LOGGING INDUSTRY RESEARCH ASSOCIATION
NEW ZEALAND

ISSN 0111-6711

REPORT

Vol. 15 No. 13 1990


# INCREASING LOG STORAGE DENSITY:

## HIGH STACKING WITH A KNUCKLEBOOM LOG LOADER; WAGNER LOG STACKER AND STEEL STANCHIONS

**Lindsay Vaughan and Paul Taylor**

*The Sumitomo LS4300 Knuckleboom log loader used for high stacking*

*ABSTRACT*

*Two trials were undertaken at the Port of Tauranga to examine methods of increasing log stack density. One involved the use of a knuckleboom log loader; the second involved the use of steel stanchions.*

*Five different treatments with a 30 tonne knuckleboom log loader were studied. Machine productivity varied from 102 to 182 m³/productive machine hour (PMH), depending on log size, distance between stacks and stack height. The additional costs ranged from \$0.56 to \$1.34/m³ for a 61% increase in stack volume; this corresponds to 7340 m³/ha.*

*High stacking over a pair of 4m high steel stanchions with a Wagner L90 increased stack volume by a further 10%. The cost of the stanchions was estimated to be \$0.69/m³ for an additional 2230 m³/ha.*

*Both these options were cheaper than off-site storage on nearby land, estimated to cost \$2.60/m³ for a volume of 12,000 m³/ha.*

*Recommendations were made for further work.*

## INTRODUCTION

The Port of Tauranga exported 1.6 million tonnes of logs in the year ending September 1990, an increase of more than 40% on the previous year. These logs cover a range of species and range in length from 5.5m to 12.1m. The logs are predominantly radiata pine in 8m and 12m lengths.

Off-site storage costs for these additional volumes have led the major New Zealand forestry companies to investigate methods of increasing log storage density on the wharf. The Wagner stackers can lift to a height of 5.5m. However, it is not possible to stack to this height with unrestrained logs. For 12m A-grade logs, stack heights average 3.5m (range of 2.5m to 4.3m) with an angle of repose of approximately 40°. Trying to stack higher results in logs rolling down the stack underneath the grapple arms.

An increasing proportion of export logs are now being debarked and sprayed with a fungicide to improve log presentation and reduce problems with bark loss in overseas harbours. These debarked logs are more difficult to handle. Log stacks of newly debarked logs typically average 2.5m in height with an angle of repose of approximately 30°.

Other methods of increasing log storage density by increasing stack height have been investigated. Tasman Forestry Limited trialled a truck-mounted Prentice 410 knuckleboom loader and a 60 tonne mobile rope crane. Stanchions have also been used to increase stack height in some New Zealand and overseas log yards. Recently, NZFP Forests Limited approached LIRA to participate in some trials at the Port of Tauranga. This report describes the result of two trials; a 30 tonne hydraulic knuckleboom log loader high stacking 5.5m, 8m and 12m logs, and a Wagner log stacker using stanchions to increase stack height.

*ACKNOWLEDGEMENTS*

*LIRA acknowledges the assistance of the staff and operators of Owens Services B.O.P. Ltd. (the log marshalling contractor), NZFP Forests Limited and Leespower Machinery.*

## HIGH STACKING WITH A KNUCKLEBOOM LOG LOADER

### THE SUMITOMO LS4300 KNUCKLEBOOM LOG LOADER

The machine used to test the concept of high stacking was a new Sumitomo LS4300, a 30 tonne track-mounted hydraulic knuckleboom loader with a Prentice 625 boom and arm, a live heel and a C848 grapple (Figure 1). It was powered by a 11 litre turbocharged Mitsubishi engine producing 174 kW. The cab had been raised by 0.9m to improve operator visibility. No additional counter-weights had been added. Previous studies with this model have included its use on landings for fleeting and loading (Kellogg 1987, Duggan 1989), and for loader logging (Moore 1990).

The operator was experienced in the use of knuckleboom log loaders and had operated the same model in Kinleith Forest.

### THE TREATMENTS

The three day trial studied high stacking by swinging from an adjoining row, by lifting from the ground, and by swinging from trucks. The five treatments studied were:

1) Swinging 12m A-grade logs through 180° from an adjoining row 14m away on to an existing row averaging 3.4m in height (Figure 2).

2) Lifting 12m A-grade logs from ground level and swinging them through 90° on to an existing row 3.4m in height. A Caterpillar 966 rubber-tyred front-end loader was used to supply logs from a nearby row.

