These costs are based on a system which accumulates waste over a number of days and on skids in close proximity to each other. This is the only way of accumulating a large volume of waste material due to the relatively low volume of waste produced each day. These systems would not be feasible in areas with a small volume of logging or a widely scattered resource.

SIZE OF WASTE RESOURCE

When considering the possibilities and options for utilising waste wood, it is useful to be able to estimate the total volume available within the relevant region (Table 4). The estimates of volumes of solid wood and branch waste in Table 4 are based on two assumptions. Firstly, that the study figures for the volume of waste as a percent of the extracted volume can be applied across the country and, secondly, that wood supply and extracted volume are similar. The figures used were 3.4% of wood supply for solid stem waste and 4.2% of wood supply for branch waste. These percentages are slightly lower than those presented in Table 1 to allow for the fact that there are proportionately less cable logging operations than were studied.

The figures in Table 4 are based on those in the National Exotic Forest Description (NEFD) (Turland et al, 1993). There are suggestions that in some areas the volume harvested already exceeds that predicted in the NEFD, so these figures could be conservative.

As New Zealand's wood supply and amount of cable logging increases, so does the volume of waste produced. Whilst the total waste figures for New Zealand are large, this volume is spread over the entire country, often in remote locations. Many of the regions have only a small supply of waste, which may make it difficult to justify the capital expense involved in setting up a system to utilise it. The central North Island is the obvious exception to this. The best option appears to be to find ways of using it as an addition to an existing supply, such as increased chip or boiler fuel supplies into existing plants.

One possibility for using much of the "unchippable" branch material is as boiler fuel. Waste wood from processing plants is already used as boiler fuel at some sites. However, much of this wood is quite dry and stem wood has a greater energy content than branch waste, especially if the branch waste is green.

Potential energy values of waste wood are: (Baines, 1993).

Pinus radiata stem wood, oven dry
19 MJ per kg, 6020 MJ per m^3
Pinus radiata stem wood, air dry
14 MJ per kg, 5300 MJ per m^3
Pinus radiata stem wood, green
10 MJ per kg, 4620 MJ per m^3
Logging residues and branch waste, green
7 MJ per kg, 2400 MJ per m^3

When burning waste wood for energy the best efficiencies are achieved in co-generation systems where steam is produced and is used to power both industrial processes, such as drying, as well as electricity generation.

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REPORT

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WASTE WOOD AT LOGGING LANDINGS

Peter Hall

ABSTRACT

The volume of waste wood created at logging landings was measured in ten studies, each of two days' duration. Of these, seven were on hauler crews and three on ground-based crews.

Daily volumes of slovens (0.4 to 3.5m³), heads (0.2 to 5.7m³) and mid-stem waste sections (2.2 to 15.7m³) were measured as was the daily volume of branch material (1.9 to 31m³). Waste assessments provided estimates of the volume of stem (22 to 104m³) and branch (9.0 to 104m³) material left on the cutover.

Over all the studies, the average daily extracted volume was 203m³. Total stem waste volume was 8.3m³ or 4.1% of the daily extracted volume. Sections of mid-stem waste make up the bulk of this (66%).

An estimate for the volumes of waste wood available as a national resource were made, based on these figures, and the predicted volume of wood available for logging.

Estimates of the costs of extracting this material to a point of use and processing it are made for two systems currently under consideration. Costs were estimated to be $20 to $21 per tonne.

An assessment of the impact of delimbing at the landing on nutrient removal is made.

INTRODUCTION

Figure 1 - A typical hauler landing edge showing the beginnings of a "bird's nest" comprising branches, heads, slovens, root balls and short sections of stem waste

Waste wood created during log making at landings is made up of branches trimmed off the stem and pieces of solid wood cut from the tree length such as slovens, small diameter head sections and low quality sections from the mid-stem. Traditionally, this material has been pushed into heaps and left to rot as there has been no demand for it.

The waste material from logging operations, especially branch material around hauler landings, can present problems and can cause a lot of expense if the material has to be dragged back on to the skid surface after logging to prevent "bird's nest" collapse. The volume of waste material produced by logging operations varies with the logging system, crop type, species and skill of the log maker.

As most of the expansion of New Zealand's harvest is on steep land, the problems that this material can cause are becoming more prominent. In many areas of New Zealand "birds' nests" and how to deal with them are becoming an issue. Waste heaps may collapse over young trees and into gullies or streams. They also provide a breeding ground for insect and pathogen pests. In some cases, they are also a substantial fire risk and are perceived as unsightly and wasteful by the public.

