Advantage

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Helicopter logging with the Bell 214B: group and single-tree selection in low-volume coastal cedar stands

Contents

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Abstract

The Forest Engineering Research Institute of Canada (FERIC) studied a light-lift helicopter logging operation in low-volume cedar stands on the central coast of British Columbia. A Bell 214B helicopter was used to harvest group and single-tree selection units. This report presents productivity and cost information for the helicopter logging operation, and discusses factors affecting the efficiency of the operation.

Keywords

Helicopter logging, Bell 214B, Group selection, Single-tree selection, Productivity, Costs, Coastal British Columbia.

Introduction

Forest engineers and planners recognize that helicopter logging is a highly specialized system with its own unique requirements for safe, cost-effective harvesting operations. However, information about the capabilities and performances of different helicopters in typical harvesting situations in British Columbia is scarce, as is information about site, stand, organizational, and operational factors that influence helicopter logging productivity and cost. FERIC has established an ongoing project to study helicopter logging operations throughout British Columbia to provide this information.

This report presents the results of a case study of a light-lift helicopter logging operation undertaken on the central coast on areas difficult and uneconomical to access by conventional ground-based or cable harvesting systems. A Bell 214B helicopter was used to harvest small patch and single-tree selection units in cutblocks with relatively high road development costs and isolated pockets of merchantable timber. FERIC, Mill & Timber Products Ltd., Cougar Inlet Logging Limited, and Transwest Timber Incorporated cooperated in this case study. The report presents the productivities and costs of the helicopter logging operation, and discusses factors affecting the efficiency of the system.

Objectives

The goal of FERIC's project is to provide forest engineers with factual information on the capabilities, productivities, and costs of helicopters currently used for logging in British Columbia through an ongoing series of short-term case studies. The objectives of this case study were to:

- Describe the harvesting operation.
- Determine productivities and costs for the falling, yarding, and loading phases of the harvesting operation.
- Compare the outcomes for two alternative scenarios for the study area—conventional harvesting only, and a combination of helicopter and conventional harvesting.
- Identify features of the site, stand, harvest plan, and system organization that may have influenced harvest productivity and cost.

Site and stand descriptions

The study site consisted of two cutblocks on public land in Seymour Inlet approximately 40 km north of Port Hardy, in the Port McNeill Forest District (Table 1 and Figure 1). The cutblocks were approximately 150 m apart and were oriented at variable aspects. Elevations ranged between 10 and 150 m above sea level. The terrain was gentle to moderate, and slopes were between 0 and 60% with dispersed rock outcroppings throughout both cutblocks. The site was in the very wet hypermaritime subzone of the Coastal Western Hemlock (CWHvh) biogeoclimatic zone (Green and Klinka 1994). Forest cover was primarily western red cedar (*Thuja plicata*), with secondary components of yellow cedar (*Chamaecyparis nootkatensis*) and western hemlock (*Tsuga heterophylla*). According to the operational cruise, the average merchantable volumes were 347 and 272 m^3/ha with decay, waste, and breakage factors of 19 and 17% for Cutblocks 1 and 2, respectively.

Table 1. Site and stand descriptions

	Cutblock 1	Cutblock 2
Cutblock area (ha)	54.2	5.0
Site characteristics		
Terrain description	broken, rock outcrops	broken
Average slope (%)	20	25
Soil characteristics		
Texture	silty loam	silty loam
Soil depth (cm)	>30, variable	10–15
Mass wasting hazard	low	low
Stand characteristics		
Species composition (%)		
Western red cedar	76	90
Western hemlock	10	10
Yellow cedar	14	-
Defects		
Decay (% of gross)	10	9
Waste (% of gross)	3	2
Breakage (% of gross)	7	7
Net volume (m^3/ha)	347	272
Forest health concerns	incidence of cedar Keithia blight and hemlock dwarf mistletoe	incidence of cedar Keithia blight and hemlock dwarf mistletoe

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Harvesting prescription and plan

The cutblocks were prescribed for harvesting with a combination of ground-based, cable, and helicopter yarding systems. Helicopter yarding units were prescribed for a mix of group and single-tree selection harvesting systems with retention of large- and small-diameter yellow cedar and small-diameter western red cedar. Helicopter extraction using a light-lift helicopter was prescribed for isolated pockets of timber too expensive to access by conventional harvesting due to high road development costs. Small average tree size, and the requirement to minimize the visual impacts of harvesting and maintain water quality, also favoured the use of a helicopter. The small average tree size suggested a light-lift helicopter would be sufficient.

Harvesting operations were scheduled for early to mid-spring to coincide with conventional harvesting plans. The study site was cruised and engineered by Mill & Timber staff and its forestry consultants. Mill & Timber solicited bids for the helicopter harvest units, and stipulated the need for a light-lift helicopter to carry out the yarding phase. Transwest Timber Incorporated was the successful bidder and proposed to harvest the area with a Bell 214B helicopter.

The study area consisted of two cutblocks. Cutblock 1 was 54.2 ha in total—10 harvest units that totalled 22.3 ha were designated for helicopter logging, 29.6 ha were designated for ground-based or cable logging, and 2.3 ha were reserved for wildlife tree patches (Figure 2). Cutblock 2 was 5.0 ha in size—three harvest units that totalled 1.0 ha were designated for helicopter logging, 3.7 ha for conventional logging, and 0.3 ha for wildlife tree patches (Figure 3). The harvest units contained an estimated net volume of 8 000 m^3, primarily western red cedar. Road right-of-ways in both cutblocks were available for landings but the segments to be used as landings were left to Transwest's discretion at the time of harvest. Yarding distances ranged from 100 to 400 m (horizontal distance). A service landing used for helicopter refuelling and in-shift maintenance was situated about 2 km from the cutblocks. A second service landing, used for pre- and post-shift maintenance, was located approximately 30 km from the cutblocks, at Mill & Timber's logging camp.

