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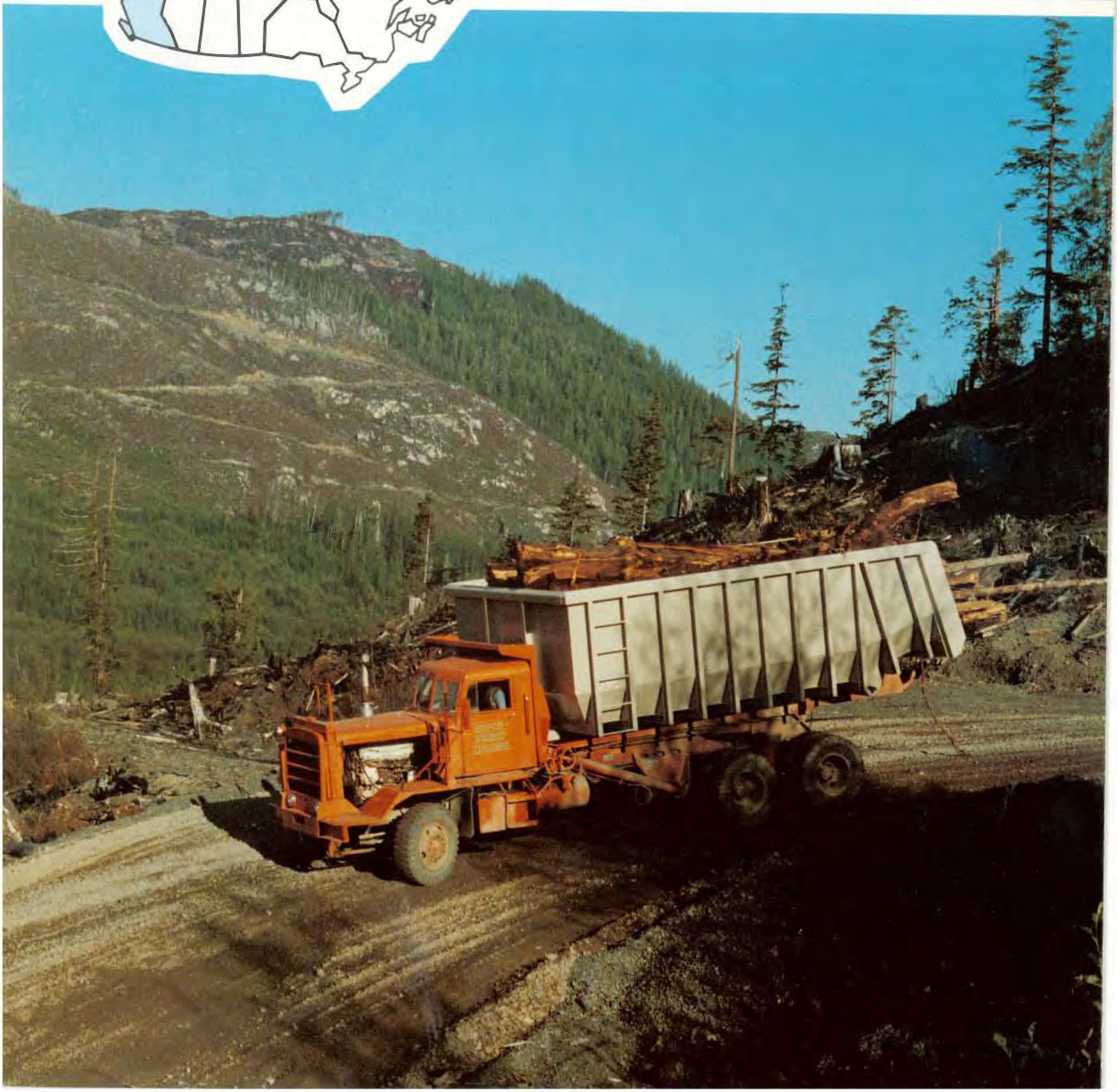
Information Report BC-X-274
Pacific Forestry Centre

FERIC Special Report No. SR-27



# Development and testing of a container system for the recovery of roadside biomass in mountainous terrain

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# Foreword

ENFOR is the acronym for the Canadian Government's ENergy from the FORest program of research and development aimed at securing the knowledge and technical competence to facilitate in the medium to long term a greatly increased contribution from forest biomass to our nation's primary energy production. This program is part of a much larger federal government initiative to promote the development and use of renewable energy as a means of reducing dependence on petroleum and other non-renewable energy resources.

The Canadian Forestry Service (CFS) administers the ENFOR Biomass Production program component which deals with such forest-oriented subjects as inventory, harvesting technology, silviculture and environmental impacts. (The other component, Biomass Conversion, deals with the technology of converting biomass to energy or fuels, and is administered by the Renewable Energy Branch of the Department of Energy, Mines and Resources.) Most Biomass Production projects, although developed by CFS scientists in the light of ENFOR program objectives, are carried out under contract by forestry consultants and research specialists. Contractors are selected in accordance with science procurement tendering procedures of the Department of Supply and Services. For further information on the ENFOR Biomass Production program, contact:

ENFOR Secretariat
Canadian Forestry Service
Ottawa, Ontario
K1A 1G5

This report is based on ENFOR project P-317 which was carried out under contract (DSS File No. 08SB.KH603-4-0032) by the Forest Engineering Research Institute of Canada, Vancouver, B.C. The Scientific Authority for the contract was G.H. Manning, Pacific Forest Research Centre, 506 W. Burnside Road, Victoria, B.C. V8Z 1M5.

