Advantage
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Improving fibre recovery by sorting undersized stems from sawlogs at the stump

Abstract

In the southern interior of British Columbia, the Forest Engineering Research Institute of Canada (FERIC) carried out a study to determine the costs and productivities of producing sawlogs and pulp logs from undersized stems. The small logs were recovered by either roadside or cut-to-length harvesting.

Keywords

Harvesting systems, Roadside harvesting, Cut-to-length harvesting, Undersized stems, Utilization, Wood chips, Chip quality, Satellite chipping, Productivity, Costs, British Columbia.

Contents

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Introduction

In western Canada, finding ways to increase fibre recovery is becoming a priority to the forest industry due to reductions in allowable annual cut and increases in harvesting costs. Utilizing undersized stems that would normally be considered waste is one option for increasing fibre recovery. While current utilization standards in British Columbia do not require forest companies to recover stems with a diameter at breast height (dbh) of less than 12.5 cm for lodgepole pine and less than 17.5 cm for other species, these stems often represent a significant percentage of the total stand volume, especially when harvesting problem forest types (e.g., stagnated overmature stands, mature overstocked stands). Feller-bunchers often push aside the undersized stems while felling and bunching the merchantable sawlog trees.

Although the technology exists to debark and process undersized stems (Araki 1999), the cost of harvesting and hauling this material is usually prohibitive (Andersson 1992). However, a FERIC study showed that processing and sorting logs at the stump reduced skidding and loading costs (Araki 1994). In this study, FERIC and the Kelowna Division of Riverside Forest Products Limited investigated the costs of handling and utilizing undersized stems using roadside harvesting equipment and a satellite chipping operation.

Objectives

The objectives of the study were to:

- Compare the volume of fibre (including undersized stems) that can be recovered from stands harvested by conventional roadside equipment to the volume harvested by cut-to-length equipment.
- Determine the cost of producing sawlogs and pulpwood using five different harvesting treatments.
- Examine the feasibility of producing pulp chips from the pulpwood at a satellite chipping facility.

Site and stand descriptions

The study took place in the southern interior of British Columbia, near Peachland (50 km southwest of Kelowna) in the Montane Spruce biogeoclimatic subzone. Two forest types were present: Forest Type 1 consisted of primarily mature lodgepole pine on dry sites, and Forest Type 2 consisted of mature lodgepole pine with white spruce and subalpine fir on wet sites. The study block had a southeast aspect and the terrain was flat to rolling. The block was 31 ha in area, 1.2 km in length, and 500 m across at the widest point. A pre-existing access road along the southern boundary was upgraded to a main road. Approximately 1 km of a temporary ring-shaped road was constructed through the middle of the block to reduce the skidding distances.

Table 1. Forest types: summary by treatment area

Treatment area	Forest Type 1 [a] (ha)	Forest Type 2 [b] (ha)	Total (ha)
Two Pass	5.1	1.0	6.1
Fall and Sort	4.2	3.3	7.5
Conventional	5.5	2.3	7.8
Sort at Roadside	5.4	2.9	8.3 [c]
Process at Stump	1.5	0.0	1.5 [c]
Total	21.7	9.5	31.2

[a] Primarily mature lodgepole pine on dry sites.
[b] Mature lodgepole pine with white spruce and subalpine fir on wet sites.
[c] Originally, the Process at Stump treatment area was >3 ha but was reduced to 1.5 ha during the study. The processor operators felt they were experiencing low productivity, and the skidder operators wanted neither to wait for the processing to be completed nor to come back to the cutblock after the processing was completed. As a compromise, unsorted bunches were skidded to roadside, and the area and volume were added to the Sort at Roadside treatment area.

Treatment area descriptions

The harvesting site was divided into five treatment areas (Figure 1), each of which included both forest types (Table 1). The treatment areas were harvested using either conventional roadside or cut-to-length harvesting systems. The conventional equipment included two Prentice 630A feller-bunchers, two John Deere 748G grapple skidders, three Lim-mit 2000B processors mounted on Linkbelt 3400 excavators, and a Linkbelt 4300 butt-n-top loader. The cut-to-length equipment included a Timberjack 1270 harvester and a Rottne RK60 forwarder. For cruise volumes on all treatment areas, sawlogs were compiled at close utilization standards, while undersized material was compiled at super utilization standards.[1]

[1] Close utilization: trees with a minimum 12.5-cm dbh (15-cm butt diameter) to 10-cm top for lodgepole pine, and a minimum 17.5-cm dbh (20-cm butt diameter) to 10-cm top for all other species. Super utilization: trees with a minimum 8-cm dbh (10-cm butt diameter) to 5-cm top for all species, and less than 12.5-cm or 17.5-cm dbh to 5-cm top depending on species.

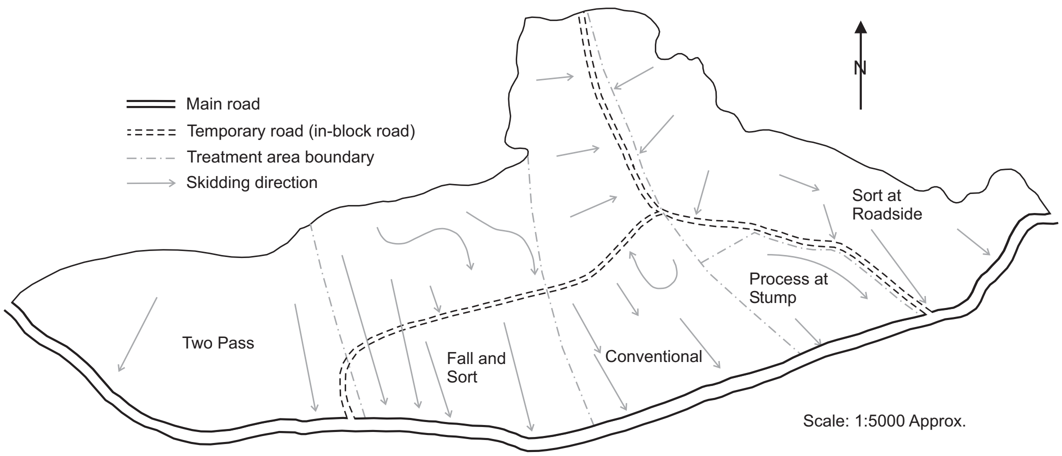

Figure 1. Study block with treatment areas identified.