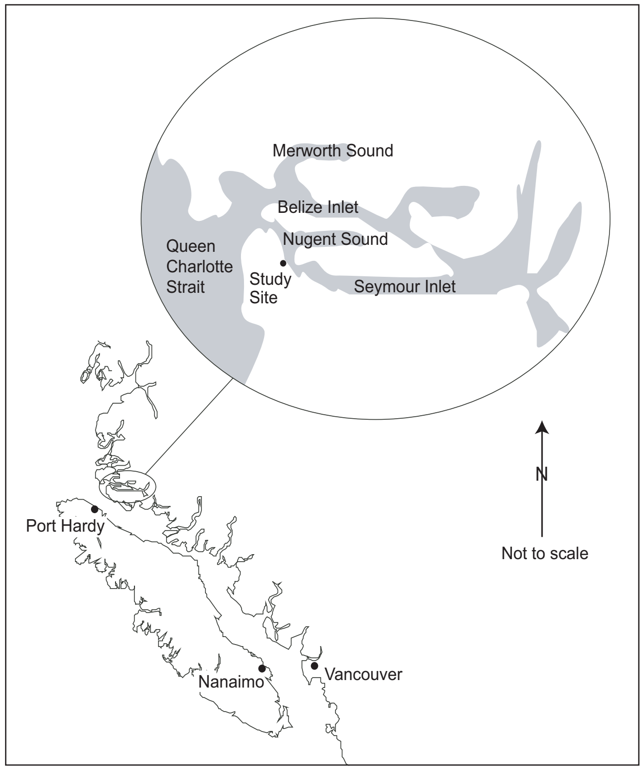


Figure 1. Study site.

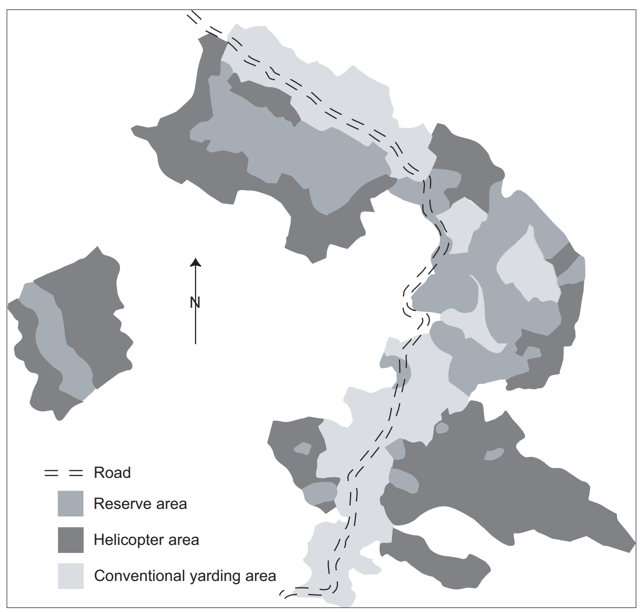


Figure 2. Harvest plan map for Cutblock 1.

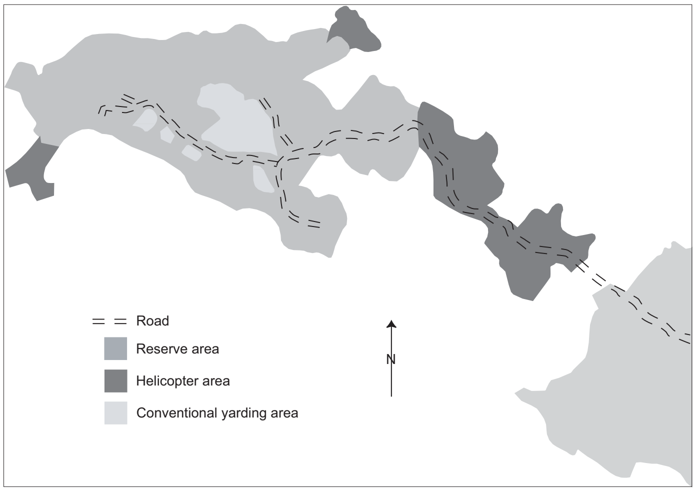


Figure 3. Harvest plan map for Cutblock 2.

Helicopter specifications

The Bell 214B[1] helicopter is a single-turbine engine, light-lift helicopter (Figure 4) designed for internal and external cargo transport applications including forestry, agriculture, and fire suppression. The Bell 214B is the commercial version of the Bell 214A, which was designed for military transport applications.

Table 2 lists the Bell 214B's specifications. With a rated payload of 3 636 kg, the Bell 214B is one of the largest light-lift helicopters routinely used for logging in British Columbia (Appendix I).[2]

Study methods

A FERIC researcher was on-site for most of the harvesting operation and collected shift-level and detailed-timing information. Shift-level information for the falling, yarding, and loading phases was supplied by the cooperators, including shift production reports, data summaries for the helicopter cycles, and daily operating reports. During the yarding phase, FERIC frequently discussed the progress of the harvesting operation with Transwest and Cougar Inlet Logging personnel to identify site, stand, layout, and organizational factors that influenced the helicopter's efficiency and productivity.

Harvesting productivities were calculated from shift-level time and volume data provided by cooperators, and harvesting costs for the helicopter system were estimated using several sources. Costs for the Bell 214B helicopter were estimated using a modified version of the costing methodology in Guimier and Wellburn (1984), plus information from the Official Helicopter Blue Book and Helicopter Equip-

Table 2. Specifications for the Bell 214B helicopter [a]

Bell 214B	
Max. permitted static load (kg) [b]	3 636
Engines (no.)	1
Engine power at takeoff (kW) (each)	2 185
Dimensions of main rotor (m)	15
Dimensions of tail rotor (m)	3
Service ceiling (m)	6 090
Standard fuel capacity (l)	722

[a] Source: The Official Helicopter Blue Book and Helicopter Equipment Lists & Prices (HELP).
[b] From Transport Canada Type Certificates for the Bell 214B helicopter.

Figure 4. Bell 214B helicopter.

[1] The 214B was certified in the United States in 1976 and was manufactured by Bell Helicopter Textron until 1981, at which point manufacturing was discontinued.

