Session II
Paper (d)

THE WYSSEN HAULER

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INTRODUCTION

This paper is intended as a position statement. Its purpose is to describe both the performance to date of the Wyssen system procedures by which the system's potential can be properly evaluated. Although the data collected so far has been sketchy a progress report will put the machine on an objective footing.

Wyssen haulers were first introduced to New Zealand some thirty years ago and used in thinning trials at Golden Downs, Whakarewarewa, Whitford and elsewhere. Some documentation of these trials is still extant (e.g. Maplesden). The system eventually fell into disfavour through high costs related to lengthy rigging time requirements and difficulties in obtaining well trained bushmen.

The Marlborough Catchment Board and N.W.A.S.C.A. have since obtained a new Wyssen W30 hauler and a new automatic carriage. This paper will confine itself to the trials involving this new machinery. The detailed working of the system is not included as this has been well described elsewhere (Wyssen Skyline Cranes Co Ltd, 1984).

The Koromiko Trials

Description

The Marlborough Catchment Board initiated trials with the Wyssen System in January 1984 at Koromiko (between Picton and Blenheim). The first line setups were undertaken with the assistance of Mr Huldreich Schmid of the Swiss Logging Company, Washington, U.S.A. As a venue for training a crew in how to work the system, and for demonstrating it to a wider audience, the site was suitable. As an opportunity for the system to demonstrate its productive abilities, there were however significant drawbacks and these are discussed later.

8 lines were used to log an area of 7.3 ha. Details of these lines are shown in Table 1.

TABLE 1 : LAYOUT OF SKYLINES, KOROMIKO

Line	Length (m) Total	Productive	Area (ha)	Volume (m^3)	Supports
1	785	400	2.0	480	
2	713	180	0.4	214	
3	911	170	0.9	353	Hanger used on spar
4	832	250	0.6	257	
5	713	150	0.6	314	
6	670	270	1.2	599	1 support
7	546	210	1.0	221	1 support
8	380	120	0.6	166	
		TOTAL	7.3	2604	

On line 3, the spar tree was rigged with a hanger allowing the carriage to pass behind the spar and extract timber there. On lines 6 and 7, intermediate support trees were rigged to allow adequate load clearance over the length of the skyline.

Spars and supports were standing trees which had to be climbed, topped and guyed to support the skyline up to 20 m above the ground.

The site was steep with average slopes of 30°, ranging to more than 50°.

The hauler was sited at the top of the stand as is characteristic with this system (refer Figure 1). The clamping facility of the carriage enabled slack to be pulled in the mainrope up to 50 m laterally either side of the skyline. At least four men were required to work the system - one as the winch operator, two on the slopes in a faller/breaker out combination, and one on the landing to unhook the drags and stack them with the loader.

LIRA first became involved in the Koromiko trials in an exercise to determine skyline tensions. For this purpose a tension gauge was connected within the skyline on line 5. With this attached to a pengraph recorder a useful trace could be obtained for each hauler cycle. Recorded tensions showed good correlation with those predicted on a theoretical basis.

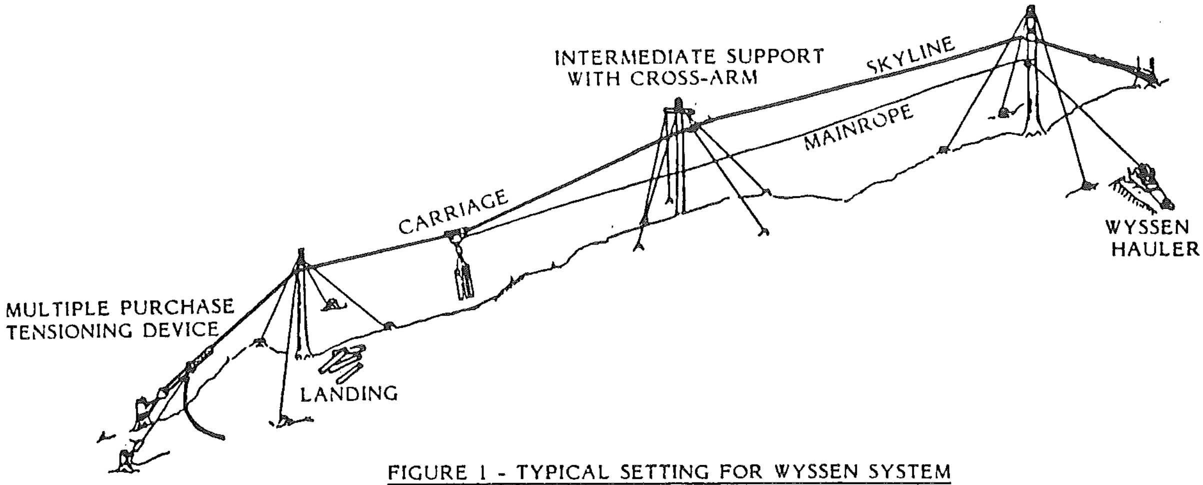


FIGURE 1 - TYPICAL SETTING FOR WYSSEN SYSTEM

Performance - LIRA Study

During the tension testing the opportunity was taken by LIRA to perform a stopwatch study of the system. It must be stressed that this study was decidedly limited (the operation was temporarily short handed and the LIRA staff member ended up working on the landing instead.) The information obtained nevertheless indicated how the machine should perform in uninterrupted circumstances. Moreover the stopwatch data was supplemented by the tension gauge pengraph traces which proved of some use for analysing cycle times. Unfortunately the tension gauge was only switched on during the travel loaded/travel empty phases of the cycle. In retrospect it should have been left running continuously to provide more complete information on total cycle times.