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Energy ENFOR from the Forest

Canadian Forestry Service, Pacific Forestry Centre

## Abstract

Field tests were conducted to determine the cost and productivity of a preproduction prototype model of a container system used to recover roadside biomass in mountainous terrain. The system recovered 82 $m^3$ of biomass per eight-hour shift. Load size averaged 20.5 $m^3$ with a cycle time of 1.99 hours. From the tests it is conservatively estimated that the recovery cost will be \$8.32/$m^3$. With a production model of the container system fully integrated into the logging process it may be possible to achieve costs of \$4.55/$m^3$. The cost of the conventional system (logging truck and choker skidder) used to recover roadside biomass is \$15.51/$m^3$.

## Résumé

On a effectué des essais sur le terrain afin de déterminer le coût et la productivité d'un prototype d'un système à container pour la récupération de la biomasse le long des routes en terrain montagneux. Le système a permis de récupérer 82 $m^3$ par quart de huit heures. La charge moyenne était de 20,5 $m^3$ et la durée totale du cycle de 1,99 heure. À partir des tests, on peut établir, selon une estimation prudente, le coût de récupération à 8,32 \$ par mètre cube. Avec un modèle de série de système à container entièrement intégré au processus d'exploitation, il serait possible d'abaisser le coût à 4,55 \$ par mètre cube. Le coût du système traditionnel (camion et débardeur à câble) utilisé pour la récupération de la biomasse le long des routes est de 15,51 \$ par mètre cube.

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# Executive summary

Field trials were conducted with a preproduction prototype model of a container system to recover roadside biomass in the mountainous terrain of the west coast of Vancouver Island. The objectives of the project were as follows:

1. to design, manufacture and test a preproduction prototype model of a roadside biomass recovery system based on the container concept;
2. to document the costs and productivity of recovering and transporting biomass with the container system when operating concurrently with active logging; and
3. to document the amount and type of roadside biomass recovered with this system.

A summary of the results of the field trials is given in Table S1.

The results compare favorably with the conventional system of a self-loading logging truck and choker skidder normally used to recover roadside biomass. Earlier studies under ENFOR contract P-251 showed a recovery cost of $15.51/m^3$ for the conventional system. The container system did not interfere with active logging in any significant way and, in fact, observations indicate that use of the system could lead to productivity and safety benefits.

Table S1. Summary of Field Results

| Item | |
|---|---|
| Number of Test Days | 19 |
| Number of Loads | 61 |
| Volume of Biomass Recovered ($m^3$) | 1249 |
| Size of Load ($m^3$) | 20.5 |
| Piece Size of Biomass ($m^3$/piece) | 0.54 |
| Time per Load (Hours) | 1.99 |
| Production/8-Hour Shift ($m^3$) | 82.0 |
| Cost/$m^3$ Recovered | $8.32 |

Figure 1. Container System Used in 1983 Field Trials.

# Introduction

With cable logging systems, roadside biomass accumulates when lower grade material is included with the turn of logs and from log breakage during unhooking and piling of the logs at roadside. In addition, merchantable logs that are too short or small in diameter to load on the conventional logging trucks during prime logging are left at roadside.

In 1983, the Forest Engineering Research Institute of Canada (FERIC) under ENFOR Project P-251, carried out field studies to determine the cost and productivity of recovering this roadside biomass. The conventional system for recovering this material (a skidder and self-loading logging truck) as well as three new systems (a highboy trailer with four bunks, a demolition trailer, and a container system) were studied. The results of the study were reported in Canadian Forestry Service Information Report BC-X-254 (FERIC Special Report SR-22)[1] and are presented here in summary form (Table 1).

[1] Sinclair, A.W.J. 1984. Recovery and transport of forest biomass in mountainous terrain. Can. For. Serv. Information Report BC-X-254.

Based on the cost results, field observations and operator comments, it was felt that further development of the container system had the greatest potential for recovering roadside biomass at a reasonable cost. The features of servicing several landings with one truck, the quick pick-up and drop-off time for the containers, the ability to load the container for a longer period of time and the reduced interdependence on active logging were considered the main benefits of the container system.

In 1984, FERIC was awarded ENFOR Contract P-317 by the Canadian Forestry Service to design and test an improved container system. The contract's title was "Development and Testing of Special Equipment for the Recovery of Roadside Biomass in Mountainous Terrain." The major objectives of the contract were as follows:

1. to design, manufacture and test a preproduction prototype model of a roadside biomass recovery system based on the container concept;

2. to document the costs and productivity of recovering and transporting biomass with the container system when operating concurrently with active logging; and

3. to document the amount and type of roadside biomass recovered with this system.

This report describes the work done under the contract.

