PROBLEMS OF THINNING AND SMALL LOG HANDLING IN SECOND GROWTH WESTERN HEMLOCK STANDS with SPECIAL REFERENCE TO THE RESEARCH FOREST ON EAST THURLOW ISLAND

by

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ABSTRACT

Diminishing virgin timber on the Coast of British Columbia leads to consideration as to how management of the second-growth forests will supply the timber industry with a sufficient quantity of good quality raw material in the future.

One of the possibilities would be intensive forest management supported by thinnings. The stands of western hemlock (Tsuga heterophylla (Rafn.) Sarg.), which comprise the largest area on the Coast, may be suited to this treatment because of their advantageous silvicultural characteristics. Little information exists on proper methods of thinning these hemlock stands. In addition, experience in logging methods and means of economically handling small logs are lacking.

Among the few experiments which have been established to study thinning of hemlock, one is located on East Thurlow Island where nearly pure stands of hemlock occur. The Research Forest on the Island was scheduled to become an experimental and demonstration area for the study of thinning techniques. Studies under way on that area have shown that the methods used, had limited economic success. Commercial thinning operations turned out to be unprofitable partly because there was no adequate road system available for logging.

Thinning problems in general, as well as the particular aspect of thinning western hemlock and the methods of handling small logs are discussed in this thesis to illustrate the basic problems involved in a development plan for the Research Forest.

Finally, this thesis presents a general road development plan for the Research Forest area and proposes a preliminary management and logging plan. Through cost analysis it is shown that the basic access road system can be constructed economically during a preparatory period by clearcutting scattered overmature stands. Subsequent thinning experiments can be based on that road network.

The approach to these problems is general rather than specific because there are few detailed data available from past experiments.

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INTRODUCTION

The Continuous Forest Inventory of the B.C.F.S. (1958) and supplementary reports (1959) (1960) show that there will be a drastic decrease in the amount of mature stands available for logging. According to the inventory, the present exploitable volume of mature hemlock on the Coast is roughly 7.6 billion cubic feet. The average cut for the period from 1952 to 1956 is 0.25 billion cubic feet. This means that if the present annual cut continues at the same rate, in thirty years, around 1990, all mature hemlock forests will be liquidated.

On the same basis the situation is even worse in the case of Douglas fir (Pseudotsuga menziesii (Mirb.) Franco.), and western red cedar (Thuja plicata Donn.)(Table 1). According to these data after eight and thirteen years, respectively, there will be a heavy pressure on virgin hemlock forests, and the presently expected liquidation period for hemlock will be shortened to an average of 23 years. At that time, an area of 4.34 million acres will be covered by second growth hemlock stands ranging from 0 to about 80 years of age and representing a volume of 21.6 billion of cubic feet, as usable, sound wood volumes.

The data given in Table 1. are based on currently exploitable volume. As the presently inaccessible stands and timber on lower sites represent an important reservoir of wood, with improved logging methods, their timber might extend the above mentioned time limit considerably.

Table 1. Time to Liquidate Exploitable Mature Forests on Basis of Present Cut.

COAST

Species	Exploitable Mature Volume - cu. ft.[1]	Average Annual Cut - cu. ft.	Years to Liquidate
Fir	2,437,653,000	295,536,608	8
Red Cedar	3,007,803,000	218,136,861	13
Hemlock	7,590,903,000	254,916,889	29

[1] Currently exploitable volume. 12 inches plus, in accessible operable mature forests on productive sites of average or better growth capacity. (Continuous Forest Inventory of B. C. pp 127.)

The immense areas of young growth forests on the Pacific Coast Region of British Columbia will soon provide foresters in general, and loggers in particular, with many problems in connection with their most economical use. As the practice of forestry is getting more and more intensive, when the idea of multiple use forestry is widely discussed and generally accepted, the problem of thinning is possibly the next step in improving present forest management practices. When thinning becomes necessary there must be enough local knowledge about the best methods to use. The only way to get scientific information is by experiments.

There has been a great amount of research work done already on thinnings, mostly in Europe, where intensive forestry has been practiced for a long time. In British Columbia most studies have dealt with Douglas fir because this is the most valuable species on the Coast. However, the area of young hemlock exceeds that of Douglas fir and the proportion of hemlock is increasing and, therefore, more studies should be made in hemlock stands.

Although a great amount of practical knowledge is already accumulated on thinnings and some research programs are under way, in general, very little is known about the special problems of thinning hemlock. Sloan (1957) was correct in his statement that among the lessons taught by experience through the centuries one is, that every forest type has its own individuality. There is a need, therefore, for special thinning experiments in hemlock stands, and that these experiments should be carried out on areas which are the most representative. Through these experiments quite accurate rules could be developed for maintaining an adequate, healthy, growing stock. Thinning studies could answer in this period the questions of: (1) necessary stocking to provide a continuous stream of the product desired, (2) what would be the best and most economical method of thinning, (3) the optimum logging method to give the highest possible profit, (4) methods of logging to prevent excessive damage.

The British Columbia Forest Service has an area of 2,000 acres on East Thurlow Island which could be used as a research and demonstration forest where various studies in connection with pure hemlock stands could be carried out. The Island is representative of good sites for hemlock forests.

Preliminary studies have been made on the area but the difficulty of access made it practically impossible to organize large scale systematic research work.

Under present market conditions, even with adequate access roads, the economic justification of commercial thinnings on East Thurlow Island is questionable. The desirability of experiments, on the other hand, is unquestionable.

Experimentation in thinning may be strictly silvical, or include the aspects of economics as would be the case on the Island. Although the pre-commercial thinnings may be very worthwhile, the practical sequence of the experiments on the Coast must start with thinnings that produce merchantable products with a value at least equal to the cost of the extraction. As previous experiments showed, this is impossible on East Thurlow Island without a permanent road system. Thinning, with its low production per acre and low volume per unit logged, cannot in most cases support the costs of constructing such a road system.

With a management plan which keeps clear cutting and thinning in the right proportion, the necessary road system can be established on the research area. This combination would make commercial thinning studies economically justifiable.

The feasibility of thinning will depend on many other factors as well. It will be influenced by logging and transportation methods used, the minimum size of the logs removed and the market conditions.

One of the primary purposes of this thesis is to evaluate the economic possibility of erecting a permanent road system necessary to the research forest to fulfill its purpose, which is to serve to best advantage the needs of research and demonstration of sound forestry practices in the hemlock zone. In a preliminary management and logging plan the possibility of commercial thinning will be proposed.

It is anticipated that these experiments will bring positive results and will be of great value in producing factual data for the forest manager in the future to find the best ways to manage the immense areas of second growth hemlock stands on the Coast. If damage to the residual stand is great and if the value of products removed is low, the research will demonstrate the impractibility of thinnings under similar circumstances. This possible negative result will give scientific confirmation to present clear cut operations.

Because of existing difficulties, the British Columbia Forest Service Research Division does not plan to establish new thinning studies in the next decade. There is a need, however, to maintain at least those experiments which were previously established on East Thurlow Island.

DESCRIPTION AND HISTORY OF THE RESEARCH FOREST ON EAST THURLOW ISLAND

General Description

East Thurlow Island is one of the several islands in the Strait of Georgia between Vancouver Island and the Mainland. It is 40 miles North-East of Campbell River and is along the East side of the Inner Passage to Alaska, which is among the most beautiful shorelines in the world.

There are some small logging camps on the Island, one of which is near a store and gasoline station at Shoal Bay, formerly called Thurlow. This supply center is very close to the Research Forest and accomodates logging crews. The island has rocky ridges, with maximum elevation of 1500 feet, wide U-shaped valleys between the ridges and lakes and swamps in great number. Hemming Lake, centrally located, is the largest. There are several good booming grounds along the shore and the best is located in Bickley Bay adjoining the Research Forest.

The northern part of East Thurlow Island was allocated to the Research Division of the Forest Service of B. C. with the original objective of studying the empirical growth and yield of hemlock. The Research Forest is within the boundaries of the experimental reserve between Bickley Bay and Hemming Lake. It is three miles long with an average width of one mile, as shown on the attached map (Appendix 1.) The total area of the forest is close to 2,000 acres. The stand data and age distribution are given in Table 2.

The site index varies from 70 to 150 for hemlock, and on the average is 134. The present distribution of species is as follows:

By total volume:	H	80%	F	15%	Misc.	5%
By number of trees:	H	87%	F	7%	Misc.	6%

The reason for the relatively higher percentage volume of Douglas fir is that, in the scattered old growth stands, Douglas fir is predominant.

The climate is typical of the Coast. Its outstanding feature is the mildness and humidity of the winters for the latitude, and the heavy precipitation on the mountains. The average yearly rainfall is 60 inches, based on 34 years observations as reported by the B. C. Department of Agriculture in 1960. The same report gives 48° F° as the annual mean temperature. The monthly averages and the absolute maximum and minimum temperatures are given in Table 3. As logging is affected by rainy days, and the thinned stands by winds, the observed values for a six-month period during a commercial thinning operation in 1954 are shown:

Days with sunshine........................21%

Cloudy - without rain.....................36%

Continuous rain...........................18%

Showers	25%
	100%
Days with calm	87%
Mild winds	8%
Severe winds	5%
	100%

Topography of the Research Forest is described as rolling, with a wide U-shaped valley between Hemming Lake and Bickley Bay. The area toward Shoal Bay, on the east side of the Forest, forms a plateau on an elevation of 200 feet.

The logging is handicapped because there are no roads except a very eroded logging trail on the west side and two old paths leading from Bickley Bay toward Hemming Lake and Shoal Bay. Several small creeks and swampy places, together with heavy debris in many places, create difficulties in yarding and hauling. The flat terrain around Bickley Bay is suited for a logging camp; the Research Division has a modern cabin there at present.

The soil over most of the area is a deep glacial deposit, silty, clayey, and subject to erosion. There are few gravel deposits but several rock outcrops of granite.

The moderate terrain and deep soil combined with the moist climate provide good sites for Hemlock stands.

Merchantable products are sawlogs and pulpwood. The closest market for them is about 40 miles away at Duncan Bay, however, booms are also towed to more distant points such as Nanaimo and Powell River.

Table 2. Stand Characteristics of the Research Forest on East Thurlow Island

Forest Type	Area Acres	Area % of Total	Species	Average Age of Stand Years	Average Annual Merchantable* Increment cu.ft.	Merch.Volume per acre cu.ft.	Total Volume cu.ft.
Scattered Old Growth With Undergrowth	116	6.0	F(H.C.Sp) H	350-500 65	--- 110	12,320	1,432,996
Second Growth	1130	59.7	H(F.C.)	65	110	7,100	8,023,000
Second Growth	241	12.7	H(C.F.)	50	no data	5,450	1,313,450
Shrubs or areas of S.I. 70 or under	410	21.6	HFC	no data	no data	------	---------
TOTAL	1897	100 %	---	---	---	------	10,769,446

* Based on trees 9" d.b.h. and over, close utilization.

Table 3. Average Monthly and Annual Mean and Absolute Temperatures for Periods Shown for Inactive Weather Station in Thurlow.

Months	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Mean	Max. and Min. Temp. Absolute Max.	Max. and Min. Temp. Absolute Min.	Period of Records
Average Temperatures F.	28	34	39	45	53	60	62	61	56	46	41	36	47	93	-1	1947-50

The Research Forest was logged using bull teams prior to 1894. In 1896 a very hot fire burned over the entire area cleaning out all the residual stand except a very few scattered Douglas fir. The trees forming the dominant canopy were established the next year. A smaller area near Hemming Lake was reburned about 1912. The area was declared a Research Forest in the late twenties.

History of Past Experiments

Hemlock Growth and Yield Studies

To lay a foundation for future studies on the research forest, sixty-six subplots were laid out, and measured in 1930 by G. H. Barnes and J. C. H. Robertson. Fifty-eight plots were in 33-year-old stands and eight in 18-year-old stands. Each subplot was carefully located and marked on a detailed map, drawn to facilitate relocation. It was intended that these plots be remeasured at 10-year intervals.

The data obtained from the sample plots were used to elaborate the widely used yield tables of G. H. Barnes (1953). His site index curves based on average total height of dominant and codominant trees are based partly on Joergensen's (1949) study of site index curves for western hemlock who collected the necessary data on East Thurlow Island.

Thinning experiments

In the early fifties the original purpose of the research forest was extended to commercial thinning experiments in second growth hemlock stands.

The Research Division of the B. C. Forest Service carried out thinning experiments on young Douglas fir stands on the Cowichan Lake Experiment Station. Joergensen (1951) who was involved in setting up these experiments, soon recognized the desirability of extending thinning experiments to hemlock stands. Our responsibility in connection with these experiments is challeneged by his words:

"If it is all possible to visualize the pattern of forest management just a few decades from now, it can hardly be questioned that any lack of production data from thinned stands will be a very serious drawback. Further it can hardly be questioned that those suffering this disadvantage can rightfully blame us their predecessors, if we neglect to make preparations to meet a situation which is more than likely to occur."

With this intention a new series of experimental plots has been established. The basic conception of the method used was as Joergensen expressed "experiments should be done on a scale small enough to avoid any excessive risk by mistakes but large enough to make the experimental results significant for practical application".

The project, called Experiment 388, was established in 1953.

The object of the experiment was:

1. To study the effects of repeated thinnings of different intensities on the major stand and tree factors and to draw up practical thinning regimes with corresponding yield tables.

2. To determine the net value on the stump of the thinning material, with production costs specified. This might be extended to include calculations of financial yield and determination of rotation.

3. To demonstrate silvicultural techniques and logging methods most suited to pure hemlock stands.

Twenty sample plots were established, each 2 x 2 chains in size. With four replications, four different thinning intensities plus one unthinned control plot were allocated randomly.

The proposed experiment as a randomized block design was done according to the following schedule.

Control: basal area at its natural level.

Very light thinning (t_1): leaving 225 sq. ft. basal area per acre.

Light thinning (t_2): leaving 200 sq. ft. basal area per acre.

Medium thinning (t_3): leaving 175 sq. ft. basal area per acre.

Heavy thinning (t_4): leaving 150 sq. ft. basal area per acre.

It was anticipated that thinning and plot examinations would be carried on as long as useful information related to practical thinning regimes will continue to accumulate. It was expected that periodical analyses would indicate when conclusive results could be finalized.

The proposed technique was to cut only trees of poor stem form and crown development. The aim was at even spacing. For commercial evaluation it was intended to keep specific accounts of all expenses applicable to the complete operation from forest to mill, as well as man hours where possible.

The study was carried out under two timber sale contracts, one in 1953-54, the other in 1959-60.

Commercial thinning experiment 1953-54

In 1953-54 the Comox Logging and Railway Co. did the experiment under supervision of the staff of the Research Division of the Forest Service of British Columbia. To make the timber sale more attractive, clearcut and thinning were combined in the operation. The clearcut area was close to the booming ground, with an average yarding distance of 900 feet. The thinning was on the area of Experiment No. 388 with average hauling distance of 0.6 mile. Total area for sale was close to 100 acres.

The final result of the experiment showed that at that time with conventional cat-logging method neither a big crew (12 men in 1953) nor a small crew (3 men in 1954) could produce profit from thinnings.

The experiment showed however many interesting details which were of importance in planning future studies. These will be illustrated in some detail.

In 1953 the logging crew consisted of twelve men and a camp was established on the shore at Bickley Bay.

The main equipment which was used during the operation included one Caterpillar tractor, model D6 with arch, one Caterpillar tractor, model D4 with arch, two welding machines, two power saws, one boat and a variety of hand tools, blocks, spare parts, etc.

Description of the operation

The D6 tractor was used for road construction chunking out tractor trails, and yarding. D4 was used in yarding only. Logs were bunched before being hooked to the tractor main line. The tractor then skidded the load to the bundling platform, where after four or five turns the logs were strapped together and pushed into the booming ground.

In the second year, after the inefficiency of the large crew was obvious, the number of men was reduced to three, and the two tractors operated together only for a short period.

The trees were ninety feet high and had an average diameter of nine inches. There were 85 cords per acre and the average cut in thinnings was 21 cords per acre. The average log was 26 feet long and contained 9 cubic feet of wood.

One interesting item from the first year's operation is a comparison between production in clearcut and thinning operations. Average daily production from clearcut areas was 562 cubic feet per day, whereas in thinnings production was 473 cubic feet per day or 47 and 39 man-days respectively. Although the crew was not experienced in thinning, the production was higher than one would expect. But even the clear cut production was not high enough to make the operation feasible.

The cost of logging during the 1954 season ($30.68 per cord) was $10.08 per cord less than in 1953, nevertheless even this lower cost was still twice as much as the local market price for hemlock pulpwood.

The high cost of the first year's operation originated from the large crew, the initial high cost of camp establishment, the heavy machinery used, the lack of access roads, the small log size and the lack of experience in thinning operation.

The cost reduction in the second year was mainly due to the small crew and the reduced size of camp, but other high cost elements were still in effect. Because of the small size of logs the daily production fell to 387 cubic feet.

Borzuchowski (1955) of the Research Division collected data during the second operation and published a paper on it. He formed the opinion based on his time study, that a somewhat larger crew (5 men) using two tractors would be more economical. In his view a D6 tractor should not have been used in both bunching and yarding, but these phases should have been executed by two separate units.

Analyzing the failure of the operation, Borzuchowski found that there was a psychological reason. One logger was a new man on the job but he showed fair interest in some forestry activities. The other two men were experienced, worked hard but they showed no interest in thinning practices. It was very obvious, wrote Borzuchowski, that they did not like the job or the place, were constantly complaining about their work and were very reluctant to accept suggestions or instructions from the research forester in charge.

A further reason for the unsuccesful experiment was the unusually bad weather, which made logging conditions difficult. The rainy weather made the yarding spurs extremely muddy. A minimum of time was spent by the loggers on cutting extraction lanes. The experimental area was almost without roads and those which were present were very poor, resembling muddy erosion lines rather than roads.

The logging methods were not altered to the special need of a thinning operation. The men felled too many trees in advance of extraction, locking themselves up in a jungle of logs and slowing down the whole operation.

Another reason was that the operation was controlled by random allocation of blocks (plots) which could not be connected easily with roads.

Damage to the residual stand varied from 10% to 58% by number of trees. Injuries in many cases could have been avoided or at least much reduced if loggers had exercised more interest in their job and more patience in adapting themselves to the more exact conditions of a thinning operation. Wind damage was light in the more exposed and already thinned stands.

The operation was cancelled by the company, at a time when 17,880 cu. ft. reamined to be cut. All trees which had been marked for thinning were felled and left on the ground. This jeopardized the commercial thinning study but made it possible to continue some silvicultural studies.

To improve operations in the future Borzuchowski made the following suggestions:

"Extraction roads should be prepared or laid out prior to cutting. The properly located skidding trails should be drained in the dangerous places that will ease the yarding difficulties and speed up the operation. All main roads should be constructed in advance and kept well drained and in all-weather condition so there will be no danger of disrupting the transportation of logs during wet periods."

G. C. Warrack, then assistant forester in the Research Division, at that time examined the operation and felt that a small crew, with experience in small-log logging, using the best organization methods could be economical. He had problems as how to solve the high damage in hemlock and how to be able to prepare roads for the next operation. His one main point was that roads should be built before felling and yarding rather than during the operation.

Commercial thinning experiment
1959 - 60

In 1959 G. C. Warrack prepared another timber sale extending for a three-year period, using past experience to overcome the difficulties of commercial thinning.

The timber sale was given to a small operator with experience in a previous thinning operation on Cowichan Lake Forest. He was interested in it and knew the silvicultural aspects of the operation well. He owned up-to-date equipment constructed for thinnings, including a Garrett Tree Farmer rubber-tired tractor.

The operator hoped to make a profit by selling pulp-wood at the mill at Duncan Bay for $14.50 a cord or at Harmac for 19 cents a cubic foot.

There were problems however which could not be overcome. The operator had little capital and this put pressure on him to get as high a daily production as possible. The operator tried to eliminate time consuming preparatory work which, if done, could have resulted in much better production on the average.

The sale area was of 130 acres adjacent to the areas thinned in the previous study but not restricted to experimental plots, giving more independence to the operator, and permitting large scale silvicultural tests. The closest point of the sale proposed for thinning was about 2,000 feet from the booming ground, the farthest about one mile. The contract was prepared for a three-year period, and contained among other things the following points: (1) The thinning ratio as given by Langsaeter (1941) should be d/D = .85 ± 10%. (2) Trees logged should be selected from those of poorest stem form and crown development. (3) Approximately 150 sq. ft. basal area per acre should be left after thinning, which was equivalent to the heaviest thinning in the previous experiment. (4) Spacing should be around 18 feet between trees left standing. (5) Stump height of 12 inches was prescribed. (6) Merchantable trees should be any living, dead or down Douglas fir, hemlock or cedar trees which, in the judgement of the forest officer, contained a log of 8 feet in length and 5 inches or over in diameter at the small end. (7) All trees felled should be topped and all slash scattered in such a manner as to lie close to the ground, and away from live trees.

A two man crew from the Research Division of B. C. Forest Service were stationed on the Island at the time of the operation, including the writer. Their duty was to scale the logs, to measure the trees on plots and to collect production and time-study data.

Description of the operation

The operator moved onto the Island, built a small cabin and employed two experienced loggers, in the summer of 1959. He operated the Garrett Tree Farmer tractor in pre-yarding, (bunching) yarding, trail preparing and bundling, while the loggers did the felling, limbing and bucking. They also co-operated in preparing the loads in pre-yarding.

The felling, bucking and limbing were done by powersaw and axe. The product was mainly 24-foot pulpwood up to 19 inches maximum butt diameter. The smallest top diameter was 5 inches. The larger logs (usually Douglas fir) were cut as sawlogs, or boomsticks up to 66 feet in length.

The logs were winched to the tractor 5 to 15 at a time and then yarded to the booming ground. The road was in poor condition, and not maintained properly. The spurs were not prepared in advance at the start, but later the necessity was so obvious that all yarding trails were constructed according to a provisional plan. The Tree Farmer was not powerful enough to remove stumps larger than 30 inches but smaller obstacles were easily overcome.

The bundling was done by a bundling device on the shore, using the tractor's blade. Two, one inch wide steel bands were used to each bundle. Later, aluminum wires proved to be more practical and economical. Two or three tractor loads made up one bundle. The bundle was pushed into the water by the tractor and stored in the water until enough bundles accumulated to form a boom, which was towed to the pulpmill in Duncan Bay.

In a later phase the bundling platform was put in the water to get higher production. Every bundle was scaled by piece tally and a record kept of the daily production. As the fallers cut more trees than the tractor could yard, the crew was reduced to two men. The daily production soon equalled that of the three-man crew.

The damage to the standing trees was very low due to the use of three simple iron-plate-aprons.

Time and production data

The writer made 46 observations on the time needed for a complete turn; 25 turns of the tractor during the period when three men were working and 21 when the two-man crew was in operation.

The analysis showed that the size of the crew did not affect significantly the yarding time as shown in Table 4.

The following production was scaled for 46 days.

Total production was 27,252 cu. ft. of which 21,292 cu. ft. was pulpwood, (118 bundles = 2,300 pieces), 3,010 cu. ft. sawlogs (90 pieces), 2,950 cu. ft. boomsticks (26 pieces).

The average daily production was 593 cu. ft.

Average number of pieces per turn was 9.63.

Average number of logs in bundles was 19.52

Average volume per bundle was 192.42 cu. ft.

Average log volume (pulpwood only) was 9.95 cu. ft.

Average tree diameter was 10" DBH.

According to these figures the anticipated 80,000 cu. ft. production for the first year could have been reached in 135 working days. Lost production was mainly the result of excessive breakdown. Because of financial difficulties the contractor gave up his operation during the next summer.

Table 4. Time Data of Yarding and Bundling Based on 46 Observations

Average yarding distance: 2,000 feet

Size of crew Men	Average time of one turn Minutes	Standard Deviation	Average time for unhooking minutes	Standard Deviation	Average time for bundling Minutes	Standard Deviation
3	61	14.25	9.23	3	13.44	6.9
2	59	10.00	9.23	3	13.44	6.9
Average	60.65	-----	9.23	-	13.44	---

As bunching was a time-consuming part of the operation, a method using pre-yarding devices to prepare loads for the tractor would have improved productivity, but it was impossible under the circumstances, because the operator had no capital for further investment.

The main problem was the lack of adequate roads, although there was no way to solve this problem. The operator was not aware of the importance of roads and did not realize that the skid trails should be prepared in advance. The lack of all-weather roads renders impossible further studies on the research forest, especially in stands which are farther from the shore. The Research Division therefore stopped all thinning studies until the prerequisite road system can be established.

The writer spent the summer of 1960 on the Island to find out whether there was any possibility of establishing an economic road-network on the area.

Before reporting further on the road system, the writer will discuss the complex problems of thinning and experimentation done on the Pacific Coast, with particular emphasis on hemlock stands.

THINNINGS

Thinning is defined by many authors as a systematic removal of some stems in an immature stand in order to give the remaining trees better conditions for growing and producing better quality wood.

Thinnings have been carried out in many European countries for more than two hundred years. Research on the effect of thinnings has been conducted for at least ninety years. As reported by Braathe (1957) the European literature on the subject is very voluminous.

The history of thinnings in America is quite recent and on the Pacific Coast it is not more than thirty years old.

The purpose of thinning

In European forestry careful planning for future needs is a very pronounced feature. The main purpose of thinning, as described, is to utilize the growing potential to the full extent and put the increment on stems of high quality. As Moller (1954) explained, in Europe the wood removed by thinnings will usually have some value, but placing too much emphasis on harvesting values will confuse the task of thinning. That is why the forester rarely looks for the trees to be removed, but rather for the most desirable stems to retain for future growth. This silvicultural aspect might be acceptable in countries where manpower is cheap, where the forests are easily accessible and where forestry personnel is abundant.

At the beginning of the transition age, from extensive forest management toward intensive forestry, the American definition of thinning is different. According to Hawley (1946) the fundamental objectives of thinning are: (1) to redistribute the growth potential of the stand to optimum advantage and (2) to utilize all the merchantable material produced by the stand during the rotation. Worthington (1961) gave the opinion that in the coastal region only thinnings of commercial type would be considered. A thinning is defined as commercial if the value of the material removed equals or exceeds the cost of logging. A commercial thinning is ideal if it can be done at a profit and is silviculturally desirable or at least not undesirable.

The latest European literature shows, that practical foresters are planning along this same line.

Thinning methods

Thinning methods vary considerably but may be grouped according to the type of the trees to be cut. The trees in a stand are classified by different authors in many ways. To simplify this problem the writer will use only four classes: suppressed, intermediate, co-dominant and dominant trees.

Low thinnings demand removal of suppressed or intermediate trees which would die before the next cut.

Crown thinning removes trees mainly from the upper and middle crown classes, especially among the co-dominants.

Selection thinning removes mainly the largest trees and is usually carried out in relatively young stands.

Free thinning removes trees from all classes with the objective that the residual stand be as evenly spaced as possible, and that the best trees shall be left, depending upon the final product desired.