[2] In general, logging helicopters are classified on the basis of their maximum rated payload as either light-, medium-, or heavy-lift. A light-lift helicopter is defined as having a payload capacity less than 4 550 kg (10 000 lb.) A medium-lift helicopter has a payload capacity between 4 550 and 6 820 kg (10 000–15 000 lb.), and a heavy-lift helicopter has a payload capacity greater than 6 820 kg (15 000 lb.).

ment Lists & Prices (HELP) (HeliValue$ Inc. 2000) (Appendix II). Hourly costs for other machinery involved in the harvesting operations were calculated using FERIC's standard costing methods (Appendix III). Labour costs were based on the IWA British Columbia Coast Master Agreement using 2002 rates. FERIC's cost estimates do not include stumpage or profit. The costs presented in this report are FERIC's estimates only and are not the actual costs incurred by either the licensee or the helicopter contractor.

Results and discussion

Description of the harvesting operation

Mill & Timber's conventional full-phase logging contractor, Cougar Inlet Logging, performed falling, yarding for conventional logging operations, and log clearing and loading activities. At the time of the study, the Cougar Inlet Logging crew had no previous experience with helicopter logging or partial cutting.

Falling

Fallers walked to and from their falling sites daily because no road access was available into the helicopter yarding units and the closest support helicopter was based too far away to be a cost-effective alternative. Trees were felled cross-slope. According to fallers, most trees designated for falling leaned heavily and contained considerable rot. Bucking specifications were geared to the Bell 214B helicopter. Larger logs were bucked to preferred lengths to meet helicopter payload restrictions, while smaller logs were generally left tree length. Felled stems were limbed on three sides and shape defects and broken ends were trimmed to reduce the amount of unmerchantable wood yarded to the landings.

Yarding

Transwest's crews and equipment performed the yarding phase, and were scheduled to work a 10-hour shift. The Bell 214B performed all yarding activities

Figure 5. Nubbin hook.

including choker distribution using a 38-kg nubbin hook attached to a 61-m longline (Figure 5).

The yarding phase employed 10 workers: a flight crew consisting of a Bell 214B pilot and co-pilot; a rigging crew consisting of four hooktenders; a landing crew consisting of two chasers; one engineer who performed helicopter maintenance; and one on-site woods foreman.

Hooktenders worked individually in separate units of the same cutblock, located strategically so that they were not working under the helicopter's flight path. Yarding began in Cutblock 1. However, falling was not completed in the lower units of Cutblock 1 by the time the yarding crew was ready to move into them so the yarding crew moved into Cutblock 2. The yarding crew returned to Cutblock 1 after completing Cutblock 2.

The Bell 214B yarded about 28–30 turns in a 60- to 70-minute yarding cycle.[3, 4] The helicopter usually followed a fixed rotation, flying to each hooktender 3 or 4 times per yarding cycle. Additionally, the 214B generally flew 3 to 4 choker drops per yarding

[3] A yarding turn is defined as the sequence of activities required to transport one load of logs from the stump to the landing. A turn consists of the following elements: flying from the landing to the hook-up site (fly empty); securing the load of logs (hook up); lifting the turn above the stand's canopy before beginning forward flight (break out); flying from the hook-up site to the landing with a load of logs (fly loaded); and placing and releasing the logs on the landing (unhook).

[4] A cycle is defined as the period of continuous flight operations between refuelling and/or maintenance breaks, during which a series of turns is yarded. In helicopter logging, typically 25–45 turns are yarded in a 50–90 minute cycle.

cycle, consisting of 10 chokers per drop. At the end of each cycle, the Bell 214B returned to the service landing for 10 to 15 minutes and a "hot" refuelling was performed. At the landings, the chasers removed the chokers from the logs as soon as the 214B released the turn, and the hydraulic loader then cleared the logs from the drop zone and either decked them or spread them for subsequent processing and loading.

The helicopter engineer had a maintenance truck, one standard highway fuel tank, and an aircraft refuelling system to assist with routine on-site maintenance and refuelling of the Bell 214B. Maintenance shift lengths varied daily depending on the number of hours flown each shift. Usually, the engineer performed two to three hours of post-shift maintenance each shift, and was on-site for about six hours per day during the yarding operation to perform refuelling and maintenance checks. Following every fourth yarding cycle, the helicopter was shut down and a mandatory mechanical inspection, taking 45–60 minutes, was performed.

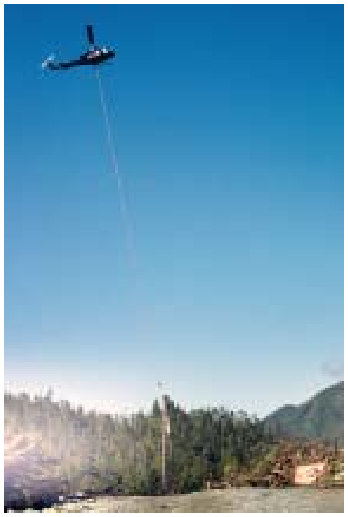


Figure 6. In-block landing located on road.

Loading

The loading phase was performed by Cougar Inlet Logging's crew and equipment, and was scheduled to work 10.5 hours per shift. The hydraulic loader, equipped with a saw attachment, was used to clear logs in the drop zone and to process and load the manufactured logs onto the log trucks for hauling. In-block roads were used as landings (Figure 6). Landings were relocated regularly to minimize flight distance from hook sites. Sometimes, more than one landing was active if hook sites were spread out through the cutblock. Generally, the log loader worked in each active landing for a portion of each shift. However, in some cases, large distances between landings prevented this.

Table 3. Shift-level productivities for the falling, yarding, and loading phases

	Cutblocks 1 and 2
Falling	
Scheduled shifts worked (no.)	47
Non-productive shifts (no.)	0
Average fallers per shift (no.)	4.5
Total faller shifts worked (no.)	209
Production per 6.5-h falling shift (m^3)	35
Yarding	
Logging helicopter	
Total shifts worked (no.)	21
Scheduled shifts with production (no.)	20
Scheduled shifts lost to weather (no.)	0
Scheduled shifts lost to mechanical problems (no.)	0
Scheduled shifts lost to other (no.)	1
Average flight hours per productive yarding shift (no.)	6.6
Production per productive yarding shift (m^3)	369
Loading	
Total loader shifts worked (no.)	21
Production per 10-h loading shift (m^3)	351

Harvesting productivity

A total net volume of 7 379 m^3 was harvested from the helicopter-yarded units in the two cutblocks.