## Design of the container system

The results of the 1983 field trials (ENFOR Contract P-251) were used when setting the design parameters for the new container system. In these trials the container system (Fig. 1) had the lowest cycle time and delay time of the three systems that recovered roadside biomass concurrent with active logging but it also had the lowest load size (Table 2). This offset the operational advantages of the container system and resulted in a recovery cost that was higher than for the other two systems. The presence of a tailgate on containers was the main cause of the lower load size as it blocked the loader operator's view of the inside of the container and he was unable to load efficiently. The tailgate also prevented log overhang which increases the effective load size of the container. The conclusion was that containers used on an operation to recover waste wood should not have tailgates. Another method to increase load size would be to increase the size of the container and the carrying capacity of the truck. The system used in the 1983 field trials was designed to meet public highway legal requirements but these requirements do not have to be met in an off-highway application. The system could be significantly wider, higher and heavier than allowed on public highways. Design parameters for the new system were based on these results and conclusions.

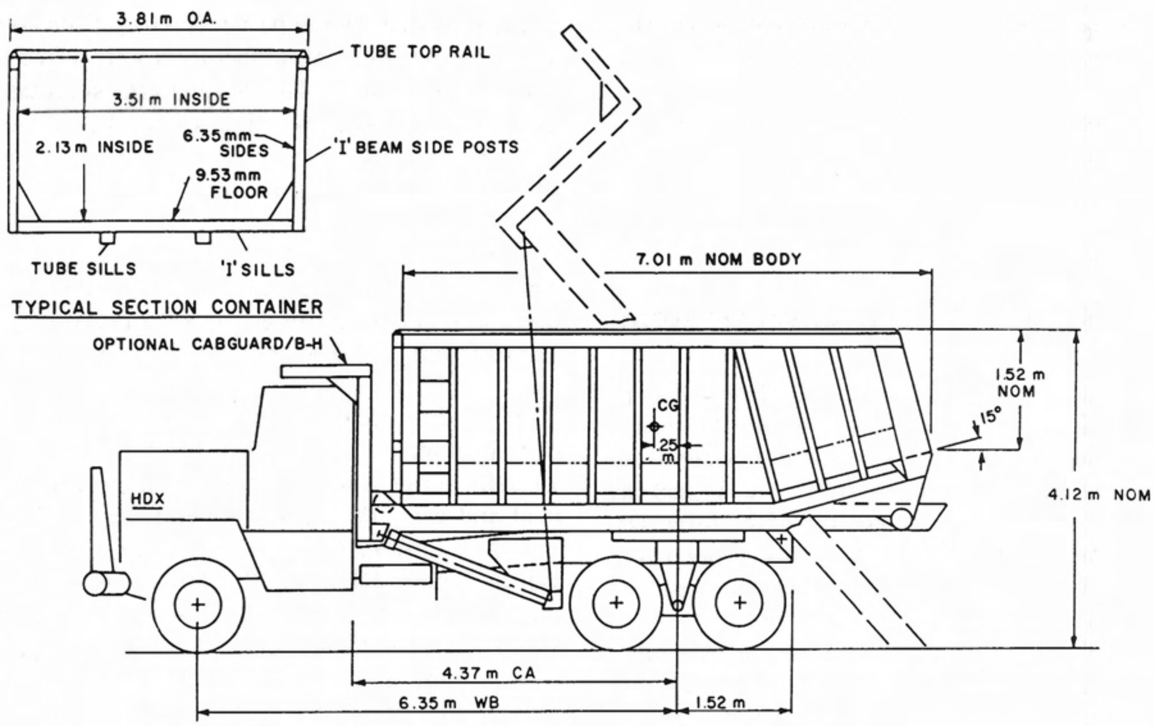
Calculations were carried out to determine the volumetric container capacity needed to carry 20 $m^3$ of biomass. It was estimated that approximately 50 $m^3$ of volumetric capacity was required. This, along with the width of other vehicles using the logging roads, minimum height of bridges, the size of the truck available and the effective loading height of the log loader, resulted in container design dimensions of 2.13 m inside height, 3.81 m outside width (3.51 m inside width) and 7.01 m length. The floor plates were specified as 9.5 mm thick and the side plates as 6.4 mm thick. It was also estimated that a 36 tonne capacity tilt and load system would be needed to get the container on the truck. Manufacturers were asked to quote on the system. The design of the successful manufacturer, Reliance Truck and Equipment Ltd., is given in Figure 2. Three containers and the roll-on/roll-off system were built.

An off-highway size truck was needed to load and carry the containers on the steep, mountainous roads. A current series truck with power-shift transmission, 375-kW engine and 54 900-kg rear ends would have been ideal. This could not be justified in a project with only a six-week field trial. Fortunately, B.C. Forest Products Ltd., had an older series truck that had enough capacity to load and carry the containers and that could be rented at a minimal charge. The truck was a 1954 Hayes Model HDX 30-80 with a Spicer 8241 manual transmission, a 260-kW Cummins engine and 20 900-kg rear ends. After minor repairs and a tune-up it was fitted with the roll-on/roll-off system and used to transport the containers (Fig. 3).