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Two Pass

The first treatment area to be harvested employed a two-pass harvesting system that used both the conventional tree-length (TL) roadside and cut-to-length (CTL) equipment. The cut-to-length equipment was used to pre-harvest all of the pulpwood, and then the tree-length equipment was used to harvest the sawlog stems.

As the harvester cut the extraction trails through the treatment area, it reached into the stand to fell both undersized and larger pulp-grade stems, e.g., snags or trees of very poor form (Figure 2). The harvester processed the stems into lengths up to 5 m and sorted them into sawlog and pulpwood bunches along the trail. The minimum top diameter of the pulpwood was 5 cm. The remaining tops and branches were left on the site. The forwarder picked up the sorted bunches of logs and placed them into separate decks at roadside. The logs were loaded onto self-loading trucks which transported the sawlogs to the sawmill in Kelowna and delivered the pulpwood to Riverside's satellite chipping operation.

After the pre-harvesting phase, a feller-buncher felled and bunched the remaining stems, a grapple skidder moved these bunches to roadside, and one of the stroke delimbers processed the stems. The log processors manufactured random-length sawlogs to a minimum 10-cm top and a maximum 20-m length for highway hauling. During processing, all sawlog tops were left as waste, and no additional material was identified as pulpwood.

Fall and Sort

In this treatment area, a feller-buncher cut and bunched full-tree undersized stems and stems that were clearly pulpwood. Sawlog stems were cut and bunched separately (Figure 3). The sorted bunches were skidded to roadside and decked separately. The sawlogs were processed at roadside. For the undersized stems, the processor delimbed multiple stems, bucked them into lengths up to 8 m, and placed these pulpwood logs on the opposite side of the road from the sawlogs. The sawlogs were hauled to the sawmill in Kelowna on 7-axle logging trucks. The original plan was that all of the pulpwood would be delivered to the satellite chipping operation, but the chipping operation did not operate in 2002 due to poor chip market conditions. Therefore, some of these pulpwood logs were hauled by self-loading trucks to the sawmill for manufacture into lumber.

Figure 2. Harvester cutting access trails and harvesting small-diameter stems.

Figure 3. Sawlog and small-diameter stems sorted at the stump by the feller-buncher.

Conventional

In this treatment, conventional roadside harvesting and processing of sawlogs for highway hauling were done, and no stems less than the close utilization standard were harvested. Any pulpwood generated during processing was set aside and left for the waste bin trucks to transport to the satellite chipping operation. Some pulpwood stems were processed and upgraded into short sawlogs. During loading, these logs were placed in the middle of a truckload of sawlogs and hauled to the sawmill.

Sort at Roadside

In this treatment, the feller-buncher cut and bunched all the undersized stems concurrently with the close utilization stems. The bunches of mixed stems were skidded to roadside where sawlogs were manufactured and decked. The undersized and pulpwood stems were processed and placed on the opposite side of the road or in the roadside ditch. A butt-n-top loader then loaded the sawlogs onto 7-axle logging trucks which transported them to the sawmill in Kelowna. Some pulpwood logs were upgraded to sawlogs and hauled to the sawmill on self-loading trucks.

Process at Stump

The feller-buncher cut and bunched all the undersized stems concurrently with the close utilization stems. The log processor went into the treatment area, processed the log bunches at the stump, and sorted the sawlogs and pulpwood into separate bunches (Figure 4). The bunches were skidded to roadside and decked separately. The butt-n-top loader then loaded the sawlogs onto logging trucks while the pulpwood was left at roadside for removal by the self-loading trucks.

The pulpwood and harvesting residue that had accumulated at roadside in the treatment areas were to be loaded into bin or hayrack trucks and hauled to the satellite yard and chipped. However, due to a depressed pulp market at the time, much of the pulpwood was pushed away from the roadside into waste piles and not recovered.

Figure 4. Stroke delimber processing sawlogs and pulpwood at the stump.

Study methods

Shift-level study

FERIC researchers were present on the study block during all of the harvesting phases to record shift-level data for most of the equipment. However, shift-level studies of the feller-bunchers were conducted using Servis recorders because the feller-bunchers were difficult to monitor full-time.

One of the Prentice feller-bunchers worked only in the Sort at Roadside and Process at Stump treatment areas, where all the sawlog and pulpwood stems were placed in bunches. The second feller-buncher worked entirely in the Two Pass, Fall and Sort, and Conventional treatment areas. During the felling of each of the treatment areas, FERIC interviewed the feller-buncher operators to get their opinions on the changes in operating procedures.

The conventional roadside harvesting equipment was scheduled to work a 12-hour shift even though each operator was paid on a production basis. The skidders shut down for 30 minutes each day for refueling and servicing but the operators did not stop for any lunch or coffee breaks during the scheduled 12-hour shift. On the other hand, the operators of the log processors took lunch breaks in addition to any time required for daily servicing and refueling. The break, servicing, and refueling time amounted to one hour per shift.

No shift-level studies were done in the loading phase. The loader operator indicated that the butt-n-top loader was in the study block for 10 days and worked a 10-hour shift. Eight 7-axle logging trucks hauled a minimum of 20 loads per day from the study block. The cut-to-length logs in the Two Pass treatment area and some of the short logs generated in the Fall and Sort and Sort at Roadside treatment areas were loaded onto self-loading trucks and hauled to the sawmill or satellite yard.

Detailed-timing study

Detailed timing was performed for 8 hours on the harvester and 27 hours on the forwarder. A cycle for the harvester included positioning the harvester head around a tree, and felling and processing the tree into short logs. A cycle for the forwarder included travelling into the block, accumulating a load, returning, and decking the load at roadside.

During detailed timing of the felling and log-processing phases, FERIC focused attention on the undersized stems and the problems they created during the harvesting phases. FERIC used a machine costing spreadsheet model with the equipment productivity data from each of the treatment areas to determine the cost of producing fibre. Detailed timing was not performed for the skidding phase.

