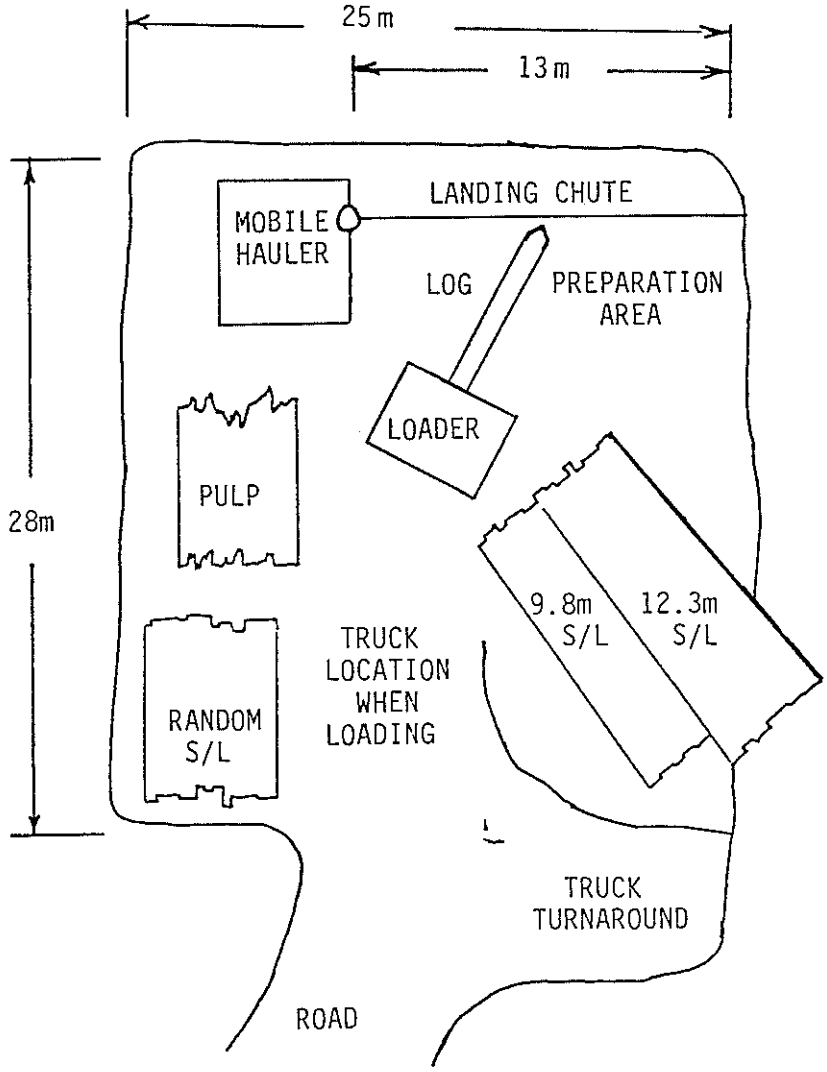

Figure 3 - Representative Landing Layout

Long log sorts were stacked adjacent to each other with some overlap at the base of the stack. Short logs and pulp were stacked approximately parallel with the loader with a small space in between the sorts. If space was more limiting than occurred in this study, it would be feasible to stack the short logs and pulp in a radial location around the loader similar to the long logs.

Approximately 0.07 hectares (25 metres by 28 metres) was used in the landing layout shown in Figure 3. It was advantageous to locate the mobile hauler as close to the landing edge as possible to avoid ground clearance problems when hauling. The shortest landing chute length was 13 metres when hauling logs. The maximum length was 42 metres when hauling partially prepared trees. It is likely that the utilised area of 0.07 hectares could have been reduced further with an operation on a purpose-built restricted landing area.

Two variations occurred from the representative layout. First, when sidehill hauling, the operating lines were located on the right side of the landing area shown in Figure 3. This required all the logs to be stacked on the left side and extended the landing area to 0.11 hectares (42 metres by 27 metres). Second, when downhill hauling, a roadside landing was used. A total area of approximately 0.07 hectares (25 metres by 27 metres) was initially excavated for stacking logs on both sides of the truck road. An additional area along the road that was cutover, but not excavated, was also used for stacking logs.

Truck scheduling is an important factor when working in a restricted area. The logging operation should be viewed as a whole system with the individual elements such as hauling, loading and cartage working together. In a restricted landing, of course there is a small space for log inventories. Also the loader must help to keep the

hauling operation running smoothly as well as loading trucks. Therefore trucks need to be scheduled into the operation at a generally consistent interval throughout the day. The loader operator should also have the flexibility to obtain more trucks or cancel trucks if the need arises.