Besides the study of cycle times 16 loads were scaled to provide an indication of load sizes.

Results

Table 2 describes the machines performance over 13 cycles.

TABLE 2 : WYSSEN PERFORMANCE - KOROMIKO

Mean cycle time is	11.25 minutes	Range 7.28 - 18.46 minutes
Travel distance for all cycles	600 m	
Mean Load Size	1.30 m^3	Range 0.59 - 1.99 m^3

A study of 29 cycles indicated 25 cycles with 1 piece and 4 with 2 pieces.

The activity breakdown for 13 cycles was :

Drop mainline to breakerout	2.3%
Walk to logs pulling mainrope	21.6%
Attach strops	6.5%
Move clear	2.6%
Lift the load	10.9%
Travel loaded	13.8%
Carriage clamp to skyline	3.6%
Lower load at landing	2.3%
Unhook log(s)	13.9%
Travel empty	14.0%
Carriage clamp to skyline	1.2%
Delays - wait for faller	1.2%
- cut logs free for breakout	5.2%
- other	0.9%
	100.0%

Discussion

The stand at Koromiko provided substantial restrictions to efficient breaking out. The self sown trees were not at a high stocking. Branching was comparatively heavy and there was live scrub within the stand. This influenced extraction in the following ways :

(a) Resistance to breaking out: The steep slopes and scrub obstructions meant that delimbing was incomplete. More force was necessary to drag the logs laterally.

(b) The scrub restricted the breakerout when pulling the line laterally. Breakout times were lengthy as a result. There would seem to be some advantage in the breakerout preparing a path to the next drag while the previous drag is on its way to the landing. In some cases such a prepared path could be used to service several drags.

In a better stand pulling slack should be a much less time consuming part of the cycle. Undergrowth resistance would be less, and prepared paths would service more wood. Pre-stropping of logs, would also be a possibility.

(c) A better stand having more logs in close proximity would allow optimum drag sizes to be prepared. Load cell testing indicated that drags of 1.7 tonnes could be handled without difficulty provided that slash and branches did not prevent breakout.

Performance: Marlborough Catchment Board Records

Because the crew were new to the machine, and for some to bushwork itself, opportunities were taken for training. Substantial time loss and interruptions occured while felling, splicing and general logging skills were developed.

Production and gang-time data collected over the last 4 months of the Koromiko operation is summarised as follows :

TABLE 3 : GANG TIME DATA, KOROMIKO, OCTOBER 1984-FEBRUARY 1985

	Man Hours	% of Total Time
Extraction	874	43
Pre-rig and line shift	353	17
Training	251	12
Maintenance	43	2
Wet time	207.5	10
Mechanical	160.5	8
Down Time		
Shutdown and Shift	170	8
Total Work Time (Exclusive of Travel Time)	2059	100
Hauler		
Machine hours (extraction)	197	
Production (m^3)	1136	
Production Rate (m^3/hr)	5.9 m^3/hr	

The summer of 1984/85 was one of the wettest on record in Marlborough which accounts for the large wet-time component (10%).

Excluding wet-time and training time, gang time breaks down on the following basis :

	(%)
Extraction	55
Pre-rig and line shift	22
Maintenance	3
Mechanical Down Time	10
Shut Down & Shift	10
	100

1. Frequent line shifts were necessary because of the low recoverable volume per hectare (approximately 357 m^3/ha) and the relatively short distances of line crossing stocked areas. Line shifts were 22% of available production time.

   With more experience in planning, the number of line shifts could possibly have been reduced.