The methods used vary with the nature of the stand, and even in a given stand, according to its age. The usual practice in North America, in even-aged stands, is that the first thinning in a young stand will resemble a selection thinning; later it will appear to be a crown thinning, and in older stands a low thinning.

Intensity

The intensity of thinning can be light, moderate, or heavy. In general the Central European slogan regarding thinning was: early, often, lightly, whereas in America there is a distinct borderline between silvicultural thinning and commercial thinning. The latter will characterize the degree of intensity, consequently the emphasis is on the material removed.

There are many ways to measure the intensity of thinning, e.g. by number of stems removed, by basal area and by volume. Another common measure of thinning intensity used by Langsaeter (1941) is the mean diameter of the trees removed (d) in relation to the mean diameter of the trees left (D).

When d/D is 0.7 or lower, the thinning is light; when between 0.7 and 1.00 it is moderate; when over 1.00 it is heavy.

The degree of thinning intensity has increased in Central Europe during recent decades, and in Scandinavia the trend is toward heavy thinnings, as reported by Moller et al (1954), and affirmed by Samset (1961).

The Effects of Thinning

Silvicultural effects

The silvicultural effects of thinning were described clearly by Hawley and Smith (1954). The temporary gaps which are periodically created in the crown canopy by most thinnings allow more precipitation to reach the forest floor and the resulting increase in soil moisture permits the roots of the trees to penetrate more deeply than before. Decomposition of litter is sometimes accelerated, thus increasing the amount of inorganic nutrients available in the soil. Temperature is generally increased at all levels within the stand as well as in the soil. Unless the temperature increase is extreme, this effect alone should accelerate photosynthesis. Furthermore, the solar radiation reaching the leaves at the lower levels in the canopy is increased. Nevertheless, the evidence indicates that these distinctly beneficial influences are counteracted sometimes by harmful effects of thinning.

There is a relationship between thinning and length of live crown. Thinnings affect directly the self pruning ability of the stand, and in some cases increase the seed production.

Removal of inferior trees that otherwise would live to the end of the rotation, leaves the better trees as seed bearers. This genetic improvement is especially important in species which regenerate easily.

Effect on yield

Hawley and Smith (1954) came to the conclusion that thinning can be used to increase the economic yield of a stand but not its gross production.

The effect of thinning on stand development has been studied by many foresters. It was found that thinning methods applied under different circumstances affect height growth, diameter growth and tree form. Several experiments showed that the effect of thinnings on height growth is very small, but diameter growth can be greatly stimulated, directly affecting yield since diameter increment and number of trees per unit area are the main factors in volume production of a stand.

Figure 1. shows the relationship between density of stocking and growth in cubic volume as given by Langsaeter (1941).

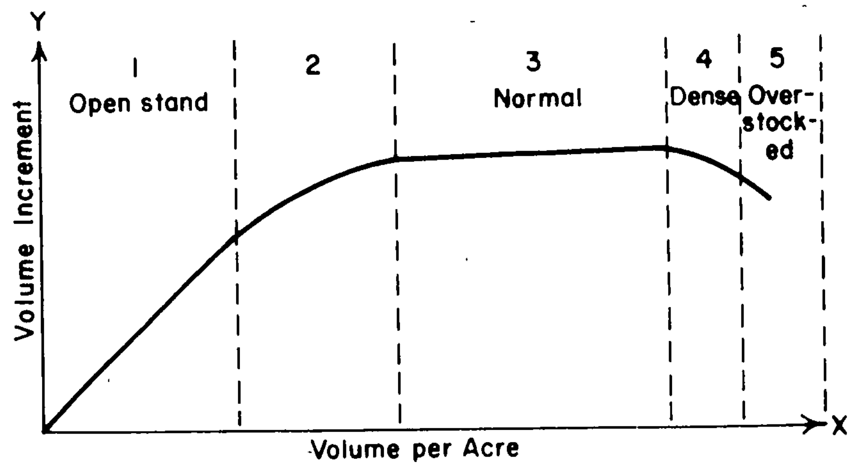

Figure 1. Relation between standing volume and volume increment.

In the broad range of stocking indicated by Density Type III, increment of cubic volume is virtually independent of variation in stocking. The usual objective of thinning is to keep the growing stock somewhere within this optimum range. By doing so, the number of trees can be reduced to an optimum number giving a higher average diameter to the stand which means better quality, the quantity remaining the same. Smith <u>et al</u> (1961) saw the main importance of the thinnings in the same way stating, "In some species the variations in tree quality can be so great that the advantages of concentrating growth on those trees of better quality can be used to demonstrate a real need for thinning."

Staebler (1959) expressed the difficulties encountered with the Langsaeter curve: "In most forest types we are a long way from being able to draw our growth growing-stock curves with sufficient precision to define the optimum range for thinning".

It remains to be determined to what extent this theory holds true for species in different climates and continents other than where it was tested, in Europe, and with two species, beech and Norway spruce.

Braathe (1957) thought that in untreated forests with unfavourable soil conditions, and retarded growth, a thinning will most likely speed up the rate of decomposition of humus and an increased volume growth might be expected.

Only a few thinning experiments have been made along this line in Europe. Experiments in overstocked, older second-growth hemlock stands in British Columbia to see the response to release could bring valuable results.

Effect on Wood Quality

It is doubtful that thinning can improve wood quality substantially.

Wangaard (1954) stated that in coniferous species the control of specific gravity by the influence of growing space must be dealt with somewhat differently than in the broad-leaf species. In order to produce timber with high strength properties in the shortest possible time it will be necessary to thin the stands carefully to maintain as good soil conditions as possible. Thus quantity and quality production are apparently combined on the more fertile sites.

Wellwood's (1961) data on fiber length and specific gravity of hemlock show that increase in rate of radial growth reduces fiber length. Thus, increasing rate of growth suddenly by thinnings may decrease the fiber length. This may further influence the strength properties of wood, lowering it's value. The studies also show that the specific gravity may decrease very slightly with increased growth in radius per decade, giving less pulp yield to thinned stands.

Benson (1958) found that specific gravity changed in Southern Pines after release are very irregular.

Unless weighing is accepted generally as a pulpwood scaling technique, the volume increase of thinned stands will be more important than specific gravity increase or decrease.

Financial Effects

An important influence of heavy thinning or initial wide spacing on stand management is that a shorter rotation can be applied to the stands because products of a given size can be produced earlier.

The effect of commercial thinning is that cash returns are available periodically throughout the rotation and are not postponed until the final harvest.

Worthington and Staebler (1961) had the opinion that a thinned stand is worth twice as much as an unthinned stand, for its full rotation age.

A forester wishing to earn a high rate of interest on his capital must seek forms of management that require small amounts of growing stock in relation to income yield. This can be achieved by wide spacing in the case of plantations, in natural stands, thinning affords a major avenue for attaining this objective.

With properly applied thinnings the amount of these intermediate returns increase cumulatively during the rotation. As Joergensen (1951) explained: "Correctly applied thinnings remove the poorer trees and leave the better ones with the result that each consecutive thinning places future volume production in a higher-quality class than it was before. Not only will the final crop benefit from this effect but also each succeeding thinning."

Other Effects of Thinning

The resistance of stands to damage of all kinds is generally increased by thinning, except in some species with a shallow root system where windthrow can occur.

It is logical to think that a well thinned stand with no snags and windfalls is more resistant to fire.

Experiments by (Langsaeter 1941) showed that thinned stands had more resistance to attack by insects and fungi and that the thinned stands in general are healthier than unthinned stands.

One of the indirect beneficial effects of thinning comes from the fact that thinnings can be made economical only if the forest area is accessible. Improved access also benefits all aspects of forest management.

Harmful Effects

Thinning may have harmful effects on the stand. The intensity of thinnings can be such that volume reduction follows, instead of growth increment. After heavy thinnings, windthrow and snowbreak may occur. With careless extraction the damage to residual trees may create infection hazard.

THINNING PROBLEMS IN THE PACIFIC COAST REGION

To demonstrate how well we are able to answer the problems of thinnings as applied to our region a short review of work done on this field will follow.

The first studies and experiments on actual thinnings were done in the United States in Douglas fir stands. Worthington and Staebler (1961) enumerated 75 articles, bulletins or other studies written on the subject. The findings and conclusions are interesting to compare. Opinions range from complete denial of the necessity of thinning to it's recognition as an imperative need.

The question arises why don't we use the accumulated results of thinning practices in Europe. Tinney and Malmberg (1948) expressed the sound belief that it is impractical to adopt other countries' findings in connection with thinnings because the growth habits and utilization standards of the Douglas fir are entirely different.

The importance of such studies was expressed by Kirkland and Brandstrom as early as 1936. It is interesting to note that the importance of a permanent road system was clearly explained: "The steps toward effective management are: to open up the property quickly ... to provide permanent roads so that the growing stock can be kept under continuous selective control ... maintaining tractor-trails through light and frequent use, as needed not only for orderly liquidation but also for efficiency in logging and for market selection and salvage". In that early study no attempt was made to evaluate the full economic advantages of the proposed thinning methods but the silvicultural aspects were discussed in detail.

Although many authors thereafter followed the same line, specifying the silvicultural problems of thinning of Douglas fir stands, the commercial aspect of the problem came into the picture very early.

The latest comment concerning the problem was given by Worthington and Staebler (1961): "Commercial thinning - thinning that pays its way - has tremendous potentialities in the Douglas fir region possibly adding as much as 1 3/4 billion board feet to the region's sustained-yield capacity.

Although not widely practiced, extensive trials have shown that in accessible stands, near favorable markets, thinning will not only substantially increase usable production of the forest but will also return an immediate profit".

To emphasize the still open nature of the problem in many respects Worthington and Staebler (1961) ended their study with these words: "In the absence of trials over long periods, long-term financial effects of thinning are virtually unknown".

Thinning of Douglas Fir Stands in British Columbia

The problem of thinning came up in British Columbia for the same reason as in United States but much later. The first studies were also in connection with Douglas fir. Although early thinnings were done at Cowichan Lake (1929), in 1951 Joergensen still complained about insufficient experiments.

In 1957, the same author reported on 35 thinning experiments underway in the province. The experiments were mainly on Douglas fir, mostly of silvicultural or pathological nature, although many have been stated as commercial studies also.

The most important findings in connection with these experiments on Douglas fir are those of Joergensen (1952) and Warrack (1959).

Joergensen (1952) reported on the results of the first commercial thinning operation practiced in British Columbia, on the Research Forest of the B. C. Forest Service at Cowichan Lake. After presenting the data the author felt that "all this was only one drop in the ocean. The shell of uncertainty that encompasses the complexity of problems related to yield and revenue from intermediate cuttings has been opened in just one place, in one type of stand, under one set of logging conditions and one type of thinning. Ahead lies a wide open field of (further) investigation".

Warrack (1959) explained the possibility of forecasting yields in relation to thinning regimes. He analyzed in his study the prediction of basal area increment related to thinning methods. Eighteen formulae have been created to provide satisfactory predicting mechanisms for periodic annual basal-area increment per cent in fir stands of 25 years or older. It was believed that the method can be applied to second growth stands of Douglas fir in the 20 to 60 age-class. In the absence of local thinning yield tables the demonstration of cubic-volume predictions provide the forester with means to program practical thinning regimes. In his estimation he supported the theory of Moller (1954) and extended it to Douglas fir stands by saying that "Volume increment over long periods is not affected by the degree of thinning within wide limits". In an evaluation of financial considerations Warrack came to the conclusion that in the Southern Coastal regions of British Columbia, "it is possible to forsee an intensive management of immature Douglas fir stands, developing thinnings as a sound economic method of realizing maximum forest wealth."

As thinning experiments are long-range experiments we are far from being able to propose the best possible management for the immense second growth areas.

Thinning Western Hemlock Stands

The thinning experiments on East Thurlow Island are concerned with almost pure hemlock stands. Therefore it seems appropriate to elaborate on the thinning problems of hemlock.

Thinnings have three aspects which are inseparable in practice but for discussion purposes can be differentiated, namely, the economical (financial), biological (silvicultural) and technical (logging) aspects. In further discussion these three aspects will be examined, keeping in mind that complete separation is impossible.

It will be shown that research on thinning hemlock is very limited at present, and the multitude of unanswered questions need further investigations. The possible methods of experiments will be referred to, without proposing definite procedures to follow on East Thurlow Island.

Silvical Characteristics of Hemlock

The silvical characteristics of Western hemlock (*Tsuga heterophylla* (Rafn.) Sarg.) are sufficiently well known to give a firm basis for further studies on stand improvement, thinning and so forth. Bernstein (1958) summarized the facts about western hemlock.

It thrives best in the humid and mild climate along the Pacific Coast, where frequent fogs and rain provide moisture during the growing season. It prefers deep, internally well drained soil but can thrive well under unfavourable soil conditions. Best development of hemlock is at elevations between sea level and 2,000 feet along the coast from Alaska to Oregon.

Western hemlock is usually subordinate in association with other coniferous species, but sometimes dominates and occasionally occurs in pure stands, as in the case of stands on East Thurlow Island. In some dense stands scarcely any herbaceous or shrubby vegetation is present.

In the Coast Range hemlock consistently outproduces its associates in both frequency of cone crops and quantity of seeds. Seed may be carried long distances by wind. Because Western hemlock is highly tolerant and germinates and survives easily, natural regeneration can be obtained with harvesting methods varying all the way from individual tree selection to clear cutting. In dense stands a large number of trees die from suppression during stand development.

Hemlock usually responds well to release even after a long period of suppression and in dense even-aged stands, natural pruning takes place early.

A number of damaging agents are reported by Bernstein (1958) among them fungi, dwarf-mistletoe, insects, the weather, windthrow, sunscald, fire and logging. Thin bark and frequent occurrence of exposed roots are reasons for a high susceptibility to damage.

Thinning Experiments in Western Hemlock Stands

Western hemlock is a good subject for silvical and commercial thinning experiments because it responds well when released and because it grows mostly in relatively even-aged stands of rapid growth and high volume per acre.

Haddock (1958) in a letter to Hopkins wrote: "The striking ability of hemlock to respond to release makes it almost imperative that we learn, somehow, to make use of thinnings".

Kirkland (1936) was one of the first who examined the possibility of thinning hemlock. For a long period thereafter there was not much interest in hemlock, because the commercial nature of thinnings seemed impossible.

Preus (1956), in his essay, could enumerate only 21 references on Western hemlock including very general descriptive textbooks.

Joergensen (1957) gave an index of all thinning experiments in British Columbia and reported that there were only three experiments under way in pure hemlock stands and another two in mixed stands containing hemlock. One of those was on the University Research Forest at Haney. Griffith (1959) reported that the thinned stands grew in basal area more than twice as fast as the trees on control plot.

Another experiment was on Turnour Island by Buckland and Marples (1953) gave data concerning the effect of thinning on dwarf-mistletoe damage.

The third experiment is the one on East Thurlow Island.

Smith et al (1961) emphasized the importance of early control of spacing in Douglas fir and hemlock stands. According to their calculations, mean annual net increment per acre of normal and open-to-normal hemlock stands differs by 67% in favour of the latter, at the stand-age at which growth culminates. Control of spacing may be gained by planting, or by pre-commercial thinning or cleaning in very young natural stands.

An experiment to determine the influence of spacing and thinning was established in mixed stands of hemlock, cedar and Douglas fir on the University Research Forest at Haney in 1959. The influence of spacing on growth of the natural stand is being studied by a carefully designed experiment. A total of 24 half-acre plots was established and six spacing distances used from approximately six feet to twenty-one feet, created by girdling the trees, which should have been thinned. It is planned that, when data on growth becomes available, plots will be analyzed on an individual-tree basis, with appropriate adjustments using multiple regression or covariance techniques.

There are experiments on thinning hemlock under way on the Pacific Coast outside of British Columbia.

In Alaska there have been experiments on the commercial feasibility of thinnings, but the results have been negative.

In Washington Staebler (1957) reported on commercial thinning tests and the silvicultural consequences. Gross increment was significantly higher in the crown thinned stands after treatment. Realized increment, which is the sum of mortality salvaged in the second thinning and increment, retained in the growing stock, showed a pronounced advantage for thinning.

During 1959, a study was initiated at the Forest Research Centre, Corvallis, Oregon, on the effect of silvicultural treatment of precommercial stands of hemlock. It was hoped that by taking advantage of the vigorous growth of young trees through intermediate cuttings, a stand of improved quality with increased wind firmness would be formed, also wood normally lost through suppression would be salvaged. Effects of various treatments, both on the stand itself and on individual trees in the stand, and costs and returns of management would be assessed. The experiment would be replicated four times, each in a different locality. There is no further data available yet on this particular study.

Damage Problem of Thinning

The susceptibility of hemlock to damage and decease made the silviculturist interested in the problem of how thinning will influence the health of hemlock stands.

Because of its thin bark Western hemlock is very susceptible to fire injury. Thinned and pruned stands are much more fire resistant than natural stands. In frequently thinned stands, the amount of fuel on the ground is minimized because of salvage and prevention of mortality. Ease of accessibility to all parts of the frequently thinned forest is important from a fire control standpoint. Skidroads and trails, if kept open through frequent use, provide ready-made fire lines.

In stands with shallow root systems, the windthrow after thinning can be of major importance. On the thinning operation on East Thurlow Island (1953-54) however, the research forester reported no windfall at all, although heavy wind storms were experienced during the operation. Bernstein (1958) however reported a heavy loss after thinning because of windthrow. The danger of windthrow is directly related to the occurrence of heavy storms after thinnings, to the length of live crown and to the location of its center of gravity, to the depth of the roots and their characteristics, to the physical nature of the soil, to the soil moisture during storms and so forth. Western hemlock has a moderately deep, well spread root system but its dense crown creates a real windthrow hazard. An early, precommercial thinning for spacing regulation is of great benefit for the stand in the respect that the root system develops better and the center of gravity of the crown remains lower. In belated thinnings, great care must be taken as to trimming intensity if the factors influencing windthrow are in an unfavourable combination.

Bernstein (1958) found that losses from snow-breaks are most severe in the inland range of Western hemlock, especially in thinned stands. The danger of snow-break is directly connected with the wetness of the snow, the area of snow holding surface of the crown and the slenderness ratio of the tree. Theoretically Western hemlock should be resistant to snow-break because it has flexible branches which easily deflect under the weight of the snow and its wood has the highest strength in compression of any conifers on the Coast, although the slenderness ratio might be high as a result of low taper.

Sunscald occurs only when the intensity of thinning creates an open stand, which is not the general practice yet in thinning hemlock stands.

Dwarf-mistletoe has many harmful effects on hemlock, as reported by Wellwood (1956). Buckland and Marples (1952) found in their investigation that the dwarf-mistletoe reduced the vigour of the trees and lowered the yield of stands below their actual potential. The best method to manage such hemlock stands, in their opinion, is to thin the trees infected with mistletoe during a selection cutting near the end of the rotation which should remove the infected trees.

According to them, thinning operations should not be carried out in the late summer or fall, at which time mistletoe is fruiting. The final clear-cut area should be large, and if seed trees are to be left to reproduce an area they should be selected for their good form and apparent freedom from mistletoe.

Wounds on trunk and roots are important avenues for the entrance of decay-causing fungi as reported by Shea (1960), because of the absence of a copious supply of resin. Evidence of decay was found in 91% of the trunk scars of hemlock examined in the corse of his investigation. However, losses due to decay averaged only 0.9% of the total merchantable cubic volume. Equipment and skidded logs were indicated as important sources of injury. Detailed planning of the location of skid trails should reduce injuries from this cause. In the commercial thinning experiment on East Thurlow Island, 27% of trees were damaged,according to Borzuchowski (1954). The factors contributing towards the incidence of tree injuries were steep topography, soft ground, heavy accumulation of debris, dense stands, lack of trails, careless yarding, lack of experience in thinning, and long logs.

It is obvious that during the thinning operation, the damage to residual trees cannot be eliminated, but its' severity can be kept at a low level. A later thinning operation in the same area (1959) showed a great improvement due to prepared yarding lines, skidding with a suitable type of tractor, using iron-plate aprons on the trees but mainly because of the loggers' understanding of need to prevent injury to the residual stand.

Wright and Isaac (1956) provided useful guides for estimating decay associated with logging injuries to western hemlock. The available tables can give forest managers a basis for estimating present losses in stands logged previously or to forecast future losses to be expected in currently logged stands.

There is some evidence that root injury is not as serious for some species, but this is not proven yet for hemlock.

There are several insects that attack hemlock. The major outbreaks cannot be influenced significantly by management methods, at least not in the short run. But good thinning practice favours the development of healthy, vigorous trees with well-established root systems. Such trees can resist attacks by insects and other diseases more easily.

<u>Economic Aspects of Thinning Western Hemlock</u>

The hemlock region supports the best sites in British Columbia for sustained production of pulp and sawlogs. In area the hemlock forests exceed the Douglas fir forest by 400 thousand acres.

Hemlock as a raw material originally was considered to be inferior as compared to other species on the Coast. As

Dimock (1958) said, "Not so long ago western hemlock was little more than a nuisance to the logger, merely something to be brushed aside in the head-long race for Douglas fir sawtimber." With today's heavy demand for paper and chemical cellulose products, western hemlock plays a vital role in our economy as a leading source of high-quality pulpwood. Harlow and Harrar (1950), quoting an eminent Swedish chemist's report said that western hemlock sulphite pulps exhibit physical and chemical properties second to none. Smith et al. (1961), in their very thorough examination of the economic problems of reforestation in the Vancouver Forest District, came to the conclusion that Douglas fir will remain a preferable species to hemlock in overall value and where it is possible the area covered by fir should be increased.

The first question which is often brought up by economists is whether to thin hemlock stands at all, or whether to follow the present practice of extensive clear-cut management without previous thinnings. There are many experts who advise the latter.

Taylor (1934), experimenting in Alaska, came to the conclusion: "The results indicate that nature can take care of dense stands and as the small sized material removed in thinning has no commercial value, it may be best to let nature take its course."

Hemlock stands of natural regeneration are usually overstocked, and consequently the mortality in the stand is high. The potential volume available from mortality alone is very substantial. It must be pointed out, however, that a great part of the loss is of no commercial value and importance, because of its small size.

There are others who are more optimistic about the possibility of commercial thinning of hemlock. Davies (1960) thought that in spite of all the present obstacles (bad market conditions, lack of access, inefficient logging methods) the Coast is in a revolutionary transition from wild forests to managed forests. As this change progresses there will be more and more dependence on small logs, and many of them will come from thinnings.

Heavy thinnings could become an economically feasible enterprise now but this would depend on the size of logs available for such operations.

A curve showing relationship between d.b.h. and logging costs (Figure 2.) indicates that there is a diameter limit below which it is not economical to cut. The level of the curve depends on the logging method used and the efficiency of the operation, whereas the marginal diameter is determined by the type of product (pulpwood, sawlog) and by the market conditions, but the general relationship will be always similar to that shown in Figure 2.

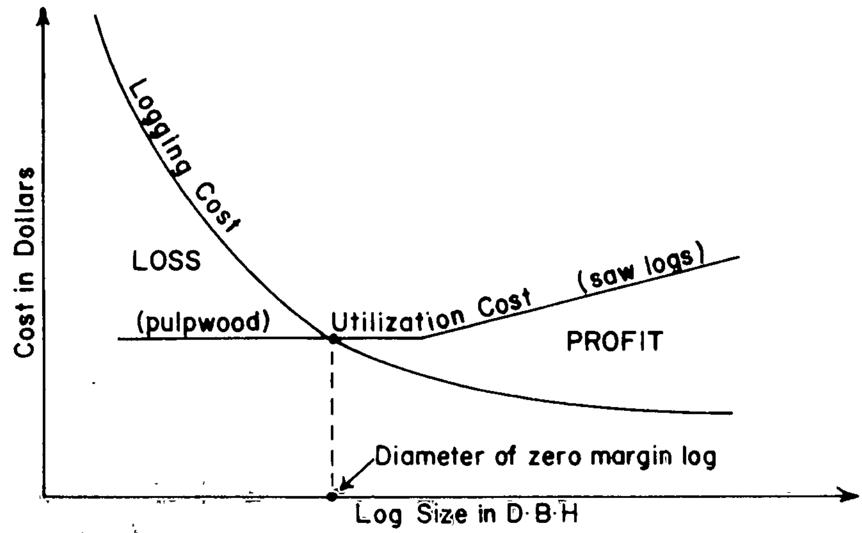

Figure 2. Graphical determination of the zero margin diameter.

Within certain limits, the utilization value per unit volume of wood is proportional to its diameter, while the production costs are inversely proportional to its diameter. Expressed graphically, the crossing point of the two curves will show the economic margin diameter at which wood can be produced and sold without incurring a loss. In an actual thinning experiment this intersection point can be easily determined.

There have been several cost studies in connection with minimum log size for commercial utilization of many species, but none in connection with hemlock.

Doyle and Calvert (1961) showed that with jack pine (Pinus bansiana Lamb.) in Northern Ontario there was no profit on logs smaller than 7.5 inches in diameter.

The study of commercial thinning in Douglas fir conducted by Worthington and Staebler (1961) was based on different operations where the average d.b.h. of the trees removed was from 8.8 inches to 19.4 inches with a mode of 13 inches. The minimum d.b.h. logged ranged from 5 inches to 12 inches.

Tessier and Smith (1961) reported, in a cost study carried out on the U.B.C. Research Forest at Haney, that alder trees smaller than 11 inches in d.b.h. and logs smaller than 8 inches in top diameter cannot be logged and milled to yield a positive conversion return.

According to Barnes (1953) commercial thinning in hemlock stands cannot start earlier than at 55 years of age if saw logs are the main product. Because pulpwood is merchantable from a 5-inch top diameter, thinnings could start at a much earlier age than that for saw-logs provided a suitable market exists. There is insufficient data to evaluate the minimum merchantable tree size in thinning hemlock.

The question remains whether the smallest profitable diameter should be the lowest limit, below which a tree should not be cut. In thinning hemlock, the silvicultural requirements might demand the elimination of some trees from lower diameter classes also. The emphasis then should be on thinnings originating at an age where marginal returns can be expected, cutting only enough higher diameter trees to compensate for trees of smaller diameter than the determined marginal minimum for that operation. With this approach the successive thinnings might create benefits and we can expect quality improvement from the final harvest.

This type of late thinning is not selective cutting or pre-logging because the aim is to leave the residual stand with higher or at least the same average diameter that it was before (d/D = 1 or over). The damage to the residual trees will be less in this case than in the opposite method of selective cuttings. The impulse for growth will affect remaining good quality trees, resulting with favorable phenotypes for the final cut.

Whether the delayed thinnings are acceptable silviculturally is a difficult question to answer with so little knowledge of the behaviour of hemlock under such circumstances.

It is obvious that to thin on a marginal basis will mean a loss of maximum profits at the time of thinning. The removal of smaller than marginal trees will decrease or eliminate the profit and this can be justified only if the remaining stand produces extra quantity or quality of wood at a rate such that the profit lost compounded to the next thinning, or to the final cut, will be repaid.

There are very few factual data available to justify the validity of this silvicultural practice. It is hoped that silvical characteristics of hemlock, responding with enough vigor to such thinnings, will fulfill the expected results. Quality improvement is more likely to occur because with heavier thinnings removal of pulpwood will allow for a greater percentage of sawlogs of higher grade in the final cut.