Shift-level study

Table 3 summarizes shift-level productivities for the falling, yarding, and loading phases.

Falling. Falling operations began in late February and continued steadily until the sites were completed in early April. In 209 falling shifts during this period, a crew varying in size from 3 to 8 fallers worked a total of 1 359 hours, including walking to the falling site and in-shift delay time.

Based on a net volume of 7 379 m^3, each faller produced an average of 35 m^3/6.5-hour shift. Falling productivity was reduced because fallers spent 1 to 1.2 hours per 6.5-hour shift walking to and from falling sites. Additionally, most of the trees designated for falling leaned heavily and contained a considerable amount of rot which increased falling difficulty and further decreased productivity. Although fallers were experienced in similar stand conditions, they had no previous experience falling for retention prescriptions. Falling was not completed on the study sites before yarding began, so this resulted in interference between the falling and yarding phases.

Overall, Transwest's rigging crew was satisfied with the quality of falling, given the constraints of the stand and site. However, they felt a falling crew with more experience in judging tree weights would have bucked more consistently to meet helicopter payload constraints.

Since completion of the project three years ago, falling productivity under similar stand conditions and harvesting prescriptions has steadily increased as a result of additional faller experience. Mill & Timber currently estimates falling productivity to be between 40 and 50% greater than reported during this study. Falling productivity could have been further improved with the use of a support helicopter to ferry fallers to and from worksites. It is estimated an additional 5–8 m^3/faller shift may have been realized. However, because of the remote location of Mill & Timber's Seymour Inlet operating area, the closest support helicopter base hangar was 30–45 minutes away under ideal travel conditions. Therefore, even with an increase in falling productivity, ferrying fallers to and from work sites was not an economically viable option for this site.

Yarding. The yarding phase operated seven days per week. Helicopter yarding began in late March and required twenty productive shifts to complete. One yarding shift was lost during the operation for reasons unrelated to the project. Transwest planned to begin yarding operations at 7:00 a.m. each morning, but the cutblocks were frequently obscured by morning fog and low cloud. As a result, yarding operations usually started between 7:30 and 8:30 a.m. The average yarding shift was reduced from 10 to 9.5 hours because the time lost in the morning could not be made up in the evening due to camp meal scheduling. Scheduled start and end times for the loader operator were not affected.

Table 4 summarizes time distributions for productive shifts assuming a 10-h scheduled shift. Pre-and-post shift maintenance and the shift lost to reasons unrelated to the project are excluded. Transwest supplied

Table 4. Shift-level time distributions for productive shifts

	Bell 214B with chokers
Productive shifts (no.)	20
Non-productive shifts (no.)	
Weather	0
Mechanical	0
Total shifts (no.)	20
Flight time (h) [a]	
Total flight-hours	131.4
Flight hours/productive shift	6.6
Non-flight time (h) [b]	
Maintenance	15.2
Refuelling	16.7
Weather	21.5
Other [c]	15.2
Sub-total	68.6
Total potential hours [d]	200.0
Ratio of flight hours to total potential hours (%)	66

[a] Information supplied by Transwest.
[b] Estimates by FERIC based on detailed timing, field observations, and discussions with cooperators.
[c] Includes time lost to in-shift mechanical delays, ending the shift early, and other organizational delays.
[d] Assumes a nominal 10-h day.

the actual number of flight hours worked during the study, and FERIC estimated the distribution of non-flight hours from field notes and discussions with Transwest.

In total, the Bell 214B recorded 131.4 flight hours during the yarding phase, or 66% of the 200 hours potentially available for yarding during the 20 productive shifts. Routine in-shift maintenance and refuelling times, closely linked to flight time, were estimated at 31.9 hours or 16% of total scheduled hours. Therefore, flight time and associated service activities accounted for 82% of the total shift time during the productive shifts. The operation was conducted during early spring when the weather was unpredictable, and an estimated 21.5 hours was lost to low cloud, fog, and high winds. An additional 15.2 hours were unavailable for flying due to in-shift mechanical delays, ending a shift early, and a pre-work meeting.

In total, the Bell 214B extracted a total payload of 7 336 591 kg, which yields an average weight-to-volume conversion ratio of 994 kg/m^3 (2 190 lb./m^3) based on 7 379 m^3 net scaled volume.[5] This conversion ratio is higher than expected. Typical conversion ratios for western red cedar growing on British Columbia's coast are between 650 and 700 kg/m^3 (1 430 and 1 540 lb./m^3) (Appendix IV). On average, the logging helicopter flew 6.6 hours or 6 yarding cycles per shift, and produced approximately 369 m^3/productive shift and 56.2 m^3/flight-hour. Yarding turn times averaged 2.1 minutes, resulting in 26 turns/flight-hour with an average turn abort rate of 6.7%.[6] The Bell 214B achieved an average load factor of 58%, considerably less than the desired average of 70% set by Transwest for this operation. The yarding helicopter performed its own support services. The additional time per yarding cycle spent retrieving and distributing chokers was not recorded separately during the shift-level evaluation and is therefore included in the overall yarding time.

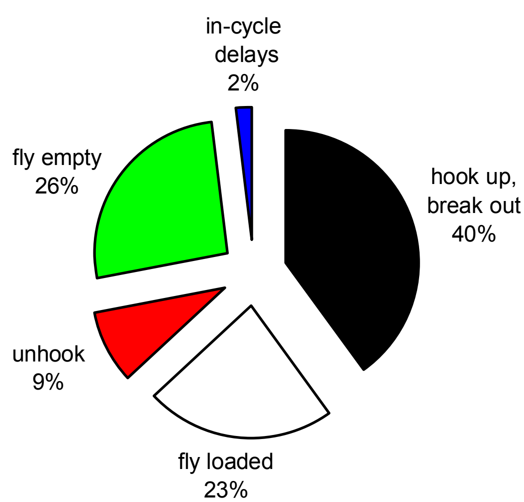
Loading. Loading activities began at the same time as the yarding phase and were completed shortly after yarding was finished. The loader operator worked 21 shifts to load and process logs at the landings. The hydraulic log loader worked a total of 220.5 hours and averaged 351 m^3 loaded per 10.5-h shift.