## Field trial method

### Field trial diary

Fabrication of the three containers and installation of the roll-on/roll-off system was completed in July 1984. The tractor and three containers were transported to Franklin River Division of MacMillan Bloedel Ltd. for shakedown trials. During these trials the container system worked well but some mechanical shortcomings were identified with the truck. The truck was moved to B.C. Forest Products' shop at Caycuse Division for repairs and overhaul. An unforeseen shutdown of the Caycuse Division prevented this work from being completed until early October at which time the truck was returned to Franklin River Division. Field trials commenced on October 11, 1984. The truck and container system worked well. Containers loaded to capacity could be pulled on, dropped off or emptied very effectively (Fig. 4). However, changes in Franklin River Division's logging plans resulted in only two yarders operating in the area of the field trials. This caused excessive delay time for the container system because not enough low grade biomass was being generated. It was decided to postpone the field trials until January at which




| | | | |
|---|---|---|---|
| 8100 kg | TARE WT. TRUCK & TILT FRAME | 16 200 kg | 8 100 kg |
| 288 kg | BODY WT. ESTIMATED | 7 200 kg | 6 912 kg |
| 8388 kg | TARE WT. (NO PAYLOAD) | 23 400 kg | 15 012 kg |
| 1080 kg | PAYLOAD (27.3 TONNES) | 27 000 kg | 25 920 kg |
| 9468 kg | | | 40 932 kg |

NOTE – ALL WEIGHTS ARE ESTIMATED AND MAY VARY

Figure 2. Design of New Container System.

time six yarders would be operating in the area. Field trials recommenced on January 23, 1985 and finished on March 2, 1985, covering 19 operating days. During this period, the trials were shut down twice because of severe snow and ice conditions.

**Field trial method**

The field trials were held in the Sarita area of the Franklin River Division (Fig. 5). Biomass was recovered from three separate logging areas. Area A had a steep, switchback access road (Fig. 6) and the three yarders logging in the area were operating at an elevation of about 1000 m. Area B was in a flat area with a yarder and grapple crane operating. Area C was in relatively steep country with two yarders and two grapple cranes working (Fig. 7).

The containers were placed in the landings or loaded while on the truck, depending on the size of the landing and the traffic congestion. When a container was full it was transported to an abandoned sortyard (Sarita Dump in Figure 5). One way transport distance varied from 9.5 to 20.5 km depending on the recovery area. The biomass was then dumped, spread out and scaled to determine the volume recovered and the distribution of species and log sizes. After scaling, some of the biomass was sorted into sawlog or pulp log grades, bundled and dumped in the water for shipment to the mills. Detailed timing records were kept on the truck's duty cycle to determine productivity, causes of delays, etc.

Figure 3. 1954 Model HDX 30-80 Hayes.

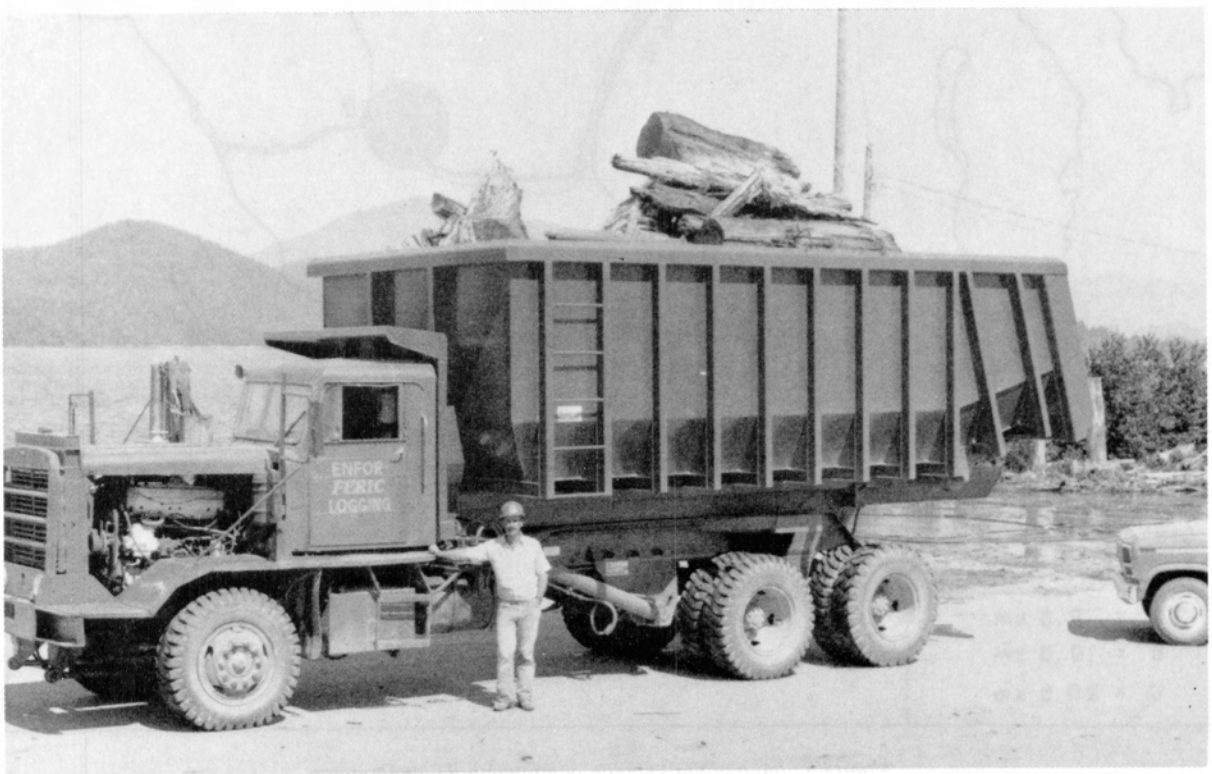



Figure 4. Loaded Container System.