In addition to the delayed thinnings a pre-commercial thinning would be necessary, of course, in an early age of the stand, for spacing regulation and selection.

The zero margin diameter is dependent not only on logging costs but also on utilization value. In the case of hemlock pulpwood the present market price ($15.00 per cord to $19.00 per unit) seems to be unreasonably low. Pulpmills elsewhere on the Continent pay higher prices for lower quality pulpwood material. The obvious reason for the local low price is the present abundance of mill waste available for chips. With altering market conditions and reasonable prices the zero margin diameter could be reduced and larger areas of hemlock stands would be available for commercial thinning.

LOGGING AND TRANSPORTATION PROBLEMS OF THINNING

The small logs which come from thinnings create a difficult economic problem for loggers. The method required must be one which is silviculturally acceptable, technically possible, and economically feasible. To connect the problem directly with hemlock stands, the problem of logging on thinnings in general will be discussed. In the case of thinning accessibility is the most important prerequisite to logging, therefore the access problem will be presented first.

The Importance of Road Network in Intensive Forestry Practices

The road network in a forest, like the blood vessels in the human body, gives life to the area, serving not only for transportation of the products removed but with the same importance for movement of workers and equipment.

The road system is closely related to the type of management of the forest. Each type of management has an optimal economic road or transport system for fulfilling its purpose.

A road was defined by Silversides (1951) as economical if it costs less per mile than the capitalized savings effected because of its existence. On that basis the roads in an extensively managed forest are only constructed to facilitate logging. In this case the roads are temporary, timber types and market conditions will alter road plans for any one year. Taking the other extreme in a forest which is intensively managed for multiple use, a permanent road system should be planned with mainly permanent lines to allow the fulfillment of all necessary forestry activities to be carried on, including silviculture and protection as well as logging. Forests used for recreational and the research purposes are closest to this ideal. In the latter case it is difficult to show the savings in dollars because of the existance of the road system, but the noted advantages are: (1) An adequate road system permits the salvage of insect-infested groups of trees as well as, the cutting of high hazard trees to reduce the possibility of insect outbreaks. (2) Execution of fire control plans is available. (3) Inaccessible timber in remote areas may be brought under management. (4) Forestry personnel and workers may reach easily any part of the forest, giving higher production in logging, planting, pruning, (5) It facilitates thinnings, pre-logging, selective cutting. In short, the harmonious work of an intensively managed forest on a sustained yield basis can be economical only if a permanent road system assists to it.

The research forest on East Thurlow Island falls close to the type of forest, previously described. As shown in commercial thinning experiments there no profit can be expected without permanent road network.

The importance of a well-established permanent road system in managing intensively a forest area is accepted as a sine qua non in Europe. There are several books or texts written on the subject in almost every country of Europe, e.g. Hafner (1956), Glaser (1951).

In America, Matthews (1942) was the first to underline the importance of forest roads, mainly in connection with the economics of logging. In his book, "Cost Control in the Logging Industry", there is basic information about the economic location of roads, the determination of the economic service standard for roads and the selection of road spacing.

The transition to more intensive management practices on the Coast will emphasize the importance of roads. More roads will be needed in the future. The 'more' does not mean necessarily more expensive investments, rather better planned, more economical road patterns, with emphasis also on roads of lower standard.

Bruce (1953) found in his study of access roads, that inaccessibility is the primary obstacle to reaching sustained yield capacity in the U.S.A. Some silviculturists are worried about the increased loss in productive area. The loss in productive area, however, is not directly proportional to loss in volume produced because the encroachment of roots and crown produces more growth on trees standing on roadsides. European reports point out that a strip eight feet wide does not reduce volume production.

An experiment made by Kramer (1958) showed that when the roads are prepared at an early stage of the stand, e.g. at the time of the first thinning, one may clear skidding trails of 9 to 15 feet width without any yield decrease, because the bordering trees will utilize enhanced increment conditions of the trail. If the skidding trails are laid out in a nearly mature stand, one will experience a certain decrease in yield but it is small (2 to 3 per cent for 9 feet trail width and trail-spacing of 100 feet). If the skidding trail can be maintained at a width of 8 feet wood production would hardly be jeopardized.

Silen and Gratkowski (1953) discussed the problem of accessibility in the Pacific Douglas fir region. In an estimate of the amount of road necessary in the staggered-setting system of clearcutting, they found, on an experimental area in Oregon, that 9.8% of the area was disturbed by roads and landings. Due to reforesting of much of the fills and part of the cuts the estimated total loss in productive forest land could be kept to a minimum of 4.1%.

Intensive management does not allow a type of practice in road network design that plans for only one year ahead. This usually results in an uneconomical pattern for a management unit. In designing a forest road, the future road network of an area should be visualized in its entirety and the detailed plans for a single road should be harmonized with the whole system. The correct process is then a long-range general road plan and the yearly road construction will be applied to this basic plan. This method is also more economical. Silen (1955) presented his opinion about more efficient road patterns for a Douglas fir stand and found that with a well established pattern, the length of roads on an area usually can be reduced without reducing its efficiency. He proposed also, that the number of roads that climb between levels can be reduced and the length of roads on different levels spaced on the economic interval can be increased with the same result. In a particular comparison Silen (1955) showed that the new pattern, though 0.62 miles shorter, had the same efficiency as the old layout.

The economic spacing of roads, according to Matthews' formula:

$$S = \sqrt{\frac{0.33R}{VC}}$$

where R is road construction costs per mile, V is cu. ft. volume per acre, C is yarding cost per 100 feet and S is road-spacing in units of 100 feet, is in reciprocal square root relationship with volume per acre. This would mean that the road network for facilitating thinnings is economical only if the spacing is wide. On the other hand, the relatively small size of logs does not allow long yarding distances. The controlling factor of road spacing, in the case of thinning, will be therefore the optimum yarding distance of the yarding method used, not taking the volume per acre available into consideration.

The road network in a forest area consists of roads of different standards which are usually called, in order of importance, main access roads, secondary roads, branch roads and spurs.

In a road development program for areas under intensive management, the standards of some roads will change during the rotation. As Berg (1961) said, roads may be developed stepwise by pushing in a pioneer road for the first thinning, and then improving the road by ditching, installing culverts, and grading as successive intermediate cuts are made.

It apparently has not occured to loggers on the Coast that secondary roads and branch roads could be of a permanent or semi-permanent nature. In case of intensive thinnings however, secondary and branch roads must be of semi-permanent nature in some cases, to reduce road maintenance costs and to make year around operations possible. The semi-permanent standard can be achieved by using inexpensive, lightly paved roads of stabilized earth and gravel. These are usually sufficient for the loads and amount of traffic expected.

There are several methods of constructing roads types of stabilized earth and gravel. Stabilization is usually begun with the strengthening enforcement of base and sub-base. The structural strength of any road is dependent upon the ability of the subgrade to carry loads under all climatic conditions. This can be achieved by mechanical stabilization, or by adding stabilizing agents such as sulphite liquor, bituminous materials, lime, portland cement, calcium chloride or sodium chloride. Surface stabilization is partly for increasing load-carrying capacity, but its main purpose is to reduce road deterioration from weather effects such as frost, absorbed water and to act as a dust-layer. The same methods as for subgrade stabilization are usually used for it with only minor technical changes in application. Edwards and Townsend (1961) gave a good evaluation of the importance of forest road stabilization in Canada.

The latest figures on earth road stabilization show that the costs are not high. "Zee" Chemical Company, for instance, claim that they can stabilize existing earth roads for $1,000.00

per mile. (Advertisement, Western Timber Industry, February 1962). They maintain that after the initial treatment with "road packer", the surface is a long lasting, all weather, surface. The only equipment needed to apply the chemical is a gravity feed sprinkler-truck followed by an ordinary grader.

Latest figures about other stabilization methods show the same low costs. Stabilization with salt in the forests of Arizona runs up to $2,000.00 per mile; Day (1962).

The most promising method would be cement stabilization with some light oil impregnation, as used on many forest roads in the U.S.A. and in Europe.

Tables in the Logging Road Handbook (1960) are available to estimate hauling costs on roads due to design elements, equipment used and road surfaces. These tables are applicable mainly to access roads designed for high speed. Nevertheless the design and construction will influence hauling costs on the secondary road system also, but in a different manner. Silversides (1951) pointed out that the design costs are very low in Canada compared to construction costs and they never exceed 5% of the total cost. Careful design, mainly an appropriate reconnaissance on the ground, soil testing if necessary, economic comparison of possible alternatives, and so forth, should increase design cost percentage but this certainly will be outweighed by the decrease in construction and maintenance costs.

This type of road network design needs technically trained men who are familiar with the special requirements of different forests, not simply engineers who are able to design a good but usually unnecessarily expensive road between two given points. Forest roads basically differ from public roads and highways in their purpose. Even the technical design elements must differ, because the nature of traffic is different. The load-transport is always directed in one direction and not alternating as on highways. The traffic flow is not continuous, is usually restricted to a part of the year and even then the traffic intensity is very low compared to public road traffic. The main difference lies in the fact that, in designing a forest road, the future road network of an area should be visualized in its entirety and the detailed plans for a single road should be harmonized with the whole system.

The suggested type of road pattern will not replace the present pattern in a short time and then only in places where intensive management can be practiced economically. The transition will originate in places where logging roads already exist. The long range road development plans for areas of this kind should be such that not only the present requirements of logging, but also the expected future forest work necessities, should be considered. These preliminary plans should not be of a rigid pattern but rather flexible to be altered in detail, if changing logging methods in the future will necessitate it.

The road network in a given management unit will largely depend on the proposed logging methods to be used. The logging methods used for thinning differ greatly from those of clear cutting. It is logical then, that the road system must differ also. To pursue this problem farther, the special problems of logging in a thinning operation will be discussed.

Special logging problems in a Thinning Operation

Small-log logging on the Coast is in a relatively recent experimental stage. As small logs are becoming more and more important as a source of raw material, the search for new ways of logging is being intensified accordingly.

Davies (1960) commented that certain methods have become standard on the Coast and it is difficult to change them. He complained about the conservativeness of loggers and of their slowness to adapt the new methods already developed and proved in other countries or other regions.

Worthington and Staebler (1960) had the opinion that engineering principles and practices of conventional logging must be modified considerably to adapt them to the particular requirements of commercial thinning.

The contrast between logging old growth, and thinning, is probably greater on the Coast than in any other forest region of the country. Equipment requirements in particular are different.

The Timberman in its May issue (1961) gave a twenty-five page pictorial report on small-log handling equipment and methods used at present. "There is no more universal problem facing the logger today than that of falling, bucking, skidding and loading small logs" - said the introduction of the report. It is interesting to see, however, that over one hundred different devices discussed are basically not new equipment, only modifications of presently-used machines. The way to find new methods and equipment is still open to those with imagination.

As the logging process is usually broken down into the working phases of felling and bucking, yarding, loading and hauling, further discussion of the problem will be grouped similarly.

Felling and Bucking

The development of light power saws has made them ideal for felling and bucking, especially in thinning. Mobile circular saws are not used on the Coast because the heavy debris make them useless, although in Europe they are used effectively. For tree-length yarding, however, they would be useful for bucking at landings due to their fast cutting.

In thinning operations the falling direction is very important. Trees should be felled toward skid trails in a herring-bone pattern to favour later skidding. In young or dense stands, felling is a time consuming operation because of frequent hangups. For that reason, the trees are usually felled toward the most favourable openings in the crown canopy, regardless of skidroads.

Limbing is done by axe or power saw. A light portable circular saw with a long handle is used in Russia and Japan with good efficiency but not tried yet in British Columbia.

Bucking is done almost universally by power saws, either at the place of felling or in case of tree-length yarding at the landings.

Tree-length yarding versus log-length yarding is a question open to debate. Some of the advantages of tree-length yarding are: (1) that bucking can be done under favourable conditions with a less well educated bucker at landings; (2) bunching costs are lower as time for choker setting is reduced; (3) yarding costs are reduced by allowing for heavier loads per turn.

In case of thinning, however, yarding in tree length has also disadvantages. The damage to standing trees increases with increasing log length and pre-yarding is more difficult. In second growth hemlock stands the product of thinning is usually fairly uniform (mostly pulpwood) which does not need skilled bucking, therefore the advantage of bucking at landings is not significant.

Worthington and Staebler (1961) reported that felling, bucking and limbing required about 1.3 man hours per hundred cubic feet in thinning operations on the Coast under average conditions in second growth Douglas fir stands.

In felling and bucking operations the problem of contract versus a day rate can be assessed. The contract payment has the advantage of high productivity which is a direct result of the incentive pay basis; but the difficult supervisory problem, which is not associated with day labor, and the effect of cutting the largest trees to increase output, will conflict with some silvicultural considerations in thinnings. Therefore day labor with possible bonuses (for low damage, no hangups and so forth) seems to be the best procedure in thinnings.

Skidding Problems of Thinning

Pre-yarding and yarding or skidding account for most of the time spent in thinning. The relatively small size of the material from thinnings creates the largest economic problem in skidding. Heavy-duty machinery, such as is used on the Coast, is uneconomical for handling small logs. (Sky-lines, the electric arch and so forth) On the other hand the logs in a thinning operation on the Coast are usually not small enough to allow the use of light equipments which are used in the East or in Europe with good effect.

Different ways may be used to solve the problem of skidding small logs economically, such as:

1. By modifying heavy-duty machines, now used to log large timber to enable them to handle small logs more effectively. (e.g. mobile highlead, smaller tractors with arches.).

2. By introducing small-log logging methods which are already used in other regions or countries but with possible modifications to adapt them to the special circumstances of the Coast. (e.g. Lasso Cable conveyor, etc.).
3. By reviving old logging methods now outmoded (e.g. horselogging, chutes, etc.).
4. By experimenting with completely new ideas such as the use of helicopters. As there is no information about their practicability in thinnings the writer will omit discussion of these new ideas.

Mobile High-lead

In the case of modified high-lead, there are already examples showing good results in salvage logging, prelogging and selective cutting, which are similar to thinnings in their extracting methods. These systems differ from the conventional form by being easily transported from one setting to another, having portable spars. The rig up time and moving time is reduced and does not require expert riggers. The most common types are the Madill steel spar, the Berger Porta-Tower, the Windrow and the Skagit mobile yarder-loader.

The last type was used with great success for salvaging old-growth Douglas fir as reported by Carow (1959).

A 90-foot portable steel spar was used in a study of pre-logging by McIntosh and Gunn (1960) who compared yarding uphill <u>versus</u> downhill. The time analysis showed the average yarding time per cunit was 14.12 minutes uphill and 17.30 minutes downhill. Average yarding distances were 365 feet and 505 feet respectively.

Tessier and Knapp (1961) reported that direct logging costs of mobile high-lead in clear-cut operations were well in line with regional averages: $4.76 per M f.b.m.

Based on results of ten portable spars in use on Vancouver Island in clear-cut operations it was found that the mobile units had yarding cost savings of $1.48 /M f.b.m. over the conventional high-lead system (Munnis 1961).

The Skagit Model RCC - 10 Sky Car, an equipment similar to mobile high-lead, was used with success in thinning operations on the Clemons Tree Farm of the Weyerhauser Company. The amount of timber removed averaged 15 M f.b.m. per acre. It was reported that practically no damage was done to the residual stand (The Timberman, August, 1961).

These systems might be applicable to thinning but only on certain topography such as on steep slopes where tractor logging would be hindered, or along already existing access roads. To keep the logging costs of these systems low, the material removed on any one setting must be substantial.

Tractors

Tractors are the most promising machines for thinning but to recommend the best type for our coastal forests is rather difficult. It is safe to say, however, that tractors under 30 hp. are too light for our thinnings, and tractors over 70 hp. cannot be used to full capacity. de Megille (1956), in a lengthy study on tractors in which he compared cost and production values for different types of tractors, came to the same conclusion, stating that for thinning under difficult conditions medium powered tractors of 40 to 50 hp. are the best.

There are many tractors available in this category, both crawler types and rubber tired.

Crawler tractors have the advantage of low pressure contact with the ground. They can bulldoze skidding trails with less difficulty than the rubber-tired types and can pull heavier loads for the same machine weight. However, as they are not easily maneuverable, damage to standing trees is usually severe. Their slow speed does not allow for long yarding distances, usually not more than 2,500 feet. Tractors similar to Caterpillar Model D6 are the maximum size which should be used, but D4 would be the most economical model and in some places the D2. In many instances the crawler tractors would be profitable additions to rubber-tired types where skidding distances are greater than one-half mile.

Rubber-tired tractors can travel at a higher speed, but their load capacity is lower than that of crawlers with the same horse power. If rainfall often soaks the ground this may render difficult, if not impossible, the use of wheeled tractors and crawler tractors will be preferable. Damage to standing trees is less with rubber-tired tractors due to their maneuverability. Operator fatigue is also reduced. They are not suitable, however, for bulldozing trails under difficult conditions.

The load carrying capacity of rubber-wheeled skidders is comparable to that of crawlers as follows:

Rubber-wheeled type	Equivalent Crawler class
10-ton	Caterpillar Model D-6
7-ton	Caterpillar Model D-4
$3\frac{1}{2}$-ton	John Deere 440

There are tractors which can be used either as crawlers or as rubber tired as necessary. The track shoes can be removed or installed in ten minutes.

Multiple use tractors have been developed in Europe and used economically, e.g. the Unimog in Germany and the Motormule in Austria. They have many special accessories which make them able to do different jobs in the forest, such as planting, spraying, road maintenance, yarding and hauling. The rubber tired Unimog was tried under British Columbia conditions but its' performance was not satisfactory. A similar unit to the Motormule, which is a fast, crawler-type tractor with trailer, might be better suited to thinning operations on the Coast.

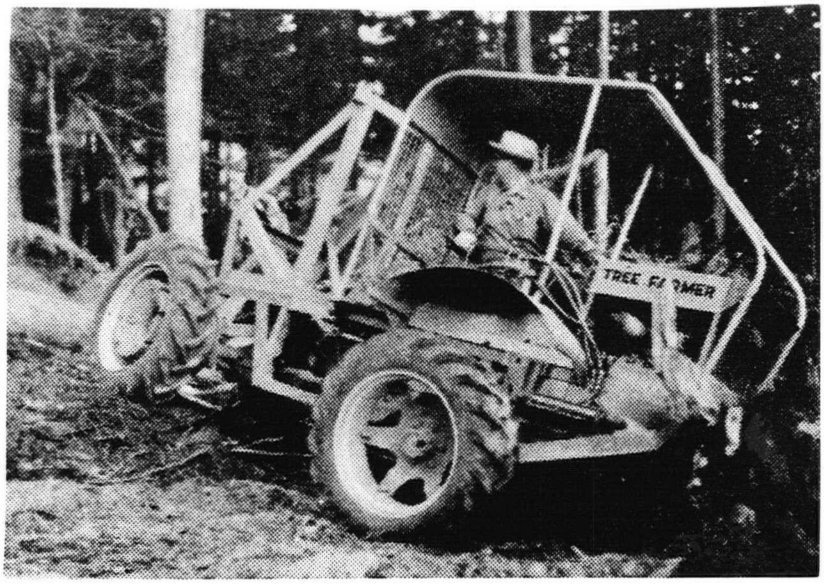

Figure 3. The Garrett Tree Farmer tractor in operation.

One of the most promising rubber-tired type of tractor on the Coast is the Garrett Tree Farmer tractor. (Figure 3.) It was used recently in the thinning operation on East Thurlow Island, where the author could gain a direct impression of its performance.

The Garrett Tree Farmer is a small ($3\frac{1}{2}$-ton), narrow gauge, compact unit with an articulated frame. Slip shafts and universal joints on the main drive shaft and four-wheel drive, give the machine a short turning radius, enabling it to weave around stumps and other obstacles, as well as to climb steep slopes. A bulldozer blade mounted on the front assembly is suitable for clearing windfalls and other obstacles from the skid trails and keeping skidway sites free. It is not powerful enough, however, to bulldoze skid trails in dense stands where large stumps and heavy debris are present. The front wheel assembly, lacking springs, is pivoted to give 18-inch oscillation to the front wheels for clearance. A slow speed logging winch operates from a power take-off and holds 75 feet of cable 1/2 inch in diameter. Travel speeds are the following:

1st gear	2.2 mph
2nd gear	4.9 mph
3rd gear	7.2 mph
4th gear	14.7 mph
Reverse	1.9 mph

Rated horsepower is 48 hp. Drawbar horsepower is 35 hp. Highest single load is 1,140 f.b.m. or two cunits of pulpwood.

Wilson (1960) reported on an operation where a tree Farmer was used successfully. In his opinion, some of the attractive features of this machine are its low operating and maintenance costs due mainly to simplicity of design, and its good performance in rough terrain, and its high volume production in the better stands. As he pointed out, inexpensive tires, absence of springs, a simple chain-drive system, and maneuverability, make the Garrett Tree Farmer an attractive machine for thinnings. According to his report, based on an operation which was carried out under winter conditions, the tractor is capable of operating in snow to a depth of 10 inches, without trails. During the three-month operational period, daily records were kept and the following results were obtained: Average production per day was 10.7 cords. Average production per man-day was 2.7 cords under poor skidding conditions. The production went up under good skidding conditions to 15.2 cords per day or 3.8 cords per man-day. The topography was broken, flat to rolling. The maximum length of yarding was 900 feet.

The Timberman reported in 1959 on an operation, where the Tree Farmer was used and in which logging costs of $16.05 per M f.b.m. with a two-man crew, and $12.63 with a three-man crew, were obtained. Logs averaged 9.5 inches upper diameter inside bark. Average yarding distance was 1,340 feet. Production was 750 f.b.m. per tractor hour.

The Tree Farmer was used by the Research Division of British Columbia Forest Service in a thinning operation at Cowichan Lake in 1959. Production was 1.8 cords per man per day, including trail construction, which took 30% of the time on the operation. At the end of the operation, the production rose to 3.0 cords per man-day with about 1,200 feet average yarding distance and a crew of three.

The Timberjack, a rubber-tired unit, worked effectively in Eastern Canada even in three feet of snow, as reported by Caplan (1962). Its average production was 16 cords during an eight-hour day, with an average skidding distance of 550 feet. The total cost per cord was $8.03. In the same operation a heavier unit, the Timberskidder, with two drums, had a daily output of 21 cords, with 2,000 feet yarding distance and with a yarding cost of $9.51 per cord. The crews were large, 6 and 7 men respectively.

Many factors should be considered in the choice of tractor. Topography and climate, soil and ground conditions (debris), density of stand and size of logs, existence or absence of trails and their standard, all are important factors which have an influence on the choice of tractors, as far as weight, horsepower and type is concerned.

As the plan on East Thurlow Island is to create an all-weather skid-trail system in the experimental forest, rubber wheeled tractors are preferable. Further experimentation is needed to find the best method of working with the tractor in thinnings, the optimum size of crew and the best load-speed relationship.

Pre-yarding

Tractors used in skidding are handicapped when there is a lack of skid trails and by the time consuming bunching, which precedes yarding. Silviculturally the best solution is for the skid trail network to be dense enough so that the tractor need not enter the stand.

Bunching with the tractor's winch in many cases is not economical, if the same tractor does the yarding. Pre-yarding or bunching should be done separately beforehand if possible. It is most advisable to prepare loads for tractors not only because of increased production but also for reasons of damage reduction.

Pre-yarding or bunching can be done in different ways, by horses, by winches, by crawler type motor cycles, or by bunching tractors.

Horses would be the most ideal means to keep damage low. They have so many drawbacks, however, that their use in the Coastal forest is restricted. The usually heavy debris and heavy logs (especially hemlock) will not allow longer pre-yarding distances than 200 to 300 feet. The necessity of the continual presence of personnel for their maintenance, even on non-working days, increases the cost. Accidents and danger of loss by illness make the operation hazardous. Finally, the main problem is that there are few good horses and experienced teamsters available on the Coast.

Crawler type motorcycles are used in Eastern Canada and in Europe and may be adaptable under certain conditions, to coastal British Columbia.

Winches are useful equipment in pre-yarding. Many sled-mounted, semi-mobile and mobile units are available as single or double drum winches. With application of blocks they can be used under almost any circumstances.

An interesting new winch on the market is the Swedish "Sepson" radio controlled mobile yarding winch. Its operation is illustrated in Figure 25. As the sketch shows, it can be operated by one man. Production data are not yet available but the technical data allow an estimate of about 2 cunit per hour with a distance of 300 feet, assuming a single load of 20 cubic feet. Technically the system allows thinnings with the smallest possible crew, even with a single man. Felling, bucking and bunching can be done prior to yarding, the latter being done when it is convenient to use a tractor or truck on a rental basis. Present price is $1,200.00 for a single drum unit and $1,600.00 for a double drum. Operating speed is 200 feet per minute; pulling power is 2,000 lbs.; motor performance is 13.5 hp.

The writer had the impression regarding the Tree Farmer operation on East Thurlow Island (1959) that the most delay was caused by bunching. If the logs could have been prepared beforehand, the tractor, with its higher speed could have had a much higher production. A solution might be to use a small crawler tractor for bunching, and to prepare trails and loads for the Tree Farmer. This solution however, would only be practical with long yarding distances. With shorter skidding distances the relatively slow crawler tractor with heavy loads can outproduce the Tree Farmer with its higher speed but smaller loads. The Tree Farmer can be economical with short yarding distances, if loads are increased to maximum, using the lowest gear ratio. This approach approximates that explained in Spiers' thesis (1956) as shown by his theoretical layout for a combined skidding operation (Figure 4). In both cases, however, the pre-yarding must be done in advance to increase output of yarding.

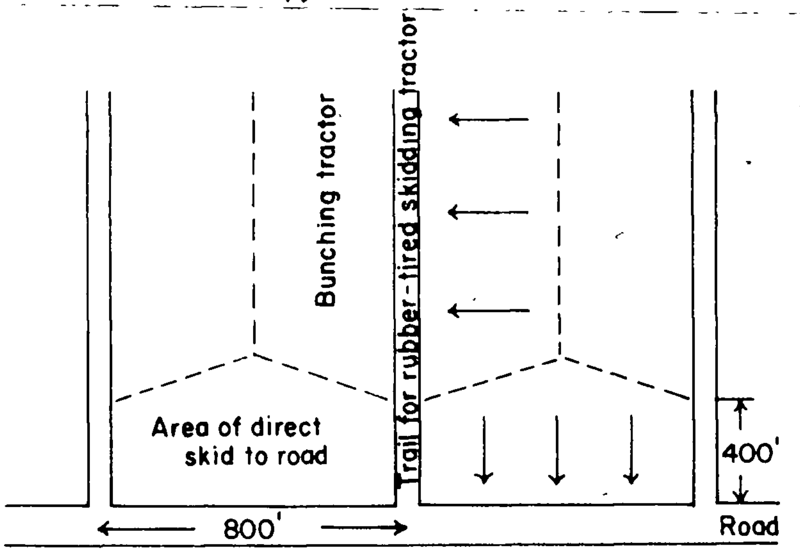

Figure 4. Theoretical layout for conbined tractor skidding operation.