A typical truck schedule for this study was :

- one or two long trucks first thing in the morning; approximately one-half hour apart for two trucks
- one long truck, continuing throughout the day at approximately two hour intervals
- a shorts truck in the late morning.

There were many times during the trial when the truck schedule was modified. Generally queues didn't develop of log trucks waiting to be loaded and landing delays didn't occur because of excessive log inventories. The distance from the truck turn around to the landing varied between a maximum of 260 metres to a minimum of 37 metres.

Systems Interactions on the Landing

Loader

The proportion of operating[2] time spent on loader activities is shown in Table 2 for both complete and partial log preparation treatments. Sorting logs comprised the largest portion of time, at around 35 percent for both treatments. The truck loading proportion time varied between treatments. This was mainly due to the relative number of trucks loaded for each treatment in relation to the sample size.

Assisting skiddies was higher (significant difference between treatments at 95% confidence level) for the partial log preparation treatment compared with complete, as would be expected. The proportion of time spent assisting skiddies in complete log preparation could be reduced because many of the logs set aside for the skiddies only involved minor trimming (not typically needed) or remeasuring logs already prepared in the bush. Time could be saved by directly sorting logs from the landing chute.

Assisting hauling averaged only 0.5 percent for both treatments and mainly occurred during yarder line shifts. When trucks were being loaded, the loader operator concentrated his efforts on loading and usually didn't assist the skiddies or hauling. This generally didn't cause hauling delays because loading time was relatively short and trucks arrived at the landing at varying intervals rather than several at the same time.

In contrast to cable operations in the PNW, with higher production rates and smaller landings, a relatively higher proportion of time is typically spent loading trucks and assisting the hauling operation (fleeting) while trucks are being loaded. The operating goal is to keep the whole system flowing smoothly. This concept could also be applied to cable operations in New Zealand when working on small landings and high producing hauling systems.

Interferences to the loader, either by the skiddies or the hauler, were about the same for both treatments. Skiddy interference occurred when they were working on log preparation and the loader was waiting. Hauler interference mainly occurred during line shifts; there was little interference during the hauling operation.

Loader idle time occurred when there was no work to do, usually during line shifts or hauler delays. The "clean landing" activity was slightly higher for the partial log preparation treatment as would be expected.

Skiddies

The proportion of operating time spent in skiddy activities is shown in Table 3 for both complete and partial log preparation treatments. The number of skiddies varied from one to four with the same weighted average for both treatments of 2.5. The high number of skiddies and wide variation was caused by the timing for the completion of this project and a move into a new block with the contractor.

The longer unstropping time in the partial log preparation treatment was mainly caused by difficulties associated with the Northbend cable system (tendency for carriage to slide away from the landing when getting slack in the strops). Different cable systems (gravity and slackline) were used for the area with the completely prepared logs and unstropping difficulties were reduced.

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2. Operating time does not include major mechanical delays or smokos.

TABLE 2 : LOADER WORK CONTENT

ACTIVITY[1]	LOG PREPARATION METHOD: COMPLETE PROPORTION (%)	COMPLETE RANGE[2] (± %)	PARTIAL PROPORTION (%)	PARTIAL RANGE (± %)
Sorting Logs	35.9	2.1	33.9	1.9
Truck Loading	12.9	1.4	16.6	1.5
Assisting Skiddies	5.1	1.0	6.7	1.0
Assisting Hauling	0.5	0.5	0.5	0.5
Interference - Skiddies	13.5	1.5	12.9	1.3
Interference - Hauler	9.0	1.2	8.5	1.2
Idle	11.3	1.3	8.9	1.2
Clean Landing	2.0	0.6	3.1	0.7
Other	9.8	1.1	8.8	1.2
Total	100.0		100.0	
Sample Size (1 minute observations)	1913		2425	

1. Activity Definitions :

Sorting Logs is removing logs from in front of the hauler and segregating logs into sale categories.
Truck Loading is placing logs on a truck and assisting or talking with the truckee.
Assisting Skiddies mainly involves the relocation of partially prepared trees from the area in front of the hauler to an adjacent location safe for work.
Assisting Hauling mainly involves loader assistance during unhooking and line shifts.
Interference - Skiddies is delaying the loader from working because skiddies are in the way, mainly involved with log preparation.
Interference - Hauling is delaying the loader from working because of hauling operations, mainly landing logs and line shifts.
Idle occurs when there is no work for the loader to complete.
Clean Landing is removing slash from the landing working area.
Other is a miscellaneous category that includes loader refuelling, maintenance, repair and non-mechanical delays.