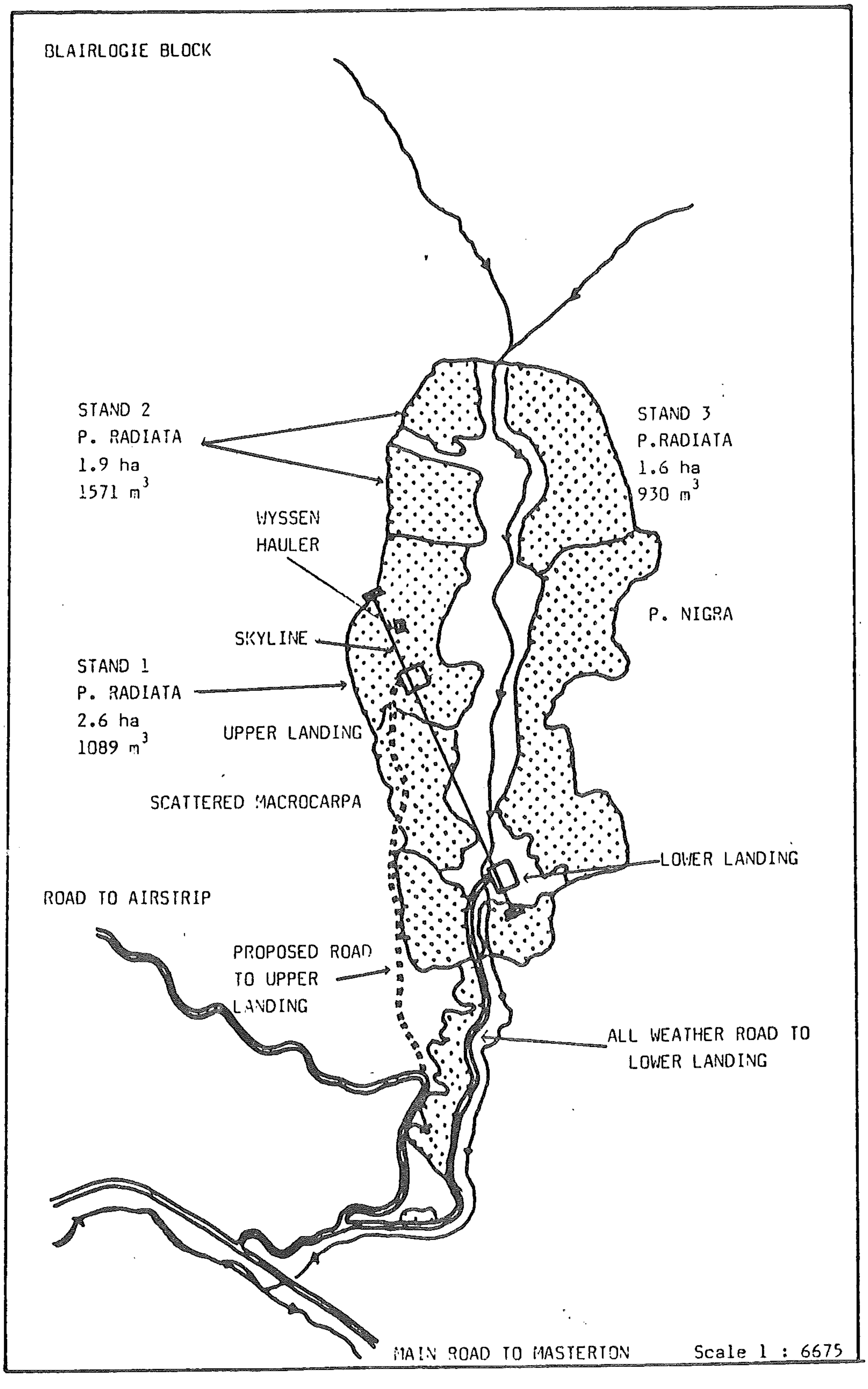
2. The average production rate per hauler hour was 5.9 m^3. Production rates varied markedly with the ease of breaking out, steepness of terrain and other factors. Monthly means ranged from 4.8 m^3/hour to 8.4 m^3/hour.

3. The shutdown and shift operation involved extra work in preparing the equipment for shipment to Masterton where the next trial with the Wyssen was to take place.

The Blairlogie Trials

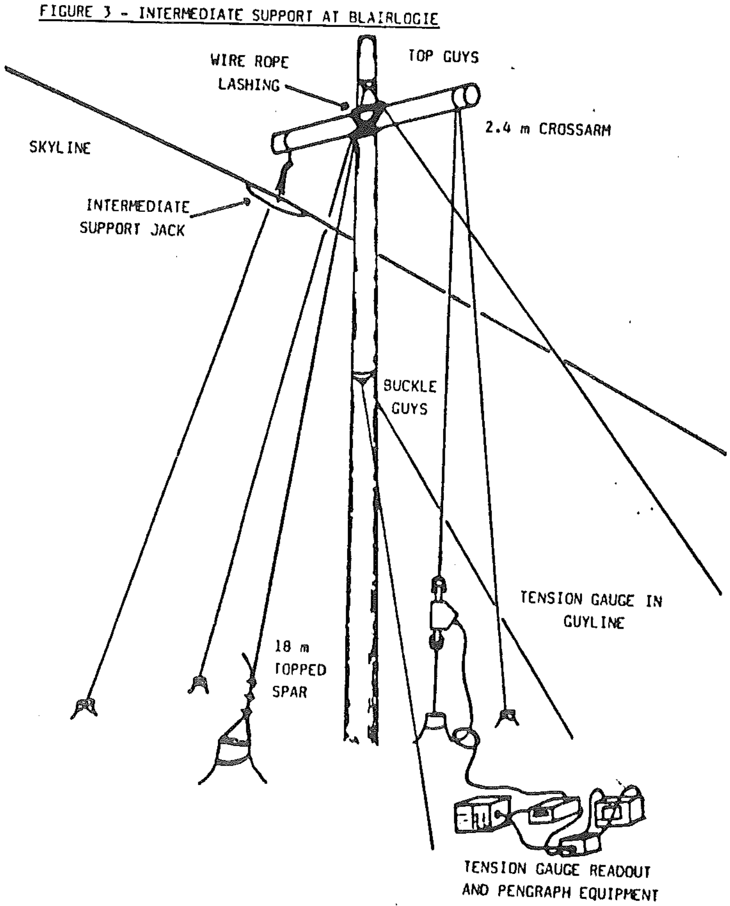
In February 1985 the Wyssen hauler was shifted to Blairlogie near Masterton. The Marlborough Catchment Board crew accompanied the machine and the system was set up in a plantation originally established by the Wairarapa Catchment Board.