If the carrying capacity for each gear ratio is known, it is possible to determine the break even point of economical yarding distance, as shown for Caterpillar Model D4 and Motor-mule on the graph as given by Leloup (1956), in Figure 5.

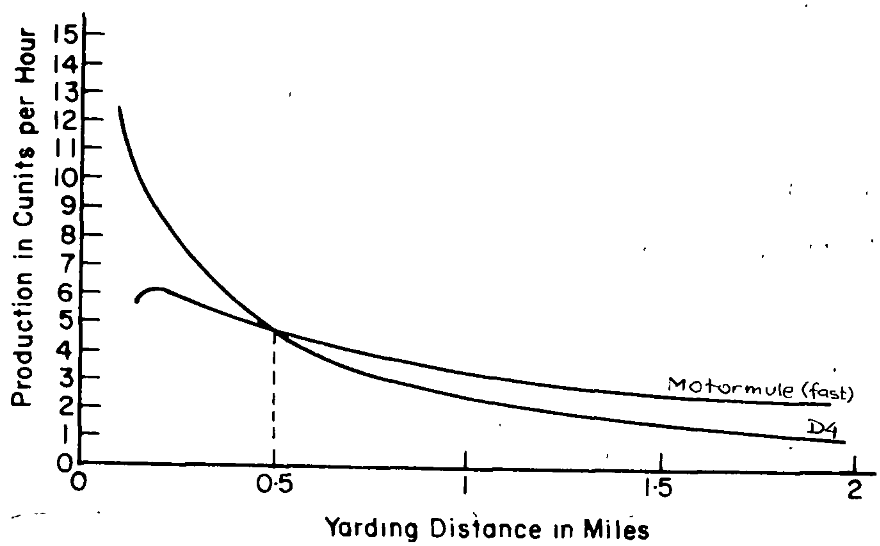

Figure 5. Comparison of slow and fast crawler type tractors on the basis of output as a function of distance.

The comparison of a Caterpillar Model D4 with a Tree Farmer gives a shorter distance of 0.4 mile for equal output, calculated with the following loads and speeds:

Caterpillar Tractor Type D4

speed with load	2.5 mph
full speed	5.3 mph
	2.4 cunit load

Garrett Tree Farmer

Speed with load	4.9 mph
full speed	14.7 mph
	1.0 cunit load

Cable Yarding Systems

Modifications of some of the European light yarding devices have been tried on the Coast in recent years. One of these, the Wyssen skyline crane, is a combination of high-lead skidding and aerial transportation. It has been used so far on the Coast exclusively for clearcut operations. It is a gravity system which has proved to be economical under special circumstances such as on steep, inaccessible mountain sides. The main advantages of its use are the small disturbances of the soil, reduced log breakage and the great saving in road construction.

Giordano (1959), in his book about logging cableways enumerated a number of similar cableway systems. Some of them were used in Europe, mainly in Switzerland, in thinning operations. Under present conditions it would seem improbable that any of these types could be used on the Coast in thinning operations. If only silvicultural aspects regulated thinnings, these systems certainly would be used in thinning steep mountain sides. Only the helicopter could exceed them in the respect of lifting the material above the stand and reducing to a minimum damage to the residual stand.

There is another Swiss cable system which is not widely known and not yet used on the American Continent. In the writer's opinion, with some modification, it would be an excellent logging device for thinnings on certain places. As it carries the load entirely in the air, the difficult ground conditions of the coastal forests would cause no problem in its operation. As the hauling process creates a continuous flow of the logs, the production rate is high despite the slow speed of individual logs.

This equipment is called a Lasso Cable Conveyor. The Lasso Pulley (Figure 6) and the Lasso hook (Figure 7), together with the endless hauling rope, are the basis of the Lasso Conveying System. The star-shaped pulleys allow for passing the hooks without difficulty. The hook is carried by the cable through friction. A special light vertical-axis single drum is mounted on the 25 hp. yarder machine (Figure 8). The layout of the system is illustrated in Figure 9.

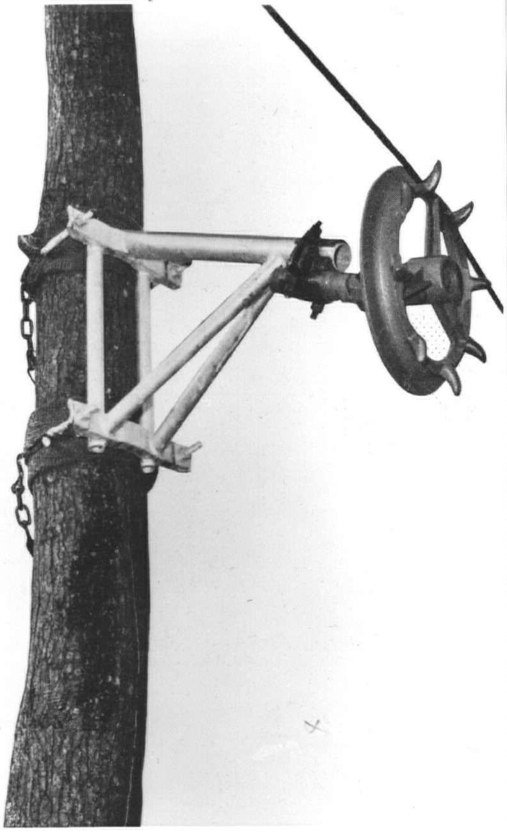

Figure 6. The Lasso Cable Pulley supporting the cable.

Figure 7. The Lasso Cable hook and the load.

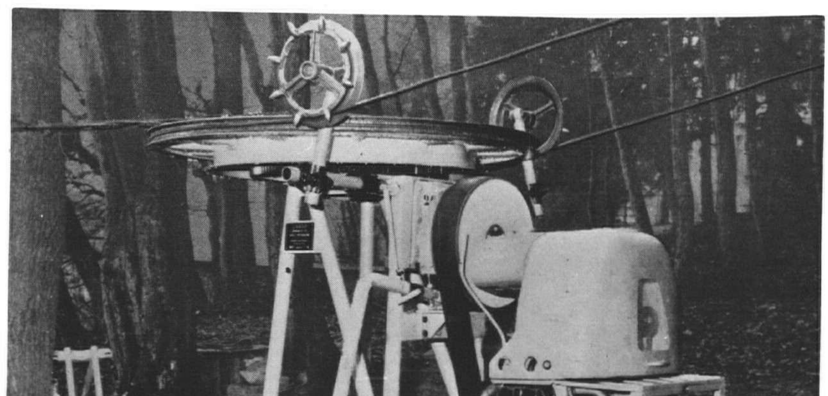

Figure 8. The Lasso Cable Yarder.

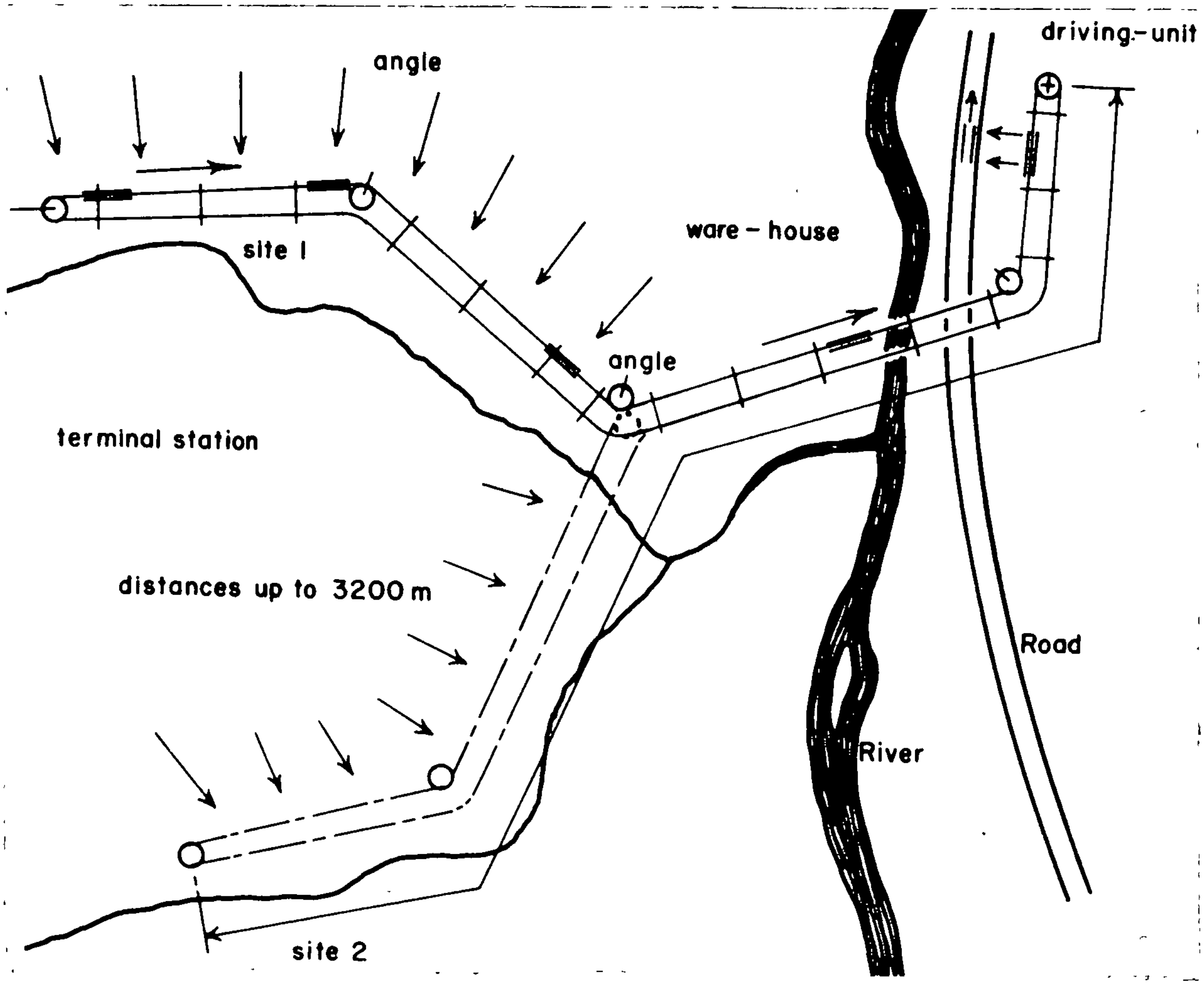

Figure 9. Typical layout of Lasso Cable

The first installation needs about ten to twenty days, but change of yarding road can be done in a few days, if properly prepared.

Cost of the unit is $30,000.00 including installation cost which is done by the company.

The Lasso Cable can be as long as two miles and the service can be continuous under all climatic conditions. Five to six men are necessary to operate the system.

The original Lasso Cable would not be practical on the Coast, because it was designed to carry light logs, usually fuelwood, but the Lasso Cable Company has lately designed a new, heavier cable, which can carry a load of 680 lbs. per hook. The loaded cable is more firmly supported in this case. (Figure 10).

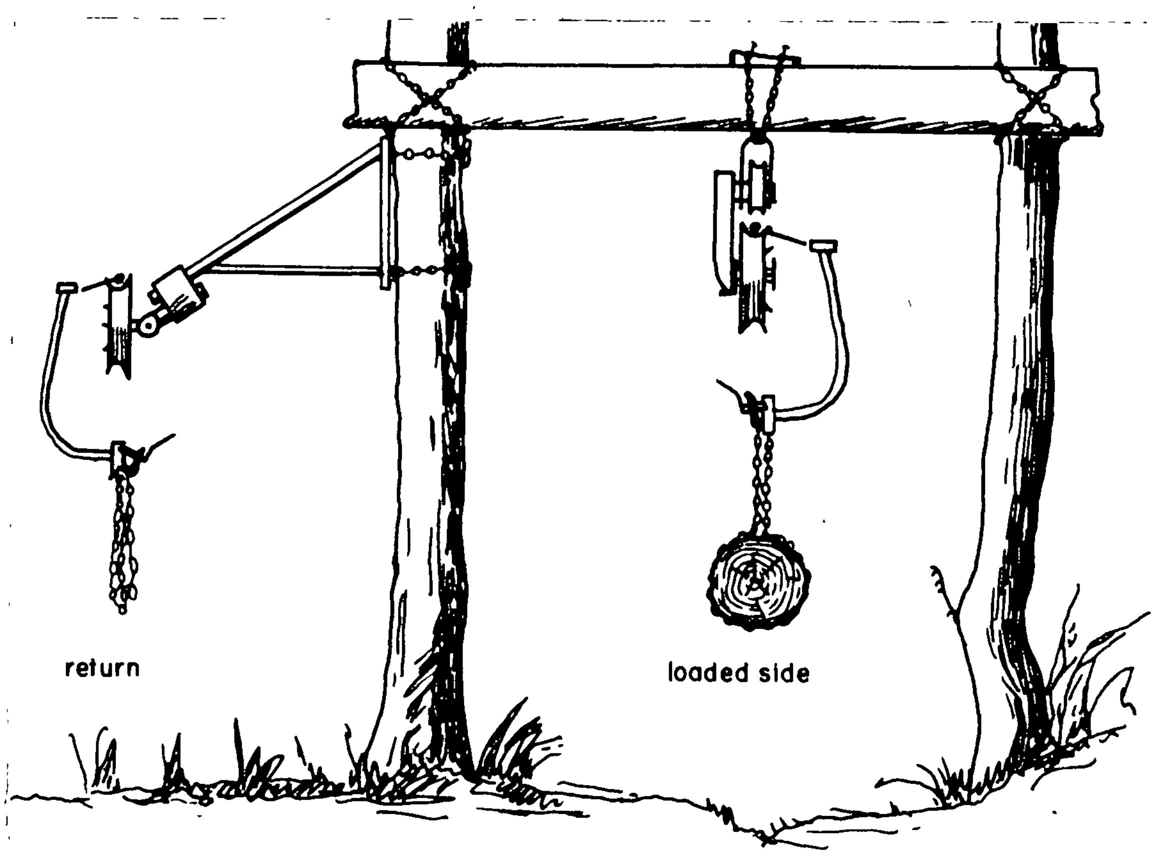

Figure 10. Support of loaded and return cables on the new system.

The endless monocable serving as carrier and traction cable, and driven by a skid-mounted diesel engine, is installed in the woods on a temporary basis, at a convenient loading height and more or less parallel to the ground. The line may form any kind of closed polygon, depending on the location of temporary landings.

At intervals of approximately 100 to 300 feet the cable is attached to standing trees by means of prefabricated, easily mountable, spiked wheels. The installation is simple and does not need skilled workers. (Figure 11). The loads are attached one by one at any point of the line by means of chokers provided with a special hook. Heavier loads are supported at both ends. (Figure 12).

Figure 11. Installation of Lasso Cable Support on Standing trees.

Figure 12. Lasso Cable in operation with heavy load.

If a convenient landing is available in the stand the line is brought down for the time of loading with specially mounted supports. (Figure 13).

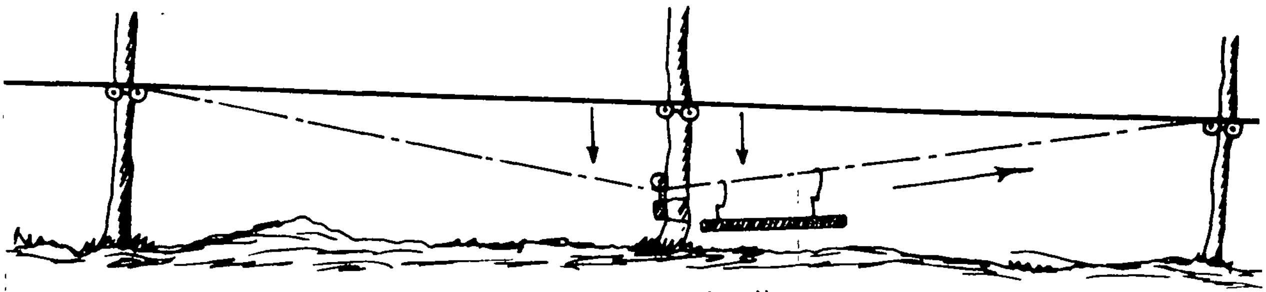

Figure 13. Temporary lowering of cable on landing.

The weight of the load keeps the hook tight on the line, and the logs travel at an average speed of six feet per second, spaced at intervals of thirty to fifty feet, to the landing. There the logs hit a simple inclined wooden platform thus causing the hook to fall off the line and dump the logs. The empty slings and hooks are returned to the woods along the line, in bundles.

Alternatively, if the loads are heavy, the cable may stop from time to time to make the loading and unloading easier.

Reviving old skidding methods

In Oregon and Washington horse logging has made new gains in thinnings. As Worthington and Staebler (1961) stated: "For thinning products with a volume less than ten cubic feet, (e.g. 9" top diameter by 24" long) horses are more satisfactory for skidding provided that the terrain is favourable and skidding distances are less than 600 feet. Well-trained, light horses, handled by a skilled teamster, give an excellent account of themselves under such conditions". The cost of horse skidding was $2.40 per hour in Washington.

As the writer has stated in connection with pre-yarding, there is little probability that horse logging will be used in our coastal hemlock stands.

Koroleff (1951) stated that yarding small logs on steep slopes can be done economically by gravity using a suspended wire rope.

Light, easily transportable, metal chutes built in sections are still in use in Europe and Eastern Canada, mostly for yarding small wood. Aluminum is a durable light metal and might be a good material from which to manufacture an easily transportable chute, constructed for steep slopes.

Loading

Efficient loading in a thinning operation requires fast, mobile, light equipment such as the following: (1) Tractors with built-on loaders, enabling them to put their load directly onto trailers (Figure 14). (2) For larger products the fork lift loader is the best available equipment. (3) Loading winches are used effectively in many cases. One of its application is the Easy Way Logger. This truck with special frame and loading winch is a very practical self-loader.

(4) Hydraulic self-loaders can be mounted behind the cab for loading trucks (Figure 15).

Worthington and Staebler (1961) had the opinion that fixed landings are unnecessary and that fixed loading devices, such as gin poles, A-frames or rollways are not satisfactory for thinning operations. Fixed landings, however, need not necessarily be equipped with fixed loading devices. A fixed landing with mobile loader would be more economical than loading along the road. Topography sometimes offers good central loading places, which assists the co-ordination of the logging operation, especially if more than one felling, bucking and yarding crew operates in one area.

As the loading cost per unit for small diameter material is high, any device which is able to load several pieces together is desirable. This can be done easily on semi-permanent landings. If the topography allows the construction of rollways this may be another solution for loading.

Production and cost data of four types of loading equipment used in thinning operation are presented in Table 5.

Figure 14. Tractor with built-on loader.

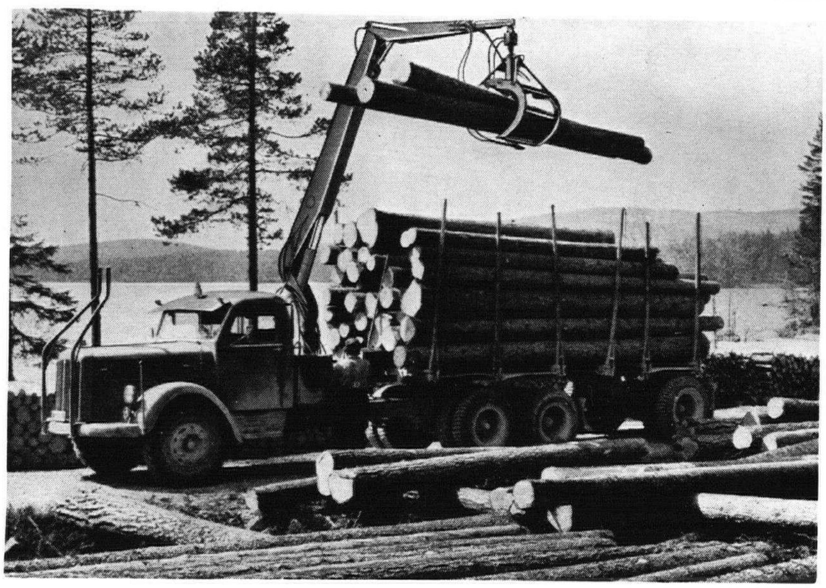

Figure 15. Truck with hydraulic selfloader.

Table 5. Production and cost data of four types of loading equipment used in thinning operations

Equipment	Production per hour cunits	Cost per hour $	Source of information
Tractor forklift	3.2	1.20	Worthington and Staebler
Truck loader	---	3.04	Worthington and Staebler
Shovel Loader (4 cu-yard)	---	2.39	Worthington and Staebler
Easy Way Logger	4.5	----	Tessier

The three first phases of logging are in the following relationship to each other, based on thinning experiments as reported by Worthington and Staebler (1961).

Felling and bucking...............34% of total time

Skidding..........................50% of total time

Loading...........................16% of total time

Crews should be assigned on the basis of experience data such as this. On a well-organized average thinning job, 3.80 man hours are required to fell, buck, skid and load 100 cubic feet of wood.

Hauling

For hauling short logs and pulpwood, a dual-axle, flatbed truck is best; for longer products normal trucks of about 150 to 200 hp. are the most economical.

For long products, a truck or tractor and trailer unit is more conventional. Hauling longer distances using the

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Hauling

For hauling short logs and pulpwood, a dual-axle, flatbed truck is best, for longer products normal trucks of about 150 to 200 hp. are the most economical.

For long products, a truck or tractor and trailer unit is more conventional. Hauling longer distances using the continuous transportation method, a truck or tractor with three trailers would be the most economical.

Semi-permanent landings are best if the economical three trailer - one truck (or tractor) system is used for transportation. This method cuts the idle time of the vehicle to a minimum so that with good organization it is possible to make the hauling continuous. One loaded trailer will be under way to the unloading (dumping) place. When the loaded truck (or tractor) arrives at the dumping place it will be unhooked and the empty trailer will be hooked to the vehicle. During the round trip, the third trailer is being loaded on the permanent landing. This trailer will be hooked to the vehicle as it arrives, leaving the empty trailer behind for reloading. This type of organized hauling was used in Hungary and in Russia with good economy, and lately in British Columbia (Alaska Pine and Crown Zellerbach Companies on Vancouver Island). Worthington and Staebler (1961) emphasized the importance of well-organized hauling, stating: "The truck is an expensive piece of equipment for a thinning job, and the savings to be made by keeping it fully occupied must not be overlooked".

The economy of hauling is dependent on: (1) use of the best type of equipment for small log transportation on a well organized hauling process, and (2) the quality of the hauling road. A road system of relatively low standard, but well designed and maintained, is best for thinnings. With present market conditions it is almost certain that thinnings can not pay even for such hauling roads. Thinning operations, when first commenced, must start along existing roads.

In Worthington and Staebler's (1961) opinion, the loading and hauling can be contracted separately from felling, bucking and skidding. Several smaller crews can provide enough logs for a well organized hauling crew to keep it busy. This proposal has the advantage that a separate hauling crew takes more care in maintaining the road than the woods-worker who is concerned more with the thinning operation itself.

The production, and cost of hauling, depend on many factors. Because one factor, the hauling distance, is a variable, differing greatly from one operation to another it is difficult to present average hauling-cost figures for thinnings. To make comparisons easy the ton-mile or cunit-mile cost data should be calculated for an operation. The Logging Road Handbook, (1960), is an excellent source from which to calculate and predict hauling-costs in a given situation.

Bundling and rafting

The special situation on East Thurlow Island required that the logs skidded or hauled to Bickley Bay be bundled and rafted for further transportation.

Bundling was performed on the shore, using a simple, bundling device. One-inch-wide steel bands, later aluminum wires, were used for bundling, two for each bundle, placed close to the end of logs. At the end of the last operation, the bundling was done in the water, which slowed down the scaling, but eliminated the problem of pushing the bundles into the water. The change of the tides was used to simplify the operation. Bundling was done with high tide, scaling with low tide.

Where trailers are used for transportation, the bundling might be performed on semi permanent landings which could reduce hauling time. About 150 bundles should make up a boom. The booms held together by boomsticks should be towed on a relatively calm water, because on rough sea the bundling bands or wires can break easily if hit by other bundles.

Bundling and rafting can be eliminated in some thinning operations in the future if portable barkers and chippers will work economically. It was reported (The Timberman, January, 1962) that one such unit installed in a Crown Zellerbach operation was successful. They feel that this is the most important technical breakthrough in wood recovery since the pulp industry began using chips from lumber residues. A somewhat smaller unit could be used on East Thurlow Island on the sea shore, as in Bickley Bay, barges could harbor without costly wharf installation.

Scaling

Scaling of materials coming from thinnings is expensive because scaling costs are higher than for big logs for the same volume. To overcome this difficulty present scaling methods should be changed in actual operations.

Scaling is required for three purposes: (1) as a basis for royalty payments to the British Columbia Forest Service, (2) as a basis for payments to contractors, if employed on that basis, and (3) as a basis for cost control related to accounting and production calculations.

In thinning experiments the nature of the study might demand that scaling should be done on a 100 per cent basis, as it was done on Thurlow Island. There are good possibilities, however, of replacing this system with others of adequate accuracy. These include a weight system using immersion tanks, and sample scaling calculating the average bundle or load size, e.g. Tessier's (1958) system.

The sample method promises the most economical results on East Thurlow Island. If the bundles are scaled to 100 per cent for a period, until the error of estimate can be reduced to an acceptable level, the further scaling can be made to a desired accuracy by sampling bundles randomly. If the relationship between bundle volume and number of pieces per bundle is established, the scaling can be done on a pieces per bundle basis.

LOGGING OF THINNING AS COMPARED TO CLEARCUT OPERATIONS

The relative importance of the logging phases can be seen by comparison of the working hours or unit costs of each cycle. Table 6 shows that the yarding phase is the most expensive in thinnings compared to clearcutting.

Table 6. Relative importance of various phases of logging in thinning and clearcut operations.

Operation phase	Man-Hour requirements in thinning Douglas fir Worthington and Staebler (1961) per cunit	per M. f.b.m.	%	Clearcutting in Vancouver Forest Distr. Smith *et al* (1961) %
Felling, bucking	1.29	1.95	19	11
Skidding or yarding	1.90	2.90	34	17
Loading	0.60	1.03	10	6
Hauling	0.49	0.77	14	15
Miscellaneous	0.43	0.77	23	51
Total	4.71	7.42	100	100

DESIGN OF THINNING EXPERIMENTS

In the previous chapters it was shown that there are many questions unanswered about economic, silvicultural and technical problems of hemlock thinning. Thinning experiments are therefore special procedures because of their complex nature. There are different opinions about the design of such experiments.

Staebler (1957) suggested that the practical sequence of experimentation should start with tests of commercial thinning often before adequate silvicultural information is available. As a result, research is faced with the problem of setting up an experiment to test economic and silvicultural aspects simultaneously.

As far as the design technique is concerned, Smith (1959) was of the opinion that study of small sample plots with a fixed number of trees would be the most economical way of experimenting.