There are a number of ways of handling these accumulations of debris, most of which involve costs and risks to the forest owner (Hall, 1993). The best way of avoiding these is by finding a constructive use for the material. To do this, it is necessary to know how much of this material there is and the shapes and sizes of the individual pieces.

In an attempt to describe the potential resource, a series of ten two-day studies were carried out. The results of these studies were extrapolated to estimate regional volumes of wood waste based on predicted regional wood supplies.

The success of a utilisation system will be affected by the size, location and make up of the waste wood resource, and how efficiently it can be recovered. Much of the waste produced at landings is branch material which cannot be used as a fibre resource for pulp, paper or reconstituted board products. Two possible uses for this material are as an energy resource or as a nutrient resource for the next rotation.

ACKNOWLEDGEMENTS

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METHOD

Figure 2 - Sections of stem waste, typical of those accumulated around most logging landings

The volume of waste wood created at logging landings was measured in ten studies each of two-days duration. Seven of these studies were on hauler crews and three on ground-based crews. The studies were carried out in four different forests in the Bay of Plenty and one forest in Nelson.

Table 1 presents a summary of the stand data.

Table 1 - Stand data

	1 GB	2 GB	3 GB	4 Hlr	5 Hlr	6 Hlr	7 Hlr	8 Hlr	9 Hlr	10 Hlr
Stems per hectare	425	435	255	410	345	450	435	305	425	270
Piece size, (m^3)	1.1	1.1	2.6	1.25	1.46	1.1	1.15	1.8	1.2	2.2
Volume per hectare	467	478	663	512	503	495	500	549	510	549
Pulp Market	Yes	Yes	Yes	Yes	Yes	Limited	Limited	Yes	Yes	Yes

(GB = Ground based, Hlr = Hauler)

The volume of stem waste created each day was measured by taking the large end, small end and length measurements of all the pieces of solid wood waste excluding branches (Figure 2). Volume was calculated by using Ellis's three-dimensional formula (Ellis 1982). These pieces were separated into three categories: slovens, mid-stem and heads. The volume of branch waste (Figure 3), was measured separately, using one of two methods:

Figure 3 - Part of a large pile of branch waste material typical of that which occurs at hauler landings

(1) Where loaders were fitted with weight scales, the branch material was pushed into small heaps and weighed before being dumped. The heaps of branches were also measured for length, width, and height. The diameter of all pieces greater than 75mm in diameter were also recorded.

(2) Where the material could not be weighed, the heaps of branch waste were measured as above, and the ratio of solid volume in the heap based on the bulk volume was estimated (McNab, 1980).

The accuracy of method (2) was checked against method (1) in two of the studies. The results from the estimate made by method (2) were within 10% of the results of the weighed heaps.

The volume of stem and branch material left on the cutover was assessed using the Van Wagner line intersect method (Warren and Olsen, 1964; Van Wagner, 1968; Van

Table 2 - Average daily extracted volume, solid waste volume, branch waste volume, and cutover residue volume by gang and logging system type. (GB = ground-based, Hlr = hauler.)

	1 GB	2 GB	*1 3 GB	* 2 4 Hlr	5 Hlr	6 Hlr	*3 7 Hlr	8 Hlr	9 Hlr	*4 10 Hlr	Avge All	std error	Avge GB	std error	Avge Hlr	std error
Extracted Vol (m^3)	149	159	400	181	156	209	264	92	163	260	203	27	236	82	189	22.7
Total Stem Waste (m^3)	2.0	3.1	17.3	9.6	4.5	7.7	13.5	7.1	6.1	11.6	8.3	1.5	7.5	4.9	8.6	1.2
Vol Slovens	0.7	0.4	1.4	1.6	0.5	2.1	3.5	1.4	1.2	0.9	1.4	0.3	0.8	0.3	1.6	0.3
Vol Stem	1.1	2.3	15.7	2.2	1.5	4.7	8.7	5.2	3.4	10.3	5.5	1.5	6.4	4.7	5.1	1.2
Vol Heads	0.3	0.4	0.2	5.7	2.5	0.9	2.2	0.5	1.5	0.4	1.5	0.5	0.3	0.06	1.9	0.7
Bulk Vol branch waste	16.8	19.2	11.6	173	54.6	31.8	70.6	64	65.8	8.8	51.6	15.5	15.9	2.6	66.9	19.5
Solid Vol Branch waste	3.4	3.8	2.9	31	11.2	6.2	14.1	11.4	12.5	1.9	9.8	2.7	3.4	0.3	12.6	3.9
Total Daily stem waste as a % of extracted vol	1.4	1.9	4.3	5.3	2.8	3.6	5.1	7.8	3.7	4.5	4.0	0.6	2.5	0.9	4.7	0.6
Solid vol of branch waste as a % of extracted vol	2.2	2.4	0.7	19.1	7.1	2.9	5.3	12.5	7.6	0.7	6.0	1.9	1.8	0.5	7.9	2.3
Total vol of waste on cutover (m^3/ha)	217	135	86	51	76	85	60	63	34	41	84.8	17.2	146.0	38.1	58.5	6.9
Vol of branches on cutover	113	73	36	29	27	27	13	22	9	19	36.8	10.1	74.0	22.2	20.9	2.9
Vol of stem on cutover	104	62	50	22	49	58	47	41	25	22	48.0	7.7	72.0	16.3	37.7	5.5