Detailed-timing data for the loading phase were not obtained in all of the treatment areas. Timing started when the loader removed the trailer from the back bunk of the truck and stopped when the driver moved the truck away from the loader to secure the load. No detailed timing of other activities between truck loads was done. While waiting for trucks to return, the loader operator continued to sort the logs in the decks in preparation for further loading.

Calculation of gross and net log volumes

The 0.01-ha fixed-area cruise plots that had been established within the block during harvest planning were relocated. All the stems greater than 8 cm dbh were measured and tallied to estimate the total standing volume. FERIC also established additional fixed-area plots to ensure adequate sampling of stand types. Thirty-two fixed-area plots were of Forest Type 1, and ten fixed-area plots were of Forest Type 2.

Table 2 summarizes the estimated gross volumes of sawlogs and pulp logs for each treatment area, based on Table 1 and Appendix I. The additional volume available from the tops of sawlogs was also estimated and included.

Calculation of volumes harvested

The production volumes were estimated by multiplying the weights of the loads removed from each treatment area by the weight ratios (in m^3/kg) for each load type, based on the weigh scale log stratum and scaling summaries provided by Riverside. The cut-to-length sawlogs were weighed at the sawmill and the pulpwood was weighed at the satellite chipping yard. A load of cut-to-length sawlogs was scaled by a government scaler to determine the weight-to-volume conversion factor. To determine the volumes for pulpwood logs, FERIC personnel scaled one sample load at the satellite yard to develop a weight-to-volume conversion factor. The cut-to-length sawlogs were counted by butt-diameter class during loading, and pulpwood was counted by butt-diameter class after delivery to the satellite yard. The log counts

Table 2. Estimated sawlog and pulpwood volumes: summary by treatment area

Treatment area	Sawlog volume		Pulpwood volume		Total volume	
	Gross (m^3)	Net[a] (m^3)	Gross (m^3)	Net[b] (m^3)	Gross (m^3)	Net (m^3)
Two Pass	2 537	2 309	584	514	3 121	2 823
Fall and Sort	3 169	2 897	689	609	3 858	3 506
Conventional	3 269	2 982	732	646	4 001	3 628
Sort at Roadside	3 489	3 185	773	682	4 262	3 867
Process at Stump	618	561	147	129	765	690

[a] Compiled to close utilization standard of 12.5-cm dbh (15-cm butt diameter) to 10-cm top for lodgepole pine, and 17.5-cm dbh (20-cm butt diameter) to 10-cm top for all other species.

[b] Compiled to super utilization standard of 8-cm dbh (10-cm butt diameter) to 5-cm top for all species, and less than 12.5-cm dbh or 17.5-cm dbh to 5-cm top depending upon species.

were multiplied by the average volume of the logs in each butt-diameter class to estimate the volumes of sawlogs and pulpwood that were produced.

Residue surveys

After all the merchantable logs were removed from the harvesting site, residue surveys using the line intercept method were done (Sutherland 1986). To determine the volume of pulpwood left at roadside, a FERIC researcher and a Riverside residue survey contractor walked along the road sections adjacent to each of the treatment areas and counted the number of stems between 10 and 15 cm in butt diameter. The tops that had been bucked from sawlogs were excluded from the count. Butts of pulpwood in the Fall and Sort and Process at Stump treatment areas were easily identifiable. For the Conventional and Sort at Roadside treatment areas, the residue survey contractor added 15% to the total stems counted for missed stems, because the undersized stems were easily hidden within the slash piles and could not be counted accurately.

Results

Shift-level study

Table 3 summarizes the results of the shift-level studies of the harvesting equipment. The harvester was seven years old and required frequent repairs to keep it operating, so it had poor machine availability (78%) and utilization (57%). The contractor has since purchased a new harvester. The forwarder had machine availability and utilization of 93% and 82%, respectively. The feller-bunchers and grapple skidders had machine availabilities of 95% and 94%, respectively, and machine utilizations of 91% and 94%, respectively. The study was conducted shortly after summer startup so all of the equipment had just been thoroughly serviced. The grapple skidders did not experience any breakdowns but the feller-bunchers and log processors had minor breakdowns for hydraulic hose replacement. The average machine availability and utilization for the three log processors were 90% and 86%, respectively.

Table 4 shows the productive machine hours (PMH) the conventional roadside harvesting equipment spent in each treatment area. Felling and bunching were easiest in the Two Pass treatment area because all of the undersized trees were gone and visibility was excellent, unlike the other areas where the undersized trees and brush impeded visibility. Grapple skidding in this area was also quite productive because only large bunches of sawlogs were left to skid.

Detailed-timing study

Two Pass harvest by harvester and forwarder (CTL)

The harvester and forwarder were used only to cut trails and to pre-harvest the undersized material in the Two Pass CTL

Table 3. Shift-level time distribution

Elements	Timberjack 1270 harvester	Rottne RK60 forwarder	Prentice 630A feller-bunchers (2)	John Deere 748G skidders (2)	Lim-mit 2000B processors (3)
Shifts with production (no.)	26	9	21	14	30
Productive machine hours (h)	112.3	88.5	199.0	118.5	280.5
Mechanical delays (h)	40.3	4.7	1.5	0.0	19.5
Service (h)	2.3	2.5	10.1	7.0	13.5
Non-mechanical delays (h)	43.1	12.3	7.4	0.0	13.0
Scheduled hours (h)	198.0	108.0	218.0	125.5	326.5
Machine availability (%)	78	93	95	94	90
Machine utilization (%)	57	82	91	94	86

Table 4. Shift-level productive machine hours, by treatment area

Phase	Treatment area: Two Pass (PMH)	Fall and Sort (PMH)	Conventional (PMH)	Sort at Roadside (PMH)	Process at Stump (PMH)	Total (PMH)
Harvester	112.3	-	-	-	-	112.3
Forwarder	88.5	-	-	-	-	88.5
Fall and bunch	24.0	47.5	60.0	57.0	10.5	199.0
Grapple skid	15.5	41.0	33.5	24.5	4.0	118.5
Process	23.5	52.5	89.5	90.0	25.0	280.5

Table 5. Detailed-timing summary: harvester and forwarder

Machine	Total time (PMH)	Cycles (no.)	Total trees (no.)	Average vol/tree (m^3) [a]	Estimated volume (m^3)	Average cycle time (min)	Productivity (no. trees/PMH)	Productivity (m^3/PMH)
Harvester	8.0	881	917	0.12	110	0.54	115	13.8
Forwarder	27.0	30	5725 [b]	0.07	376	54.0	212 [a]	13.9

[a] Average volume per tree was estimated from the stump count by diameter of trees removed by the harvester in 4 pre-marked and measured 0.125-ha plots. Average volume per log for the forwarder was estimated from the average of the scaled and counted logs at roadside.
[b] This total represents number of logs and not trees.