In general, the landings were large enough to permit continuous loading without greatly affecting the Bell 214B's yarding productivity.

Detailed-timing study

FERIC detail timed 12.5 flight hours, or 9.5% of total flight time. On average, the yarding cycles were 63.4 minutes long and turn times were 1.8 minutes at an average yarding distance of 176 m. An average turn consisted of 2.6 logs. Figure 7 shows the distribution of turn time based on activity. Turn payloads for most of the detailed-timing period were not available due to problems with the helicopter's load cell.

Figure 7. Turn time distribution based on detailed timing.



5 In the helicopter logging industry, the logging helicopter's productivity per flight-hour is typically expressed in terms of weight rather than volume. Weight is measured directly whereas volume is derived from weight, and the conversion varies from site to site due to differences in species composition, wood density, cull factor, and waste allowance. Appendix IV presents average weight-to-volume ratios used by Canadian Air-Crane for the main commercial conifer species in coastal British Columbia.

6 Turn abort is described as discontinuing a turn (lift) due to excessive load weight, hangups, or mechanical difficulties.

Factors affecting helicopter yarding productivity

Based on field observation and discussions with cooperators, yarding productivity was considered "below average" during this study. FERIC estimated average productivity for this site should have ranged between 61 000 and 76 000 kg/flight-hour (90 and 110 m^3/flight-hour) based on turn times of 2–2.5 minutes and weight targets of 70% of rated payload—an increase of 34–54 m^3/flight-hour compared to this study. The principal factors affecting yarding productivity were identified as cull factor,[7] flight path slopes, harvesting prescription, and the use of only one log loader.

Cull factor

Cull factor was identified as the greatest influence on productivity. The cutblocks were comprised mainly of decadent western red cedar which inherently contained a high amount of unavoidable decay, waste, and breakage within felled and bucked logs. This made it difficult to gauge wood quality prior to manufacturing. Large amounts of in-block slash were present and made the hooktenders' job of locating merchantable logs and setting cull-free turns more difficult. Furthermore, the cull factor may have been higher because the helicopter yarding crew had relatively little experience with coastal tree species and log grades.

Initially, Transwest budgeted for a cull factor of about 4%, which falls within a commonly accepted range of 4 to 7% for typical coastal mixed wood stands. However, once harvesting was completed, FERIC estimated the cull factor[8] at close to 30% for this site. Therefore, the gross volume yarded during this study was likely closer to 80 m^3 per flight-hour. The difference between the gross and net volume yarded per flight-hour accounts for more than half of the difference between the average productivity estimate and the net productivity reported in this study.

The high cull factor may have been partially reduced with more aggressive in-woods manufacturing, provided utilization limits allowed. However, in low-volume coastal stands such as the study site it is not uncommon to have a higher than average cull factor. Nevertheless, helicopter logging contractors in British Columbia are typically paid according to the project's net scale volume rather than total weight flown. Therefore, minimizing the amount of cull yarded is very important to overall yarding productivity and cost.

Flight path slope

Transwest identified flight path slope as having a considerable impact on yarding productivity. The slope of the flight path to the landings varied between 0 and 15% during the detailed-timing period. Because of the retention harvesting prescription, the helicopter had to dead-lift[9] turns above the stand's canopy before beginning forward flight. A helicopter requires more torque for dead-lifting compared to a controlled descent where adequate cutblock-to-landing deflection is available. The added torque requirement on the Bell 214B required payloads to be reduced to prevent an increase in turn times and maintenance costs. FERIC estimated that about 300 kg/turn or 12 m^3/cycle[10] less was yarded because the helicopter had to reduce its payload to dead-lift turns above the stand's canopy. Dead-lifting was also believed to increase the fly loaded time because forward momentum had to be gained without the assistance of gravity and therefore the helicopter's initial acceleration was reduced. FERIC estimated that the fly loaded time

[7] Cull factor is defined as the weight of unmerchantable material flown to the landing, expressed as a percentage of the total weight of wood flown.

[8] Cull factor was estimated using total gross weight yarded (7 336 591 kg) and an average coastal weight-to-volume conversion ratio for western red cedar of 700 kg/m^3.

[9] Dead-lift is described as lifting a turn straight up from the ground to a height above the stand canopy before beginning forward flight.

[10] Yarding productivity loss estimates were derived using the helicopter's actual load factor (58%), its target load factor (70%), calculated cull factor (30%), and a turn time estimate of 2.2 minutes.

was increased by about 25% compared to "normal" operating conditions, resulting in a productivity reduction of about 1–2 turns or 5 m^3/flight-hour.

Harvesting prescription

Transwest also believed productivity was affected by the harvesting prescription. Single-tree selection conditions often made it difficult for pilots to meet target payloads because logs were widely distributed and generally were yarded individually to minimize residual tree damage and maintain reasonable turn times. It is difficult to estimate the productivity loss because the number of logs and corresponding payload per turn was not tracked, and a clearcut control was not available for comparison. However, Krag and Evans (2003) reported that turn time generally increased as the level of stand retention increased due to increases in hook-up times (including vertical lift to clear surrounding trees).

Use of one log loader

Employing only one loader when two or more landings were active created congestion at landings operating without the loader, increased log unhook time, made choker retrieval more difficult, and raised potential safety concerns at these landings. Detailed timing was not carried out for yarding operations working without the loader, so the loss in productivity attributed to this factor could not be estimated. Additional equipment was not readily available because the project's remote location made the cost of barging in another loader prohibitive.

Harvesting costs

Table 5 summarizes the main costs for this operation. The per-unit stump-to-truck harvesting cost, including falling, yarding, processing and loading, was estimated at \$75.33/m^3. The yarding phase comprised the largest portion of the harvesting cost (65%), followed by the falling phase (29%), and the loading and processing phase (6%). Refer to Appendix II and III for detailed helicopter and log loader machine costing.