There are several items to note from Table 2:

1. Gang 3 was working in large piece size (2.6m³) on flat to rolling terrain with delimbing at the stump. The daily volume of stem waste may appear high. However, the waste volume as a percent of the extracted volume is only slightly above "average" values due to the very high production. Large piece size and therefore large diameters will obviously give comparatively greater volumes for a given length of waste than a smaller diameter log.

2. Gang 4 was in a stand with a smaller piece size (1.25m³) with trees of very heavy branching habit. A high number of malformed (double leader or basket whorl) heads were observed. This was the reason for the comparatively large volume of solid waste in heads and the large volume of branch material.

3. Gang 7 was working in similar conditions to Gang 6 with a piece size of 1.15m³. The log maker made errors requiring recutting of logs to shorter lengths. This created large sections of waste and a much higher daily volume of mid-stem waste.

4. Gang 10 was in a stand of medium to large piece size Douglas Fir (2.2m³). Large diameters, especially at the butt where several large sections of waste were created in order to remove draw wood, contributed to the high volume of stem waste. The volume of branch waste, both at the skid and on the cutover, was low due to the mature stand having only a small number of live branches in the light crowns of the trees.

Wagner and Wilson, 1976). The daily extracted volumes for each study were derived by multiplying an average extracted piece size (MARVL) for the setting being logged and counting the number of pieces extracted per day.

The waste utilisation system costings were derived using the methods described in Wells (1981) and Goldsack (1988).

RESULTS AND DISCUSSION

A summary of the volumes of stem waste, branch waste and residue on the cutover is presented in Table 2.

Over all studies, the average daily extracted volume was 203m³. The total stem waste volume was 8.3m³ or 4% of the daily extracted volume. Sections of mid-stem waste make up the bulk of this.

Branch waste made up 80% of the bulk volume of the waste heaps, but on average the solid volume of branch waste (9.8m³ or 6% of daily extracted volume) was only slightly more than the volume of stem waste.

There was a large difference in the volume of branch material extracted by ground-based and hauler crews, with hauler crews producing approximately four times as much. As a result of this, there was a marked difference between ground-based and hauler crews in the volume of residue left on the cutover.

Hauler crews also extracted, then wasted, a greater volume of head material.

SIZE AND SHAPE OF MATERIAL

A series of frequency distributions show the percent of pieces that fell into various length and volume classes.

Figure 4 - Frequency distribution (%) of solid wood waste by length for ground- based crews.