Table 6. Detailed-timing summary: feller-bunchers

Treatment area	Total time (PMH)	Cycles (no.)	Total trees (no.)	Average vol/tree (m^3) [a]	Estimated volume (m^3)	Average cycle time (min)	Productivity (no. trees/PMH)	Productivity (m^3/PMH)
Two Pass TL	6.1	526	1567	0.45	697	0.70	257	114.3
Fall and Sort	7.3	536	1903	0.30	577	0.82	261	79.0
Conventional	11.3	801	2539	0.38	975	0.85	225	86.3
Sort at Roadside & Process at Stump	4.4	516	1452	0.32	462	0.51	330	105.0

[a] Average volume per tree estimated by measuring the butt diameters in the bunches created by the feller-buncher.

treatment area. Table 5 summarizes the detailed-timing results for these machines. The detailed-timing studies show the productivity of the harvester and forwarder were well matched (13.8 and 13.9 m^3/h, respectively) unlike in the shift-level study where the forwarder was 27% more productive than the harvester.

Felling

Table 6 summarizes the detailed timing of the two feller-bunchers.

Feller-buncher production was highest in the Two Pass TL treatment area because of the large average tree size (0.45 m^3). The operator liked felling in this treatment area because all of the undersized trees had been pre-harvested, so no brushing was required and access trails were already established. However, the operator commented that the harvester did not cut low stumps and this restricted movement of the feller-buncher.

Productivity was lowest in the Fall and Sort treatment area because cutting, sorting, and bunching undersized stems are relatively time consuming, and because small stems have a fraction of the volume of merchantable stems. Very small stems accidentally pushed over by the feller-buncher operator were left where they fell, i.e., not all of the undersized stems were placed in the bunch of pulpwood stems. Even though one of the objectives of this study was to recover all of the pulwood, some stems were pushed over during felling and not recovered (Table 7). The operator built bunches of pulpwood stems by moving the feller-buncher back and forth from the falling edge to the bunches. This procedure reduced the machine's productivity, but the operator commented that he enjoyed the change in felling procedure because he had to develop a strategy to cut sawlogs and pulpwood separately.

The feller-buncher operator in the Sort at Roadside and Process at Stump treatment areas liked that all the trees that he cut were destined for the same bunch. Under normal conditions, the operator had to decide whether to cut and utilize undersized trees, or to push them aside. The operator felt cutting them was often easier and quicker.

Most of the undersized stems in the Conventional treatment area were pushed aside as the feller-buncher head was positioned near a merchantable tree. In the Sort at Roadside and Process at Stump treatment areas, the feller-buncher operator still attempted to knock down stems less than 10 cm in butt diameter, but some nevertheless became part of the bunches.

Skidding

Detailed-timing data were not gathered for the skidding phase because the skidding operation was not conducted efficiently. The skidder operators began work before felling was completed. Therefore, they moved around the treatment areas as the trees were being felled, and often had to skid bunches to inappropriate locations. They also turned bunches around to skid them to the different locations. Nevertheless, the skidders were very productive in all of the treatment areas because the average skidding distances were <100 m and the proposed in-block road provided a lot of decking area.[2] The skidding distances in the Two Pass TL treatment area were slightly longer than in the other treatment areas because all of the bunches were skidded to the main road even though some could have been decked on the in-block road. Similarly, in the Fall and Sort treatment area, the bunches at the west end of the treatment area were skidded to the main road instead of to the in-block road.

Processing

Initially, FERIC attempted to minimize the differences in productivity associated with operator skill by trying to schedule the processor operators to work equally in all five of the treatment areas. However, the operators were paid according to production and production was difficult to track as the operators were moved from one treatment area to another. Therefore, FERIC readjusted the schedules so that the operators worked in specific treatment areas.

2 The in-block road was constructed after the skidding and log processing phases were completed to facilitate hauling.

Table 7. Stems pushed over during felling: summary [a]

Treatment area	Cycles (no.)	Stems meeting the pulp utilization standard (no.)	Stems pushed over (no.)	Average pulp stems/cycle (no.)	Average pushed over stems/cycle (no.)
Two Pass TL	84	0	0	0.0	0.0
Fall and Sort	32	115	98	3.6	3.1
Conventional	372	313	1511	0.8	4.1
Sort at Roadside & Process at Stump	699	994	933	1.4	1.3

a During felling, FERIC observed the feller-bunchers and attempted to count the number of pulpwood pieces that ended up being pushed over based on the butt-diameter class. While counting the stems was easy, categorizing them by butt-diameter class was difficult because these observations were made visually from a distance (for safety reasons).

Two processor operators, who produced approximately 500 m^3/day,[3] worked in the Fall and Sort, Conventional, Sort at Roadside, and Process at Stump treatment areas. A third processor operator, who produced 400 m^3/day, worked in the Fall and Sort and Conventional treatment areas only.[4] One of the high-producing operators delimbed all of the stems in the Two Pass TL area.

Compared to the other treatment areas, productivity was high in the Two Pass TL treatment area because stems were large and similar in size, with few undersized stems and little debris (Table 8). The lowest processor productivity occurred in the Process at Stump treatment area because the machines had to frequently move and position themselves near the bunches in the block. The unsorted undersized stems in the roadside bunches in the Sort at Roadside treatment area slowed log processing because it was difficult to pick up and free the tops of the small stems from the decks, and to move them aside without breaking them. Also, in this treatment area the operators had to move much more debris away from roadside to create decking areas for the processed logs. In the Conventional treatment area, where the average cycle time was 0.40 minutes, the operators handled the pulpwood and sawlogs similarly, processed them into short logs, and placed them on top of the sawlog deck. The average cycle time in the Two Pass TL treatment area was slightly higher at 0.48 min because all of the stems had to be measured and bucked to a predetermined log length suitable for highway hauling.