FIGURE 2



Three years ago attempts were made to log the Blairlogie block by conventional means. These proved unsatisfactory from a soil and water conservation point of view and were curtailed by the Wairarapa Catchment Board. More recently the Board approached P.F. Olsen & Co., Forestry Consultants, to assess the stand's likely value and estimate the costs of different logging alternatives. A map of the block and mensuration data are shown in Figure 2. At the Catchment Board's request the alternative that the consultants reviewed in detail involved construction of a lengthy access road to the upper reaches of the block. Difficulties in the construction, surfacing and maintenance of such a road were recognised in its cost - in excess of $22,000. With the roading option as a base for comparison the Wairarapa Catchment Board elected to trial the Wyssen system and in this case the machine was set up in strictly a transport capacity. The working span was just 300 m long with a slope of 21%. An intermediate support was again rigged, in this case an elaborate model as illustrated in Figure 3. Logs were hauled to an upper deck by a Cat D4D tractor equipped with a logging arch. This machine was owned by an independent contractor whose operation was out of phase with that of the Wyssen. Substantial stocks could be accumulated at the upper deck during periods when the Wyssen crew returned to Marlborough on furlough.

FIGURE 3 - INTERMEDIATE SUPPORT AT BLAIRLOGIE



During operation of the Wyssen wood was cut to length at the upper deck and pre-stropped. The amount of wood preparation at the lower skid was therefore considerably reduced, enabling this skid to be small and remain relatively uncongested. Five men worked in conjunction with the Wyssen system; one operated the winch, two were employed at the upper deck, another at the lower skid and a fifth man operated the front-end loader.

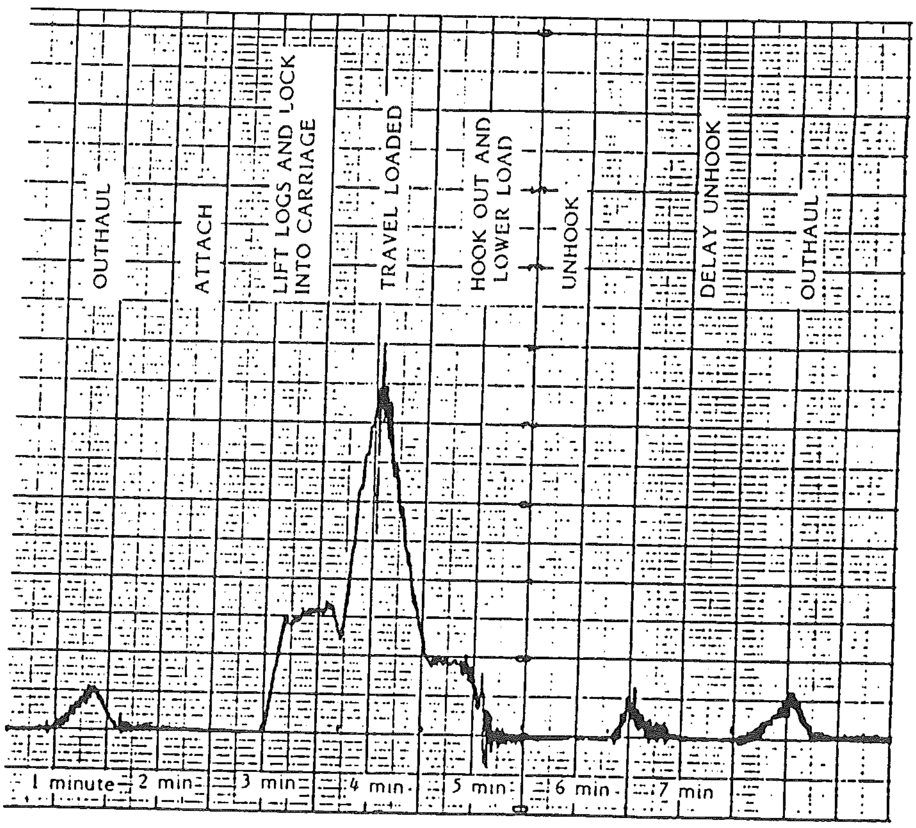
LIRA Study Procedure

This involved the following :

1. Stopwatch study
2. Tension gauge trace
3. Volume scaling

The stopwatch study procedure was straightforward and measured 40 cycles. The tension gauge was then connected within one of the load bearing guylines on the intermediate support. This gave a tension trace on which the major elements within each cycle could be identified. Because the pengraph trace proceeds at a precise rate it is straightforward to obtain element and cycle times from the trace. The procedure is illustrated in Figure 4. A further advantage of the pengraph trace is that it provides an indication of load sizes.