Table 5. Cumulative falling, yarding, and loading phase costs

	Falling (\$/m^3)	Yarding (\$/m^3)	Loading and processing (\$/m^3)	Total (\$/m^3)
Prime costs				
Yarding helicopter	-	32.52	-	32.52
Other equipment	-	0.29	2.66	2.95
Chainsaws	1.62	0.16	-	1.78
Choker replacement	-	0.16	-	0.16
Labour	13.17	6.74	1.37	21.28
Sub total	14.79	39.87	4.03	58.69
Other costs				
Mobilization	-	0.86	0.05	0.91
Crew transport	0.53	0.30	0.20	1.03
Supervision	3.13	1.41	-	4.54
Crew room and board	2.15	1.69	0.18	4.02
Overhead	0.95	3.20	0.22	4.37
Project costs	0.12	1.64	0.01	1.77
Sub-total	6.88	9.10	0.66	16.65
Total	21.67	48.97	4.69	75.33

Average falling and loading phase costs were estimated at \$21.67/m^3 and \$4.69/m^3, respectively. The falling cost is noticeably high compared to other recent FERIC helicopter logging studies and reflects the productivity effects of long walks in and out of falling sites each day, falling difficulties experienced due to heavy tree lean and high rot content, and a lack of falling experience with retention prescriptions.

The average yarding cost for the two cutblocks, estimated at \$48.97/m^3, reflects the effects of weather-related delays, flight path slopes, the low-volume dominantly decadent western red cedar stands, and the availability of only one log loader during yarding. The yarding helicopter alone accounted for 67% of the total yarding cost and 43% of the total stump-to-truck cost. Yarding crew labour and overhead costs account for 14% and 7% of the total yarding cost respectively.

The overall harvesting cost calculated for this study is comparable to harvesting costs presented in other recent FERIC helicopter logging reports. However, the proportion of cost attributed to each harvesting phase differs significantly between this study and the others. In Krag and Evans (2003) and Dunham (2002a, b), the falling costs were 35–65% less than falling costs for this project and yarding costs were 25–30% higher than yarding costs for this project but loading costs were comparable. However, although all of these studies were carried out in coastal stands, Krag and Evans (2003) and Dunham (2002a, b) involved medium and heavy-lift helicopters working in higher-volume and better quality stands.

Conventional yarding compared to combined helicopter and conventional yarding

In low-volume coastal stands such as observed in this study, access development (i.e., roads) is often the deciding factor in determining the areas that can be economically developed. In the past, Mill & Timber typically harvested similar cutblocks using conventional yarding methods only (a combination of cable yarding and loader forwarding). However, with high road development costs and low-volume stands, helicopter yarding was believed to be a useful tool to increase the volume of available timber in the operating area and thus reduce development and total harvesting costs. Mill & Timber proposed to harvest the study area using a combination of helicopter and conventional yarding systems. This analysis was based on a feasibility analysis by Mill & Timber on the study area, which included extensive field reconnaissance and layout, data on proposed road lengths, and data on the area developed for the two scenarios.

The use of a helicopter to harvest a portion of the study site that was initially designed for conventional harvesting systems resulted in changes to the equipment complement, redistribution of harvest volume between extraction modes, harvesting time frame, and amount of required road development. These changes had the potential to affect several important cost categories. To evaluate the financial consequences of these changes, an analysis was performed for two harvesting system options—conventional (cable and ground-based) yarding only, and conventional-plus-helicopter yarding (Table 6).[11] The analysis assumed the following:

- Falling cost for conventional yarding was 50% less than the falling cost calculated in this report for helicopter logging. Less time is required for fallers to walk in and out of work sites because a larger road network is in place.
- The same harvest volume was accessible to both systems.
- A total of 2.12 km of road was developed prior to harvesting to access cutblocks beyond the study site. Therefore, the cost of this development was not written off against the cutblocks included in this study.

[11] Costs presented in this analysis are prime costs only for the stump-to-truck phases only and do not include crew transportation, supervision, room and board, and overhead.

Table 6. Prime cost comparison for conventional harvesting only and helicopter and conventional harvesting

	Option 1 - Conventional only			Option 2 - Conventional and Helicopter		
	Accessed by existing roads	Accessed by proposed roads	Combined	Conventional (existing road access)	Helicopter	Combined
Volume yarded (m^3)	8 607	5 201	13 808	6 429	7 379	13 808
Area to be harvested (ha)	20.3	23.3	43.6	20.3	23.3	43.6
New road required (m)	0	6 910	6 910	0	0	0
Development and harvest costs						
Road cost ($/$m^3$)	0.00	139.50	52.55	0.00	0.00	0.00
Falling cost ($/$m^3$)	7.40	7.40	7.40	7.40	14.79	11.35
Yarding cost ($/$m^3$) [a]	20.45	20.45	20.45	20.45	41.44	31.67
Loading cost ($/$m^3$)	4.03	4.03	4.03	4.03	4.03	4.03
Total cost ($/$m^3$)	31.88	171.38	84.43	31.88	60.26	47.05

[a] Conventional yarding cost is based on costs derived in other recent FERIC studies where yarding systems and operating and stand conditions are comparable. Helicopter yarding cost is based on the helicopter yarding cost calculated in this report (unit cost includes prime costs plus most of the project costs identified in Table 5).

- Main and branch road construction cost was estimated at $105/m.[12]
- No road deactivation was planned following harvest due to rocky soil conditions, which resulted in poor effectiveness of debuilding roads.
- There were no substantial differences in loading costs between the two systems.

Harvesting the study site using a combination of conventional and helicopter yarding systems increased the overall harvesting cost by $15.17/$m^3$ compared with conventionally harvesting the area using only the existing roads. However, the use of a helicopter yarding system increased the harvest volume from 8 600 m^3 to 13 000 m^3. Conversely, if this same volume (13 000 m^3) was harvested using only conventional systems, 6.9 km of new road development would have been required, resulting in an overall harvesting cost increase of $37.38/$m^3$ compared to the conventional/helicopter yarding option. In the final analysis, the use of a combination of conventional and helicopter yarding enabled Mill & Timber to harvest 5 200 m^3 of incremental volume and reduce the overall harvesting cost by blending the relatively high cost of helicopter yarding with the lower costs of the conventional systems.[13]

Conclusions

Due to high road development costs and low-volume stands, Mill & Timber harvested the study area using a combination of helicopter and conventional yarding systems. A total of 7 379 m^3 was harvested by helicopter from a mix of group and single-tree selection harvesting units within two cutblocks. The areas were felled over a two-month period with 209 falling shifts. The falling crew varied in size from 3 to 8 fallers and averaged 35 m^3/6.5-h shift.