2. 95 percent confidence level that the proportion of time for each activity is within the ± range.

TABLE 3 : SKIDDIES WORK CONTENT

ACTIVITY	LOG PREPARATION METHOD COMPLETE PROPORTION (%)	COMPLETE RANGE[4] (± %)	PARTIAL PROPORTION (%)	PARTIAL RANGE (± %)
Unstrop Logs	4.8	0.7	6.7	0.7
Log Preparation :				
Measuring/Marking	6.3	0.8	8.3	0.7
Crosscutting	1.5	0.3	5.5	0.6
Trimming Broken Ends	2.1	0.4	3.5	0.5
Cutting Slovens	1.2	0.3	2.1	0.4
Delimbing	7.4	0.8	5.3	0.6
Total Log Preparation	18.5	1.2	24.8	1.2
Assisting[1]				
Hauling or Loader	6.1	0.8	8.2	0.7
Waiting[2]				
Hauler or Loader	60.2	1.5	47.9	1.4
Other[3]	10.3	0.9	12.4	0.9
Total	100.0		100.0	
Sample Size	4186		4887	

(1 min. observations, all skiddies)

1. Assisting mainly occurs for hauling, during line shifts.

2. Waiting occurs because of hauling when there are no trees on the landing for log preparation and it occurs during line shifts. Waiting on the loader occurs when the loader's activity interfers with work that could be completed by skiddies.

3. Other is a miscellaneous category that includes saw refuel and repair, saw stuck and non-mechanical delays.

4. 95 percent confidence level that the proportion of time for each activity is within the ± range.

There was a significant difference (99 percent confidence level) between log preparation time for the two treatments. As expected, more time was spent in the partial log preparation option, with most of the difference attributed to crosscutting time. As discussed in the previous loader section, the skiddies spent a higher proportion of their time in log preparation with the complete log preparation treatment than needed. This was primarily a function of the high number of skiddies and because they were working with a new technique.

The data shows that the skiddies spent most of the time waiting for work, especially in the complete log preparation treatment. The majority of waiting time was attributed to the hauler rather than the loader.

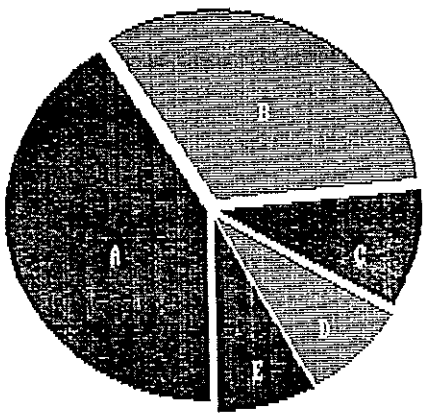
It appeared that only one skiddy was required all the time with complete log preparation.

It is interesting to compare the time between complete log preparation when only one skiddy was used and partial log preparation where the average number of skiddies was 2.5 (figure 4).

There is a significant difference in the "wait" and "log preparation" activities (99 percent confidence level). The one skiddy spent less time waiting and more time working on log preparation, thus being more fully utilised. Two skiddies were adequate to keep up with the work load in partial log preparation.

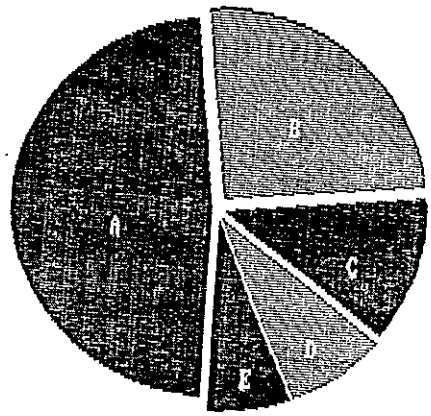
Figure 4- Comparison of Skiddies Work Content between Log Preparation Options

Complete Log Preparation
One Skiddy



Activity	Proportion
A Waiting	41 %
B Log Preparation	32 %
C Other	10 %
D Unstrop	9 %
E Assisting	8 %

Partial Log Preparation
Weighted Average of 2.5 Skiddies



Activity	Proportion
A Waiting	48 %
B Log Preparation	25 %
C Other	12 %
D Assisting	8 %
E Unstrop	7 %

In both treatments, the assisting activity mainly occurred for hauling, during line shifts. There was almost no assistance during loading. With a contrast to PNW operations, the skiddy often lends assistance getting the trailer unloaded and hooked up and securing the load for cartage. The end result is to minimise the truck time on the landing and again aim toward a smooth flow of wood through the system with a high degree of interaction from everyone involved.