Others like Joergensen (1952) were in favour of larger sample plots of equal area established before the thinning begins, in a randomized block designed in such a way that different sites, different logging conditions and different degrees of treatments would be replicated. This, in time, will form a pattern of case histories. The first commercial thinning experiment on East Thurlow Island in 1953-54 was arranged in this fashion.

According to Staebler (1957) the best method would be to have the entire area, thinned by a given treatment, become the observation unit. Reliable cost and conversion returns can be obtained only from a commercial operation. He reasoned that some inefficiency is inevitable while the operator gains experience. Certain fixed costs which are incurred in establishing any logging operation, should be distributed over enough volume to keep them from being unrealistically large per unit volume. In addition, commercial thinnings conducted primarily for research are usually expected to have substantial demonstrational value. For this purpose, pilot plant size operations are most useful. This system was to be followed in the operation in 1959-60 on East Thurlow Island.

It might be possible that some other thinning schemes could also be experimented with at the commercial level. The vision of such new schemes is implied in reports from the Scandinavian countries dealing with new trends in thinning.

MECHANIZATION OF THINNING OPERATIONS

Samset (1961) in his paper: "Influence of Mechanization on Silviculture." dealt with the problem of thinning in an age of ever increasing labour costs, and came to the conclusion that both the logger and the silviculturist must give up their conservative ideas in the face of increasing mechanization in forestry work. He disagreed, however, with the ideas of both Braathe (1957) and Hagstrom (1961) who were respectively of the opinion that thinking too much about harvesting value will confuse the task of thinning, and, on the other hand, that future machinery and equipment will decide the methods of silviculture.

After presenting much argument and pointing out some results of new thinning experiments in Scandinavia, Samset (1961) came to the compromised conclusion that thinnings in even aged conifer stands are necessary but for profitable logging and without appreciable silvicultural danger, the number of thinnings must be reduced to a few, not more than four, but preferably to two or even one. These thinnings must start in the last stage of the forest, not much prior to stand maturity.

Precommercial thinning in his opinion should be done at a very young age, mostly in stands which are overstocked. Because this cannot be done profitably the cheaper it can be achieved the better. Mechanization could be used to replace the expensive manpower used for that purpose in Europe. A solution might be to use bulldozers before sapling age to create parallel roughly-cleared strips. Kramer (1958) showed that such strips of 9 to 15 feet width, some of which might be used later as skidding trails, do not decrease yield because the bordering trees will utilize the improved growing conditions. The cost of this operation will be balanced by savings obtained from better access to thinning areas in the future and may even allow a second selection thinning at a later date.

Commercial thinnings at a later age of the stand will allow more economical use of machines. To do this effectively a good road network is an absolute necessity. This constitutes a very important silvicultural enterprise, and facilitates the effective management of the forest property.

It is desirable however, that yield studies should be conducted in these types of thinnings, as the only data yet available are in connection with Norway spruce stands.

In the case of few, heavy, late thinnings the thinning scheme must be such that the logging machinery used could work with the highest possible efficiency.

Gayer's group system of natural regeneration was very popular in Europe but could not be brought into practice simply because it was not possible to serve the randomly created groups around openings in the canopy. The lack of geometrical order was eliminated by Wagner and Roth who proposed group arrangements in definite lines thus creating a basis for a road network to assist in logging.

Thinning schemes could aslo be arranged in geometrically organized manner. They could be done in strips or in patches or even with alternating clearcut and thinning strips or patches. The possible higher production of clearcuts will help the operator to make a profit more easily. A first attempt of that kind was initiated by G. Warrack in the 1959 thinning experiment on East Thurlow Island by arranging three twinplots, one of each being clearcut the other thinned. The plot size was 0.2 of an acre. The ideal microclimatic conditions created on the small patches were obvious and a good regeneration was observed in the following year. If Douglas fir had been planted on them good results would have been certain.

Thinnings or alternate clearcut and thinning can be organized in strips, according to the scheme shown on Figure 16.

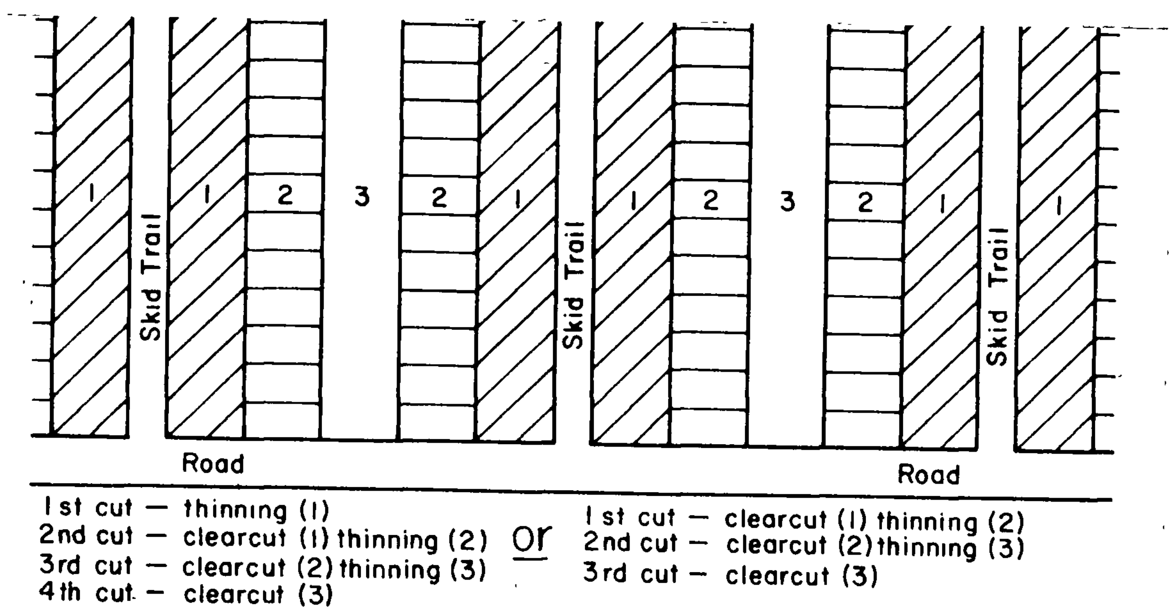

Figure 16. Theoretical scheme of strip thinning.

The strips along the skid trails would be thinned first or will be clearcut. The number of strips and their width will depend on the number of thinnings planned.

A similar pattern, practiced since 1952 on a 40,000 acre stand near Port Arthur, Ontario, can be seen on Figure 17. (Pulp and Paper Magazine of Canada, September, 1960) This stand became a woodlands laboratory in which foresters of the Abitibi Power and Paper Co. Ltd. carry on numerous cutting, planting, seeding and thinning experiments designed to maximize yield and protect the forest, the same aim as that of the Research Forest of East Thurlow Island.

If Kramer's (1958) findings would hold also in hemlock stands, namely, that 8 to 10 feet wide trails reduce yield of older stands only by 2% to 3% thinnings could be replaced by clearcutting narrow strips of 10 feet wide alternating with 20 to 30 feet wide strips of the residual stand.

The present practice of uniform thinning with a predetermined intensity, might be changed into thinnings with uniformly changing intensity, e.g. the intensity of thinning would be the heaviest along skid trails, with gradual transition into lighter thinnings in relation to increasing distance from the skid trails.

These systems certainly need a much denser road and skid trail network than it is now customary in clearcut operations. Skid trail system will be a great asset to silviculture even if their standard is low with no further maintenance until the next thinning. These skid trails in cases of emergency such as fire, insect outbreak can be reconstructed easily. Old skid trails on East Thurlow Island which were used more than fifty years ago, could be traced easily in 1960. There was a delayed regeneration on the skid trails but the trees were suppressed and soon died. These thin snags and the debris from other mortality which are now covering these trails could be easily removed with a small bulldozer. It was apparent that the trees along the skid trails were of larger diameters than the average stand diameter. This fact would enable one to determine whether these skid trails reduced yield in stands alongside or not.

The skid trail spacing always will depend on the type of yarding and bunching system used as well as upon the available volume per acre and the silvicultural requirements.

The direction of the strips must take into consideration the prevailing wind direction and topographical requirements to minimize wind damage and help in yarding.

If the skid trails are laid out in a more less parallel manner, depending on topography, the yarding process will usually be facilitated. On flat and rolling topography, tractors would be the best equipment, on steep slopes a light Wyssen skyline crane, in rough places the

Lasso Cable system. A system similar to a hi-lead but with a mobile tail-spar could offer good results as shown on sketch, Figure 18, and proposed by Tessier (1962). In this case the thinning and clearcut areas will show as adjoining triangles. This pattern and the later proposed chess-board like pattern will have many silvicultural advantages, e.g. better microclimatic conditions, better resistance to erosion, and so forth.

Parallel roads would enable the operation to use a type of equipment which can be visualized as a cross between the Lasso Cable type of conveyor and mobile spars with intermediate supports on standing trees or on temporary spars if necessary. The yarding method would be similar to the action of the steam plows used in the early years of mechanized agriculture.

This method would resemble somewhat patch logging, except that the patches would be separated by the same size of left over stands in which the thinning will be practice and the size of patches would be smaller and of triangular or rectangular shape.

Walker (1961) reported on similar type of thinning in New Zealand. (Figure 19). Tractor logging is being practiced there with truck hauling. The absolutely flat terrain allowed the laying out of road and skidroad net-work in an idealistic way. (Figure 20). It can be seen that the proper layout of permanent landings is an important feature in the network design. This pattern can not be used on the Coast, but the idea behind it can be adapted, and the layout modified to the mountainous topography.

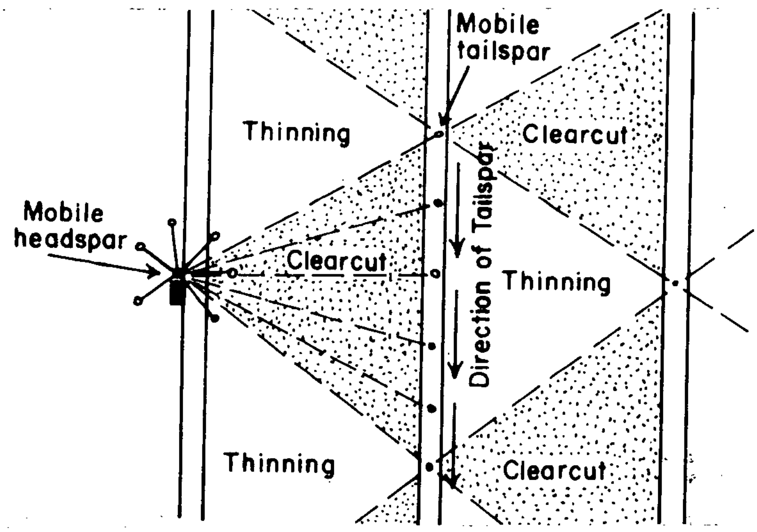

Figure 18. Theoretical scheme on triangle patch thinning.

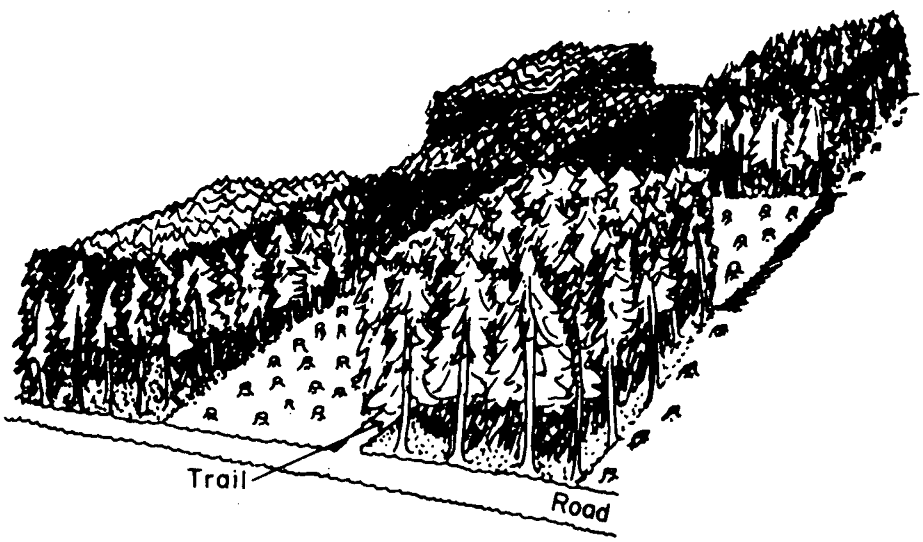

Figure 21. Chess-board like arrangement of patch thinning.

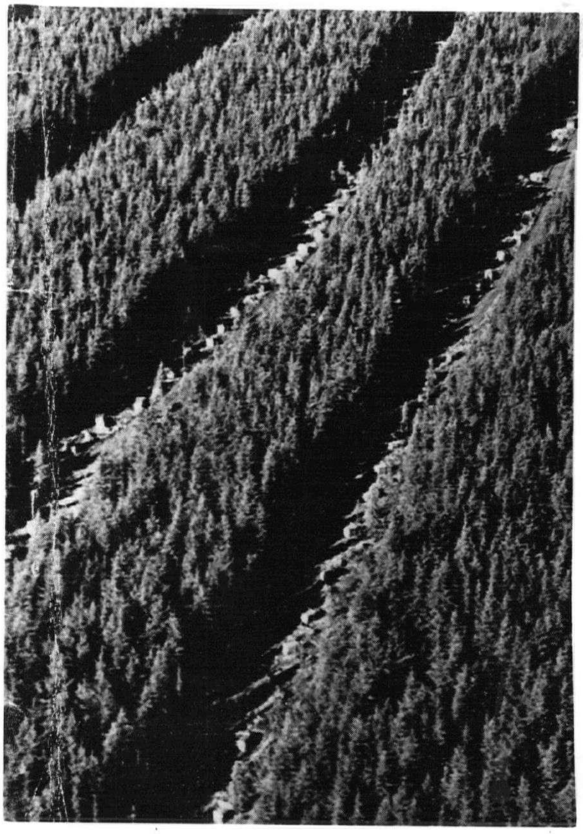

Figure 17. Strip cut near Port Arthur, Ontario.

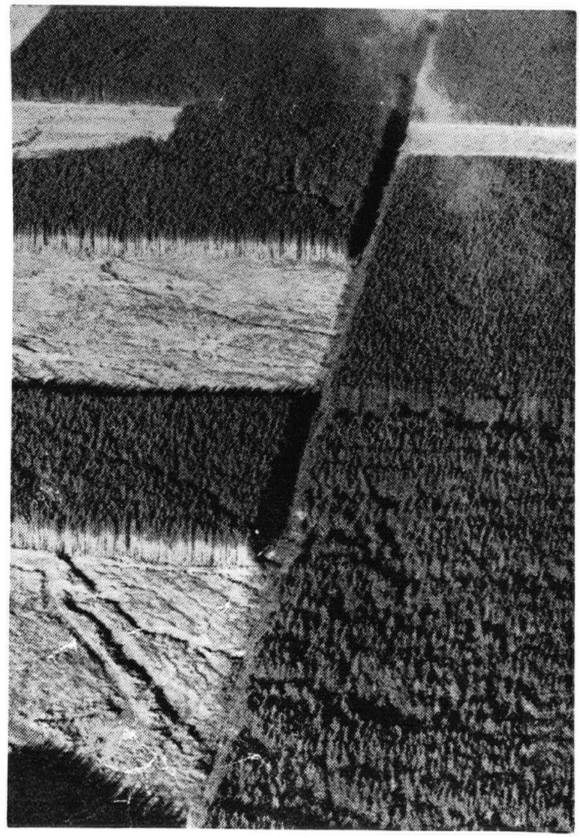

Figure 19. Square patch logging in New Zealand.

Figure 20. Road and skid trail layout for thinning in New Zealand.

The size of the squares would depend on the yarding method used and on the topography, as these will influence the skid trail or road spacing. For example if horse logging were used the patches could be about one acre or less. The same size could be used with winches. In the case of tractor yarding the size of one square should be between 1.6 and 5 acres giving a maximum pre-yarding distance of 264 to 462 feet. Road spacing would then be 528 to 924 feet respectively.

The silvicultural advantage of this pattern would lie in the establishment of improved microclimatic conditions, good protection from the wind of any direction and more ideal fire control.

The cutting order will depend on the number of thinnings planned. The clearcut acres will most probably regenerate in hemlock easily. This new stand will be about ten years old when the No. 2 patches will be clear-cut. These patches then can be planted with Douglas fir, under the protection of the previously regenerated hemlock patches. There will certainly be some hemlock regeneration among the Douglas fir but it can not be such as to suppress the fir. In this way the value of the stand can be increased.

Whether the aforementioned schemes could be applied to older, second growth stands on the Coast is debatable.

It might be worthwhile to try it on experimental basis and the Research Forest on East Thurlow Island would certainly be a good place where the necessary comparisons might be made easily with the conventional thinning experiments.

It could be argued that it would be better to use hemlock stands which are already accessible, closer to markets and easily manageable for experiments. It would certainly be necessary to see new experiments established because the problems needing answers are many. Thinning experiments are long range experiments and since there are very few existing it would be the wrong policy to abolish an already existing experiment, with almost ten years of accumulated data.

The information required from these experiments to develop adequate thinning schedules may include such items as: Influence of spacing on tree growth by d.b.h., age and site classes; influence of change in spacing on the same factors. Influence of spacing, d.b.h., age and site on mortality; influence of d.b.h. on cost of logging; influence of d.b.h. on value of production; influence of logging on injuries and so forth.

PRELIMINARY ROAD LOCATION PLAN FOR THE RESEARCH FOREST ON EAST THURLOW ISLAND

As earlier investigations on the Island clearly showed there is no possible way to thin commercially without an adequate road system. There is no assurance, however, that the thinnings *ipso facto* will be feasible after the road network exist, because there are other requirements such as above marginal log size, appropriate logging methods, and favourable market conditions. But even so the road network is of primary importance.

In planning an optimum road network some preliminary determinations should be made. It should be calculated whether or not there is enough timber to cover the construction costs of the road system. In order to give useful information to the man who will design the final location in detail, some advice should be given beforehand regarding design elements and other special engineering aspects of the road. Before a road system can be developed it is necessary to decide on the logging methods which will be used, as different logging methods require different network scheme. After that a preliminary layout of the road system can be done on maps or aerial photos. This layout should be then checked on the ground to reveal every problem that could affect the final layout of the network.

The preliminary nature of this plan implies that it does not replace the necessary considerations to be made in connection with the final location plan. It is only a helpful tool to make the correct final decision from technical and economical points of view.

General Considerations On The Road Network

It was anticipated that tractor logging and truck hauling would be the most economical in thinning on the Research Forest and the road network should be designed to make this possible.

Aerial phots taken in May of 1960 were of great assistance in arranging the preliminary layout of the roads.

The topography made it possible to locate more alternatives in the road network on the photos.

When the area was logged around the turn of the century, a network of skidroads were left behind, but these are now impassable because of log debris or young trees growing on them. Some of the skid trails, however, can be reconstructed easily and they have been used as parts of the planned system of new roads. Two of the old trails are being used now: the Hemming Lake trail and the Shoal Bay trail (Appendix 1), but they are not suitable for vehicles due to narrowness and lack of bridges.

Scattered old growth stands were left from earlier clearcut operations and could be spotted easily on the photos. Since these stands were covered with 100% coverage in 1960 important data is available to evaluate the economical possibility of building the main roads.

The position of the old stands, the field survey on possible re-use of the existing old trails, examination of the location and various soils and gravel deposits, creeks and swampy places made it possible to choose from the various alternatives for the best road network. (Appendix 1).

As the direction and location of the creeks and swamps together with rock outcrops are the main influence on the construction and maintenance costs of the roads, much time was spent on finding the best possible location for the roads to eliminate expensive bridges and avoid swamps and rocks.

As the map shows (Appendix 1) there are several small creeks and some swampy places in the area. The soil is clayey or silty and erodes very easily. That is why the creek beds are deep, making difficult to cross them otherwise than with bridges. Smaller temporary creeks could be crossed, however, by culverts.

The shape of the Research Forest is such that the main access road has to consist of two branches.

The positions of the old stands make it necessary that the main two branches of the roads should run in about the same direction as the old Hemming Lake trail and Shoal Bay trail.

The Hemming Lake trail has a central location and easy grades, except the last mile to Hemming Lake with a 10 per cent adverse grade. Running on the west side of the main creek, however, it has to cross a number of side creeks. These have wide deep beds, in some places of swampy nature. In the first mile, six to eight bridges and two to four large culverts should be built. The best young stands cover this side of the main creek. The fertile soil with its high clay and silt content is, on the other hand, of the lowest quality for a subgrade.

From the engineering point of view, and also due to the presence of merchantable old growth timber on the other side of the creek, the location of the main road seemed to be more economic on the east side of the main creek. It could then cross over to the west side and join the old Hemming Lake trail where there are no side creeks on the right side of the creek. (Road A and B on the map.)

This approach will also help to give a better location for the old Shoal Bay trail which at its start from Bickley Bay has a very steep slope. With a well situated switch-back from the planned road "A", it will join the old trail at a point very convenient for joining other branch roads or creating a semi permanent loading place (road C on the map). This would enable it to serve almost the entire plateau lying east of Bickley Bay.

The two main access roads can be connected with the main log dump in Bickley Bay where the flat shoreline creates an ideal place for dumping or storing the logs. The flat area is large enough for a logging camp as it has already been previously used for that purpose. A permanent, well-designed cabin for office and accommodation for the research crew, was built here in 1954.

The two main roads have been marked on the ground with red plastic ribbons attached to the trees.

The location of "A" and "B" main roads on the east side of the main creek leaves the west side without access. Secondary road "D" was therefore planned to serve this area. It partially follows the recent yarding road which was used in the previous thinning operation. This road is washed out so badly that "D" road should be put beside it, leaving the original trail as a drainage ditch.

The first 2,100 feet of the old Hemming Lake trail is very much handicapped as a road because of many small creek crossing. For this reason, road "D" swings westerly and then easterly to avoid these creeks. It ends at the next big side creek bed, thus eliminating the need for any costly bridges.

The planned total length of the main roads is 3.25 miles.

The main roads are evenly distributed on the area. The secondary branch road system is based on them. In most cases old trails which have not been maintained but are readily visible have been used as branch roads. These roads are shown on the map with red lines and are marked on the ground with red plastic ribbon on trees. The red roads with dotted lines on the map are not taped on trees but have been reconnoitered in the field. The branch roads are numbered on the map from one to nineteen.

The secondary road system was planned to tractor logging.

The economical spacing between these roads was found to be approximately twenty chains, according to the following calculation. The average road construction costs for such roads as given by Worthington and Staebler (1961) is $6,600.00 per mile. This amount is realistic under the circumstances, because the topography is gentle, there are almost no rock outcrops along the planned roads, and the layout was planned in such a way as to avoid culverts and bridges, running mostly parallel with the creeks, on the flat, relatively dry land between the creeks. Available volume for thinning per acre according to the last experiments on the Island is two thousand cubic feet, removing one-third of the total merchantable volume. The cost of skidding by tractors per cunit is \$5.25 for 800 feet average yarding distance or \$0.66 for 100 feet as given by Worthington and Staebler (1961). The spacing using Matthew's formula:

$$S = \sqrt{\frac{0.33 \times 66,0000}{20 \times 0.66}} = 1,300 \text{ feet} = 20 \text{ chain}$$

The secondary road system will serve the logging and other forestry work in the following way: No. 1 road serves the east area close to the cabin and joins with a switch-back to road "A".

No. 2 road would play an important role between roads "B" and "D" serving the good stands closed in between the two main creeks where E.P. 27 and 28 are marked.

The valley of the creek leading to Hemming Lake (through E.P. 97) is barely accessible from No. 9 road. It is planned therefore to open it up by the roads No. 4 and No. 5 joining directly to road "B".

No. 7 road, together with No. 6 would be the main hauling road for Stand No. 5. Old Stand No. 4 could be served by an old trail, now No. 8 road.

No. 9, as a secondary road is the continuation of road "B" and would be the axis of a road system serving the south part of the area. This branch road has not been elaborated at this time.

No. 10 road, through E.P. 91 is a well laid out old trail. It would need only minimal maintenance work to rebuild it.

Roads Nos. 11 and 12 reach a scattered old stand but the general topography suggests that if the stand were logged it should be brought to Shoal Bay on good existing logging road which runs outside the boundary of the Research Forest.

No. 14 is the continuation of road "C", with acceptable adverse grades running through good second growth stands.

Nos. 15, 16 and 17 are also old trails and would not need much construction work to bring them into usable condition.

The branch roads Nos. 1 to 19 with some later extensions are able to serve the whole area. They could be built successively whenever the actual forest work makes them necessary.

The total length of the secondary road system, when completed would be approximately 35,310 feet = 6.7 miles.

The road system as it is now on the map is only one of the many possible solutions. The present plan implies some other possible variations.

(1) If emphasis were put on the problem of the stands to the west of the main creek then road "D" should be

built as one of the main roads. Two bridges should be then constructed beyond its end on the old Hemming Lake trail. In that case road "A" and "C" would still exist as main roads to open up the Shoal Bay plateau, but road "B" would be constructed only as a branch road whenever it would be necessary.

(2) No. 1 road could be built as a main road instead of "A" and "C" and join with a bridge with the Shoal Bay trail. In that case "A", "B" and "C" would be branch roads.

(3) The original system would go in effect but road "B" would continue with branch road No. 2 as a main road, leaving the other parts of it as a secondary road.

The final decision as to which of these systems would best serve the area could be the result of a meeting on the subject between the engineering crew and officers of the Research Division, after the crew finished its preliminary survey or location of the lines mentioned before.

To see if there is any possibility of covering the expenses of the road system, we must examine the available funds by the clearcut operation of the old stands.

Estimated funds available for road construction

In the first five years of operation there should be a clearcut of scattered old growth patches. With allowances in stumpage price the following calculation show, that the planned all-weather road network can be constructed to the necessary standard in the first five year period.

Theold growth stands were cruised by the writer by grade on 100 per cent basis in 1960 and No. 1 logs were tallied separately. Mature volumes were compiled using log-position volume tables. (Fligg and Breadon (1960)). In the cruising notes, remarks were entered for every tree concerning its health, lowest branch, etc. The compiled data has been used in the following calculation.

Table 7. January, 1962 log prices in the Vancouver Forest District.

Species	Price per M f.b.m. Grade(sawlogs)			Price per cunit Grade(sawlogs)			Pulpwood price per cunit (As No.3)
	3	2	1	3	2	1	
	$	$	$	$	$	$	$
Douglas fir	57.00	67.00	77.00	31.30	36.90	43.20	31.30
Cedar	57.50	47.50	57.50	20.60	26.10	31.60	20.60
Hemlock	43.75	50.00	55.00	24.00	27.50	30.20	24.00

Note: Prices are as given in the B. C. Lumberman, January, 1962.

Table 8. Road construction charges available per cunit in dollars.