The Bell 214B completed yarding in 20 working days and averaged 369 m^3/9.5-h shift. One hydraulic log loader equipped with

[12] Per unit road construction cost was supplied by Mill & Timber and is based on historical road construction costs incurred in its operating area.

[13] Under the policy framework in place at the time of the study, it was necessary for Mill & Timber to demonstrate to the B.C. Ministry of Forests that a combination of helicopter and conventional systems meet the "least cost test" and that timber was not being "isolated" as a result of helicopter logging.

a saw attachment completed bucking and loading activities in 21 shifts, averaging 351 m^3/10.5-h shift.

FERIC estimated the total cost of falling, helicopter yarding, and loading at \$75.33/m^3. Falling accounted for \$21.67/m^3 or 29% of the total harvesting cost. Long walks in and out of falling sites, falling difficulties experienced due to heavy tree lean and high rot content, and lack of falling experience with retention prescriptions reduced productivity and increased cost compared to falling in other coastal helicopter logging operations.

Loading accounted for \$4.69/m^3 or 6% of the total harvesting cost. In general, landings were large enough to permit continuous loading without having a large impact on yarding productivity. However, employing only one loader when more than one landing was active created congestion at landings operating without the loader.

Helicopter yarding accounted for \$48.97/m^3 or 65% of the harvesting cost with the cost of the logging helicopter alone at \$32.52/m^3 or 43%. Yarding productivity and cost were primarily affected by cull factor, flight path slopes, harvesting prescription, and the use of one log loader. Because of these factors, yarding productivity was considered "below average" during this study. FERIC estimated that the average helicopter yarding productivity should have been 10–25% higher than observed in this study.

Detailed timing was carried out on 9.5% of the total flight time. On average, yarding cycles were 63.4 minutes long. The average turn was 1.8 minutes long, with 2.6 logs/turn at a yarding distance of 176 m.

The use of a helicopter to harvest a portion of the study site that was initially designed for conventional harvesting systems resulted in changes that had the potential to affect several important cost categories. An analysis of prime costs was performed to evaluate the financial consequences of these changes. In the final analysis, the use of a combination of conventional and helicopter yarding systems enabled Mill & Timber to harvest 5 200 m^3 of incremental volume and reduce the overall harvesting cost by blending the relatively high cost of helicopter yarding with the lower costs of the conventional systems.

Implementation

The results of this study reflect some of the operational challenges associated with light-lift retention helicopter logging. The following recommendations should improve the efficiency of proposed helicopter yarding operations:

- Consider the effects of stand and log quality on helicopter yarding productivity. Cull factor was identified as the greatest influence on yarding productivity. FERIC estimated that the cull factor of yarded logs was close to 30%, which is more than triple the commonly accepted range for typical coastal mixed species stands. However, in stands such as observed in this study, higher than average cull factor is to be expected. High cull factor was primarily a reflection of higher than average amounts of unavoidable decay, waste, and breakage within felled and bucked logs which made it difficult to gauge wood quality prior to manufacturing, large amounts of in-block slash, and yarding crew inexperience with coastal tree species and log grades. Identifying stands with a potential to produce high cull factor is important for both the licensee and helicopter logging contractor to accurately estimate net volume and helicopter productivity. This can be particularly significant for a helicopter logging contractor because most contractors in British Columbia are paid according to the project's net scale volume rather than total weight flown.
- Consider the effect of flight path slope on yarding productivity. The slope of the flight path to the landings varied from 0 to 15% during the detailed-timing period. Because of the retention harvesting prescription, the Bell 214B had to dead-lift turns above the stand's

canopy before beginning forward flight. A helicopter requires more torque for dead-lifting compared to a controlled descent when adequate cutblock to landing deflection is available. Therefore, the added torque requirement on the Bell 214B required payloads to be reduced. Dead-lifting also increased the fly loaded time because forward momentum had to be gained without the assistance of gravity, and this reduced the helicopter's initial acceleration. According to Transwest, flight path slopes are one of the most important factors affecting yarding productivity. Many helicopter logging operators like to operate on flight path slopes of between 20 and 35%.

- Consider the effects of harvesting prescription on falling and yarding productivity. Single-tree selection conditions often made it difficult for the helicopter to achieve target payloads because logs were widely distributed and had to be yarded individually to minimize tree damage and maintain reasonable turn times.
- Ensure the equipment complement is adequate to handle the volume being yarded and the number of active landings. The loader was able to handle the daily volume when only one landing was active. However, when additional landings became active, congestion at landings operating without the loader created choker retrieval problems, and increased unhook times and safety concerns for the landing crew.
- Consider organizational factors that may affect yarding shift length. An additional 1.5 to 2.0 hours of daylight per yarding shift may have been realized if the yarding crew had not been tied to a camp dinner schedule. As a general rule, helicopter logging crews work from sunrise to sundown to maximize flight hours per shift.

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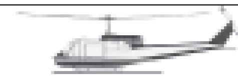
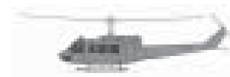
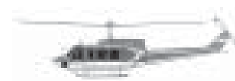
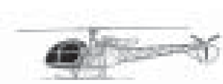
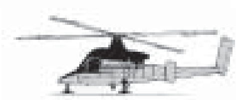
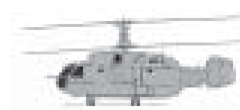
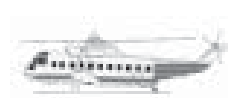
Appendix I

Specifications for helicopters commonly used for logging in B.C. [a]