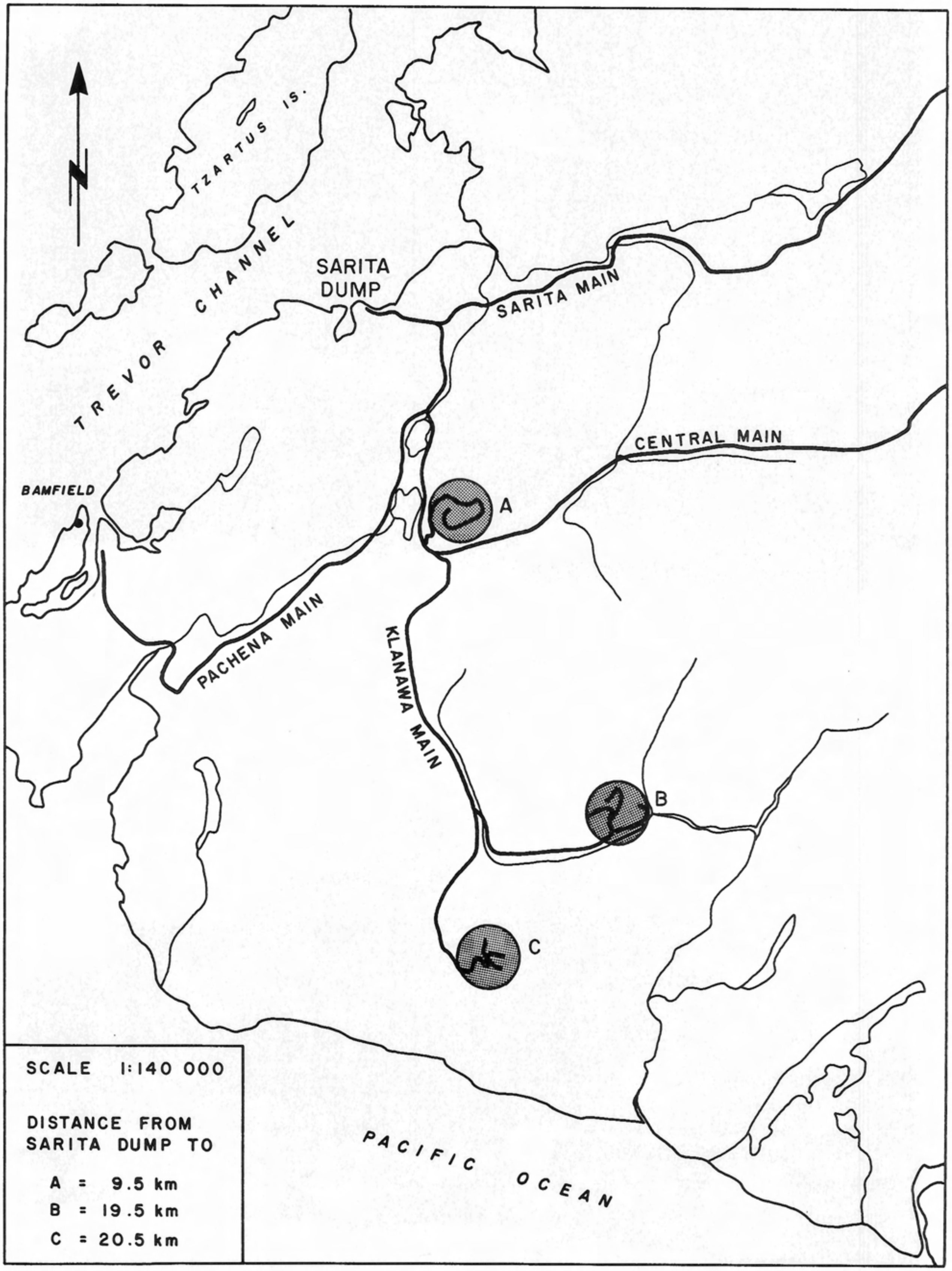



Figure 5. Map of Sarita Area — Franklin River Division.

Figure 6. Area A Terrain.

Figure 7. Area C Terrain.

Figure 8. Direct Loading of a Container.

## Field trial results and discussion

### Productivity results

The results of the detailed timing records are given in Table 3. Delays for fueling, waste disposal and snow were removed from the timing results because they would not be of much significance on a yearly, operating basis.

It took about two hours cycle time to recover a load of biomass (Table 3). For a variety of reasons the effective operating day during the field trials was only about six hours. Under normal production conditions the effective operating day would be eight hours. With a two-hour duty cycle the system should be able to recover four loads of biomass per day.

The container system normally caused minimal interference with active logging. However, in some cases the landings were too small to allow the container to be dropped on the ground for loading without interfering with production. To minimize interference in such circumstances, the loader operator would radio for the container when enough material had accumulated and it would be loaded directly into the container while still on the truck (Fig. 8). It is estimated that if another $500 per landing had been spent on enlarging small landings, then adequate space would have been available for the containers, and the proportion of "Containers Loaded While on Ground" to "Containers Loaded While on Truck" would have increased.

Two benefits of biomass recovery not noted in the earlier ENFOR project were observed in these field trials. Firstly, there was considerably less buildup of low grade material in the landing and along the roadside bank. This made for more efficient, safer loading and yarding functions. Secondly, shorter, smaller merchantable logs were loaded into the container as well as the non-merchantable grades that the container system was originally intended to recover. This increased the effective load size on the prime logging trucks carrying the merchantable logs and has the potential to reduce the truck loading time and log sorting time in the log sortyard.