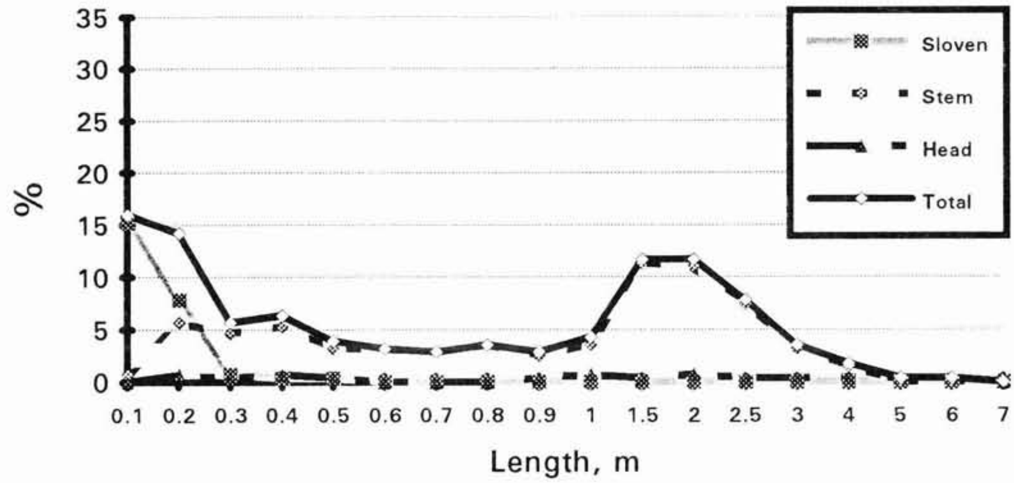
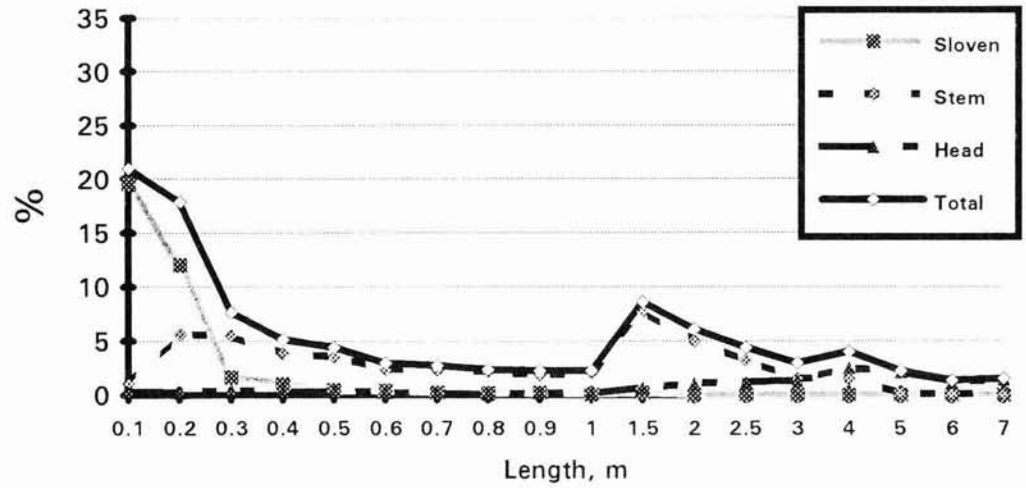


Figure 5 - Frequency distribution (%) of solid wood waste by length for hauler crews.



Both the length distributions follow the same pattern, with a large number of very short pieces and a small number of long pieces. The peak at the 1.5m interval is due to the change in length categories from 0.1m to 0.5m and then to 1.0m intervals. The peak at 1.5m on the ground-based graph (Figure 4) is higher than the one for hauler crews (Figure 5). However, this is misleading. In ground- based systems more slovens and heads are removed before extraction to landings so there is a greater proportion of mid-stem waste but not a greater volume.

Figure 6 - Frequency distribution (%) of solid wood waste by volume for ground based crews