3) Swinging 8m debarked A-grade logs through 90° directly from the back of trucks on to an existing row averaging 2.4m in height.

4) Swinging 5.5m K-grade logs through 180° from an adjoining row 9m away on to an existing row averaging 3.2m in height.

5) Lifting 5.5m K-grade logs from ground level and swinging them through 90° on to an existing row averaging 3.2m in height. A Caterpillar 966 loader was used to supply logs from a nearby row.

*Figure 2 - High stacking 12m A-Grade logs by swinging from a nearby row*

## STUDY METHOD

A Husky Hunter portable computer loaded with the work study program SIWORK 3, was used to study the high stacking operation. The work cycle was divided into five elements:

- **Swing Unloaded** - Swinging empty and positioning the grapple above the log(s).

- **Grapple On** - Hooking the grapple on the log(s) and raising it.

- **Swing Loaded** - Swinging with the log(s) and placing on the row.

- **Adjust Log** - Moving the log(s) until the end is flush and the log(s) is secure.

- **Production Delays** - Minor delays caused by moving the machine, tidying the row or waiting for the stacker or loader to lay down logs. All major delays (waiting for trucks, refuelling, smokos, etc.) were excluded.

Information on the number of logs and log volume for each row were provided by Owens. Row height was measured at 2.5m intervals on the short rows (under 40m) and 5.0m intervals on the longer rows (over 40m).

## RESULTS

### Cycle Times and Productivity

Cycle times and levels of productivity are summarised in Table 1. Cycle times vary from 0.56 to 0.85 mins/cycle, with productivity ranging from 102 to 182 $m^3$/PMH. Log size, distance between stacks and stack height are the key factors affecting productivity.

When swinging the 12m logs from an adjoining stack 14m away (Treatment 1), it was apparent the distance was greater than desirable. Additional time was needed to pull the logs toward the loader in order to heel them and then pushing the logs away from the loader after swinging to get them flush with the row. If this distance was reduced to around 8m, productivity could be expected to rise from 116 to around 144$m^3$/PMH. Swinging from ground level through 90° (Treatment 2) resulted in productivity levels of 173$m^3$/PMH.

The highest levels of productivity were recorded when unloading the 8m debarked logs from trucks and swinging them through 90° (Treatment 3). A payload of 1.7$m^3$ was similar to that recorded with the

**Table 1 - Productivity of Sumitomo LS4300 knuckleboom log loader**

| Treatment | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Log length: | 12m | 12m | 8m | 5.5m | 5.5m |
| Log grade: | A-grade | A-grade | A-grade debarked | K-grade | K-grade |
| Unloading from: | Row 14m away | Ground alongside row | Truck | Stack 9m away | Ground Alongside Row |
| Swing Angle: | 180° | 90° | 180° | 180° | 90° |
| Elements | | Element times (mins) | | | |
| Swing unloaded | .13 | .13 | .12 | .13 | .14 |
| Grapple on & lift | .24 | .18 | .13 | .21 | .19 |
| Swing loaded | .27 | .17 | .17 | .17 | .18 |
| Adjust log | .18 | .08 | .04 | .13 | .15 |
| Production delays | .03 | .02 | .10 | .04 | .06 |
| Cycle time | .85 | .58 | .56 | .68 | .72 |
| 95% Confidence Limits | ±.04 | ±.04 | ±.11 | ±.08 | ±.12 |
| No of cycles studied | 154 | 150 | 59 | 94 | 35 |
| Mean piece size ($m^3$) | 1.53 | 1.53 | 1.24 | .43 | .43 |
| Pieces per cycle | 1.08 | 1.09 | 1.37 | 2.83 | 2.86 |
| Payload ($m^3$) | 1.65 | 1.67 | 1.70 | 1.22 | 1.23 |
| Productivity | | | | | |
| Pieces/PMH | 76 | 113 | 147 | 250 | 238 |
| $M^3$/PMH | 116 | 173 | 182 | 108 | 102 |
| 95% Confidence Interval | 111-122 | 162-186 | 152-227 | 96-122 | 88-123 |

12m logs and achieved by increasing the number of 8m logs carried in the grapple. The location of the loader close to the truck and the row appeared close to the optimum, resulting in minimal "adjust log" times. The slippery nature of the debarked logs resulted in intermittent avalanches when the stack collapsed, increasing production delays.

Lower levels of productivity were achieved with the shorter 5.5m logs, when swinging from an adjoining stack 9m away ($108m^3$/PMH) or from off the ground ($102m^3$/PMH) (Treatments 4 and 5).