FIGURE 4 - PENGRAPH TRACE OF ONE CYCLE



The way in which the tension gauge was connected meant that a correlation of the guyline tension with the suspended load could not be easily calculated from analysis of the system's geometry. Although it is theoretically possible, to determine the tensions within reasonable levels of confidence requires very accurate measurements of skyline and guyline angles at the intermediate support. Such accurate measurements were not obtained.

An alternative was to scale several drags at the landing and compare the scaled volume with the tension gauge results. Fifteen such pairs of results were obtained before rain curtailed further use of the gauge. Linear regression analysis was used to relate the scaled volumes to the tension gauge readings. A reasonable relationship was obtained ($r^2 = .75$) as illustrated in Figure 5.

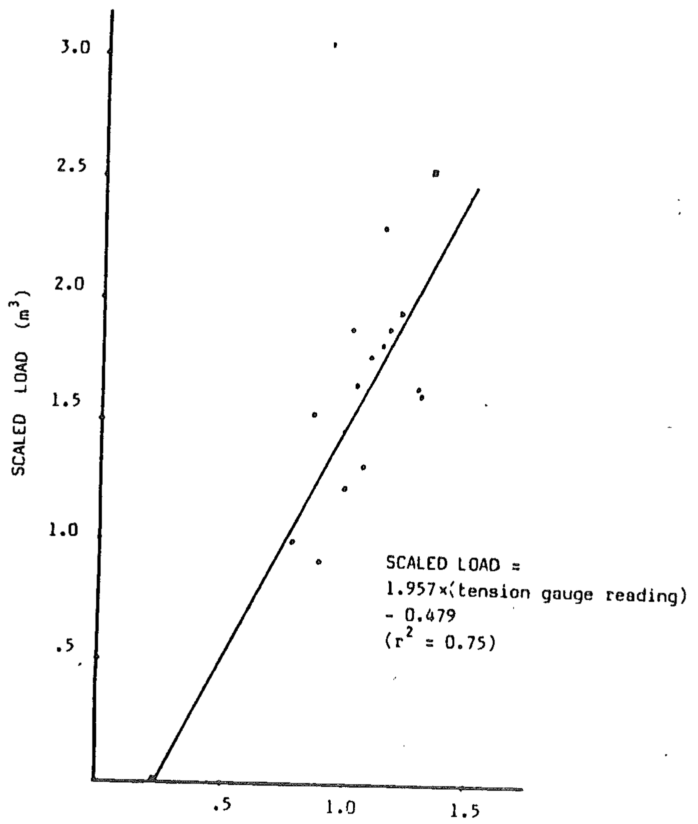


FIGURE 5 - THE RELATIONSHIP BETWEEN SCALED VOLUME AND THE TENSION GAUGE READING (15 LOADS)

Results

Table 4 enables a comparison of the results obtained from a stopwatch study (40 cycles) and the tension gauge trace (50 cycles). Total cycle times identified by the two methods differed by only 2%, and most element proportions were very similar. It appears though, that unhooking delays were overestimated using the tension gauge method and the 'raise rigging/clamp off/outhaul' combination was correspondingly underestimated.

Although the tension gauge time study method enables less detailed analysis of each cycle, it nevertheless can be used with success. It's advantages lie especially in :

(a) the method does not require a field workers continuous attention;

(b) an indication of load size can also be obtained.

Using the relationship plotted in Figure 5, the tension gauge trace was used to determine the distribution of load sizes. This is plotted in Figure 6.