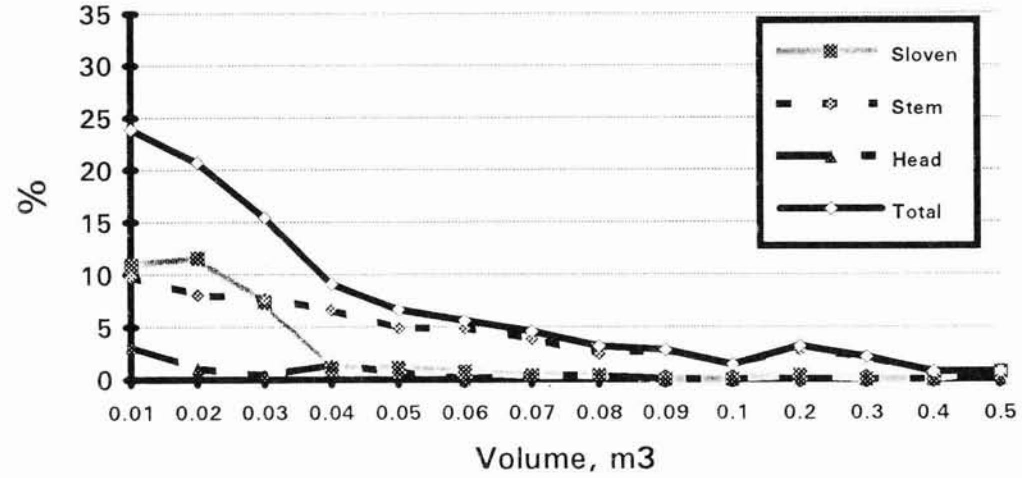
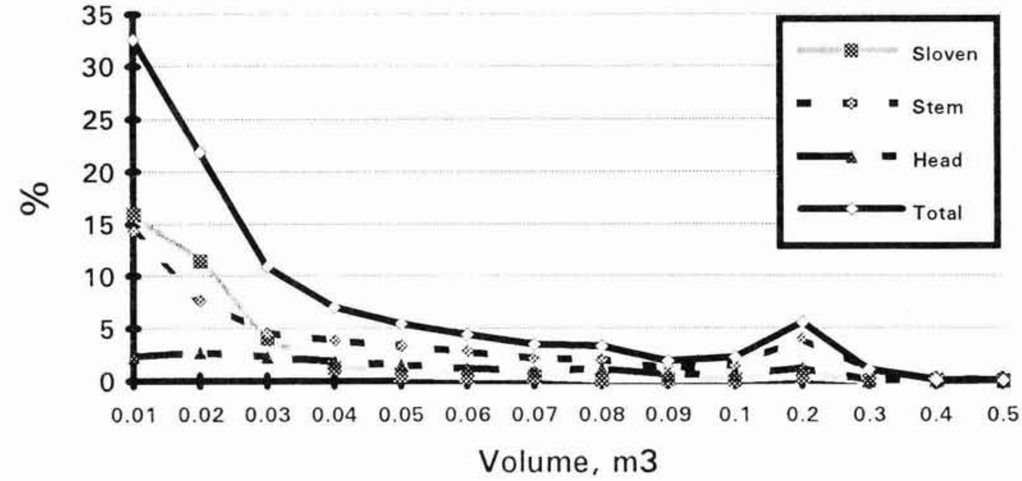


Figure 7 - Frequency distribution (%) of solid wood waste by volume for hauler crews



Figures 6 and 7 have the same distribution pattern and show the bulk of the pieces are less than $0.05m^3$. It is useful to know the volume of wood made up of pieces of certain dimensions as a small number of large pieces can make up a significant amount of the volume. Table 3 shows that 35% of the pieces were greater than 1.0m in length and these contributed 55% of the stem waste volume. Eight percent of the pieces were greater than $0.1m^3$ and made up 25% of the stem waste volume, where the average piece size was only $0.04m^3$. These figures would be important if collection of this material was being considered. The choice of loading and handling machinery and trucking configurations would have to be based on the size and shape of the material being handled.

Table 3 *- Volumes of solid stem waste that are; greater than, (>), 1 m length, > 0.1 m^3, > both 1 m and 0.1 m^3, > 1 m or 0.1 m^3.*

	Average All	Std error	Average GB	Std error	Average Hlr	Std error
Daily Volume,(DV)	**8.3**	1.5	**7.5**	2.7	**8.6**	3.2
% of DV > 1.0 m	**55.7**	6.5	**48.0**	7.4	**59.0**	6.4
% of DV > 0.1 m^3	**24.3**	7.8	**27.0**	9.1	**24.0**	4.9
% of DV > 1.0 m & 0.1 m^3	**28.1**	6.7	**30.9**	12.4	**26.9**	4.3
% of DV > 1.0 m or 0.1 m^3	**59.2**	6.5	**50.7**	7.6	**62.9**	6.2
Pieces per Day, (PD)	**223**	34	**152**	25.9	**255**	34.2
% of PD > 1.0 m	**34.8**	3.7	**32.4**	5.0	**35.8**	3.4
% of PD > 0.1 m^3	**8.7**	2.8	**11.4**	4.9	**7.5**	1.7
% of PD> 1.0 m & 0.1 m^3	**7.8**	2.6	**10.2**	4.6	**6.8**	1.4
% of PD > 1.0 m or 0.1 m^3	**34.8**	4.5	**29.3**	7.3	**37.1**	3.3
Mean piece size of stem waste, m^3.	**0.036**	0.005	**0.040**	0.009	**0.034**	0.004

POSSIBLE UTILISATION SYSTEMS

Part of this project's objective was to produce costings for some of the possible systems for collecting, transporting and utilising this material. At present, there are at least four systems being considered for this in various parts of New Zealand. Two of these plan to utilise just the stem waste to produce wood chips, and two propose to shred all the waste material (stem wood and branch waste) for use as boiler fuel.