Cycle times were shorter than Treatment 1 (swinging 12m logs from an adjoining row) but slower than Treatments 2 and 3 (lifting 8m and 12m logs). This was caused by increased "grapple on" and "adjust log" times because of the extra number of logs carried. Average pay loads were approximately 75% of that recorded with the larger logs. A larger grapple would be needed to obtain a payload with these shorter logs, but "grapple-on" and cycle times would increase.

### Production Costs

Using the LIRA costing format (Wells 1981), an indicative daily cost can be calculated. These costs were based on purchase prices of $300,000 for the Sumitomo LS4300, $358,000 for the Caterpillar 966 loader, a residual value of 25% after five years and an interest rate of 18%. The results in Table 2 are based on 7 PMH/day and 240 days/year.

Production costs for the five high stacking treatments are shown in Table 3. A Caterpillar 966 loader was used to provide a regular supply of logs to the Sumitomo loader when it was lifting from the ground (Treatments 2 and 5). As it was only needed for a small proportion of the time, 25% of its daily cost has been included in these costs, on the assumption that it could be effectively used elsewhere for the remainder of the time.

**Table 2 - Daily Machine Costs**

| | Sumitomo LS4300 ($/day) | Cat 966 ($/day) |
|---|---|---|
| Owning and Operating Costs | 465 | 677 |
| Operator Costs | 160 | 160 |
| Travel & Equipment | 14 | 14 |
| Overheads (2%) | 13 | 17 |
| Profit (10%) | 65 | 87 |
| TOTAL | $717 | $955 |

**Table 3 - Production Costs for High Stacking**

| Treatment | | Log Length | Productivity ($m^3$/day) | Cost ($/day) | Cost ($/$m^3$) |
|---|---|---|---|---|---|
| 1. | Swinging from row | 12m | 812 | 717 | 0.88 |
| 2. | Lifting from ground | 12m | 1211 | 956 | 0.79 |
| 3. | Swinging from truck | 8m | 1274 | 717 | 0.56 |
| 4. | Swinging from row | 5.5m | 756 | 717 | 0.95 |
| 5. | Lifting from ground | 5.5m | 714 | 956 | 1.34 |

These costs assume full utilisation of the loader; this is unrealistic if it was only swinging logs off trucks (Treatment 3). A separate loader would be needed for some of the time to provide a regular supply of logs to the knuckleboom loader when lifting off the ground (Treatments 2 and 5).

The costs of swinging 12m logs (Treatment 1) could be reduced by decreasing the distance between the rows from 14m to around 7m. Costs for handling the 5.5m logs (Treatments 4 and 5) could also be reduced by the use of a larger grapple on the knuckleboom loader.

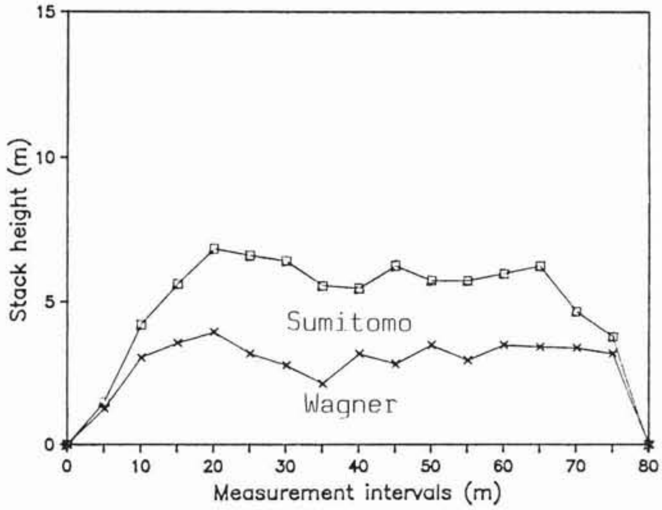


*Figure 3 - The effect of high stacking on row height*

**Additional Volume Stored**

Details on the additional numbers of logs and volume that can be stored by high stacking are shown in Table 4 along with row height.

**Table 4 - Effect of High Stacking**

| Log Length | High Stacking 5.5m | 12.0m |
|---|---|---|
| Extra logs added | | |
| (No.) | 363 | 796 |
| (as %) | 59 | 74 |
| Extra volume added | | |
| ($m^3$) | 153 | 1224 |
| (as %) | 58 | 68 |
| Row height | | |
| (before) | 3.3m | 3.4m |
| (after) | 6.8m | 5.9m |

A comparison of the stack profiles is shown in Figure 3.