Hauling

The proportion of operating time spent in hauling activities for the two log preparation treatments in both uphill and downhill hauling is shown in Table 4. Interference from either the loader or skiddies is minimal in both treatments. Hauling operations were not delayed from working in a relatively restricted landing area.

The activity sampling data showed differences in hauling activities that can be attributed to differences between log preparation methods, cable systems, or hauling direction :

(1) The proportion of time for hooking was significantly higher (99 percent confidence level) when hauling complete preparation logs. The mean number of logs per drag was 4.1 in the complete treatment versus 2.9 in the partial treatment. Mean drag volumes were however 4.24 m3 versus 3.59 m3 in the complete and partial treatments respectively.

TABLE 4 : HAULING WORK CONTENT

	LOG PREPARATION METHOD					
	COMPLETE		PARTIAL			
	UPHILL HAULING		UPHILL HAULING		DOWNHILL HAULING	
ACTIVITY	PROPORTION (%)	RANGE[5] (± %)	PROPORTION (%)	RANGE (± %)	PROPORTION (%)	RANGE (± %)
Hook	31.2	2.1	24.3	2.3	26.5	2.8
Inhaul	19.6	1.8	20.6	2.2	24.2	2.7
Unhook	11.9	1.4	16.4	1.9	10.2	1.9
Outhaul	12.6	1.4	8.8	1.6	11.1	1.9
Hauling Delays[1]	1.2	0.4	2.2	0.7	7.3	1.6
Other Delays[2]	7.2	1.1	3.9	1.1	5.0	1.4
Interference - Loader[3]	0.2	0.5	0.1	0.5	0.1	0.5
Interference - Skiddies[4]	0.1	0.5	0.0	0.0	0.0	0.0
Line Shift	16.0	1.6	23.7	2.3	15.6	2.3
Total	100.0		100.0		100.0	
Sample Size	1913		1402		1023	

(1 min. observations)

1. Hauling Delays occur while logs or trees are being hauled to the landing.

2. Other Delays are delays outside the normal hauling cycle and include rigging equipment, wire rope or hauler problems.

3. Interference - Loader occurs when a loader activity, such as sorting logs, delays hauling.

4. Interference - Skiddies occurs when an activity such as crosscutting delays the hauling operation.

5. 95 percent confidence level that the proportion of time for each activity is within the ± range.

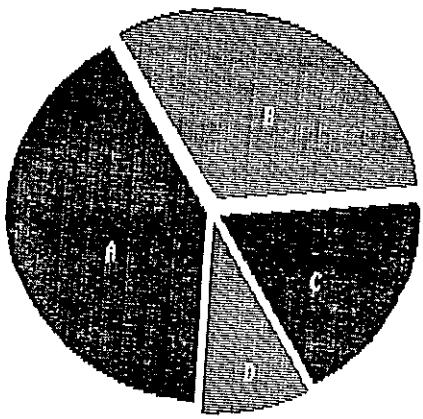
(2) The proportion of time for unhooking was the highest (significant difference at the 99 percent confidence level) for the uphill, partial preparation treatment, primarily because of the difficulties, noted earlier, with the North Bend system.

(3) Hauling delays were significantly higher (99 percent confidence level) for downhill hauling compared with uphill hauling. These delays occurred mainly in the bush rather than the landing.

Time proportions for inhaul and outhaul are influenced by different average hauling distances (approximately 145 metres for partial - downhill; 140 metres for partial - uphill; and 130 metres for complete - uphill).

It is important to consider the proportion of time spent in the main areas of the hauling operation (figure 5). Data in figure 5 is a weighted average of the three options shown in Table 4.

Figure 5 - Hauling Work Content by Grouping of Activities



Group of Activities	Proportion
A Hook and Unhook	41 %
B Inhaul and Outhaul	32 %
C Line Shifts	18 %
D Delays and Interferences	9 %

Hooking and unhooking logs comprised the largest proportion of operating time thus showing the importance of these activities on hauling production. Only approximately one-third of the operating time was spent actually pulling logs to the landing or returning the carriage to the breakerouts. Line shifts consumed almost 20% of the operating time. There are opportunities to increase production by reducing hooking time (e.g. prestropping) and speeding up line shifts (e.g. prerigging).