FIGURE 6 - DISTRIBUTION OF LOAD SIZES

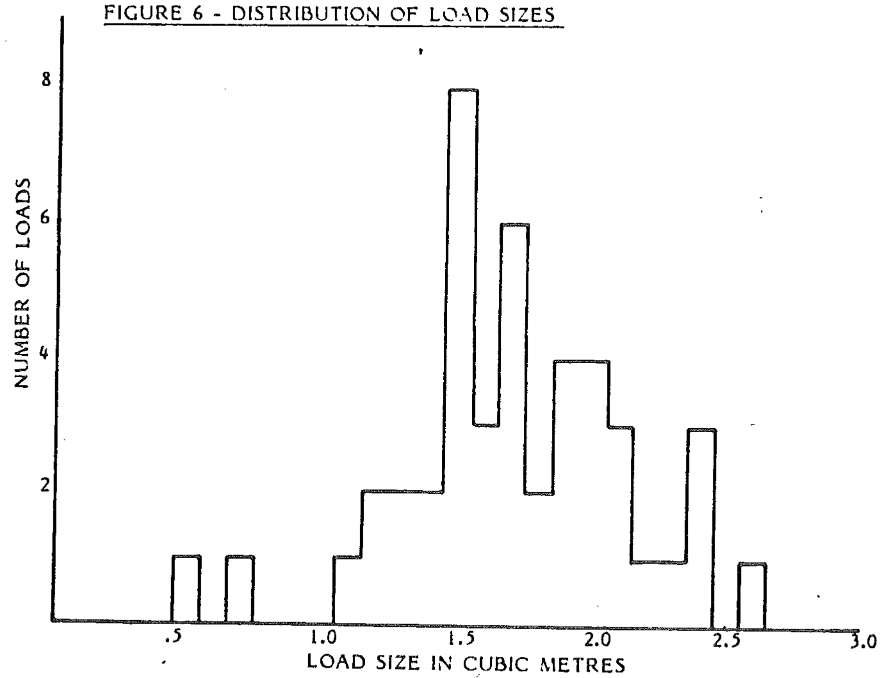


TABLE 4 : WYSSEN PERFORMANCE AT BLAIRLOGIE

	Stopwatch Mean	Stopwatch Range	Strain Gauge Mean	Strain Gauge Range
Cycle time (with operational delays)	5.95		6.07	
Activity Breakdown %	%		%	
Raise rigging 4.7) Clamp Off 1.8) Outhaul 11.9)	18.4		11.7	

Unlock	1.7)		
Lower hook	3.5)	26.9	23.1
Attach logs	21.6)		
Lift	9.7)		
Lock in	1.6)	11.3	11.1
Travel Loaded		17.0	18.9
Hook Out	2.2)		
Lower Load	5.1)	7.3	10.4
Unhook		13.3	13.1
Delay/unhook		3.9	9.7
Delay/lift		1.9	2.0
		100.0%	100.0%

Discussion

1. The results demonstrate that in a transport mode the potential to optimise drag sizes seems much improved. The mean load size at Blairlogie was 1.71 m^3 compared to 1.30 m^3 at Koromiko.

2. From the results and observation it is also more difficult to identify significant sources of inefficient performance or delay. One area in which improvements could have been achieved was in unhooking the logs at the landing as there were delays associated with strops that could not be freed. If a system of exchange strops were used the hauler would not be held up and jammed strops could be freed during fleeting operations by the loader.

3. The operation at Blairlogie appeared to make efficient use of available manpower with the breakerouts sharing some of the processing work. Moreover there were the advantages of the lower skid being cleaner and smaller. Both of these features are important in environmentally sensitive sites.

4. One major source of delay which must be avoidable through adequate planning is that of interference from trucks - for safety reasons trucks cannot be loaded beneath the working skyline. It is important therefore that trucks can manoeuvre to a point away from beneath the skyline.

5. For most efficient performance of the Wyssen system it is

obviously important that the tractor operation keeps buffer stocks replenished at the upper deck. Determining the respective production capabilities of the tractor and skyline operations is necessary if they are to be kept in balance.

6. From the results obtained at Blairlogie it is possible to calculate a likely longer term production level for the system in similar circumstances. A calculation procedure is shown in Appendix I. One of the more important variables in the calculations is that of the machine utilisation, assumed in this case to be 60%. The figure is essentially arbitrary but influenced by the Wyssen's utilisation at Koromiko (55% utilisation after wet-time and training deducted, from the Marlborough Catchment Board records). In fact in a review of studies by the FRI, Murphy (1979) suggests an average utilisation of only 45%.

   Appendix I indicates that long term daily production in the order of 87 m^3 per day should be obtainable from the Wyssen if used in situations similar to those at Blairlogie.

<u>The Cost of the Wyssen</u>

A sample costing procedure for the Wyssen system is presented in Appendix 2. The format adopted follows that described in the LIRA costing handbook (Wells, 1981).

There is room for doubt with some of the assumptions, particularly those affecting the machines productivity, its likely repair and maintenance costs, its level of utilisation, the interest rates applicable to funds invested, and the anticipated rope life. Because the database is still meagre, rather than quote a single cost, a sensitivity analysis has been performed and a range of possible answers presented.

The costing example considers the Wyssen operating as a transport system (i.e. a Blairlogie-type situation) and the results in summary are :

	Daily Production	
	87 m^3/day	65 m^3/day
Base costing	\$7.24/m^3	\$9.65/m^3
Dephased operation	\$8.67/m^3	\$11.56/m^3
Labour gang of 3 men instead of 4	\$6.15/m^3	\$8.20/m^3
Repair and maintenance costs - 100% of depreciation	\$7.44/m^3	\$9.92/m^3
Machine life 7 years	\$7.52/m^3	\$10.03/m^3
Rope life 1000 operating hours	\$7.60/m^3	\$10.13/m^3

(The various assumptions are explained in Appendix 2.)

It is appropriate to compare the cost of the Wyssen as a transport system to the cost of building a road to serve stands 1 and 2 at Blairlogie (refer Figure 2).

The estimated volumes from these stands was assessed by P.F. Olsen and Co. Ltd as 2660 m^3 and the cost of a road to logging truck standards as $22,000, giving a direct roading cost of $8.27/$m^3$. This is comparable with the estimated costs for the Wyssen.