An attempt is made to predict the likely costs of three of these systems. As they are all still in the development stage these costs should be considered as indicative only.

System 1

Stockpile all waste material on skid at a cost of $0 (that is, no charge for material or payment to the logging crew as it is currently a problem to the forest owner and is already handled by the logging gang as waste). The stockpile is removed on a regular basis to avoid congestion on the skid.

- Load waste into a truck with Bell Logger or similar
- Truck over a lead distance of 75 km at 18.5 cents per tonne kilometre
- Tip at waste hogger, load into hogger with excavator and grapple

- Hog and use as boiler fuel.

Loading the trucks would be the limiting factor. If it is assumed that the Bell Logger can produce 16 loads of 26 tonnes in eight machine hours, then total production would be 416 tonnes a day.

Costs Per Day

		$
1.	Transport for machine operator	65.00
2.	Loader (Bell)	280.00
3.	Machine operator	215.00
4.	Transport waste wood	5,770.00
5.	In feed to hogger ($1.50 per tonne)	620.00
6.	Hog waste into boiler fuel (2.75 per tonne)	1,150.00
		$8,100.00

Cost per tonne $8,100/416 tonnes = $19.50 tonne.

If the forest owner decides the material has a value and the logging contractor wants to be paid for handling this material then this figure could rise significantly.

If any of these systems are put in place the laws of supply and demand will dictate the future worth of the waste material.

System 2

Stockpile on skid at $0 per tonne as above, all solid wood waste greater than 0.6 m in length:

- Load waste wood out on a regular basis by a Bell Logger or excavator

- Transport over 150 km lead distance at 17.5 cents per tonne kilometre

- Dump and feed into mobile drum debarker

- Feed into mobile chipper

- Chips blown into stockpile at point of sale.

Costs Per Day

		$
1.	Transport for machine operator	65.00
2.	Loader (Bell)	280.00
3.	Machine operator	215.00
4.	Transport waste wood	5,460.00
5.	Drum debark ($3.00 tonne)	1,250.00
6.	Chip ($1.30 tonne)	540.00
7.	Loader for chipper and debarker	280.00
8.	Operators of chipper etc (2 men)	400.00
		$8,490.00

Cost per tonne $8,490/416 tonnes = $20.40 per tonne.

This figure may change dramatically if there is a price attached to the waste wood prior to loading.

System 3

One of the other systems that is currently being considered is the collection of all the stem waste for trucking to an existing facility for chipping along with the current chip log material. The waste wood would be fed in as a mix with the standard chip logs; the longer chip logs would help to feed the short waste sections into the chipper. The waste would not be debarked, but as it is only a proportion of the material going into the chipper and some of the bark is knocked off during handling, the bark content is not expected to be a problem.

A trial of this system produced chip of an acceptable quality with bark content of less than 1%. The costs for this system would be similar to those for System 1.

Table 4 - Regional wood supply and associated waste wood volumes (Thousands of m^3 per annum

	1991 to 1995			1996 to 2000			2001 to 2005			2006 to 2010		
Region	Wood supply	Stem waste	Branch waste	Wood supply	Stem waste	Branch waste	Wood supply	Stem waste	Branch waste	Wood supply	Stem waste	Branch waste
Northland	538	18	22	818	28	34	1606	55	67	2284	78	96
Auckland	696	24	29	1061	36	45	1274	43	53	1314	45	55
Central Nth Island	8380	284	352	8006	272	336	10022	341	421	10109	344	424
East Coast	237	8	10	484	16	20	1238	42	52	1511	51	63
Hawke's Bay	695	24	29	827	28	35	1534	52	64	1474	50	62
Southern Nth Island	492	17	21	628	21	26	1183	40	50	1185	40	50
Total Nth Island	11083	376	465	11824	402	496	16857	573	708	17877	607	751
Nelson - Marlbgh	1203	41	51	1785	61	75	2382	81	100	2438	83	102
Canterbury	370	13	16	509	17	21	691	23	29	738	25	31
West Coast	126	4	5	269	9	11	374	13	16	376	13	16
Otago - Southland	924	31	39	1318	45	55	1812	62	76	1869	63	78
Total Sth Island	2623	89	110	3881	132	163	5259	179	221	5422	184	228
Total NZ.	13661	465	574	15705	534	660	22116	752	929	23299	792	979