**IMPLICATIONS OF HIGH STACKING WITH A KNUCKLEBOOM LOG LOADER**

The use of a knuckleboom loader for high stacking would require some changes in the existing work methods. One option would be to leave access lanes beside the rows designated for high-stacking by swinging from an adjoining row. Ideally these lanes would be 6m to 10m wide but lanes up to 14m wide could be handled with some drop in productivity. After high stacking, the empty row and access lane could be filled.

While high levels of productivity were achieved by swinging logs from trucks, it would be difficult to maintain a supply of trucks without undue delays to trucks or loader.

The third option is to use rubber-tyred loaders or Wagner stackers to supply the knuckleboom loader with logs at regular intervals. This would require sufficient space beside the row to provide access for these machines, and tie up a machine for up to 25% of its time.

One problem experienced with high stacking was keeping the sides of the high stacked rows vertical. This was particularly noticeable with 5.5m logs. However, this should be overcome as the operator gained experience.

The major routes used by the stackers for transporting logs would need to be wide enough to allow adequate clearance to carry 12m logs if the adjoining rows are to be high stacked.

## HIGH STACKING WITH A WAGNER L90 AND STEEL STANCHIONS

*Figure 4 - Wagner L90 stacker loading over stanchions*

A separate trial examined the use of stanchions with the Wagner stackers. Stanchions were placed at one end of two existing rows and additional logs were added by the Wagner L90 over the top of the stanchions (Figure 4). Breaking out was also evaluated.

## THE WAGNER LOG STACKERS

Wagner log stackers dominate the large log handling machinery market in New Zealand. These machines are purpose-built for handling logs and have some significant features which distinguish them from other types of mobile log handling equipment such as large pivot steer machines.

The Wagner is designed to lift and carry large volumes of logs. The large wide-spaced wheels at the front give the machine added stability and reduce ground pressure, while the tricycle design allows a small turning circle. The boom lifting height and log carriage tilt angle allow the weight to be better distributed over the axles of the machine.

Lifting capacity varies from 27 to 45 tonnes, depending on model. The Wagner L90 used in this study can lift 40 tonnes.

## STANCHION DESIGN AND PLACEMENT

The stanchions for this trial were made from the chassis of a disused rail wagon. The chassis was cut in half and two feet provided some lateral stability. The longer foot was welded to the outside to reduce the possibility of tyre damage. The main upright, which was not braced, consisted of an I-beam with a web thickness of 13mm and web depth of 390mm.

The stanchions were put in place with a Caterpillar 966 loader. The loader was able to put its forks under the stanchion and hold it upright with its clamp arm. Two lifting pockets cut in the base member would assist positioning.

## RESULTS

The additional number of logs and volume that can be stored is shown in Table 5. For a long row (around 80m) of 12m logs containing about 1800m$^3$, the extra 186m$^3$ represents a 10% increase in volume for each set of stanchions.

## STANCHION COST

Stanchions made from used materials would cost approximately $2500 per pair with a nominal life of five years. The costs associated with depreciation and the cost of capital would average $770 per year. If they were only used when space was at a premium (say six times per year), then the additional cost would be $0.69/m$^3$.

No allowance has been made for the extra time involved in loading or unloading them. Although it was slower to load over the stanchions, having the logs restrained allowed the Wagner to stack higher than normal (Figure 5).

**Table 5 - Effect of Stanchions at one Row End**

| Log Length | Extra Logs | Extra Volume | Row Height | |
|---|---|---|---|---|
| | | | Before | After |
| 12.0m | 121 | 186m$^3$ | 1.7m | 4.8m |

*Figure 5 - The effect of stanchions on row height*

# DISCUSSION

## BREAKING OUT HIGH STACKS WITH A WAGNER

The Wagner had no difficulties in breaking out the high stacked rows of 8m and 12m logs (Figure 6).

Concern was expressed at the possibility of logs at the top of the stack (up to 7m above the ground) rolling over the log carriage and on to the operator's compartment. Subsequent trials showed that this was not a problem.

Breaking out over stanchions was slower, as the first load required the forks to be placed halfway up the stack and slid between the logs and it was difficult to acquire a full payload. After the next three or

*Figure 6 - Wagner L90 breaking out a high stacked row of 12m logs*

four loads, the stanchions could be removed, allowing loadout to proceed normally. Providing care was taken when inserting the forks and breaking out the first few loads, log damage and breakage was minimal. Stanchions could not be used on logs shorter than 5.5m because of the width of the Wagner's forks.