Planning

The planning procedures applied before setting up the Wyssen system are demanding compared to those for other systems. Because each load descends the skyline under gravity alone the suspended logs must remain clear of the ground, and the skyline must have sufficient fall. The traditional compromise associated with all skylines arises; the skyline must be sufficiently tight that the load is suspended, but there must still be sufficient deflection (or sag) that the skyline is not overstrained.

For each new line the ground profile is determined. This may be plotted in the first instance from topographic maps - if they are available. A field survey is always desirable where there is any doubt about clearance. The profile information when plotted can be used to identify critical points where clearance will be restricted, or indeed whether it is feasible to extract timber over the profile at all. Likely intermediate support trees are identified during the ground survey and their dimensions and locations are recorded.

Feasible payloads are calculated using the Chain and Board technique, although a hand-held programmable calculator with the appropriate software could be used for this purpose. An anticipated refinement to the planning procedure will be to analyse the forces on intermediate supports to determine their necessary dimensions, and the optimum guyline placement.

Conclusion

1. Although this paper has described what study data is available to date on the Wyssen, it has also identified where information is insufficient. Further production studies are clearly necessary, particularly to identify avoidable and unavoidable delays. A better definition of shifting times would be invaluable to facilitate planning for the system.

2. It would be instructive to test the Wyssen :

    (a) Extracting timber from a well-stocked stand
    (b) As a transport system over long distances.

3. Although the role of the Wyssen as a transport system appears promising, for many stands, in North Island locations especially, there may not be sufficient fall for the gravity carriage to work properly. It may be necessary to look to the Wyssen Unimat, an option where the carriage does not rely on gravity for its loaded travel.

4. The Wyssen carriage has the significant advantages that go with a clamping carriage. It can be used with other haulers as Huldreich Schmid has done in the United States. A recent report by Hemphill (commissioned by LIRA) recommended the use of clamping carriages. Although he did not recommend the Wyssen specifically, since it is already in the country it would appear sensible to evaluate it fully before undertaking the expense of importing something else.

5. The Wyssen system involves, as a matter of course, a number of features which LIRA, overseas visitors and New Zealanders who have toured overseas have been promulgating for some time. These include :

   - The use of intermediate supports.
   - The practice of rigging standing trees using climbing gear (which seemed about to become a lost art until recently).
   - The role of tail tree/intermediate support analysis. Information is available from the U.S. as are hand-held calculator programmes.
   - The cable extraction of wood in log lengths.
   - Long span total suspension cable logging.
   - Swinging: (The use of a cable system purely to transport logs rather than extract them.) This is not commonly considered as a modern alternative. In fact as a cable system it has a long history. The North Bend system, for instance, was originally derived in swinging operations. If large areas are to be restricted to cable logging exclusively, the use of swinging systems will become essential.
   - Thorough planning :

     (a) Surveying profiles
     (b) Identifying intermediate supports
     (c) Deflection/tension/payload analysis

   - Prestropping
   - Dephased logging.

It is significant that the Wyssen system should embody so many differences from typical New Zealand cable logging operations. It should be the subject of continued scrutiny from progressive thinkers in the New Zealand logging industry.

References

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Murphy G. (1979) The Forest Research Institute's work on Cable Logging : A review of its main findings. N.Z.J.For. 24(1) 76-84.

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APPENDIX I

ESTIMATED PRODUCTION CAPACITY OF WYSSEN AS A TRANSPORT SYSTEM

It is assumed that the full day on site is 8½ hours or 510 minutes

40% of available time	(Less: smoko breaks	60 minutes
	(Less: access to/from hauler	30 minutes
	(Less: general rigging allowance, daily skyline tension check	15 minutes
		405 minutes
	(Less: line shift times and other longer delays	100 minutes
60% of available time		305 minutes

Average cycle time (determined from 90 cycles at Blairlogie)	6.0 minutes
Number of cycles per day	51
Average load size	1.7 m^3
Daily Production	87 m^3

APPENDIX 2

INDICATIVE COST OF WYSSEN AS A TRANSPORT SYSTEM

In the following example the Wyssen is assumed to be working as a transport system (as it was at Blairlogie). Although in this role it was the capacity to out-produce the system feeding it, in the first instance it is assumed that the Wyssen works continuously, and is producing an average of 87 tonnes per day (as per Appendix I).

A sensitivity analysis at the end of this section illustrates the effect of changing the more critical assumptions made in this example.

MACHINE DAYS

The costing is prepared on the basis of :

Total possible machine work days per year	260
Less statutory holidays	11
Less annual leave allowance	15
Less major location shifts, weather downtime etc	20
Available machine days	214

WYSSEN HAULER DAILY COST

The 1984 prices (including duty but before devaluation) for the hauler and carriage were $66,900 and $28,520 respectively. A 10 year life and 20% resale value are assumed. Repairs and maintenance are assumed to be 50% of depreciation. Interest charges on the money invested are assumed to be 15%.