An example (Ewart, 1993) is a wood and coal fired boiler where the two fuels are mixed and fed in at a ratio of 4:1 wood to coal. The addition of the coal raises the boiler fire temperature and reduces the degree to which the wood fuel needs to be dried before burning. A system capable of powering a 50 mW boiler with a 12 mW electricity generator attached (24% of the boiler capacity) would use around 400 tonnes a day of wood waste and 100 tonnes a day of coal, 16.7 and 4.2 tonnes per hour respectively. A plant of this size would require approx 146,000 tonnes of wood fuel per annum.

Systems such as this and smaller versions would have potential to reduce logging residue and mill residue disposal problems if they were attached to a large wood processing facility. Several co-generation systems exist within the New Zealand wood processing industry and more are being planned. These are a potential market for waste wood from logging operations.

*Table 5 - Nutrient removals (**kg per ha**) from extracted branch material*

	N Nitrogen	P Phosphorous	K Potassium	Ca Calcium	Mg Magnesium
Hauler	112	32	99	64	18
Ground based	26	7	23	15	4

**Note : Nutrients from stem wood removal are not included*

NUTRIENT REMOVAL

A further aspect to the issue of waste wood, especially branch waste, and what to do with it is the removal of nutrients from the site. The following is an estimate of the impact of both ground-based and cable logging operations on nutrient removal from the cutover in the form of branch and needle material.

There is a substantial difference in the effects of the two different systems as ground-based systems usually delimb at the stump and hauler systems do not.

One tonne of branch material, which would have a bulk volume of approximately 5.5m³, would contain levels of nutrients similar to the following (Webber and Madgwick, 1983):

N	=	4.15 kg
P	=	1.18 kg
K	=	3.68 kg
Ca	=	2.37 kg
Mg	=	0.68 kg

If a stand has a stocking of 270 stems per hectare, piece size of 2.7m³ and produces a similar volume of branch material per tree at the skid as was found in these studies, the volume of branch material removed would be 27 tonnes per ha for cable logging and six tonnes per ha for ground based logging. The amount of nutrients these volumes represent is shown in Table 5.

Hauler logging in this scenario is removing over four times the amount of nutrients from the cutover than ground based logging.

For hauler operations the N removal due to delimbing at the landing is about 25% of the above ground N from each tree and 6.5% of the total N in above and below ground components. The inclusion of the removal of the stem raises the total loss of N in above and below ground components, due to hauler logging, to approximately 14%. However, removal of total N does not give a complete picture as not all of the total N on a site is available to the tree. The removal of a small amount of total N (14%) translates into an even smaller loss of available N. Whether this level of nutrient loss is going to affect the growth of the next rotation has not been determined. Growth trial results vary, with some suggesting that it may not be significant (Smith, 1994), whilst others suggest that in the longer term retention of slash on the cutover gives significant growth gains (Balneaves, 1989). It is likely that the effects will vary from site to site depending on the fertility of the soil.

CONCLUSIONS

Volume of Waste Material

The size of the whole waste wood resource is small and is widely scattered with few large concentrations. The likely volumes of waste wood being produced are:

Ground-based, stem waste - 2.5% of extracted volume

Ground-based, branch waste - 1.8% of extracted volume

Hauler, stem waste - 4.7% of extracted volume

Hauler, branch waste - 7.9% of extracted volume

Make Up of Material

The stem waste material produced each day is made up of hundreds of small pieces. Typically, for ground-based operations 152 pieces per day and 255 pieces per day for haulers.

The average piece size of the stem waste over all the studies was $0.036m^3$, $0.04m^3$ for ground-based and $0.034m^3$ for haulers.

Most of the bulk volume of the waste heaps (80%) is made up of branch material. Some of this material could be used as boiler fuel.

Fifty-five percent by volume of the stem waste is made up of pieces that are over one metre in length (35% of the total number of pieces). This is the material most likely to be used as a chip wood resource.

Site Impact

The difference between delimbing at the landing rather than at the stump on nutrient removal is large.

Costs

It appears to be physically and economically possible to recover some, or all, of the stem waste from landings for chipping.

If the material can be stockpiled into volumes which are sufficiently large to be worth collecting, the material could be transported to a central site and processed by chipping or hogging at a cost of $20 to $21 tonne.

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

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