Breaking out high stacks of 5.5m logs posed problems. These smaller logs tend to cross as they fell, making it difficult for the Wagner stacker to fill the log carriage. A smaller pivot steer loader was used to straighten logs and realign the ends (Figure 7).

*Figure 7 - Cat 966 loader with a high stacked row of 5.5m logs*

**OFF-SITE STORAGE**

Off-site storage used industrial land 1.3 km from the Port and involved unloading the truck and stacking the logs with a rubber-tyred front-end loader after the logs had been tallied. These logs are later reloaded and trucked, usually direct to the ship. The additional costs incurred for unloading, storage, reloading and trucking are estimated to be $2.60/m^3$.

**STORAGE OPTIONS**

Three storage options are compared in Table 6 in terms of the volume stored and additional cost. They assume that six rows of 12m logs, each 80m long, can be stored on a single hectare, with the rest of the area occupied by access lanes and by space between the stacks.

Stanchions are the cheapest option and require few changes in work methods and machinery, but will only allow for a 20% increase in stack volume.

The costs of high stacking with a knuckleboom loader could be reduced if adjoining stacks were only 6 to 8m apart. The increased level of productivity would reduce high stacking costs to a level comparable with using stanchions. However, this would require good forward planning to ensure its effective use.

Off-site storage on nearby industrial land is a more expensive option because of the additional handling, trucking and storage costs.

Three other off-site storage options are rail wagons, a central log yard or landings in the forest. These costs vary between forest owners. Individual forest owners will need to compare their own costs with those in Table 6.

**Table 6 - Storage Options for 12m logs - Volumes and Cost**

| Option | Additional Volume $m^3$/row | Additional Volume $m^3$/ha | Additional Cost ($/$m^3$) | Comments |
|---|---|---|---|---|
| Stanchions | 372 | 2230 6 | 0.69 | Stanchions at both ends of row |
| High Stacking | 1224 | 7340 | 0.88 | |
| Off-site storage | 2000 | 12000 | 2.60 | |

## RECOMMENDATIONS

*INVESTIGATE the cost of other storage options.*

These include storage on landings in the forest, at central log yards, or on rail wagons off-site.

*UNDERTAKE further work on stanchions.*

This should cover stanchion design, material and manufacture. Investigate the potential for movable stanchions so the Wagner stackers can maintain increased stack height along its length by progressively moving the stanchion out from the stack and loading in behind.

*EVALUATE other high stacking machines.*

This should cover the larger knuckleboom log loaders, grapples, boom modifications, rubber-tyred bases as well as other types of machines.

*UNDERTAKE a systems review to look at more efficient methods of log handling from the forest landing to the export wharf.*

Consider the option of bundling logs and developing work methods to suit new machines.

## CONCLUSIONS

These trials examined two options for increasing log stack density at the Port of Tauranga and compared them with the costs of off-site storage on industrial land nearby. These conclusions refer to the results achieved with 8.0 and 12.0m logs.

Stanchions are the cheapest option considered and provide storage for a further 2230 $m^3$/ha at an additional cost of $0.69/$m^3$. It also has the advantage of using existing machinery and work methods.

High stacking with a hydraulic knuckleboom loader is slightly more expensive at an additional cost of $0.88/$m^3$, but could provide storage for a further 7430$m^3$/ha. This option requires careful forward planning and some changes to existing work methods to ensure efficient use of this machine.

Both these options provide substantially lower costs than that of off-site storage on industrial land nearby, where the costs of unloading, storage, reloading and trucking were estimated to be $2.60/$m^3$ for a volume of 12,000$m^3$/ha.

## REFERENCES

Duggan, M (1989) : "Processing Options for Hauler Landings". LIRA Report Vol. 14 No. 17.

Kellogg, L (1987) : "Small Landing Operations using a Mobile Hauler and a Knuckleboom Loader". LIRA Report Vol. 12 No. 7.

Moore, T (1990): "Pilot Trials with Loader Logging in New Zealand". LIRA Report Vol. 15 No. 2.

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

---

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

---

*For further information, contact:*

N.Z. LOGGING INDUSTRY RESEARCH ASSOC. INC.
P.O. Box 147,
ROTORUA, NEW ZEALAND.

*Fax: (073) 462-886* *Telephone (073) 487-168*