(a) Owning Costs

$$\text{Depreciation} = \frac{95150 \quad x\ 0.8}{10 \text{ yrs } x\ 214 \text{ days}} \qquad = \quad \$35.60/\text{day}$$

$$\text{Return on Investment} = \frac{\text{Average Capital Invested } x\ 15\%}{214 \text{ days/year}}$$

$$\text{where ACI} = \frac{(95150\ x\ 0.8)\ x\ (10 + 1 \text{ yrs})}{(2\ x\ 10 \text{ yrs})} + (95150\ x\ 0.2)$$

$$= \$60,900$$

$$\text{Return on Investment} = \frac{\$60,900\ x\ .15}{214} \qquad \$42.69/\text{day}$$

$$\text{Insurance} = \frac{\text{ACI } x \text{ insurance rate}}{\text{days/year}}$$

$$= \frac{\$60800\ x\ .02}{214} \qquad \$5.70/\text{day}$$

Owning Costs = $84.00/day

(b) Operating Costs

Fuel - 30 litres/day @ $0.783/litre	$23.49/day
Oil and filters @ 20% of fuel cost	$4.70/day
Rigging :	
Skyline : 800 m of 24 mm Ø rope for 2 years (2000 operating hours) $10700/418 days	$25.60/day
Mainrope :	
800 m x 10 mm ø for 2 years @ $3.00/m $2400/418 days	$5.74/day
Repairs and Maintenance :	
Assume these represent 50% of depreciation	$17.80/day
Operating Costs	$77.33/day
Total Machine Cost for Wyssen	$161.33/day

The machine owning and operating costs are roughly equal as tends to be the case in most operations where this costing technique is applied.

LABOUR

It is assumed that a gang of four is employed - one machine operator, two breakerouts and one skiddy. The assumed labour cost is $95.00 per machine day (214 days per year) and this includes payment for travel time, holiday pay, and ACC levy.

4 men @ $95/day	$380/day

CHAINSAWS

2 saws @ $16/day	$ 32/day

GANG TRANSPORT

2000 c.c. vehicle 70km/day @ $0.50/km	$ 35/day

INCIDENTALS

Radio communications, fire gear, gang hut, tapes, tools etc $1500/214 days	$ 7/day

ADMINISTRATION

Accounting, legal, statutory documentation, phone calls, postage etc $3000/year	$ 14/day
DAILY COSTS FOR WYSSEN SYSTEM	$630/day

At the estimated production level of 87 m^3/day the corresponding cost per cubic metre would be $7.24/$m^3$. This represents the cost of transporting logs with the Wyssen and to this must be added the costs of extraction and loading.[3] In the Blairlogie situation these would be in the order of $15/$m^3$, giving a total cost in excess of $22.00/$m^3$.

SENSITIVITY ANALYSIS

In the following table the effect of changing some of the cost and production assumptions is demonstrated. The changes are detailed in the notes following the table.

TABLE 5 : SENSITIVITY ANALYSIS SHOWING EFFECT OF CHANGING CRITICAL ASSUMPTIONS ON COST OF WYSSEN AS TRANSPORT SYSTEM

	Daily Production	
	87 m^3/day	65 m^3/day[1]
Base costing	$7.24/$m^3$	$9.65/$m^3$
Dephased operation[2]	$8.67/$m^3$	$11.56/$m^3$
Labour gang of 3 men instead of 4[3]	$6.15/$m^3$	$8.20/$m^3$
Repair and maintenance costs - 100% of depreciation[4]	$7.44/$m^3$	$9.92/$m^3$
Machine life 7 years[5]	$7.52/$m^3$	$10.03/$m^3$
Rope life 1000 operating hours[6]	$7.60/$m^3$	$10.13/$m^3$

Notes :

1. This level of production represents a 25% reduction in the potential of 87 m^3 per day calculated in Appendix I. Such a drop in production could result from smaller average payload sizes, or longer cycle times (as would occur over a longer span) or a reduction in machine utilisation (in this case from 60% utilisation to 45%).

2. In the dephased operation option it is assumed that the Wyssen is only worked for 10 days in every 20, because it can out-produce the primary extraction operation. The cost increase reflects the reduced opportunity to spread fixed costs. It is assumed that the labour, their chainsaws and transport will be employed elsewhere during the 10 'off' days and therefore the daily cost of these does not increase.

   This cost does not represent the actual situation at Blairlogie where the Marlborough Catchment Board crew travelled from Blenhein to work the machine. If the travel and accommodation costs associated with that situation were included the system cost would be closer to $9.60/m^3$ for production of 87 m^3 per day.

3. The system cost for cubic metre is clearly sensitive to the cost of labour. If there were one less man in the crew - for instance one breakerout rather than two - there would be a significant saving.

4. The effect of doubling the repair and maintenance costs for the Wyssen does not affect the result greatly.

5. Reducing the machines anticipated life from 10 years to 7 years does not affect the result greatly.

6. The rope life is halved from 2000 hrs to 1000 hrs.

In this sensitivity analysis just one factor has been changed at a time. The changes are essentially cumulative, which indicates that if a conservative basis were adopted, the cost per cubic metre could be in the order of $9.50/m^3$ for 87 m^3/day, or $12.70/m^3$ for 65 m^3/day.