The container system worked as well with the grapple cranes as with the yarding towers. Originally, the container system had been designed for use with yarding towers which use landings for decking the logs (Fig. 9). However, since the project was first proposed, many companies have begun replacing the towers with yarding cranes (Fig. 10). These cranes do not use landings for decking logs but windrow them on the roadside as they move along the road. A loader then moves down the road and loads the logs on logging trucks. It was thought that the container system would interfere with this logging system but this was not the case. The container could be loaded when a prime logging truck was not being loaded. This required more effort in scheduling and dispatching the container truck and the container had to remain on the truck rather than on the ground but the system did not affect the yarding crane/loader productivity.

**Recovery volumes**

Every load of recovered biomass was scaled to determine volume, number of pieces, and species mixture. Summary results are given in Tables 4 and 5. More detailed results are given in the Appendix.

Inspection of Tables 4 and 5 shows that most of the biomass, both in terms of number of pieces and volume of pieces, is in larger-diameter, longer logs. The predominant size is 4.8 to 7.1 m in length and greater than 40 cm in butt diameter. As with earlier studies, while logs are recovered over a variety of size classes, the volume is concentrated in larger-diameter, longer logs. This means that many pieces contribute little to the volume of material recovered but add to the cost of recovery.

The piece size recovered increased in these trials relative to the biomass field trials in 1983. In the earlier trials, the piece size for the container system was 0.34 $m^3$ per piece where as in these trials it was 0.54 $m^3$ per piece. The main reason for this was using containers that allowed logs to overhang beyond the end of the container.

During the field trials, 61 loads of biomass (Table 3) were recovered. This converts to a load average of 20.5 $m^3$ per load. The design specifications for the trial were 20 $m^3$ per load. Use of a more current series truck with greater load carrying capacity and wheelbase would have permitted larger loads. On an operational basis, loads of 20 $m^3$ should be easily achievable.

Figure 9. Yarding Tower and Landing.

Figure 10. Yarding Crane.

**Productivity and cost estimate**

Field trial results indicate that the container system should be able to recover a minimum of 82 m³ of biomass per shift. Use of a current series truck and a system that is integrated into the production system may recover 125 to 150 m³ per shift. However, for the purposes of this estimate, 82 m³ per shift is used as a productivity estimate.

A cost estimate cannot be based on the truck used in these field trials because it was obsolete. However, if a current series truck was purchased and modified to use the container system then the capital cost of the system would be the same as a current series, off-highway logging truck ($450 000). At present the B.C. Ministry of Forests allows $85.29/hour for these logging trucks when calculating stumpage cost allowances, and logging companies pay the same amount when hiring owner-operators. Therefore, a cost of $85.29/hour is allowed for a container system.

The cost estimate is:

Cost per shift = 8 hours × $85.29/hour
= $682.32

Volume per shift = 82 m³
Cost per m³ = $682.32 / 82
= $8.32/m³

If the system could reach the optimistic estimate of 150 m³ per shift then recovery costs would be reduced to $4.55 per m³. However, this production level could not be reached during field trials and is not used in the estimate.

The productivity and costs of the container system compare favorably with the conventional system tested in 1983 under ENFOR project P-251 (Table 6). With the container system, biomass can be recovered for almost half the cost of the conventional system.

At an hourly charge-out rate of $85.29/hour an owner-operator would make a reasonable return on his investment in the container system.

Obviously, the container system which operates concurrent with active logging interferes more with logging production than the conventional system which recovers biomass after active logging has ceased. However, field trials indicated that the interference is minimal and could result in logging productivity gains and costs reductions. In addition, the container system can reduce the costs of recovery of lower grade logs by 46%.

## Conclusion

A preproduction prototype model of a roadside biomass recovery system based on the container concept was designed, manufactured and field tested. A current, off-highway size truck would improve the performance and carrying capacity of the system tested which used an obsolete truck.

The container system recovered 82 $m^3$ of biomass per shift at a cost of \$8.32/$m^3$. This compared favorably with the cost of the conventional system of a self-loading logging truck and choker skidder used to recover low grade biomass (\$15.51/$m^3$). The cost of a production model of the container system could approach \$4.55/$m^3$ if the system was fully integrated with the logging operation and used a current series truck.

The container system recovered 2302 pieces or about 1250 $m^3$ of biomass in 19 days of field trials. Loads averaged 20.5 $m^3$. The volume of biomass was concentrated in the 4.8 to 7.1-m length class and the greater-than-40-cm diameter class. However, the number of pieces of biomass were more uniformly distributed than the volume per piece of biomass.