TRUCK LOADING

Times for loading shorts and longs log trucks are shown in Table 5. The loading times are with an operator that had previous experience on an 18 tonne hydraulic knuckleboom loader before this trial with the 30 tonne loader. There were machine operating differences and the general mode of operation was different (e.g. layout with a large landing versus a small landing area) however the data didn't show a learning curve trend.

Truck preparation time was only about 1.5 minutes longer for the shorts trucks compared with the longs trucks. Logs were loaded on both truck types from the back of the truck. For the shorts truck, the trailer was lifted off the truck and set in a nearby location. After loading the truck unit, the trailer was lifted and positioned for hooking up to the truck; the trailer was then loaded in a similar manner.

Truck loading times were about five minutes longer for short logs compared with long logs however the mean number of logs per load were 75 and 20 respectively. With long logs positioned at approximately a 35 to 45 degree angle from the truck, there was a minimum distance to swing logs from the log deck to the truck. Also, the loader was positioned behind the truck and adjacent to the log deck so that he could easily grab logs and immediately place them in a heeling position for loading. Little time was spent adjusting the log in the grapple before swinging. Short logs were not heeled when loading; they could be easily rotated in the grapple (if needed) while swinging the logs from the deck to the truck. There was approximately a 90 degree angle for swinging short logs.

There are several log sorting practices commonly followed in the PNW to save space when working in restricted areas such as :

- positioning one sort adjacent to a different sort without any space in between;

- mixing two log types together in one stack when fleeting from the landing chute, sorting is then completed when loading;

- taking logs after hauling (still located in the landing chute) and loading them directly on a truck when a truck is at the landing;

TABLE 5 : TRUCK LOADING TIMES

VARIABLE AND STATISTIC	LOG TRUCK TYPE SHORTS TRUCK	LONGS TRUCK
Loading Cycle Time (min)[1]		
mean	16.6	12.1
maximum	*19.6*	*25.8*
minimum	*13.8*	*7.3*
sample size	*10*	*22*
Delays and Foreign Elements (min)[2]		
mean	2.2	1.2
maximum	*4.0*	*4.0*
minimum	*0.0*	*0.0*
sample size	*10*	*22*
Total Loading Time (min)		
mean	18.8	13.3
maximum	*25.7*	*26.6*
minimum	*14.7*	*7.5*
sample size	*10*	*22*
Truck Preparation Time (min)[3]		
mean	4.5	2.9
maximum	*5.8*	*4.8*
minimum	*2.6*	*2.0*
sample size	*8*	*18*
Number of Logs/Load		
mean	74.9	20.3
maximum	*107.0*	*37.0*
minimum	*54.0*	*12.0*
sample size	*10*	*22*

1. Loading Cycle consists of three elements : sort logs in deck; swing load to truck and adjust logs on truck, if needed; swing unloaded back to deck.

2. Delays that occur during the loading cycle and stop work. Foreign Elements that occur occasionally during the loading cycle, such as moving the loader to a new position.

3. Truck Preparation is the time to unload the trailer and hook up.

- placing several different log types on the same truck (e.g. 12 metre and 11 metre long logs).

In this study, two long log sorts (12.3 metre and 9.8 metre lengths) were stacked adjacent to each other without any space in between. Also a limited trial was conducted with a mixing of the two long log types in the same stack. The operation didn't lend itself to a rigorous test of this procedure because there was a relatively high proportion of 12.3 metre logs, however five trucks were timed when loading from a mixed stack. Truck loading cycle times are shown in Table 6 for the different truck and sort types.

Sorting logs from mixed stacks was longer than separate stacks (significant difference at 99 percent confidence level). Even though there is a significant difference in sorting time, there would only be a 1.2 minute difference in total loading time between mixed and separate stacks (assumes 20 cycles/load and the same time for other loading cycle elements). It was also interesting that sorting short logs took the least amount of time; primarily because no time was required to heel the log. In addition, a higher number of short logs were handled with each loading cycle compared with long logs.

LOADER DELAYS

The mechanical availability of the loader for the 28 days of monitoring was 95 percent. There were 2.9 hours lost to a broken hose (one occurrence) and a broken O-ring on the main hydraulic control bank (one occurrence). An additional 3.8 hours of delay was attributed to the grapple (one occurrence). Accounting for smokos and personal delays, the machine was used 87 percent of the time. Adding in the operational delay times (loader waiting for work) of 11 percent resulted in a machine utilisation of 76 percent.