Loading

A total of 198 truckloads of logs were loaded and hauled in a 10-day period by 8 logging trucks in the Conventional, Sort at Roadside, and Process at Stump treatment areas. Of these, 30 truckloads were detail-timed (Table 9). The detailed-timing results confirmed the contractor's belief that the loading phase was not affected by changes in the harvesting procedures. The average loading time was lowest in the Sort at Roadside treatment area (18.4 min compared to 19.5 and 20.8 min for Process at Stump and

[3] From discussion with the processor operators.

[4] Discussions with the contractor and Riverside personnel indicated the different productivity rates of the processor operators.

Table 8. Detailed-timing summary: processing

Treatment area	Total time (PMH)	Cycles (no.)	Total trees (no.)	Estimated volume (m^3)	Average cycle time (min)	Productivity	
						(no. trees/PMH)	(m^3/PMH)
Two Pass TL	5.4	670	981	437	0.48	182	80.9
Fall and Sort	16.1	2 194	3 464	1 049	0.44	215	65.2
Conventional	4.7	701	832	321	0.40	177	68.3
Sort at Roadside	4.1	469	616	196	0.52	150	47.8
Process at Stump	7.8	915	1244	342	0.51	159	43.8

Table 9. Detailed-timing summary: loading

Treatment area	Prepare truck (min/load)	Load (min/load)	Strapping load (min/load)	Travel to strapping area (min/load)	Total loading time (min/load)	Total logs (no./load)	Average volume [a] (m^3/load)
Conventional	3.9	20.8	10.3	1.2	36.2	165	48.2
Sort at Roadside	4.1	18.4	7.5	1.3	31.3	170	48.1
Process at Stump	4.6	19.5	9.2	1.5	34.8	161	48.3

[a] Load average obtained from weigh scale summaries.

Table 10. Volumes harvested by treatment area: summary

Description	Volume harvested (m^3)				
	Two Pass	Fall and Sort	Conventional	Sort at Roadside	Process at Stump
CTL sawlogs	622	-	-	-	-
Sawlogs	1 450	2 230	2 218	3 272	579
CTL pulpwood hauled	379	-	-	-	-
Pulpwood hauled	-	182	-	110	
Pulpwood left at roadside	-	135	27	195	39
Total	2 451	2 547	2 245	3 577	618

Conventional, respectively). However, the contractor commented that logs from the Two Pass treatment area were the easiest and quickest to load because the tree-length logs were similar in size and length, with few random short sawlogs present in the decks.

Although the pulp logs in the Conventional, Sort at Roadside, and Process at Stump treatment areas were actually hauled to the sawmill, they should have been hauled to the satellite chipping facility. The cycle time from the harvest site to either facility was equal even though the satellite yard was 10 km further away. The trucks had to go across the bridge and through Kelowna at a very slow speed as compared to driving to the Bear Creek yard on the west side of Okanagan Lake.

Harvesting summary

Table 10 summarizes the estimated volumes that were harvested and hauled, and that could have been hauled from each treatment area. Although the majority of the pulpwood was not utilized as originally planned, it was included in the harvest volume. The pulpwood volumes left at roadside as estimated by the residue surveys were included in the volumes harvested for each treatment area.

From the sample load scaling, the sawlogs that were produced from pulpwood stems taken from the Fall and Sort and Sort at Roadside treatment areas averaged 7 m in length, 12 cm in butt diameter, and 10 cm in top diameter. They also had an average volume of 0.08 m^3/log . The pulpwood from the cut-to-length operation that was sample scaled indicated that the piece size averaged 0.04 m^3/log.

Table 11. Estimate of residue in the treatment areas

Treatment area	Estimated volume of residue (m^3/ha)	Estimated volume of residue (m^3)
Two Pass TL	24.4	149
Fall and Sort	41.5	311
Conventional	51.2	399
Sort at Roadside	37.1	308
Process at Stump	70.0	105

Recovery of pulpwood and residues

Because the satellite chipping facility did not operate in 2002, the amount of pulpwood and residue varied between treatment areas (Tables 10 and 11). All of the pulpwood in the Two Pass treatment area was processed and hauled while most of the pulpwood in the Fall and Sort and Process at Stump treatment areas was processed but not hauled. In the Conventional treatment area, the pulpwood was not skidded to roadside. The majority of the pulpwood in the Sort at Roadside treatment area was not processed even though it was skidded to roadside. Instead, it was pushed back from the roadside and left in the residue piles.

Table 12 compares the cruise volume to the volume that was hauled to the sawmill and/or left at roadside. Fibre recovery was lowest (62%) in the Conventional treatment area. The fibre recovery for the Process at Roadside treatment area was the highest

(93%). Depending on the harvesting treatment, there was an increase in fibre recovery ranging between 11% (73% minus 62%) and 31% (93% minus 62%) from conventional harvesting. When the majority of stems were placed in the bunches by the feller buncher, there was a higher probability that the processor would try to make a merchantable log from the marginal stems. Therefore, the Sort at Roadside and Process at Stump treatments had the highest fibre utilization in this case study.

Table 12. Comparison of cruise volume and estimate of utilized volume

Treatment area	Net cruise volume (m^3)	Utilized volume (m^3)	Utilized volume (%)
Two Pass	2 823	2 451	87
Fall and Sort	3 506	2 547	73
Conventional	3 628	2 245	62
Sort at Roadside	3 867	3 577	93
Process at Stump	690	618	90
Total	14 514	11 438	79

Costs

The volumes in Tables 13 to 16 include the estimated pulpwood (see Table 10) that was left at roadside in each treatment area. These numbers assume that it was all processed and that it would be hauled to the sawmill or satellite chipping plant. The cost per cubic metre for each harvesting phase in each treatment area was determined by multiplying the hours required for the task (based on the shift-level machine productivity) by the hourly equipment rate (Appendix II).