# Appendix

Table 1. System Productivities and Costs — Summary

| Item | Conventional | Integrated Systems | | |
|---|---|---|---|---|
| | Self-loading | Four-bunk Trailer Truck | Demolition Trailer | Containers |
| Number of Test Days | 9 | 9 | 2 | 8 |
| Number of Loads | 36 | 26 | 7 | 39 |
| % Delay Time | 2 | 26 | 24 | 20 |
| Size of Load ($m^3$) | 20.3 | 21.8 | 15.9 | 10.9 |
| Volume Recovered ($m^3$) | 730.07 | 565.77 | 111.07 | 425.01 |
| Piece Size ($m^3$/piece) | 0.43 | 0.68 | 0.69 | 0.34 |
| Time per Load (Hours) | 2.04 | 2.61 | 2.03 | 1.52 |
| Production/8-Hour Shift ($m^3$) | 79.8 | 66.6 | 61.7 | 57.2 |
| Cost/$m^3$ Recovered | $15.51 | $9.19 | $9.24 | $9.62 |

[1] Sinclair, A.W.J. 1984. Recovery and transport of forest biomass in mountainous terrain. Can. For. Serv. Information Report BC-X-254.

Table 2. Comparison of Recovery Systems Used Concurrently with Active Logging

| Item | System | | |
|---|---|---|---|
| | Four-bunk Trailer | Demolition Trailer | Container |
| % Delay Time | 26 | 24 | 20 |
| Time per Load | 2.61 | 2.03 | 1.52 |
| Size of Load ($m^3$) | 21.8 | 15.9 | 10.9 |
| Piece Size ($m^3$/piece) | 0.68 | 0.69 | 0.34 |
| Cost/$m^3$ Recovered | $9.19 | $9.24 | $9.62 |

Table 3. Total Distribution of Time Expenditures

No. of Operating Days = 19
No. of Operating Hours = 121.1
Operating Hours/Day = 6.4
Containers Loaded while on Ground = 15
Containers Loaded while on Truck = 46
Total Loads Recovered = 61

| Time Element | Time (Hours) | Hours/ Load | % |
|---|---|---|---|
| Travel Empty | 43.3 | 0.71 | 36 |
| Recover Loaded Container | 1.9 | 0.03 | 2 |
| Load Container with Biomass | 15.6 | 0.26 | 13 |
| Travel Loaded | 35.3 | 0.58 | 29 |
| Unload Logs | 4.9 | 0.08 | 4 |
| Delay | 20.1 | 0.33 | 17 |
| Total | 121.1 | 1.99 | 100 |

| Type of Delay | No. of Events | Time (Hours) | % |
|---|---|---|---|
| Truck Down Mechanical | 11 | 8.25 | 41 |
| Wait for Log Loader | 11 | 6.75 | 34 |
| Wait for Logs | 9 | 5.08 | 25 |
| Total | 31 | 20.08 | 100 |

| Loading Analysis | Number | Total Time (Hours) | Time/Load (Hours) |
|---|---|---|---|
| Containers Loaded While on Truck | 46 | 15.6 | 0.34 |
| Containers Loaded While on Ground | 15 | 1.9 | 0.13 |
| Total | 61 | 17.5 | – |

Table 4. Amount of Material Recovered (pieces)

| Butt Diameter Class (cm) | | Length Class (m) 0-2.3 | 2.4-4.7 | 4.8-7.1 | 7.2+ | Total % | Pieces |
|---|---|---|---|---|---|---|---|
| 0-9 | | 4 | 7 | 1 | 0 | 1 | 12 |
| 10-19 | | 34 | 109 | 74 | 19 | 10 | 236 |
| 20-29 | | 24 | 207 | 282 | 126 | 28 | 639 |
| 30-39 | | 10 | 220 | 298 | 111 | 28 | 639 |
| 40+ | | 5 | 222 | 393 | 156 | 34 | 776 |
| Total | % | 3 | 33 | 46 | 18 | 100 | |
| | Pieces | 77 | 765 | 1048 | 412 | | 2302 |

Table 5. Volume of Material Recovered ($m^3$)

| Butt Diameter Class (cm) | | Length Class (m) 0-2.3 | 2.4-4.7 | 4.8-7.1 | 7.2+ | Total % | Volume |
|---|---|---|---|---|---|---|---|
| 0-9 | | 0.03 | 0.08 | 0.04 | 0.00 | 0 | 0.15 |
| 10-19 | | 0.72 | 6.02 | 6.18 | 2.03 | 1 | 14.95 |
| 20-29 | | 1.92 | 29.17 | 60.31 | 36.06 | 10 | 127.46 |
| 30-39 | | 1.52 | 64.55 | 127.78 | 59.62 | 20 | 253.47 |
| 40+ | | 1.69 | 175.12 | 414.62 | 261.05 | 68 | 852.48 |
| Total | % | 0 | 22 | 49 | 29 | 100 | |
| | Volume | 5.88 | 274.95 | 608.93 | 358.76 | | 1248.51 |

Table 6. Comparison of the Container System with the Conventional System

| Item | Conventional System | Container System |
|---|---|---|
| Size of Load ($m^3$) | 20.3 | 20.5 |
| Piece Size ($m^3$/piece) | 0.43 | 0.54 |
| Time per Load (Hours) | 2.04 | 1.99 |
| Production/8-Hour Shift ($m^3$) | 79.8 | 82.0 |
| Cost/$m^3$ Recovered | $15.51 | $8.32 |