The fuel consumption rate was 15.4 litres per operating hour.

SUMMARY

This study showed an effective use of an hydraulic knuckleboom loader for working on a restricted landing area with a cable hauling system. The main study conclusions related to landing size and organisation are :

1. There were minimal interferences and delays between hauling, log preparation, sorting and loading in a restricted work area. In addition, the hauling distance was short in this study thus creating a relatively high degree of pressure for the loader operations. The loader kept up with the work load.

   The landing activities integrated well and there was a smooth wood flow from the bush to the truck. Scheduling of trucks was an important factor for a successful operation.

   This conclusion is, however, limited to the characteristics of the case study (e.g. hauler production level, number of log sorts and landing space utilised). More time would be required for fleeting or truck loading in a system with a higher production level, less available landing space, or more log sorts. The study data indicates however that there is potentially more time available for the loader to work on fleeting or truck loading than occurred in this study.

2. The results (landing interference and delays) were similar between partial and complete log preparation options. Complete log preparation, carried out in this study, only involved one additional log cut than partial log preparation.

   It appears that there are further opportunities available in other conditions when a substantial portion of the log preparation is completed in the bush. Firstly, less loader time is spent assisting skiddies to complete log preparation. More time can be spent on loading when logs are prepared in the bush. Secondly, the number of skiddies can be reduced when more of the log preparation work is completed in the bush. The extra skiddy would contribute more towards breaking out or felling and log preparation. Thirdly, the hauler can be positioned closer to the landing edge when hauling shorter pieces that have been prepared in the bush. This is an advantage when ground clearance is limiting on the cable span, especially close to the landing edge with short tower mobile haulers.

TABLE 6 : TRUCK LOADING CYCLE ELEMENTS

VARIABLE AND STATISTIC	LONGS TRUCK SEPARATE SORTS	LONGS TRUCK MIXED SORT	SHORTS TRUCK
Sort (min)			
mean	.17	.23	.11
maximum	*.83*	*1.01*	*.44*
minimum	*.01*	*.06*	*.03*
sample size	*282*	*83*	*303*
Swing Loaded (min)			
mean	.37	.34	.30
maximum	*1.28*	*1.57*	*.95*
minimum	*.13*	*.15*	*.11*
sample size	*292*	*87*	*313*
Swing Unloaded (min)			
mean	.15	.11	.12
maximum	*1.10*	*.23*	*.25*
minimum	*.05*	*.06*	*.04*
sample size	*268*	*76*	*295*
Number of Logs/Cycle			
mean	1.2	1.1	2.3
maximum	*3.0*	*2.0*	*8.0*
minimum	*1.0*	*1.0*	*1.0*
sample size	*299*	*87*	*320*

It should be remembered that the results in this study compare two different methods of varying levels of log preparation in the bush. There may be significant interferences and delays when working on restricted landing areas with tree length material and this should be investigated further. Also a truly complete preparation of all logs in the bush may result in too many small pieces for hauling. The importance of value recovery from future Radiata pine stands will influence log preparation practices in the bush or on the landing (Murphy, 1987). In addition to landings, felling practices and hauling production rates need to be studied further for the different log preparation options.

3. The smallest utilised landing area, with four log sorts and complete processing, was 0.07 hectares (25 metres x 28 metres) including a landing chute of 13 metres. Partial log preparation required a longer landing chute distance; other space requirements were similar. There are opportunities for working on a smaller landing area and increasing the number of log sorts.

4. General observations regarding landing layout :

   - Loader activities should be confined to an area adjacent to the hauler with minimal movement around the landing.

   - When using a central landing, log sorts should be located radially around the loader with the piles slightly over-lapped at the base. A similar concept could be followed for a continuous roadside landing; log sorts can also be arranged adjacent to each other on both sides of the road.

   - The space needed for each log sort and the location of each sort is influenced by the relative proportion of wood in each sort and how fast the hauler is changing lines and adjusting position on a landing (more critical with a mobile hauler). Also important is the direction that the hauler is moving; either towards log sorts or away from them.

   - Often non-excavated, cutover areas, outside the designated landing area, can be used for stacking logs.

It is anticipated that a substantial number of future logging operations will require efficient use of relatively small landing areas on steep terrain. LIRA will continue investigating this area.

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