Species Grade	Selling price at mill per cunit	Stumpage Ccf	Profit 15% of selling price	Cost of logging excluding r.const'n.	Total deductable per cunit	Remaining fund for roads per cunit
	$	$	$	$	$	$
Df 1	42.30	4	6.35	12.45 [1]	22.80	19.50
2	36.90	4	5.53	12.45	21.98	14.92
3	31.30	1	4.69	16.06 [2]	21.75	9.55
H 1	30.20	4	4.53	12.45	20.98	9.22
2	27.50	4	4.12	12.45	20.57	6.93
3	24.00	1	3.60	16.06	20.66	3.34
C 1	31.60	4	4.74	12.45	21.19	10.41
2	26.10	4	3.92	12.45	20.37	5.73
3	20.60	1	3.09	16.06	20.15	.45

1. Tessier and Knapp (1961)

2. Worthington and Staebler (1961)

Table 9. Total income available for road construction.

Species Grade	Merchantable Volume Available in 5 years cut cunit	Total Amount Available for roads $
Df 1	1329	25,915.50
2	1116	16,650.72
3	1117	10,667.35
H 1	105	968.10
2	2451	16,985.43
3	7577	25,307.18
C 1	79	822.39
2	200	1,146.00
3	461	207.45
H right of way	1845	6,052.30
	Grand total	$ 104,722.45

The construction of 6.7 miles of secondary roads will cost $44,220.00 with an average cost of $6,600.00 per mile.

The remaining $60,500.00 will allow construction of main roads with an average cost of $18,600.00 per mile. This seems unreasonably high for this area but gives the opportunity to raise the stumpage price to a more realistic level. The cost of road construction must be covered by the operator governed by the timber sale contract.

The writer is of the opinion, however, that as much money should be spent on initial all-weather road construction as is realistically possible in order to create a situation where even pre-commercial thinning might be practiced with the hope that the low hauling costs, on the then existing good roads will bring these operations above the marginal limit.

Design elements

The proposed road system is planned as a permanent network because this is the best way to serve the experimental forest in its aim to create an intensively-managed research area with continuous yearly operation. The nature of this network demands some special considerations as the design elements concerned.

Cross section

The design of cross section is usually facilitated by using standard cross-section types. The British Columbia

Forest Service Engineering Services Division has its own Forest road specification describing seven road classes. According to Worthington and Staebler (1961) it was found that on the coast for thinnings, a 16 foot road bed with a three-foot allowance for ditches is most satisfactory. For the right-of-way, five feet was cleared on both sides of such roads. This type of road would be closest to that of No. 5 class roads in the forest service standards. Specifications for it are: surface width - 12 feet; subgrade width - 16 feet; ditch depth - 1 foot; R W width - 50 feet.

It is seen that the right-of-way is approximately 20 feet wider than Worthington's (1961) specification. Taking into consideration the wet climate and the clayey soil of the island, the proposed 50 feet of right-of-way is most advisable in order to permit adequate drying. The clear cut on the right-of-way area will enable the contractor to increase his productivity and will help to pay off the construction costs of the road.

The surface width is only wide enough for a single lane, which will necessitate the construction of turnouts at convenient distances, if the amount of traffic requires it.

The main road system, however, should be of a higher class than the branch roads because it will serve the whole area's transportation. The Forest Service of British Columbia third class road is the most appropriate, with one chain right-of-way width.

Specification will be: surface width - 18 feet; subgrade width - 24 feet; ditch depth - 1½ feet; R W width - 66 feet.

Slopes of cut and fill will be 6:4 and 2:1 respectively, or as the subgrade material requires.

The cross section on curves changes, being widened and superelevated.

The wider road in curves and the superelevation make it possible to maintain the speed of the vehicles. Long vehicles like logging trucks with trailers must have enough width to keep the wheels on the road surface. In the design of forest access roads in British Columbia there is not enough emphasis on widening of the road on curves. Reference books to the engineering surveys of British Columbia Forest Service (1957) do not even mention this.

The widening (W) depends on the radius of curve (R) and the length of the log transported, or better, on the distance between the trailer axle and the truck rear axle (L). An equation giving good approximation, based on the geometry of the vehicle on the curve is: (Figure 22)

$$W = \frac{L^2}{2R}$$

W is the widening, L is the distance between first and rear axles and R is the radius, all measurements are in feet.

The necessary widening for some standard radii and degrees of curvature have been calculated for the standard logging truck in British Columbia and the data are given in Table 10. This table shows clearly that in curves above 300 feet radius or under 20 degree of curvature the widening can be neglected.

Table 10. Relationship between curve data and widening for logging truck with trailer on a single lane road.

$l = 51$ feet, $l^2 = 2{,}601$ feet^2

R radius in feet	D	feet widening	Degree of Curvature D^o	R feet	Widening in feet
75 (Rmin)	76°30'	17.3	76°30' Dmax	75.-	17.3
150	38°10'	8.7	20°00'	286.48	4.5
300	19° 6'	4.3	10°00'	572.96	2.3
1000	5°42'	1.3	6°00'	954.93	1.4

As the design speed for logging roads is low the super-elevation can be a standard 1.25 inch per one foot based on icy road conditions.

Grades

Hauling costs are greatly affected by the grades. The effect of grade on travel time, as stated in Logging Road Hand Book (1960) is of a quadratic nature. Despite the afore-mentioned fact, it is conservative to limit the grade on forest roads to less than 8% for favourable and less than 3% for adverse grades. The less the grade is, the longer the road has to be to overcome a given height difference. It means that the gain in hauling costs will be overcome by higher construction costs. The traction force and braking power of the vehicles used on the Coast is so powerful that the limitation of grades for this reason does not enter the picture. The main limiting factor on Thurlow Island will be soil condition. The clayey silty soil would not allow a higher grade than 8 per cent without the danger of erosion. The rolling topography makes it possible to design the alignment with grades around 6 per cent and adverse grades below 3 per cent.

Curves

Radius of curve affects the travel speed in a quadratic manner according to the Logging Road Handbook (1960).

Minimum radius should be determined which would allow to maintain the design speed on the road. Assuming 30 m.p.h. design speed the minimum radius should be 229' or equivalent a 25°30' degree of curve.

If the topography is rough, the use of curves with this minimum radius would cause high construction costs. Bearing this in mind, it is useful to determine the absolute minimum possible radius for curves where the vehicle is able to proceed with lowered speed. This depends only on the structural feature of the vehicle, and can be done graphically (Figure 22).

As the figure shows the absolute minimum radius would be 75 feet. This radius will apply to the main roads only, where logging trucks will haul the logs from the old stands. On secondary roads sharper curves could be used if necessary.

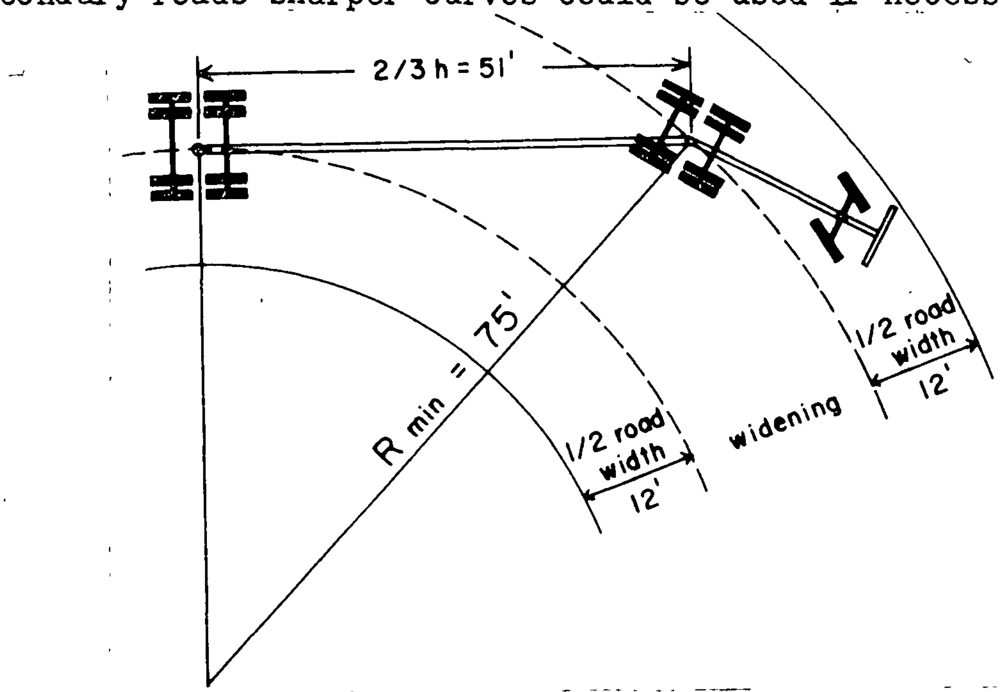

Figure 22. Graphical determination of absolute minimum radius for truck and trailer.

The importance of the main roads makes it advisable that the curves should be designed with transition curves. On highways this is largely for safety reasons. On forest roads, however, their use is mainly for economical reasons, as a good alignment with appropriate transition curves fits the road much better to the terrain than using circular curves. The construction costs will consequently be lower.

The alinement of the main roads (A, B, C and D) should show the least possible curves and as long tangents as possible.

Drainage

To solve the problem of the drainage is the most important in the preliminary design of the alignment. Construction costs are greatly affected by the installations necessary to avoid erosion or washouts, (culverts, bridges, retaining walls). On the Coast $2.00 to $4.00 per linear foot may be spent for forest roads whereas the cost of forest bridges is around $50.00 per foot. The reduction in the number of such installations is then very important. The total cost of the roads, however, is affected not only by construction costs but also by yearly maintenance cost. An inadequate drainage system will result in high maintenance and high hauling costs. The alignment therefore should be such that with the possible least number of installations the best possible drainage will be achieved.

The necessary drainage installation should be for both surface and subsurface drainage. To make the drainage effective, well-maintained, normal-sized ditches, culverts with adequate cross sections and with well-constructed inlets and outlets, should be established.

The surface drainage provides for the removal of the rain water from the surface of the road, and will be necessary on all roads in that area. If the surface water is allowed to soften the subgrade, the road will lose its efficiency under traffic. Surface drainage can be provided by maintaining the side grade of the cross section and by simple surface-drainage installations.

The subsurface drainage is even more important in that type of soil. A wet substratum cannot give either a good road or a firm subfoundation for the surface. Because of the wet climate on the island and the nature of the soil, there should be no hesitancy in spending sufficient money to make the subsurface drainage system efficient, as this will effect a considerable saving in the subsequent cost of maintenance. The subsurface drainage can be constructed using rocks for fill, with or without drainage pipes.

The cross drainage structures which provide for the passing under the road of a creek or stream, crossed by the line of road, can be a culvert of a bridge depending on the size of waterflow. The relatively small watershed area allows the use of culverts for the most part because the side creeks are not heavily flooded even after heavy rains, as noted by the author during the field operation. Culverts should be installed where the waterflow necessitates it and at least in every ten-chain distance along the road.

Single wooden culverts might be used with cedar stringers as the material is available for it on the location. In the installation, care should be taken to provide a correct foundation, and in the construction of the inlets and outlets.

The inlet should be built with a catch basin to hold the silt and solid matter. This should be cleaned from time to time to prevent early clogging of the culvert. The outlet should be constructed with a stone apron to prevent washouts.

The erection of one bridge with a thirty-foot span and several smaller bridges, which can be of a simple log-stringer type using the available logs nearby, will be necessary.

An easily-constructed type of bridge might be an alternative for the large bridge, if calculations would show it more economical. Bridges with glued, laminated beams or with nailed "I" and box beams are such types. Nailed beams have been very common for bridges during World War II. Their advantages are that it does not need skilled workers for construction, any small size material can be used such as two by fours and their carrying capacity can be increased very easily if necessary by the use of additional flanges. Plywood sheets can be used as webs. If there is no further use for the bridge it can be easily taken apart and transferred to another place, which is not the case in this situation, however. The main construction elements of such a bridge as described are shown on Figure 23.

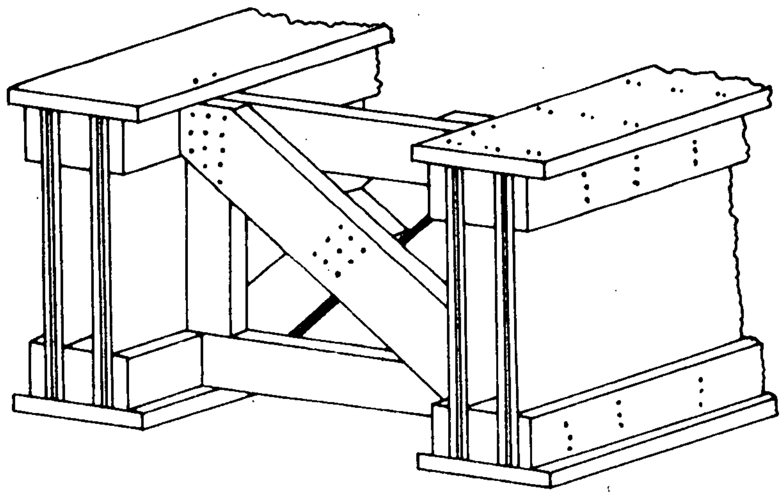

Figure 23. Cross section of nailed "I" beams with plywood webs.

Surfacing

The all-weather nature required of the roads makes it necessary to cover them with a resistant surface.

The simplest, cheapest and temporarily-adequate surface would be gravel. There is a problem, however, to get good gravel material, because there are only a few gravel deposits in the area. The best source for graveling the first part of the road would be the seashore. The next closest good gravel deposit is about 2.5 miles from the shore. The location crew for final layout should take extra time to search the vicinity of the main road lines to look for gravel deposits. Sufficient test pits should be dug at suitable locations. The final cost of road surfacing to the desired standard will depend on hauling distances and the quality of the gravel. It is anticipated that gravel deposits will be available to allow an overhaul of less than one mile. There are many rock outcrops near the planned road system, but the rock is too solid to crumble by blasting. To install a rock crushing machine might be economical in the long run, because it could provide crushed gravel for later maintenance, it is difficult, however, to justify it for less than ten miles of road work.

The material for the subgrade will be mostly sand, silt, clay mixture which covers the largest part of the area. At the time of the final road location a thorough soil analysis will be necessary. If the results of the soil tests necessitate it, stabilization of the soil should be done, because the funds available for construction are adequate. The fixation of the subgrade and surface can be done either mechanically by mixing soils with gravel or sand in a given ratio, or by the addition of other substances such as cement, sodium chloride, bitumen, etc. as described before. Stabilized earth roads are increasing in importance as forest roads throughout the world, because of their cheapness and, if well constructed, of their ability to resist the action of traffic and weather.

The area will have a continuous program, as the nature of sustained-yield management and thinnings require. According to Worthington and Staebler (1961) temporary roads are not compatible with such a program and will prove uneconomic.

The main roads (A, B, C, and D) and numbered branch roads should be designed and constructed to a higher standard so that they will permit all-weather use with a minimum of maintenance for the balance of the rotation.

Skid trails are not designed in advance and will be constructed to a lower standard as semi-permanent extraction lines.

Road construction costs

Road construction cost per mile for main and branch roads are difficult to predict precisely because of the preliminary nature of this road network design. Due to observations on the scene it can be stated however, with good probability, that the easy topography will create no real difficulties in construction, but the soil will necessitate some kind of stabilization and a thorough drainage which will increase costs.

In any case the road construction costs would not run much above the sum which is available and calculated previously.

To support this opinion an abbreviated road-cost estimation for the main roads follows in tabular form. (Table 11).

Table 11. Cost estimate for main roads A, B, C, D(3.25 miles)

Description	Quantity	Unit	Basic Price	Total Cost
Clearing and Grubbing				
a) Right of way	26	acre	350.00	9,100.00
b) Gravel pit	1	acre	350.00	350.00
Roadway and Drainage Excavation				
a) Solid rock	100	cu.yds.	2.76	276.00
b) Other material	48,000	cu.yds.	0.35	16,750.00
Overhaul on Excavation	---			---
Compacting	32	day	120.00	3,840.00
Watering	12	1,000 gal.	3.50	42.00
Gravel base and Gravel Surfacing	26,800	cu.yds.	0.35	9,370.00
Gravel Haul	26,800	cu.yds.		
	13,400	cu.yds.	0.04	536.00
	13,400	cu.yds.	0.10	1,340.00
Installations				
a) Culverts	26	piece	70.00	1,820.00
b) Bridges	30	linear ft.	50.00	1,500.00
		Total basic costs		44,924.00
Additional Allowances (mobilization and demobilization, overhead, contingency, freight and haulage)	35	%		15,700.00
			GRAND TOTAL	$ 60,624.00

The calculation followed closely the method used by the British Columbia Forest Service Engineering Division. Roadway and drainage excavation was estimated according to ground conditions along main roads with an average 10 per cent side slope. Compacting costs were based on an anticipated 1,500 cu. yard per day basis. One gallon for each four cubic yards was estimated for watering. Gravel base and gravel surfacing costs include a one foot stabilization on the total width of the subgrade and an additional one foot for the width of surface. A maximum of one mile overhaul for gravel was estimated. Only installation costs were included for culverts and bridges, because local material can be used for their construction.

The main road construction costs will be $60,624.00 for 3.25 miles, or $18,650.00 per mile. This amount coincides very closely to available funds calculated previously as $18,600.00 per mile.

PRELIMINARY MANAGEMENT PLAN FOR THE RESEARCH FOREST ON EAST THURLOW ISLAND

Objectives

This management plan has the objectives of obtaining a sustained yield on 1,487 acres, building up a research forest with a permanent program mostly on thinnings and creating a demonstrational forest of the coastal hemlock region. The objectives indirectly suppose that through an adequate road system, the protection of the forest from fire, insects and diseases will be possible and that the quality and the quantity of the crop will be successively improved.

Summary of basic facts

The basic data in connection with the area, such as forest types, local conditions, growth and volume available, have previously been presented. To make orientation easier the areas and volumes available are repeated in the following table. (Table 12). The 410 acres of shrubs or inaccessible areas with stands of site index 70 or under were excluded from the calculation because their production does not contribute significantly to the total yield of the Research Forest.

It is usual to start the organization of a sustained yield unit by dividing the area into compartments. This was already done when the area was mapped and is shown on the attached map. (Appendix 1.)

Table 12. Main stand characteristics of the Research Forest on East Thurlow Island.

Forest types	Area Acres	Merchantable volume per acre intermediate utilization cubic feet	Total volume cubic feet
Scattered old growth	116	12,320	1,432,996
65-year old HFC second growth	1,130	7,100	8,023,000
50-year old HFC second growth	241	5,450	1,313,450
Shrubs or inaccessible areas			
S.I. 70 or under	410	---	----
TOTAL	1,897		10,769,446

The old stands were cruised in 1960, the second growth stands in 1952. The present annual average growth for the even-aged second-growth stands was based on latest experimental-plot measurements showing 110 cubic feet per acre. All the volumes represent merchantable volumes for trees above 8 inches d.b.h.

Allowable annual cut and cutting methods

Because only a rough approximation of the allowable cut is desired in the preliminary plan the determination of indicated cut is done by using the uniform-area regulation method. The almost uniform even-aged second-growth cover representing 73% of the area would suggest the same. The site index is also fairly uniform.

The rotation to be chosen is based upon the average d.b.h. at which mean annual increment culminates. According to Smith et al (1961) in normal hemlock stands this average d.b.h. is 12 inches on S.I. 150. This would mean, according to their tables, a rotation of about 65 years. Based on the above-mentioned suppositions the average annual cut will be 10,769,446 ÷ 65 = 165,000 cu. ft. This is well in line with the gross merchantable timber on 23 acres of 65-year old HFC stands, (7,100 x 23 = 163,300 cu. ft.), and even better when compared to the average current annual growth on the whole area. (1,500 x 110 = 165,000 cu. ft.) The sustained yield can easily be maintained under that plan with the necessary checks at about ten-year intervals. It is hoped that the thinnings, and the establishment of open to normal stands by thinning, will increase the yield progressively.

To start with thinning experiments as early as possible, the old stands must be clearcut first to cover the cost of building the necessary road network.

The object of regulation is to direct the management unit in such a way that it will reach the desired balanced position with the least sacrifice, in the shortest time. In the first five years there should be an overcut by volume to eliminate the stagnating old stands and to get funds for the road network. The yearly road construction was calculated on a two-mile per year basis.

The yearly clearcut will be according to the plan shown in Table 13.

Table 13. Cutting plan for old stands.

Year No.	Stand No.	Area of Cut acres	Volume available mature	Volume available immature	Road to Construct Name on Map
1	No. 1	24.3	147,670	73,080	A, B (0.8 mile), C.
2	No. 2 Part of No. 3	14.4 10.0	119,629 42,300	99,960 84,000	B (0.5 mile), D, No. 1,2,3.
3	Part of No. 3	23.0	97,400	193,200	No. 10 to 17.
4	Part of No. 3	19.2	81,400	161,600	No. 4, 5, 6, 18, 19.
5	No. 4 and No. 5	24.6	186,236	189,840	No. 7, 8, 9.
		115.5	674,635	801,680	TOTAL 1,476,315

The next sixty years of the rotation will be on a clearcut and thinning basis with an average yearly clearcut of 23 acres and thinnings on about 30 acres, or as the future experiments require. Thinnings will be kept under experimental status as long as required. The yearly 53 acres under logging are very close in size to the areas cut in the 1953 and 1954 operation. The yearly volume to be clear cut will be around 150,000 cubic feet, somewhat less than that calculated, because of the overcut in the first five years; plus the volume of thinnings which will depend on the nature of experiments.

The cutting order is not determined in this plan, because it will depend mainly upon the research forester in charge, who can determine and prepare the timber-sale contracts according to the research program in progress. The cutting order will be affected also by the type of the experimentation used.

If the sequence of the cuts follows the directions from Bickley Bay toward Hemming Lake and from Bickley Bay toward Shoal Bay, the proposed road network makes it possible to work toward both directions separately with two or three small crews at the same time. This would allow comparative studies with different crews and methods.

This preliminary management plan is a tentative one and that approach is justified by G. S. Allen (1944) who stated: "Rational forest practice requires a solid foundation of experience, research and detailed knowledge of the region and forest types to be managed. Since all three prerequisites are lacking to a great extent in hemlock forest types, management recommendations can be regarded only as strictly tentative and of a very general nature. They may form a basis for initial management to be replaced or improved in the light of increased knowledge".

The management plan should be revised therefore after the first decade, and modified if necessary according to the accumulated data during that period.

PROPOSED LOGGING METHODS

The proposed methods for logging are discussed separately for the initial five years of the management, when the old stands will be clearcut and for the thinnings afterward. As logging methods for thinning are in a more or less experimental stage on the Coast, the proposed methods should be revised if more experience will advise it.

Clearcut

There will be no special problem involved in logging the scattered old stands which will be clearcut in the first five years, according to the proposed management plan.

The scattered mature trees in the old stands are interspersed with second growth stands. This situation will require the use of prelogging practices, removing the small trees first.

The main roads are planned in order to get the shortest possible yarding distances. Because of the oblong shape of the old growth areas it will be possible to keep the external yarding distances to about 800 feet. This will make practical any high-lead or tractor yarding system.

If high-lead is used, any of the mobile spar tree systems might be applicable but using a local tree for a spar would be preferable. There are conventional high-lead operations on the Island at present using raised spars. As fir trees are available for spars in the old stands, the conventional high-lead should be used.

The other possibility is to use tractors with arches for direct yarding to the shore. The topography makes it possible, but the ground conditions in wet weather could create difficulties. With crawler-type tractors the problem could be easily overcome for the first two or three years as the short hauling distances would allow direct yarding to Bickley Bay. Old stands farther away, however, will need truck transportation to make the logging economical. This could be served better by high-lead logging.

The ground allows to locate landings (places) along the road at almost any convenient point.

Slash disposal and burning should be done on clearcut areas to reduce the fire hazard and to facilitate reforestation.

The areas should be replanted with Douglas fir, or Sitka spruce or perhaps with some exotic species for spacing-experiments. Hemlock will come in by natural regeneration. As there are no deer on the Island, satisfactory survival can be expected provided other factors are favourable.

Table 14 shows the proposed yearly order of the clearcut operation.

Table 14. Logging methods and sequence of cut with the expected output.

Years to clearcut	Area Acres	Logging method proposed	Av.yard distance feet	Hauling distance feet	Volume to cut cunit	Daily output cunit	Working days necessary
1	24.3	Crawler tractor	2,000		2,200	31	70
2	14.4	Crawler tractor	3,000		2,200	25	89
	10.0	High-lead	400	5,000	1,260	45	28
3	23.0	High-lead	600	6,000	2,900	33	85
4	19.2	High-lead	600	8,000	2,400	33	73
5	11.0	High-lead	400	12,000	1,750	45	39
	13.6		500	12,000	1,950	40	49
				TOTAL:	14,660		

As the clearcut operation will be close to the average on the Coast the data for each phase can be borrowed from Tessier and Knapp (1961) showing the following cost figures:

Table 15.

Item	Cost per M f.b.m.
Falling and bucking	$ 4.52
Yarding and loading	7.05
Hauling	7.91
Road maintenance	.63
Supervision	.69
Miscellaneous	1.87
Road construction	5.11
TOTAL:	$ 27.78

Daily output was estimated according Brandstrom's (1933) data.

Settings and landings are shown on the map. (Appendix 1)

As the calculation shows,the relatively small size of the scattered old stands would allow a shorter period for their liquidation. This could be done in a two or three year period by bigger companies. This would solve the road-construction problem for the area in a shorter time, giving better opportunity for thorough preparation for thinning experiments.

Thinning Operations

After the overmature stands have been cut and the necessary road system constructed, commercial thinning experiments could start.

Thinnings conducted in any manner designed by the research personnel should be combined with clearcuts. This will attract loggers who are not enthusiastic about thinning if there is not a good possibility of raising the profit above the marginal limit.

As the preliminary management plan proposed, each year 23 acres should be clearcut and thirty acres would be thinned.

There are many ways to arrange the logging operations. Two proposals will be made as now considered as the best possibilities.

Tractor and truck logging

The first alternative is based on the use of uniform logging methods upon the entire area. The road location plan was prepared with this system in mind. The individual logging sites will be using a medium-light tractor for yarding (like the Tree Farmer) and tractor "swing" or truck and trailer hauling.

A small logging crew of three or four men should be used. When the operation is farther out in the forest, bunching should be done.

Using the average data from six experimental thinning operations as given by Worthington and Staebler (1961), the daily production would be approximately seven cunits or eight cords. The proposed yearly cut of 150,000 cubic feet could be achieved in that case in 214 days. With three different thinning and logging crews, a 50,000 cubic feet per year contract would be more attractive. The road network would allow this without conflict. In this case the operation could be carried out under optimal weather conditions, interesting comparisons could be made and replications could be arranged with good organization.

The cut should start with thinnings, leaving the clearcut areas until the last. This will prevent the spread of dwarf mistletoe as suggested by Marples et al.(1955)

The temporary yarding route should be prepared in advance of the felling and bucking, to create the best opportunity for bunching and yarding. The tractor must not use the permanent roads for arch skidding but only for hauling with trailers.

The semi permanent landings should be prepared prior to the loading and hauling operations.