Manufacturer	Model	Rated payload capacity (kg)	Engines (no.)	Engine power [b] (kW)	Diameter main rotor (m)	Diameter tail rotor (m)	Diagram
Bell	204B	1814	1	820	14.6	2.6	
Bell	205A	2268	1	1044	14.6	2.6	
Bell	212	2268	2	671 (each)	14.7	2.6	
Bell	**214B**	**3636**	**1**	**2185**	**15.2**	**2.6**	
Boeing	V-107 II	4773	2	932 (each)	15.5	n/a	
Boeing	CH-234LR	12727	2	3039 (each)	18.3	n/a	
Sikorsky [c]	S-64E	9072	2	3356 (each)	22	5	
Sikorsky [c]	S-64F	11340	2	3579 (each)	22	5	
Eurocopter	SA-315B Lama	1134	1	640	11.0	1.9	
Kaman	K-1200	2722	1	1342	14.7 (×2)	n/a	
Kamov	KA-32A	5000	2	1645 (each)	15.9 (×2)	n/a	
Sikorsky	S-58T	2268	2	700 (each)	17.1	2.9	
Sikorsky	S-61N	3629	2	1044 (each)	18.9	3.2	
Sikorsky	S-61N Shortski	4084	2	1044 (each)	18.9	3.2	

[a] Helicopter capabilities will vary with flight conditions and installed options.
[b] Engine power at takeoff.
[c] Now manufactured by Erickson Air-Crane Inc.

Appendix II

Helicopter costs [a] ($/flight-hour)

	Bell 214B
OWNERSHIP COSTS	
Total purchase price (P) $	2 800 000
Expected life (Y) y	10
Expected life (H) h	24 910
Scheduled hours/year (h) = (H/Y) h	2 491
Net flight-hours/year (fh) h	1 892
Salvage value as % of P (s) %	40
Interest rate (Int) %	9
Insurance rate (Ins) %	12
Salvage value (S) = ((P•s)/100) $	1 120 000
Average investment (AVI) = ((P+S)/2) $	1 960 000
Loss in resale value ((P-S)/(fh•Y)) $/flight-hour	88.79
Interest ((Int•AVI)/fh)/100 $/flight-hour	93.23
Insurance ((Ins•AVI)/fh)/100 $/flight-hour	124.31
Total ownership costs (OW) $/flight-hour	306.34
OPERATING COSTS	
No. of pilots required for the operation (pil)	2.5
Annual pilot base salary (PS) $/y	40 000
Annual flight hours/pilot (pilh) h/y	757
Pilot flight-hour rate (pil$) $/h	80
Annual pilot flight pay (PF) = (pilh•pil$) $/y	60 560
Wage benefit loading (WB) %	45
No. of co-pilots required for the operation (copil)	2.5
Annual co-pilot base salary (coPS) $/y	13 000
Annual flight hours/co-pilot (copilh) h/y	757
Co-pilot flight-hour rate (copil$) $/h	27.00
Annual co-pilot flight pay (coPF) = (copilh•copil$) $/y	29 644
No. of engineers (eng)	2.5
Engineer salary (ES) $/y	75 000
Fuel consumption (F) L/flight-hour	606
Fuel (fc) [b] $/L	0.85
Oil as % of fuel (fp) %	1.5
Annual parts inventory (Inv) = % of P	2.5
Wages for the operation, including fringe benefits	
Pilot (((PS•pil)+(pil$•pilh•pil)/fh)•(1+(WB/100))) $/flight-hour	192.67
Engineer ((ES•(1+WB/100))•eng)/fh $/flight-hour	143.70
Co-pilot (((coPS•copil)+(copil$•copilh•copil)/fh)•(1+WB/100)) $/flight-hour	64.07
Total wages (W) $/flight-hour	400.44
Fuel (F•fc) $/flight-hour	515.10
Oil ((fp/100)•(F•fc)) $/flight-hour	7.73
Maintenance $/flight-hour	558.00
Parts inventory ((Inv/100)•(P/fh)) $/flight-hour	37.00
Helicopter registration fees $/flight-hour	1.42
Total operating costs (OP) $/flight-hour	1 519.68
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) $/flight-hour	1 826.02

[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] Includes cost of barging fuel to remote location.

Appendix III

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

	Hydraulic log loader 31-tonne class
OWNERSHIP COSTS	
Total purchase price (P) $	500 000
Expected life (Y) y	10
Expected life (H) h	14 400
Scheduled hours/year (h)=(H/Y) smh	1 440
Salvage value as % of P (s) %	30
Interest rate (Int) %	9
Insurance rate (Ins) %	3
Salvage value (S)=(P•s/100) $	150 000
Average investment (AVI)=((P+S)/2) $	325 000
Loss in resale value ((P-S)/H) $/h	24.31
Interest (((Int/100)•AVI)/h) $/h	20.31
Insurance (((Ins/100)•AVI)/h) $/h	6.77
Total ownership costs (OW) $/h	51.39
OPERATING COSTS	
Fuel consumption (F) L/h	25
Fuel (fc) $/L	0.40
Lube and oil as % of fuel (fp) %	15
Annual repair & maintenance (Rp) $	37 500
Fuel (F•fc) $/h	10.00
Lube and oil ((fp/100)•(F•fc)) $/h	1.50
Repair and maintenance (Rp/h) $/h	26.04
Total operating costs (OP) $/h	37.54
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) [a] $/h	88.93

[a] These costs are estimated using FERIC's standard costing methodology for determining machine ownership and operating costs for new machines. The costs shown here do not include supervision, profit or overhead, and are not the actual costs for the contractor or the company studied.

Appendix IV

Weight-to-volume conversion factors used by helicopter logging contractors in coastal B.C.

Species	Range	Average
Western hemlock	2 000–2 200 lb./m^3 (910–1 000) kg/m^3)	2 100 lb./m^3 (950 kg/m^3)
Western red cedar	1 450–1 550 lb./m^3 (660–700 kg/m^3)	1 500 lb./m^3 (680 kg/m^3)
Douglas-fir	1 750–2 000 lb./m^3 (790–910 kg/m^3)	1 900 lb./m^3 (860 kg/m^3)
Amabilis/grand fir	1 750–1 850 lb./m^3 (790–840 kg/m^3)	1 800 lb./m^3 (820 kg/m^3)
Sitka spruce	1 600–1 700 lb./m^3 (730–770 kg/m^3)	1 650 lb./m^3 (750 kg/m^3)
Yellow cedar	1 700–1 800 lb./m^3 (770–820 kg/m^3)	1 750 lb./m^3 (790 kg/m^3)