Table A1. Length and Diameter Distribution of Pieces — Balsam

| Butt Diameter Class (cm) | | Length Class (m) | | | | Total | |
|---|---|---|---|---|---|---|---|
| | | 0.2.3 | 2.4-4.7 | 4.8-7.1 | 7.2+ | % | Pieces |
| 0-9 | | 1 | 3 | 0 | 0 | 1 | 4 |
| 10-19 | | 7 | 24 | 34 | 6 | 15 | 71 |
| 20-29 | | 7 | 50 | 80 | 22 | 33 | 159 |
| 30-39 | | 3 | 54 | 74 | 17 | 31 | 148 |
| 40+ | | 1 | 33 | 54 | 8 | 20 | 96 |
| Total | % | 4 | 34 | 51 | 11 | 100 | |
| | Pieces | 19 | 164 | 242 | 53 | | 478 |

Table A2. Length and Diameter Distribution of Volume ($m^3$) — Balsam

| Butt Diameter Class (cm) | | Length Class (m) | | | | Total | |
|---|---|---|---|---|---|---|---|
| | | 0.2.3 | 2.4-4.7 | 4.8-7.1 | 7.2+ | % | Volume ($m^3$) |
| 0-9 | | 0.01 | 0.04 | 0.00 | 0.00 | 0 | 0.05 |
| 10-19 | | 0.14 | 1.36 | 2.81 | 0.55 | 3 | 4.86 |
| 20-29 | | 0.57 | 7.03 | 17.14 | 5.59 | 18 | 30.33 |
| 30-39 | | 0.50 | 15.56 | 31.07 | 8.46 | 33 | 55.59 |
| 40+ | | 0.21 | 20.26 | 50.37 | 8.25 | 47 | 79.09 |
| Total | % | 1 | 26 | 60 | 13 | 100 | |
| | Volume | 1.43 | 44.25 | 101.39 | 22.85 | | 169.92 |

Table A3. Length and Diameter Distribution of pieces — Cedar

| Butt Diameter Class (cm) | | Length Class (m) | | | | Total | |
|---|---|---|---|---|---|---|---|
| | | 0.2.3 | 2.4-4.7 | 4.8-7.1 | 7.2+ | % | Pieces |
| 0-9 | | 1 | 2 | 0 | 0 | 0 | 3 |
| 10-19 | | 4 | 28 | 6 | 2 | 5 | 40 |
| 20-29 | | 4 | 36 | 53 | 26 | 16 | 119 |
| 30-39 | | 1 | 66 | 79 | 42 | 25 | 188 |
| 40+ | | 1 | 100 | 198 | 101 | 53 | 400 |
| Total | % | 1 | 31 | 45 | 23 | 100 | |
| | Pieces | 11 | 232 | 336 | 171 | | 750 |

Table A4. Length and Diameter Distribution of Volume ($m^3$) — Cedar

| Butt Diameter Class (cm) | | Length Class (m) | | | | Total | |
|---|---|---|---|---|---|---|---|
| | | 0.2.3 | 2.4-4.7 | 4.8-7.1 | 7.2+ | % | Volume ($m^3$) |
| 0-9 | | 0.00 | 0.02 | 0.00 | 0.00 | 0 | 0.02 |
| 10-19 | | 0.08 | 1.50 | 0.52 | 0.27 | 0 | 2.37 |
| 20-29 | | 0.26 | 4.99 | 12.14 | 7.25 | 4 | 24.64 |
| 30-39 | | 0.16 | 19.44 | 33.59 | 23.63 | 13 | 76.82 |
| 40+ | | 0.58 | 86.28 | 217.88 | 183.41 | 82 | 488.15 |
| Total | % | 0 | 19 | 45 | 36 | 100 | |
| | Volume | 1.08 | 112.23 | 264.13 | 214.56 | | 592.00 |

Table A5. Length and Diameter Distribution of Pieces — Hemlock

| Butt Diameter Class (cm) | | Length Class (m) | | | | Total | |
|---|---|---|---|---|---|---|---|
| | | 0.2.3 | 2.4-4.7 | 4.8-7.1 | 7.2+ | % | Pieces |
| 0-9 | | 2 | 2 | 1 | 0 | 0 | 5 |
| 10-19 | | 23 | 57 | 34 | 11 | 12 | 125 |
| 20-29 | | 13 | 121 | 149 | 78 | 34 | 361 |
| 30-39 | | 6 | 100 | 145 | 52 | 28 | 303 |
| 40+ | | 3 | 89 | 141 | 47 | 26 | 280 |
| Total | % | 4 | 34 | 44 | 18 | 100 | |
| | Pieces | 47 | 369 | 470 | 188 | | 1074 |

Table A6. Length and Diameter Distribution of Volume (m³) — Hemlock

| Butt Diameter Class (cm) | | Length Class (m) | | | | Total | |
|---|---|---|---|---|---|---|---|
| | | 0.2.3 | 2.4-4.7 | 4.8-7.1 | 7.2+ | % | Volume ($m^3$) |
| 0-9 | | 0.02 | 0.02 | 0.04 | 0.00 | 0 | 0.08 |
| 10-19 | | 0.50 | 3.16 | 2.85 | 1.21 | 2 | 7.72 |
| 20-29 | | 1.09 | 17.15 | 31.03 | 23.22 | 15 | 72.49 |
| 30-39 | | 0.86 | 29.55 | 63.12 | 27.53 | 25 | 121.06 |
| 40+ | | 0.90 | 68.58 | 146.37 | 69.39 | 59 | 285.24 |
| Total | % | 1 | 24 | 50 | 25 | 100 | |
| | Volume | 3.37 | 118.46 | 243.41 | 121.35 | | 486.59 |