Table 13. Estimated cost to fall and bunch the treatment areas

	Total harvested volume [a] (m^3)	Time (PMH)	Productivity (m^3/PMH)	Cost (\$/m^3)
Two Pass CTL [b]	1001	112.3	8.9	34.10
Two Pass TL [c]	1450	24.0	60.4	3.10
Fall and Sort [c]	2547	47.5	53.6	3.51
Conventional [c]	2245	60.0	37.4	5.00
Sort at Roadside & Process at Stump [c]	4195	67.5	62.1	3.00

[a] Harvested volume includes the pulpwood left at roadside.
[b] Timberjack 1270 harvester @ \$303.77/PMH.
[c] Prentice 630 feller-buncher @ \$188.32/PMH.

Table 14. Skidding and forwarding cost summary by treatment area

Treatment area	Volume skidded [a] (m^3)	Time (PMH)	Productivity (m^3/PMH)	Cost (\$/m^3)
Two Pass CTL [b]	1001	88.5	11.3	12.40
Two Pass TL [c]	1450	15.5	93.5	1.10
Fall and Sort [c]	2547	41.0	62.1	1.70
Conventional [c]	2245	33.5	67.0	1.60
Sort at Roadside [c]	3577	24.5	146.0	0.70
Process at Stump [c]	618	4.0	154.5	0.70

[a] Harvested volume includes the pulpwood left at roadside.
[b] Rottne RK60 forwarder @ \$139.66/PMH.
[c] John Deere 748G grapple skidder @ \$106.32/PMH.

The felling cost was lowest in the Sort at Roadside, Process at Stump, Two Pass TL, and Fall and Sort treatment areas (Table 13). The felling cost in the Conventional treatment area was the highest (excluding the cut-to-length harvesting) because the undersized material was pushed aside. The operator spent time clearing pathways to the merchantable trees and none of the undersized material was placed in the bunches.

The grapple skidding cost was lowest in the Sort at Roadside and Process at Stump treatment areas because the skidding distance was the shortest in these two treatment areas (Table 14). The delimbed bunches were also easier to skid in the Process at Stump treatment area. In the Fall and Sort treatment area, the skidding distances were the longest and the cost was the highest, because some of the bunches were skidded to the main road instead of the in-block road.

However, the costs to forward cut-to-length logs from the Two Pass CTL treatment area were the highest of all extraction methods. These costs were high because the forwarder productivity was low and the estimated hourly cost to operate it was high.

In the Conventional treatment area, the processing productivity was lower and the cost was higher than for the other treatments where stems were processed at roadside because the majority of the Conventional treatment area was processed by the slowest operator (Table 15). In the Sort at Roadside treatment area, the processor operators were reluctant to continue processing and sorting the undersized stems in the deck because they were getting paid by volume, and this work

Table 15. Processing cost summary by treatment area

Treatment area	Harvested volume [a, b] (m^3)	Time (PMH)	Productivity (m^3/PMH)	Cost (\$/m^3)
Two Pass TL [b]	1450	23.5	61.7	2.80
Fall and Sort	2547	52.5	48.5	3.60
Conventional	2245	89.5	25.1	7.00
Sort at Roadside	3577	95.2 [c]	37.6	4.70
Process at Stump	618	25.0	24.7	7.10

[a] Harvested volume includes the pulpwood left at roadside.
[b] Lim-mit 2000 processor @ \$175.51/PMH.
[c] Assumes pulpwood stems left at roadside would be processed.

Table 16. Estimated delivered wood cost by treatment area

Treatment area	Felling cost (\$/m^3)	Skidding cost (\$/m^3)	Processing cost [a] (\$/m^3)	Loading cost (\$/m^3)	Hauling cost (\$/m^3)	Total cost (\$/m^3)
Two Pass CTL	34.10	12.40	-	-	12.60 [b]	32.90 [c]
Two Pass TL	3.10	1.10	2.80	1.80	6.00	-
Fall and Sort	3.50	1.70	3.60	2.00	6.80 [a]	17.60
Conventional	5.00	1.60	7.00	2.00	6.90	22.50
Sort at Roadside	3.00	0.70	4.70	2.00	6.90 [a]	17.30
Process at Stump	3.00	0.70	7.10	2.00	6.90	19.70

[a] Assumes all pulpwood brought to roadside was processed.
[b] Hauling cost adjusted to include estimated additional cost of loading and hauling pulpwood left at roadside and assumes all logs except Two Pass CTL were hauled by conventional trucks.
[c] Total cost averaged to reflect cost for the whole treatment unit.

appeared to reduce their productivity. Therefore, the majority of the undersized stems in this treatment area were not processed. The operators still sorted the undersized logs from the sawlogs and pushed them back away from the roadside which didn't take as much time as processing them.

Table 16 shows the estimated delivered wood cost for each treatment area, assuming all sawlog and pulpwood fibre delivered to roadside was processed and hauled. Loading costs were based on the estimated hourly equipment rate (Appendix II) divided by the average load size for each treatment.

The cycle time for the self-loader was estimated at 5.0 h for a 50 km distance (one way) and the conventional truck had an estimated cycle time of 3.5 h. Although self-loading log trucks actually hauled the pulp, using a butt-n-top loader and conventional log trucks would have been cheaper. Therefore, hauling costs are based on the assumption that all wood, except the Two Pass CTL, was hauled by conventional trucks.

The self-loading logging truck cost \$109/PMH (Appendix II) to operate. The butt-n-top loader worked 10 h/shift at a rate of \$196/PMH; the daily cost was divided by the average loads/shift (20 loads) and average load size for the loads hauled from the treatment areas (Table 17) to determine the loading cost in terms of \$/m^3. The 7-axle logging truck's hourly rate was calculated to be \$95/PMH (Appendix II).

Discussion

Upgrading pulpwood to sawlogs

The initial plan to use a satellite chipping operation to recover all of the pulpwood and waste was not done due to a poor chip market. Instead, the sawmill anticipated salvaging as much lumber as possible from the pulpwood. To minimize the cost of processing these small stems, multi-stem processing during harvesting was accepted. However, after processing of the stems in the Sort at Roadside treatment area was initiated, it was evident that the productivity of the processor was too slow. Therefore, the pulpwood was pushed back from the roadside and not sent to the sawmill. Eight loads of pulpwood were sent to the sawmill from the study area. FERIC was unable to track these loads after they were delivered to the sawmill and the amount of lumber that was recovered is not known. However, in an earlier FERIC study (Araki 2002), the lumber recovery for small diameter tops (10 to 13.5-cm) was 163 foot board measure per cubic metre (fbm/m^3). The same study showed that the recovery for jack pine pulpwood (mostly tops) was only 39 fbm/m^3.