Approximate cost of thinnings will run close to that reported by Worthington and Staebler (1961) based on six thinning operations on the Coast and shown in Table 16.

Table 16. Cost of thinning operations

Item	Cost per cunit
	$
Falling and bucking	3.26
Yarding..........................	5.25
Loading..........................	2.17
Hauling..........................	2.81
Miscellaneous....................	2.57
TOTAL:	$16.06

Necessary minimum daily production

In the chapter with regard to economic problems of thinning it was pointed out that for every thinning operation there is a minimum diameter limit specified. This diameter value can be described graphically as the intersection point of two curves, the curve showing the relationship between utilization price and diameter and the curve of logging costs vs. diameter of trees to cut.

For the operator, however, it is more practical to draw the level of necessary minimum daily output. This can be done with a simple calculation if some basic cost figures are known. As these data are usually given as hourly costs or costs per unit volume, the cost equation for normal profit operation can be expressed as follows:

$$\frac{\text{Average total cost of operation per one hour}}{\text{Minimum hourly output}} + \text{Additional fixed cost per output unit} =$$

$$= \text{Selling price per unit.}$$

Using symbols for the values in the equation:

$$\frac{C_{hourly}}{O_{Min.}} + F = P$$

and the o_{min} from it: $O_{min} = \frac{C}{P-F}$

and the daily output: $O_{min/daily} = H \times O_{min/hour}$

Where H is working hours per day.

The average cost per hour must be calculated in a way,that the values involved must represent the actual efficiency of the operation. If theoretical maximum values only would be available a reduction factor for actual efficiency must be introduced.

To illustrate the calculation, let us determine the necessary daily output of the thinning on East Thurlow Island on the same basis as it was done in 1959 by a three-man crew, and the Garrett Tree Farmer tractor at the beginning of the operation.

1. Calculation of C. value.

Total cost of operation per one hour:	$
a) Felling, bucking and bunching $2 \times \frac{\$ 18.88^{1}}{8} =$	4.70
b) Cost of owning and operating powersaw [2]	0.46
c) Yarding and Bundling $\frac{\$ 20.48^{1}}{8} =$	2.58
d) Cost of owning and operating [2] Garrett Tree Farmer per hour (operators wage not included)	1.23
TOTAL	$ 8.97..C

1 From wage scale for independent logging operations 1960-61

Cat driver.................... $ 20.48

Faller and bucker day rate.... $ 18.88

2 Worthington and Staebler (1961)

2. Calculation of F value

Additional fixed cost per 100 cubic feet.	$
a) profit 15% of selling price	2.85
b) miscellaneous (payroll taxes, supervision, scaling, bookkeeping and office expenses) Worthington and Staebler (1961)	2.57
c) towing one cunit to Marmac (Towing Co.)	0.58
d) stumpage	1.00
	$ 7.00..F

3. Selling price at Harmac (19¢/cu.ft.1959) $19.00..P

The necessary hourly output then:

$$0 = \frac{8.97}{19.00-7.00} = 0.747 \text{ cunit}$$

and the necessary daily output = 8 x 0.747 = 5.98 cunit

As the actual average production was 593 cu. ft. per day the operation with a three-man crew was not profitable.

The operator changed his crew to two. If we calculate the necessary minimum daily production for this crew we will get 441 cu. ft. Because of later breakdown of the tractor and unusually wet weather, which made the yarding trails almost impassable the daily production fell down considerably, which forced the operator to give up the contract.

This type of calculation can be done in any given operation. The minimum necessary daily production, if compared to actual production, will show the profit ratio. The actual daily production should be further compared to the optimum production theoretically possible in a given work organization in order to estimate the efficiency of the operation.

Alternative plan for thinning operations

The alternative solution of thinning operations would divide the area into three separate units as shown on the sketch (Figure 24).

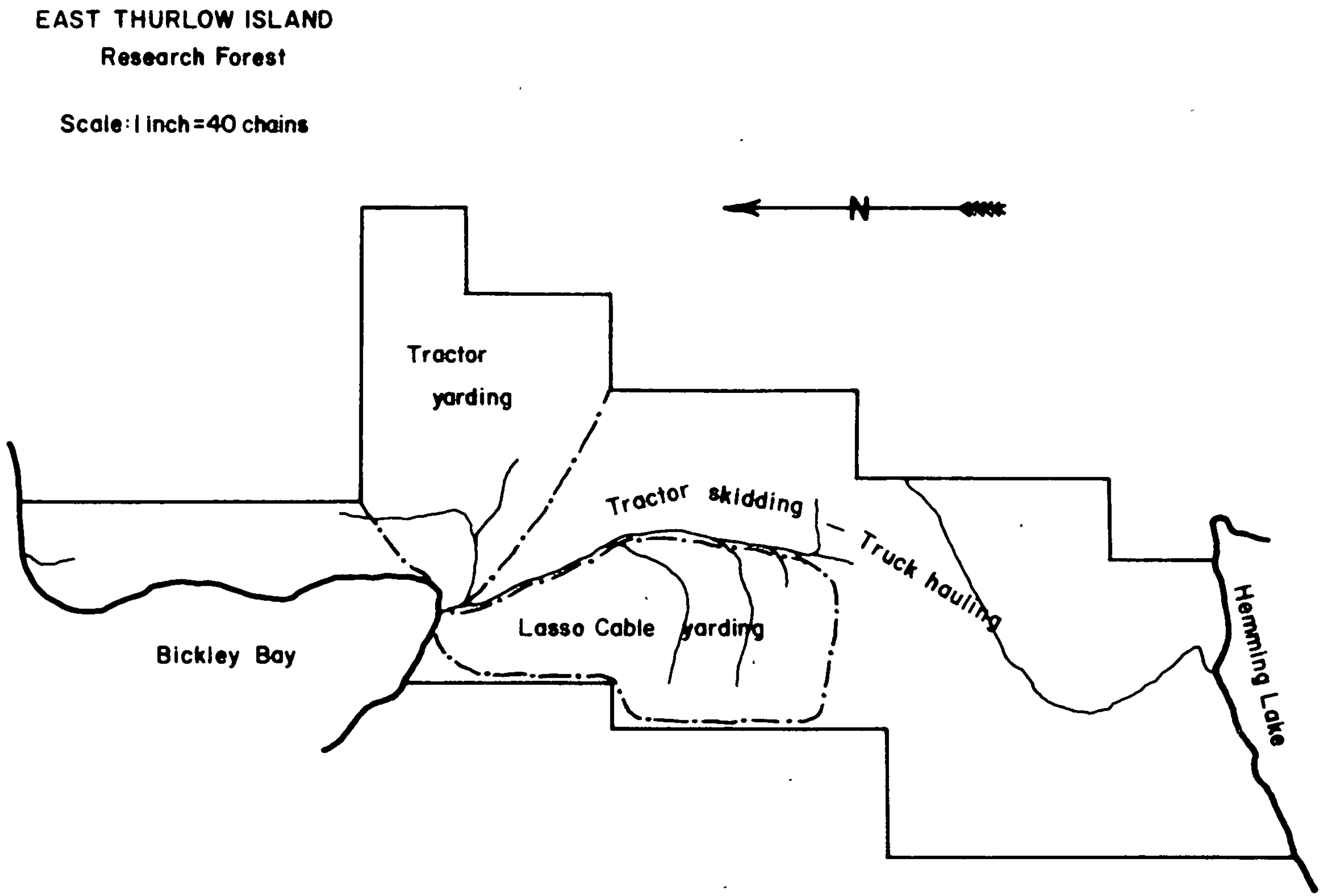

Fig. 24 Thinning operation lay-out for the Research Forest.

The areas along the main access road A and B would be logged in the same way as proposed in the first alternative.

The areas east of Bickley Bay on the plateau would be logged with tractors, yarding directly to the shore, in the same manner as proposed by Spiers (1956) and previously described. Up to a one-half mile one tractor would be used for greater distances and a bunching tractor should help to prepare trails and loads.

In the areas west of the main creek, which are covered with the best young stands, the Lasso Cable should be used. The broken terrain, heavy debris together with the presence of good sized trees along the trails for supports, would all be factors for success.

The motor would operate on the shore and a supplementary counterweight of simple construction could be established at the end of the line in one of the deep side creek canyons.

In between the side creeks, good temporary landings could be placed. The material could be yarded to the landings by using winches or light tractors.

The operational length of such a system is about two miles, which would facilitate the transportation of logs from as far as the divide between Hemming Lake and Bickley Bay.

This alternative will, of course, alter the original road location plan according to the need of this system as indicated on Appendix 2.

Estimated production and cost of Lasso Cable
if installed on East Thurlow Island

The basic data for the calculation were obtained from logging operations on Thurlow Island in 1959, from the Lasso Cable Company in Switzerland and from the Wood Handbook (1960).

Specific gravity of hemlock usually ranges from 0.38 to 0.42 and averages 0.40, At 74% moisture content one cubic foot of green hemlock weights 43.4 lbs. In the 1959 operation the average logsize was ten cubic feet., or 434 lbs. plus bark, which would be about 7 per cent more by volume, giving an approximate value of 450 lbs. This means that the full load capacity of 680 pounds per hook is not realized and it would actually be possible to carry logs of 28 cubic feet volume, e.g. 18" x 16' or 14" x 24' size logs.

For an eight hour day the daily production would be, assuming 2 minutes for loading and 5 feet per second travel speed:

$$\frac{8 \times 60}{2} = 240 \text{ pieces} = 2,400 \text{ cubic feet per day}$$

It would take 70 days to bring out one year's cut according to the management calculation. To reduce logging costs at least two years cut would be necessary to log in one season.

Cost analysis:	Charge per year $
Ownership costs:	
Depreciation based on ten years.........	3,000.00
Interest on investment $\frac{30,000 \times 11}{20} \times 0.06$..	990.00
Insurance and other uninsured risks 5 % of average investment of $16,500.00...	825.00
Operation costs:	
Labour $20.00 including Workmen's Compensation, holiday pay, etc.(12% of total payroll)(5 men for 140 days)...........	14,000.00
Supplies and repairs (10 gallons gasoline per day @ 28 cents)..............	392.00
Spare parts(Manufacturer's estimate)......	600.00
Maintenance(lubrication service) (Manufacturer's estimate).................	300.00
TOTAL:	$ 20,107.00

With a yearly production of 3,360 cunits the yarding cost per cunit will be: $5.98 (24 cunit per day x 140 = 3,360 cunit)

Assuming that other cost items of the extraction process will be similar to thosepublished by Worthington and Staebler (1961) for the Hemlock Forest Experiment Station, the total logging cost per cunit will be:

	$
Felling - Bucking	2.86
Bunching	4.38
Yarding	5.98
Miscellaneous	2.15
Total	$15.37 per cunit.
or	$12.72 per cord.

The cost would allow, according to the calculations, a commercial thinning showing a marginal profit.

On East Thurlow Island the Lasso Cable operation would eliminate construction of a road system on the right side of the main creek, where the topography is the most rugged and the debris is heavy. This type of operation could be started anytime because the necessary pre-yarding equipment could reach the stands easily on the available old trails and would allow thinning experiments to start before the scattered old stands will be clearcut.

The main advantages of the operation would be: the mobility of the installation, the continuous service under all climatic conditions, the use of unskilled labourers.

The pre-yarding could be done by mobile winches, like the radio operated "Sepson" double drum winch, type 40-05 which costs $ 7,950.00 or Swed Krone - $1,590.00.

This winch would reduce the bunching cost according to the following calculation:

	$
Ownership costs:	
Depreciation (five years).........	340.00
Interest or investment............	61.00
Insurance and other uninsured risks........	26.00
Operation costs:	
Labour (two men for 140 days)@$20.	5,600.00
Supplies and fuel (1 gal. gas... per day @ 28¢)....................	40.00
Maintenance, spare parts, wire rope etc..........................	80.00
Total	$ 6,147.00

Estimated production based on technical data of the winch, with an average yarding distance of 150 feet is 24 cunits per day.

Cost per cunit $\frac{6,147}{24 \times 140}$ = \$ 1.82

Taking in consideration that the Lasso Cable with a maximum yarding distance of 10,000 feet can serve an area of 138 acres it would mean that on East Thurlow Island with an appropriate layout one could stay in one place for at least two years.

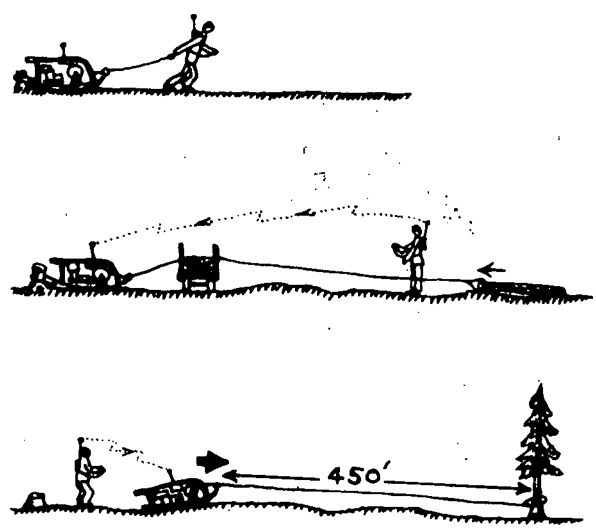

Figure 25. Sepson radio operated whinch.

Figure 25. Lay-out and operation of the "Sepson" radio-controlled winch.

SUMMARY AND CONCLUSIONS

Future management of second-growth Western hemlock stands on the Coast of British Columbia depends on experiments to provide foresters with facts about the silvical, economic and technical aspects of thinnings. Evaluation of the few past experiments shows that there are not enough data accumulated yet to prescribe management methods for young hemlock. Such problems as thinning methods, effects of thinnings, economic and technical ways of handling small logs and the mechanization of thinning operations have been inadequately investigated for hemlock stands.

Experiments in the Research Forest on East Thurlow Island might provide solutions for many questions about commercial thinning, if a well developed road system were established there.

Scattered old growth stands, if clearcut, should provide sufficient funds for road development. All-weather main and branch roads are essential. It is highly probable, that with adequate roads as described herein commercial thinning experiments on the Research Forest can be established successfully.

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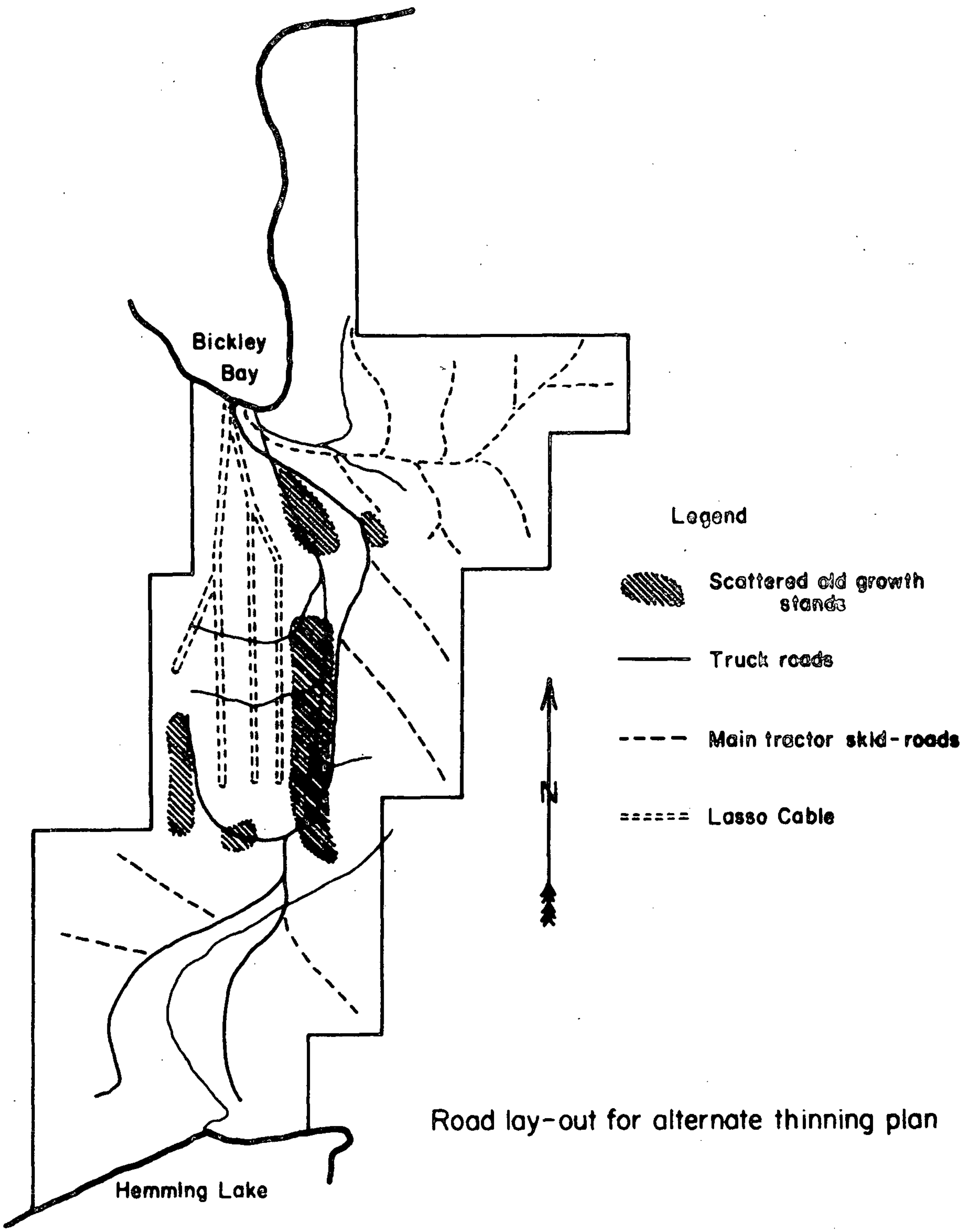
PRELIMINARY ROAD
LOCATION PLAN
E.P. 294 EXPERIMENTAL RESERVE
EAST THURLOW ISLAND.
Revised June 1947.
Scale:- 1 inch = 10 chains.
LEGEND.
Main roads
Branch roads
Culvert
Bridge
Old stand with merchantable 2nd growth
Old stand without merchantable 2nd growth
Settings
Spar tree
Reserve Boundary.
Lot Lines __ Run.
Lot Lines __ Not Run.
Maintained Trails.
Type Lines.
Sub-type Lines.
Key Reference Posts.
0.10 Acre Subplot Number 22.
Substitute type for date if not immature __ Areas within reserve boundaries only.
SHOAL BAY
Thurlow P.O.
BICKLEY BAY
Good Salmon Fishing.
HEMMING LAKE
Old Stand No. 1
Old Stand No. 2
Old Stand No. 3
Old Stand No. 4
Old Stand No. 5
L 156
L 317
L 316
L 234
L 1435
L 1503
L 1023
L 1022
L 1021
L 1020
L 1016
L 1018
L 1017
L 1019
L 1695
L 1696
L 1694
L 1697
L 1698
L 1693
L 1689
L 1688
L 1690
L 1687
L 1683
L 1677
L 1676
L 1691
L 1686
L 1684
L 1692
L 1685
L 22
Scrub and Rock 56
Scrub H·F·PL 121
1902 D·F·H 31
1897 H·F·C 1130 SI 120-150
1912 F·H·C 144
1912 F·H·C 97
1919 N·S·R 37
24M H·F·B 14
Swamp 11
E.P. 92
E.P. 93
E.P. 94
E.P. 89
E.P. 302
E.P. 303
E.P. 304
E.P. 90
E.P. 95
E.P. 96
E.P. 97

Appendix II

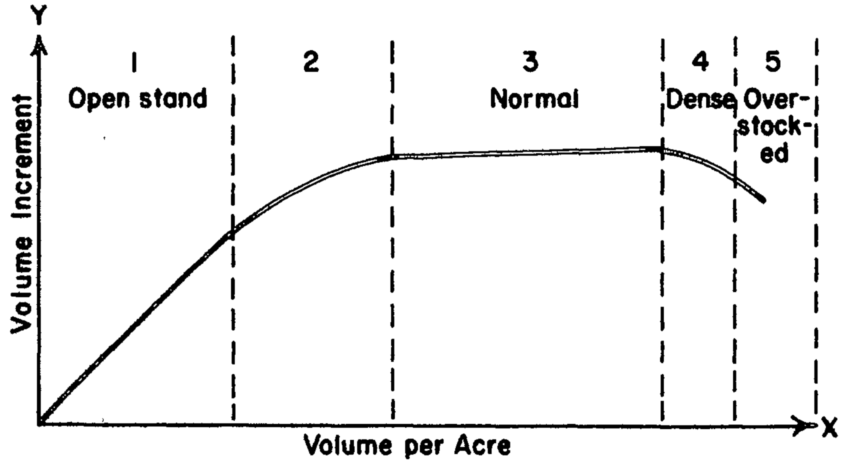
EAST THURLOW ISLAND

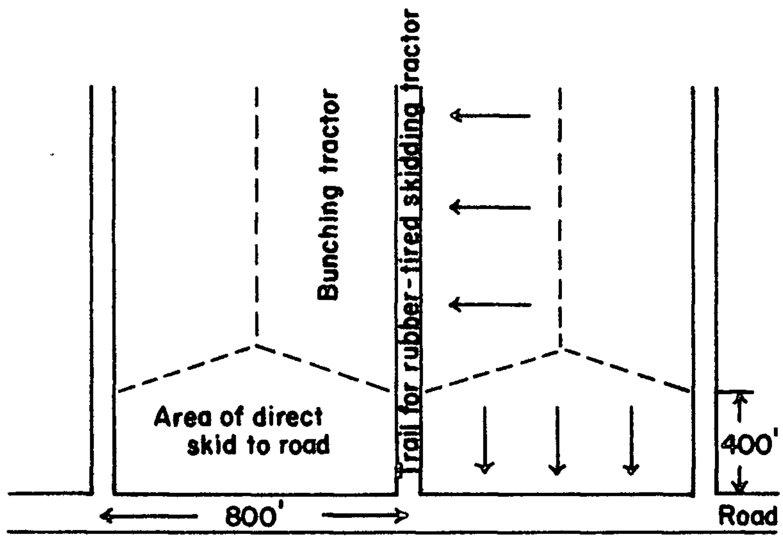
Research Forest

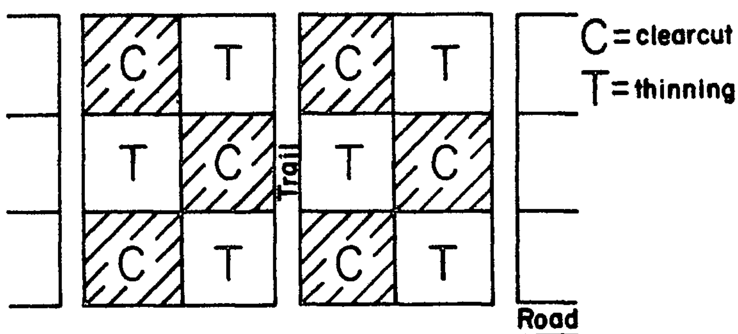
Scale: I inch = 40 chains

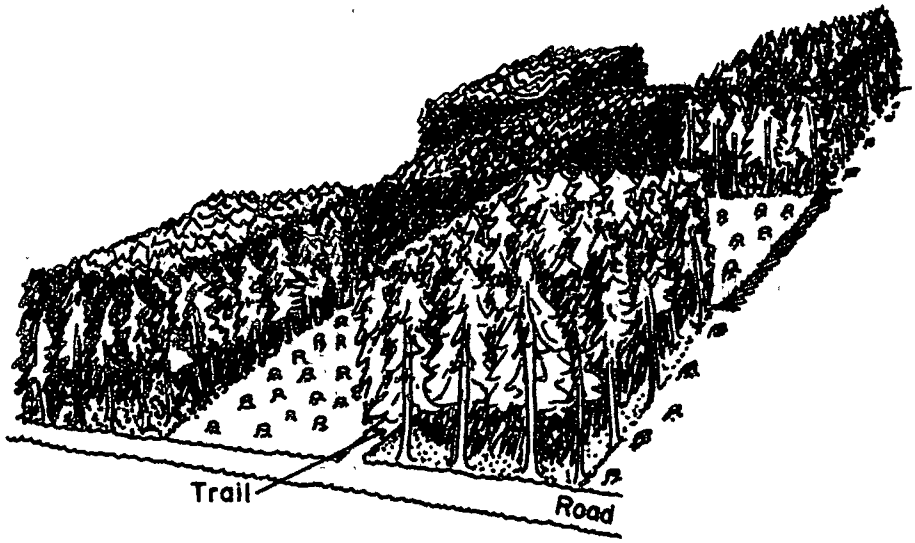


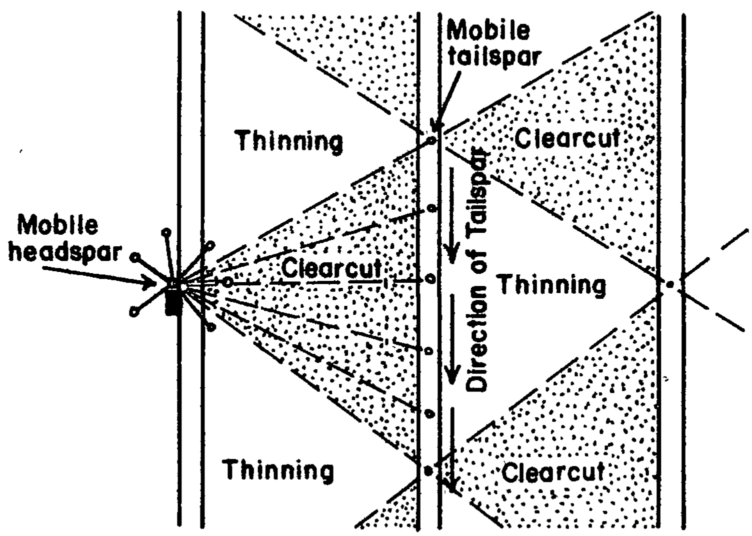
Road lay-out for alternate thinning plan

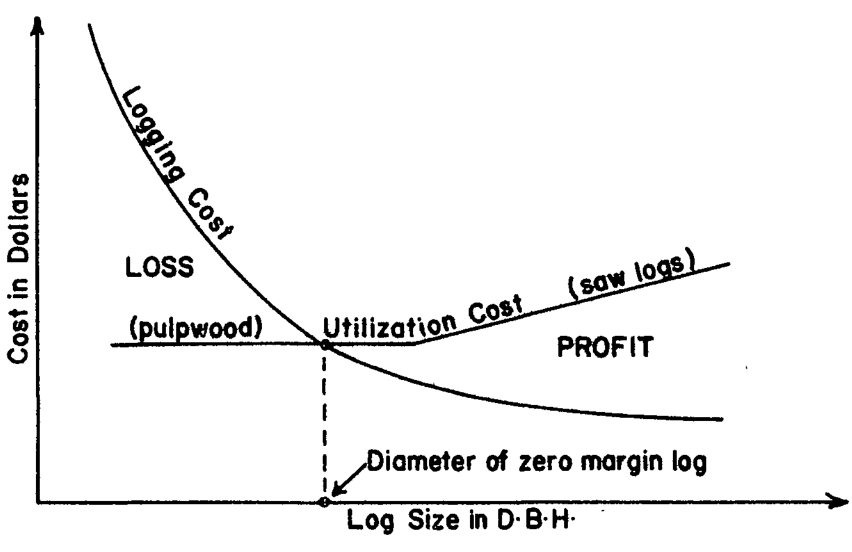

Y
1
Open stand
2
3
Normal
4
Dense
5
Over-stocked
Volume Increment
Volume per Acre
X