Table 17. Hauling summary from scale records

Treatment area	Self-load log truck		7-axle log truck	
	(m^3/load)	(\$/m^3)	(m^3/load)	(\$/m^3)
Two Pass CTL	43.5	12.53	-	-
Two Pass TL	-	-	55.8	5.96
Fall and Sort	36.4	14.97	48.5	6.85
Conventional	-	-	48.2	6.90
Sort at Roadside	36.7	14.85	48.1	6.91
Process at Stump	-	-	48.3	6.88

Chipping of pulpwood and residues

If the pulpwood and residue had been collected and chipped as originally planned, the least-cost method of recovering the undersized stems using conventional methods would have been that used in Fall and Sort where the feller-buncher sorted the sawlogs and pulpwood and placed them in separate bunches. The pulpwood would not be processed, so the cost to place the material at roadside was $6.60/t (Appendix III). FERIC estimated that the cost to load and haul the pulpwood to the satellite chipping operation would be $16.35/t. The waste recovery program used an old excavator (Caterpillar EL200) with a grapple ($120/PMH) and three waste-bin trucks ($74/PMH) to load and haul the pulpwood and sawlog waste. Three bin trucks made three 60-km one-way trips each day and carried 24 t/load. The total daily cost for the loader and trucks was $3330/day. Using a chip recovery of 70% (based on putting this waste material through the Deal processor [Araki 1999]) and moisture content of 25%, the net wood cost was calculated to be $43.80/BDt.[5] The chipping cost was estimated to be $16.65/BDt for a total of $60.45/BDt.

Conclusions and implementation

FERIC studied the costs and logistics of recovering pulpwood from undersized stems at sites that were harvested by different types of equipment and systems. Five treatments were studied near Kelowna in the southern interior of British Columbia.

Depending on the harvesting equipment and system used, the incremental fibre recovery ranged between 11 and 31% more than conventional roadside harvesting. Shift-level studies determined that the total cost delivered to the sawmill and satellite chipping facility ranged between $17.30 and $32.90/m^3. The most expensive method of recovering the pulpwood was the two-pass harvesting system. This involved using cut-to-length equipment to pre-harvest the pulp component before the conventional equipment mechanically felled, bunched, and skidded tree-length stems to roadside for processing. Unfortunately, the study did not include a treatment where only CTL harvesting was compared with the other harvesting trials and this should be explored in a future study.

If conventional roadside harvesting equipment is to be used, the feller buncher should fell and sort the stems at the stump. Although this might increase felling costs slightly, the overall harvesting cost would likely be the cheapest method of producing sawlogs and pulpwood together. Early sorting enabled the skidder to place the different log sorts at different locations at roadside, or in distinguishable sections in roadside decks without adding any costs to skidding. This also enabled the processors to multi-stem process the pulpwood to maintain production and minimize costs.

During the study, the decision was made to upgrade some of the pulpwood to sawlogs. Self-loading trucks were used to haul these sawlogs to the sawmill. The butt-n-top loader could have treated these logs similarly to the short sawlogs and placed them in the middle of the loads. Since the sawlogs produced from pulpwood were decked separately, it would be easy to load these extra logs at little additional cost.

This study indicated that it is possible to recover undersized stems for chips, but a complete recovery study from the stump to a finished lumber product needs to be initiated to determine the net value gain/loss from utilizing undersized stems for lumber.

Although this study was not able to process any of the waste and undersized stems into chips, projected costs showed that it is feasible to harvest these stems using

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[5] Calculated as the estimated cost (provided by Riverside personnel) to load and haul the waste material to the satellite chipping yard divided by the chip recovery multiplied by the solid wood content: ($24/t)/((70/100) × (1-(25/100))).

conventional roadside harvesting equipment depending on the chip market. A study to determine the actual amount, quality, and cost of producing pulp chips from undersized stems needs to be done.

While this study used stroke delimbers to process the stems, trials using quicker dangle head log processors at roadside and at the stump (modified cut-to-length) need to be done as a comparison to the systems tested in this study.

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Appendix I

Summary of forest types[a]

Description [b]	Close utilization [c]	Super utilization [d]	Total
Forest Type 1			
Gross volume (m^3/ha)	402.7	65.8	468.5
Net volume (m^3/ha)	370.5	60.5	431.0
Trees/ha (no.)	1597	1015	2612
Forest Type 2			
Gross volume (m^3/ha)	434.9	49.6	484.5
Net volume (m^3/ha)	400.1	45.6	445.7
Trees/ha (no.)	1460	720	2180

[a] The cruise summaries in Appendix I were multiplied by the hectares of each forest type in the treatment areas (see Table 1).

[b] Forest Type 1 primarily of mature lodgepole pine on dry sites, and Forest Type 2 is mature lodgepole pine with white spruce and subalpine fir on wet sites.

[c] Close utilization: trees with a minimum 15-cm butt-diameter and 10-cm top.

[d] Super utilization: trees with a minimum 10-cm butt-diameter and 5-cm top.