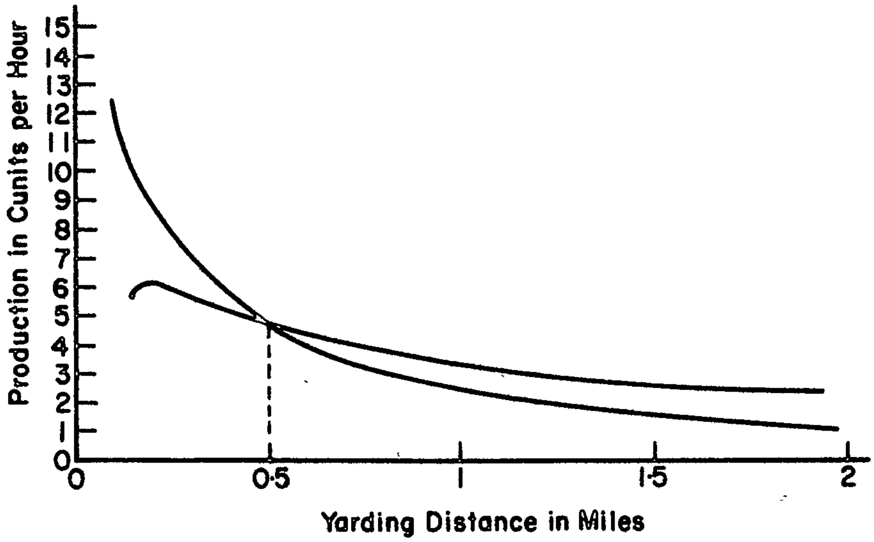

Bunching tractor
Trail for rubber-tired skidding tractor
Area of direct skid to road
400'
800'
Road


C = clearcut
T = thinning
C
T
T
C
C
T
Trail
Road

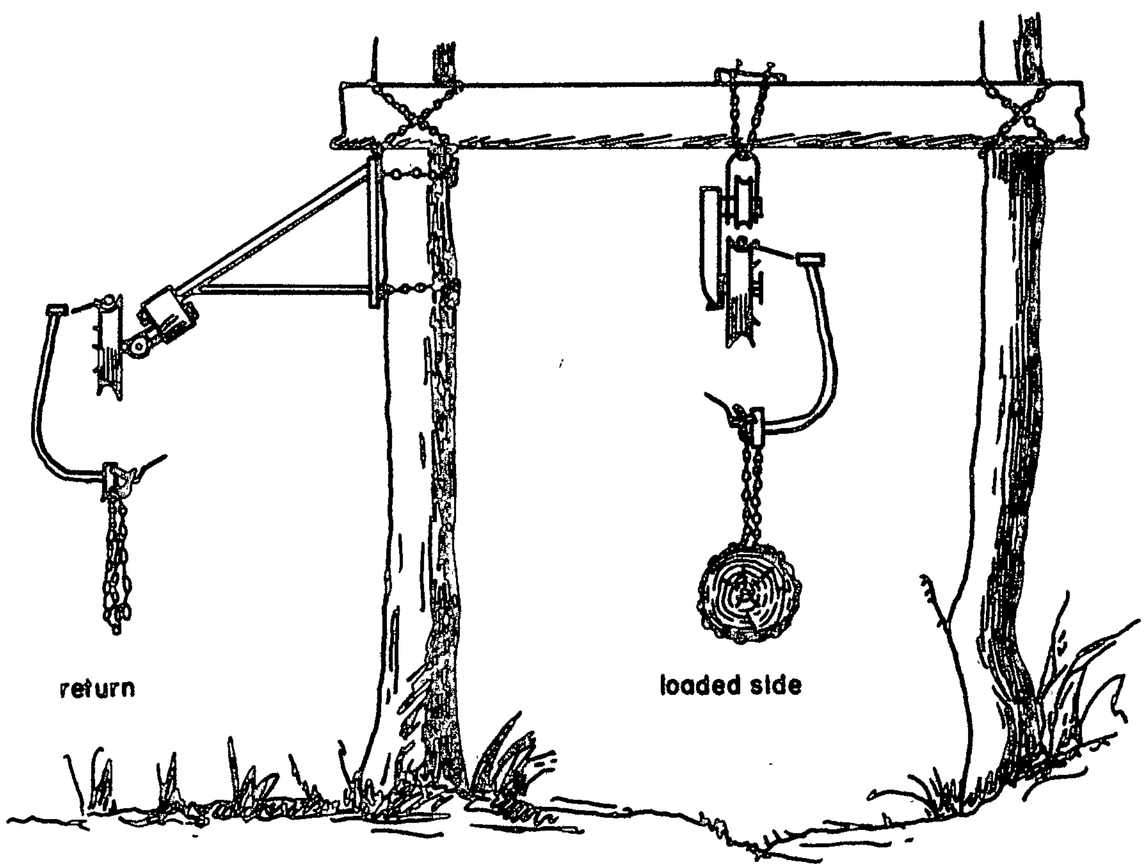

Trail
Road


Mobile tailspar
Thinning
Clearcut
Mobile headspar
Clearcut
Direction of Tailspar
Thinning
Thinning
Clearcut

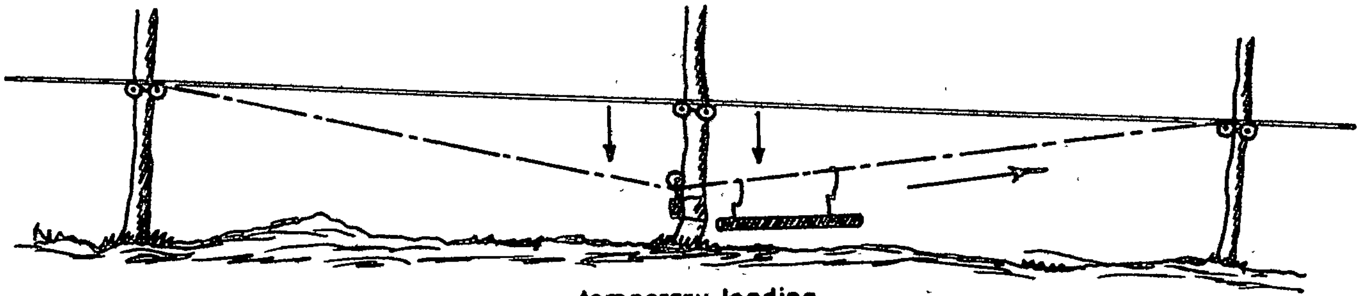

Cost in Dollars
Logging Cost
LOSS
(saw logs)
Utilization Cost
(pulpwood)
PROFIT
Diameter of zero margin log
Log Size in D·B·H·



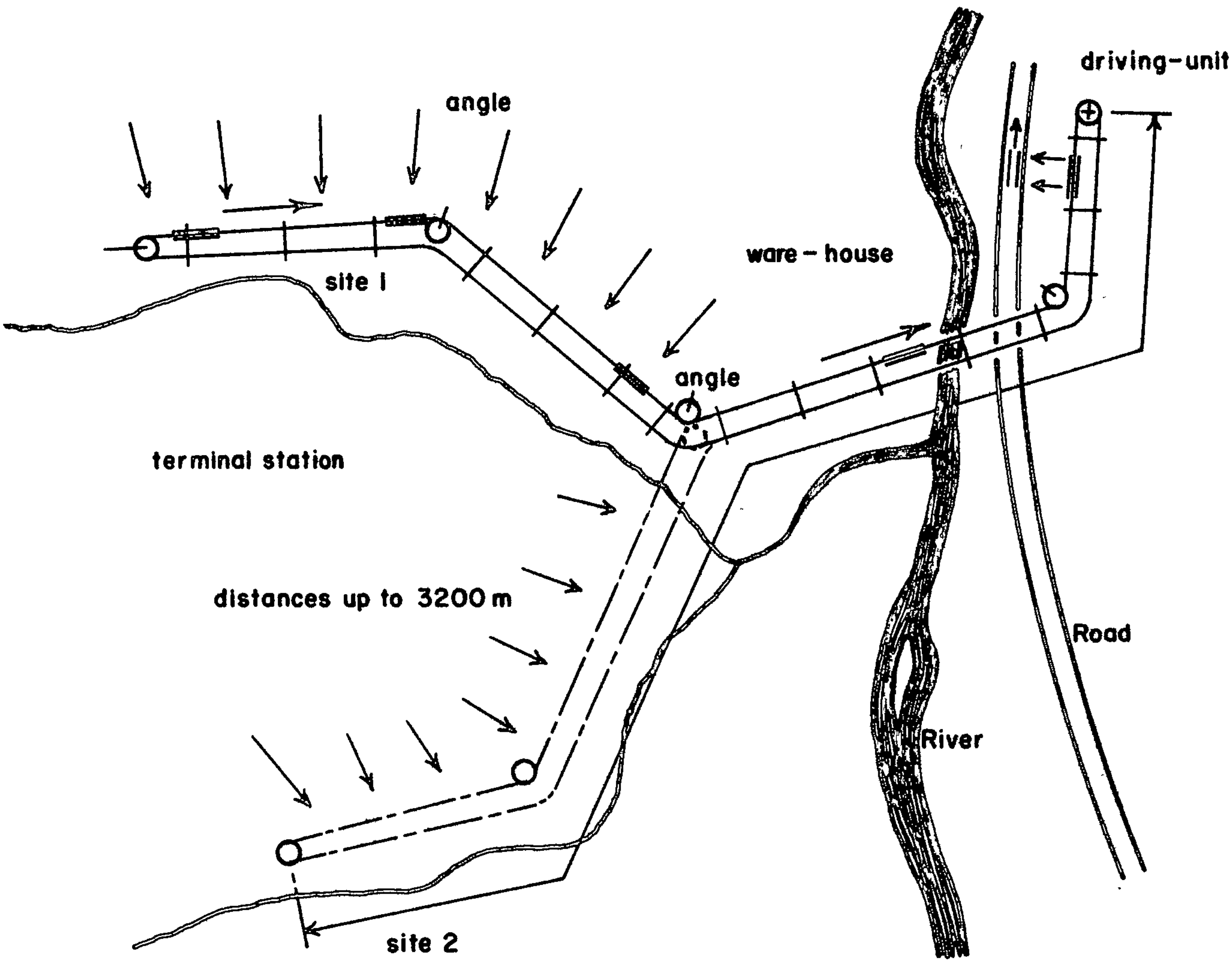
Production in Cunits per Hour
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
0·5
1
1·5
2
Yarding Distance in Miles

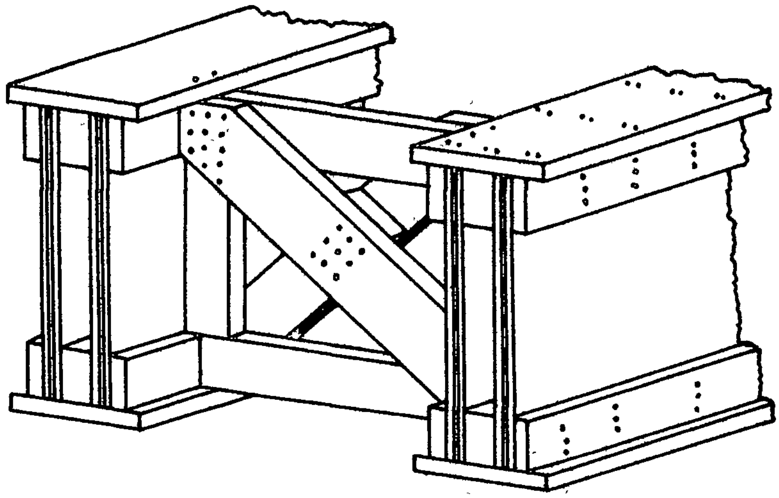


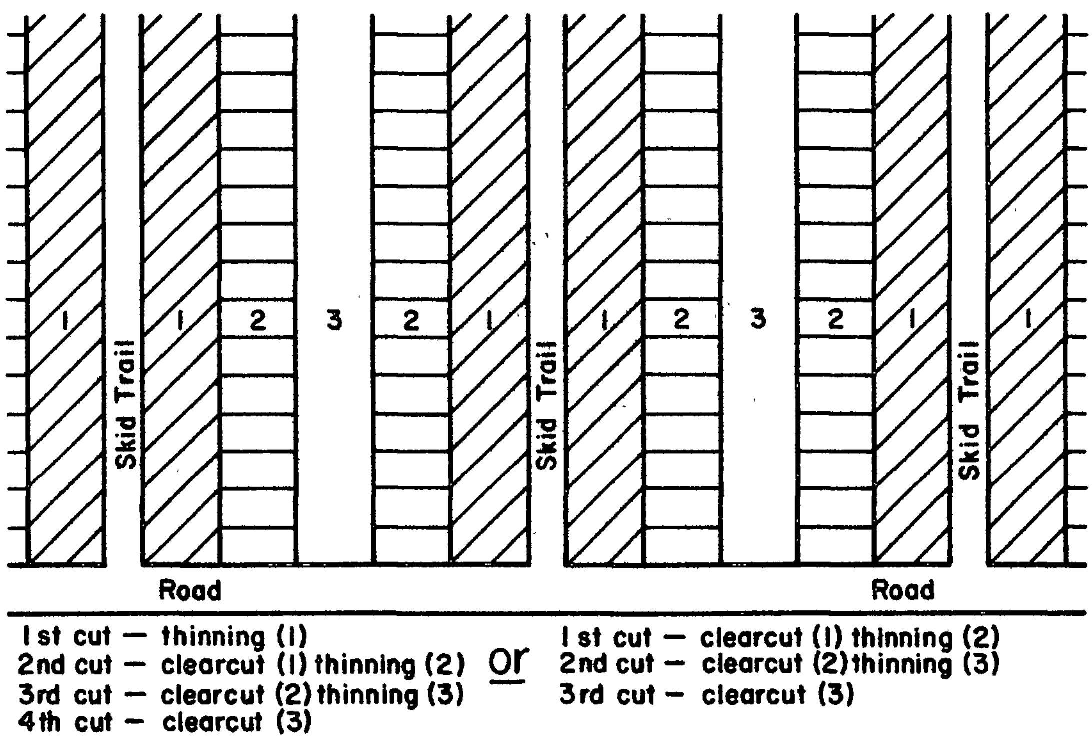
return
loaded side



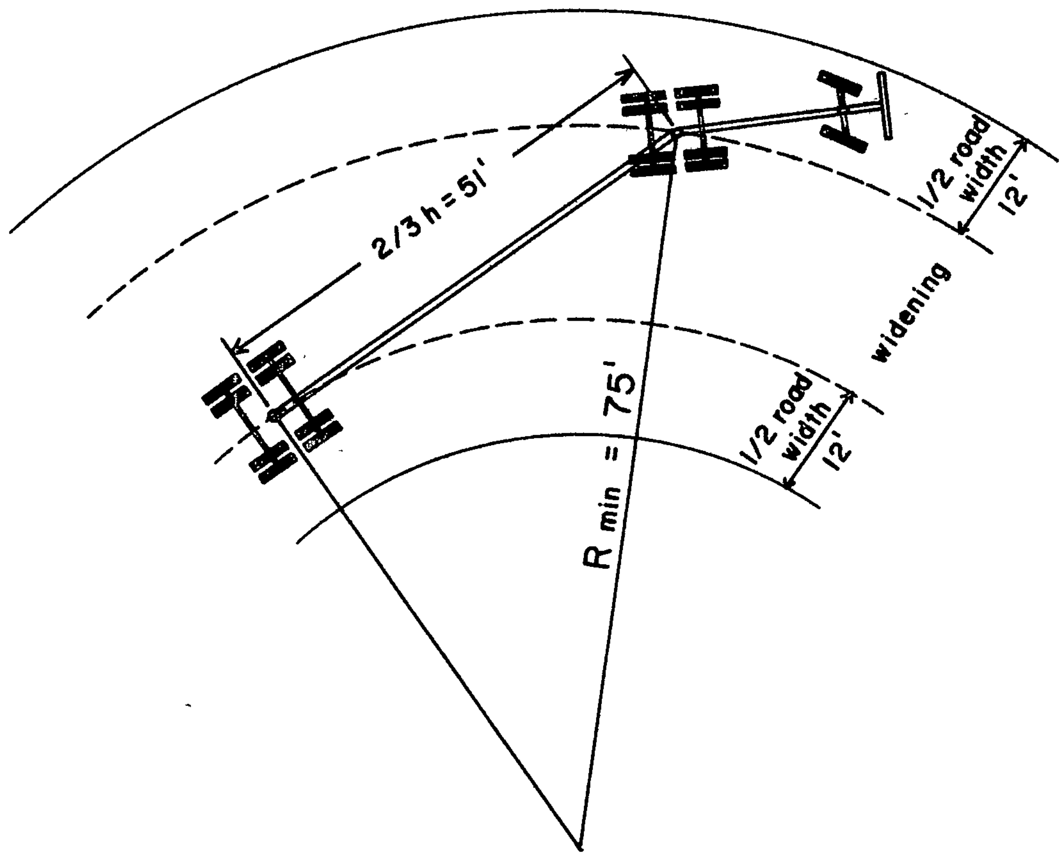
temporary loading

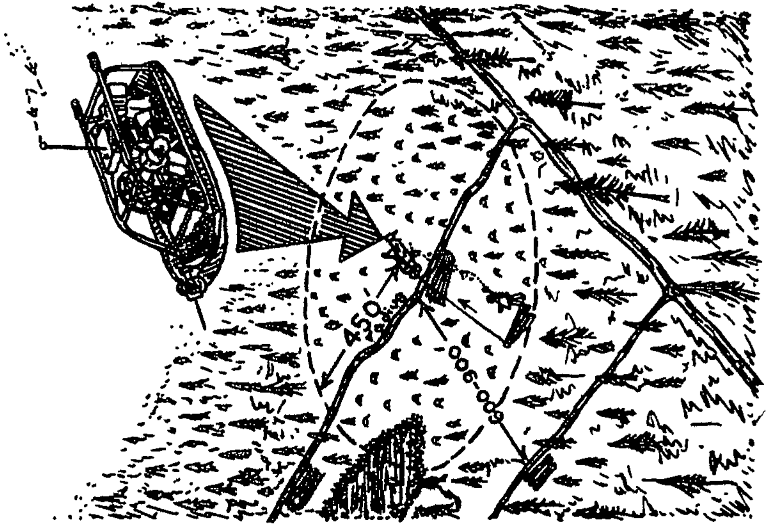






1
Skid Trail
1
2
3
2
1
Skid Trail
1
2
3
2
1
Skid Trail
1
Road
Road
1st cut — thinning (1)
2nd cut — clearcut (1) thinning (2)
3rd cut — clearcut (2) thinning (3)
4th cut — clearcut (3)
or
1st cut — clearcut (1) thinning (2)
2nd cut — clearcut (2) thinning (3)
3rd cut — clearcut (3)


2/3 h = 51'
1/2 road width
12'
widening
1/2 road width
12'
R min = 75'


450

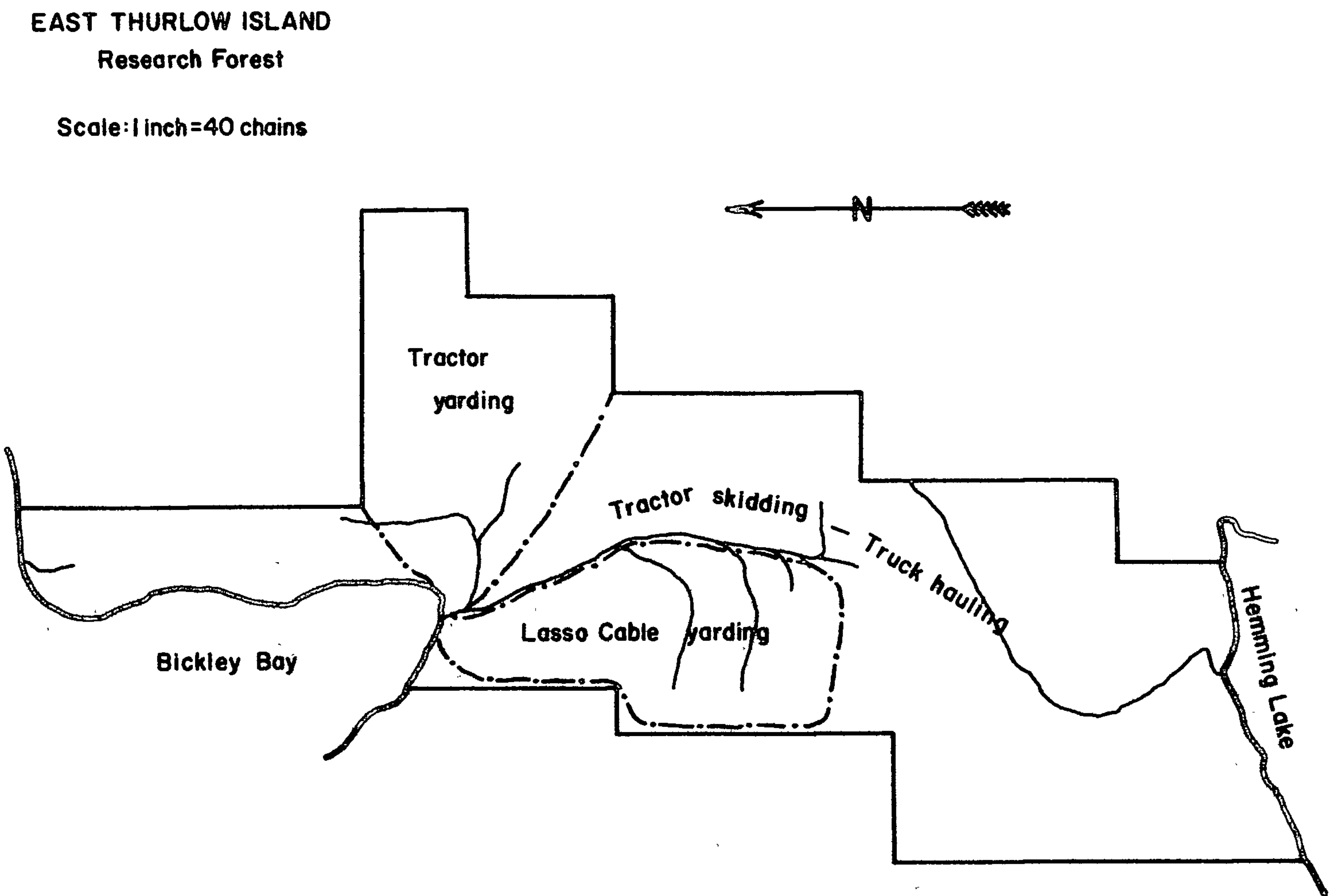


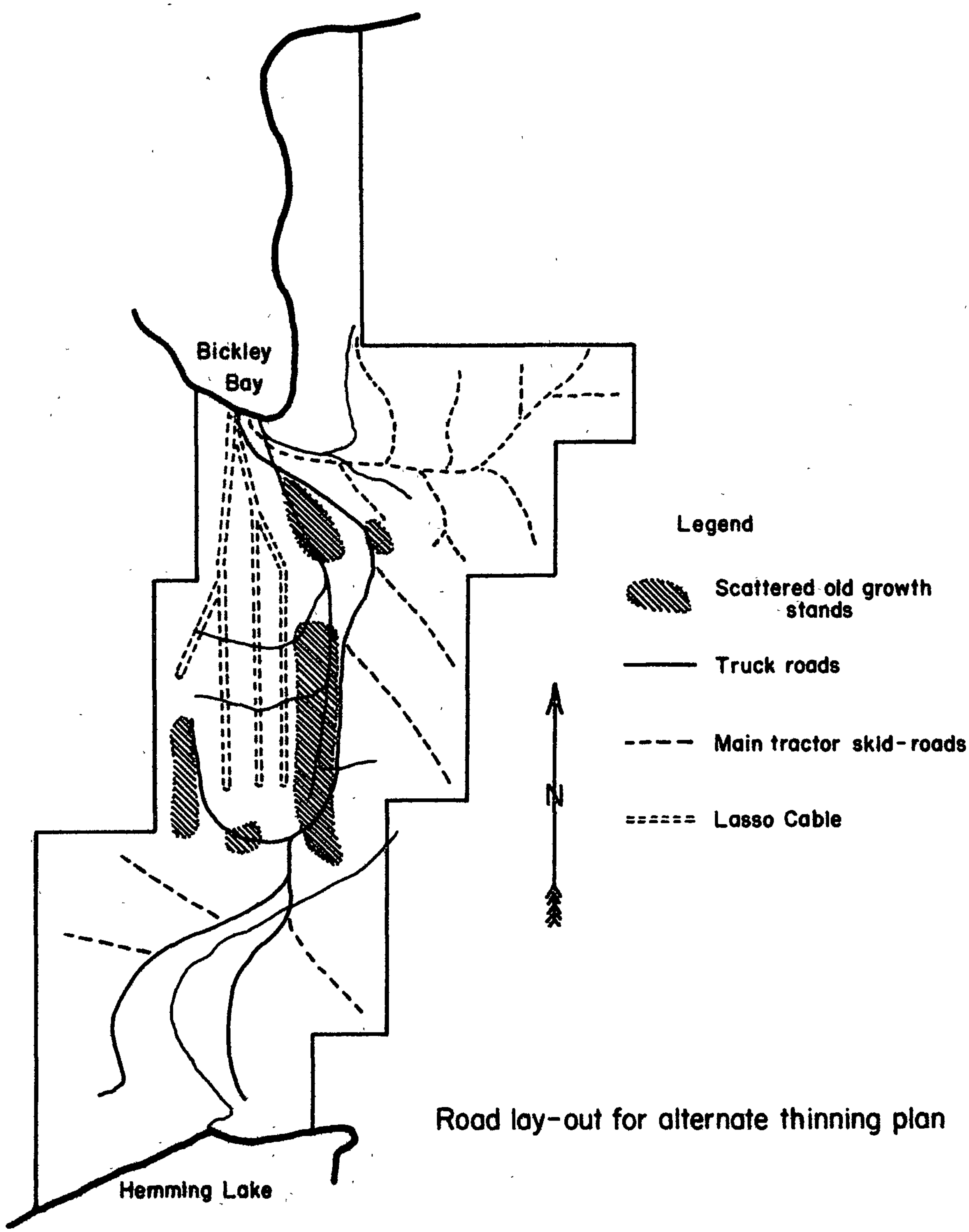
Fig. 24 Thinning operation lay-out for the Research Forest.

Appendix II

EAST THURLOW ISLAND

Research Forest

Scale: I inch = 40 chains



Road lay-out for alternate thinning plan