Appendix II

Machine costs[a] ($/scheduled machine hour (SMH))

	Timberjack 1270 harvester	Rottne RK60 forwarder	Linkbelt 3400 Lim-mit 2000	Prentice 630 feller-buncher	John Deere 748G skidder	Linkbelt 4300 Butt-n-top
OWNERSHIP COSTS						
Total purchase price (P) $	611 000	350 000	450 000	500 000	220 000	550 000
Expected life (Y) y	5	5	4	4	4	4
Expected life (H) [b] h	10 000	10 000	8 000	8 000	8 000	8 000
Scheduled hours/year (h)=(H/Y) [c] h	2 000	2 000	2 000	2 000	2 000	2 000
Salvage value as % of P (s) %	30	30	25	25	30	30
Interest rate (Int) %	7	7	7	7	7	7
Insurance rate (Ins) %	3	3	3	3	3	3
Salvage value (S)=((P•s)/100) $	183 300	105 000	112 500	125 000	66 000	165 000
Average investment (AVI)=((P+S)/2) $	397 150	227 500	281 250	312 500	143 000	357 500
Loss in resale value ((P-S)/H) $/h	42.77	24.50	42.19	46.88	19.25	48.13
Interest ((Int•AVI)/h) $/h	13.90	7.96	9.84	10.94	5.00	12.51
Insurance ((Ins•AVI)/h) $/h	5.96	3.41	4.22	4.69	2.14	5.36
Total ownership costs (OW) $/h	62.63	35.87	56.25	62.50	26.40	66.00
OPERATING COSTS						
Fuel consumption (F) L/h	20	15	20	35	27	35
Fuel (fc) $/L	0.45	0.45	0.45	0.45	0.45	0.45
Lube & oil as % of fuel (fp) %	15	15	15	15	15	15
Annual repair & maintenance (Rp) %	20	20	20	20	20	20
Shift length (sl) h	10	10	12	12	12	10
Wages $/h	26.31	24.17	24.98	25.88	23.85	24.98
Wage benefit loading (WBL) %	35	35	35	35	35	35
Fuel (F•fc) $/h	9.00	6.75	9.00	15.75	12.15	15.75
Lube & oil ((fp/100)•(F•fc)) $/h	1.35	1.01	1.35	2.36	1.82	2.36
Repair & maintenance ((Rp•P)/h) $/h	61.10	35.00	45.00	50.00	22.00	55.00
Wages & benefits (W•(1+WBL/100)) $/h	35.52	32.63	33.72	34.94	32.20	33.72
Prorated overtime (((1.5•W-W)•(sl-8) •(1+WBL/100))/sl) $/h	3.55	3.26	5.62	5.82	5.37	3.37
Total operating costs (OP) $/SMH	110.52	78.65	94.69	108.87	73.54	110.20
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP)						
$/SMH	173.15	114.52	150.94	171.37	99.94	176.21
Utilization	57	82	86	91	94	90
$/PMH	303.77	139.66	175.51	188.32	106.32	195.79

[a] These costs are based on FERIC's standard costing methodology for determining machine ownership and operating costs. These costs do not include supervision, profit, or overhead, and are not the actual costs incurred by the contractor or company.
[b] Expected life based on the average hours industry has experienced (ranged between 6 000 and 10 000 hours.)
[c] Scheduled hours worked by Riverside contractors.

Appendix II (continued)

Machine costs[a] ($/scheduled machine hour (SMH))

	Caterpillar EL200 excavator	Bin Truck	Self loading truck	Logging truck 7-axle
OWNERSHIP COSTS				
Total purchase price (P) $	250 000	185 000	280 000	200 000
Expected life (Y) y	4	5	5	5
Expected life (H) [b] h	8 000	10 000	10 000	10 000
Scheduled hours/year (h) = (H/Y) [c] h	2 000	2 000	2 000	2 000
Salvage value as % of P (s) %	30	30	30	30
Interest rate (Int) %	7	7	7	7
Insurance rate (Ins) %	3	3	3	3
Salvage value (S) = ((P • s)/100) $	75 000	55 500	84 000	60 000
Average investment (AVI) = ((P + S)/2) $	162 500	120 250	182 000	130 000
Loss in resale value ((P-S)/H) $/h	21.88	12.95	19.60	14.00
Interest ((Int • AVI)/h) $/h	5.69	4.21	6.37	4.55
Insurance ((Ins • AVI)/h) $/h	2.44	1.80	2.73	1.95
Total ownership costs (OW) $/h	30.00	18.96	28.70	20.50
OPERATING COSTS				
Fuel consumption (F) L/h	30	20	30	30
Fuel (fc) $/L	0.45	0.45	0.45	0.45
Lube & oil as % of fuel (fp) %	15	15	15	15
Annual repair & maintenance (Rp) %	20	10	20	20
Shift length (sl) h	10	10	10	12
Wages $/h	24.98	24.17	24.98	24.55
Wage benefit loading (WBL) %	35	35	35	35
Fuel (F • fc) $/h	13.50	9.00	13.50	13.50
Lube & oil ((fp/100) • (F • fc)) $/h	2.03	1.35	2.03	2.03
Repair & maintenance ((Rp • P)/h) $/h	25.00	9.25	28.00	20.00
Wages & benefits (W • (1 + WBL/100)) $/h	33.72	32.63	33.72	33.14
Prorated overtime (((1.5 • W-W) • (sl-8) • (1 + WBL/100))/sl) $/h	3.37	3.26	3.37	5.52
Total operating costs (OP) $/SMH	77.62	55.49	80.62	74.19
TOTAL OWNERSHIP AND OPERATING COSTS (OW + OP)				
$/SMH	107.62	74.45	109.32	94.69
Utilization	90	100	100	100
$/PMH	119.58	74.45	109.32	94.69

[a] These costs are based on FERIC's standard costing methodology for determining machine ownership and operating costs. These costs do not include supervision, profit, or overhead, and are not the actual costs incurred by the contractor or company.

[b] Expected life based on the average hours industry has experienced (ranged between 6 000 and 10 000 hours.)

[c] Scheduled hours worked by Riverside contractors.

Appendix III

Estimated cost to produce chips from pulpwood and waste residue

Description	Cost
Fall and skid to roadside (($5.20/m^3)/(0.786 t/m^3) ($/t)	6.60
Load pulpwood and waste ($120•10)/(24 t/load•9 loads) ($/t)	5.55
Haul waste to satellite yard ($74/h•3.5 h)/24 t ($/t)	10.80
Total cost to deliver to satellite yard (TDC) $/t	22.95
Chip recovery (Cr) (%)	70
Moisture content (MC) (%)	25
Net fibre cost (TDC/((Cr/100)/1-(MC/100))) ($/BDt)	43.80
Estimated chipping cost ($295/h+$105/h)/24 BDt ($/BDt) [a]	16.65
Total cost ($/BDt)	60.45

[a] Estimated hourly cost of $295/h for the Deal processor and Forano chipper at Bear Creek yard and $105/h for the Cat 966 front-end loader.