PEATLANDS OF NEWFOUNDLAND AND POSSIBILITIES OF UTILIZING THEM IN FORESTRY

by
Leo Heikurainen
Professor of Peatland Forestry
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FOREST RESEARCH LABORATORY
ST. JOHN'S, NEWFOUNDLAND
INFORMATION REPORT N-X-16

FORESTRY BRANCH
MARCH, 1968

CANADA
DEPARTMENT OF FORESTRY
AND RURAL DEVELOPMENT

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ABSTRACT

Classification of the peatlands, that is required for their utilization for forestry purposes, must be based on the vegetation. In accordance with this statement the Newfoundland peatlands were divided into eleven different groups or peatland types: namely, 1) dwarf shrub bogs, 2) small sedge bogs, 3) sedge bogs, 4) herb-rich sedge bogs, 5) *Sphagnum* fens, 6) brown-moss fens, 7) sedge tree swamps, 8) fen-like tree swamps, 9) *Kalmia* black-spruce swamps, 10) herb-rich black-spruce swamps, and 11) alder swamps.

All these peatland types were described in regard to their vegetation, depth and kind of peat layer, general characteristics of their occurrence, extent, possible tree stands, etc. The chemical analyses carried out have indeed indicated that there are distinct differences in the nutrient conditions between the peatland types studied.

In order to get a conception of the value of Newfoundland peatland types with reference to forest drainage, a comparison was made between them and Finnish peatland types on the basis of vegetation and nutrient conditions. The attempt to find Finnish peatland types corresponding to those described in Newfoundland was successful, and, as the capability for drainage of the Finnish types has been thoroughly studied, some conclusions could also be drawn with respect to the capability for drainage of Newfoundland peatlands. The capability for drainage is expressed by means of site-quality indexes analogous to those used in Finland. Examination of the climatic conditions prevailing in Newfoundland as well as the rate of tree growth revealed that growth conditions there are comparable to those of Middle Finland. Against this background it is possible to discuss the profitability of forest drainage in Newfoundland.

Forest drainage activities in Finland as well as biological and technical solutions for such operations are discussed in the present report in order to provide a background to the suggestions made for Newfoundland conditions. Special proposals are made regarding the ditch systems to be employed and the machinery to be used under the conditions prevailing there. In addition, some general suggestions are made as to peatland fertilization and some other silvicultural treatments.

Before starting a large-scale forest drainage program in Newfoundland, quite a great deal of research work must be performed. This report considers also some of the most important tasks of this research activity.

Upon the whole, there are great possibilities of utilizing peatlands for forestry purposes in Newfoundland, even if the climatic conditions prevailing there are not very favourable.

The bulk of Newfoundland peatlands being open peatlands, the costs of undertaking will be rather high. Utilization of forest covered swamps for forestry purposes would be economically more profitable, but, such peatlands do not occur to a very large extent in Newfoundland.

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1. INTRODUCTION

From October 6 to November 23, 1967, I visited Newfoundland as a consultant invited by the Canadian Department of Forestry and Rural Development, Newfoundland Region, to study the possibilities of utilizing Newfoundland peatlands for forestry purposes. For this reason I got a vacation from my duties at the University of Helsinki. The main subject was to establish a classification of peatlands for forestry purposes. The second job was to make suggestions about how to start forest drainage work.

During my visit in Newfoundland I got very valuable help from many persons and institutions, such as the Canadian Department of Forestry and Rural Development, The Provincial Forest Service, Bowaters Pulp & Paper Mills Ltd., Price (Nfld.) Ltd., and the Department of Agriculture Experimental Farm and Memorial University of Newfoundland. Especially I wish to express my thanks to Dr. W.J. Carroll, Regional Director of the Department of Forestry as well as to Mr. Frederick C. Pollett and Mr. Eric Salter, who were my guides and assistants during my stay in Newfoundland.

Some of the results obtained were reported in two lectures in St. John's, the first of which was held for Newfoundland foresters on October 14 and the latter at Memorial University on October 17. The results and thoughts presented in these lectures were naturally of a very preliminary character. This report attempts to be of a more final nature; however, due to the short time available for the study the results presented here are somewhat preliminary. Besides, my visit took place quite late in the season with regard to the development of the vegetation.

2. FIELD WORK

T h e t r a v e l s I made in order to perform my task can be seen from the map (Fig. 1). On the first trip, along the Trans Canada Highway from St. John's to Port aux Basques, I was introduced to some large and representative peatland areas that had been selected beforehand, and in some other places, too, I tried to become familiar with the nature of the peatlands of the island. During later trips I chose research areas on my own. The study travels were made by car. For a two day period I had the opportunity to use a helicopter, and landed at many places which looked interesting enough for closer examination. The routes of these flights are also shown on the map. During the excursions made at the end of my visit I collected peat samples for nutrient analyses. The places of sampling are also marked on the map. Some trips were made in order to give me an idea of the afforestation trials established on the island, as well as of agricultural experiments on peatlands; in addition, they aimed at making me familiar with the machinery used in such amelioration works.

I made many v e g e t a t i o n d e s c r i p t i o n s during my excursions. Detailed analyses of the plant cover were made on random plots, each of which measured one square metre in areas To describe the peatland areas under study in this connection or certain parts of them, 2 to 6 samples plots were described depending on the nature of the vegetation. The descriptions were made using coverage percentages. The total number of such 1-sq.m. plots amounted to about 400 from 113 research areas. Because the plants encountered were partly unknown to me, it was necessary to collect a great number of plant samples for identification. Determination of the vascular plants collected were made by Dr. David Murray of Memorial University of Newfoundland and the mosses were determined after my return to Helsinki by Dr. Pekka Isoviita. In this connection I wish to mention that I had, before my voyage to Canada, an opportunity to get familiar to some extent with the vegetation of Newfoundland; this was possible with the help of Dr. Teuvo Ahti and Dr. Isoviita, both from the University of Helsinki. I wish to express my thanks to both of them and to Dr. Murray. Without their help the fast orientation into the vegetation would have been impossible.

In connection with the vegetation descriptions, attention was also paid to the size of the peatland area; in addition the depth of the peat layer was measured and the peat kind and humification degree of the surface peat determined.

After I had obtained a fairly clear impression of the peatland types, I collected p e a t s a m p l e s f o r n u t r i e n t a n a l y s e s and pH measurements from places representing the different types. In order to obtain representative peat samples partial samples were taken from four points at each place of sampling, such that two small samples measuring 2 x 2 x 2 inches in

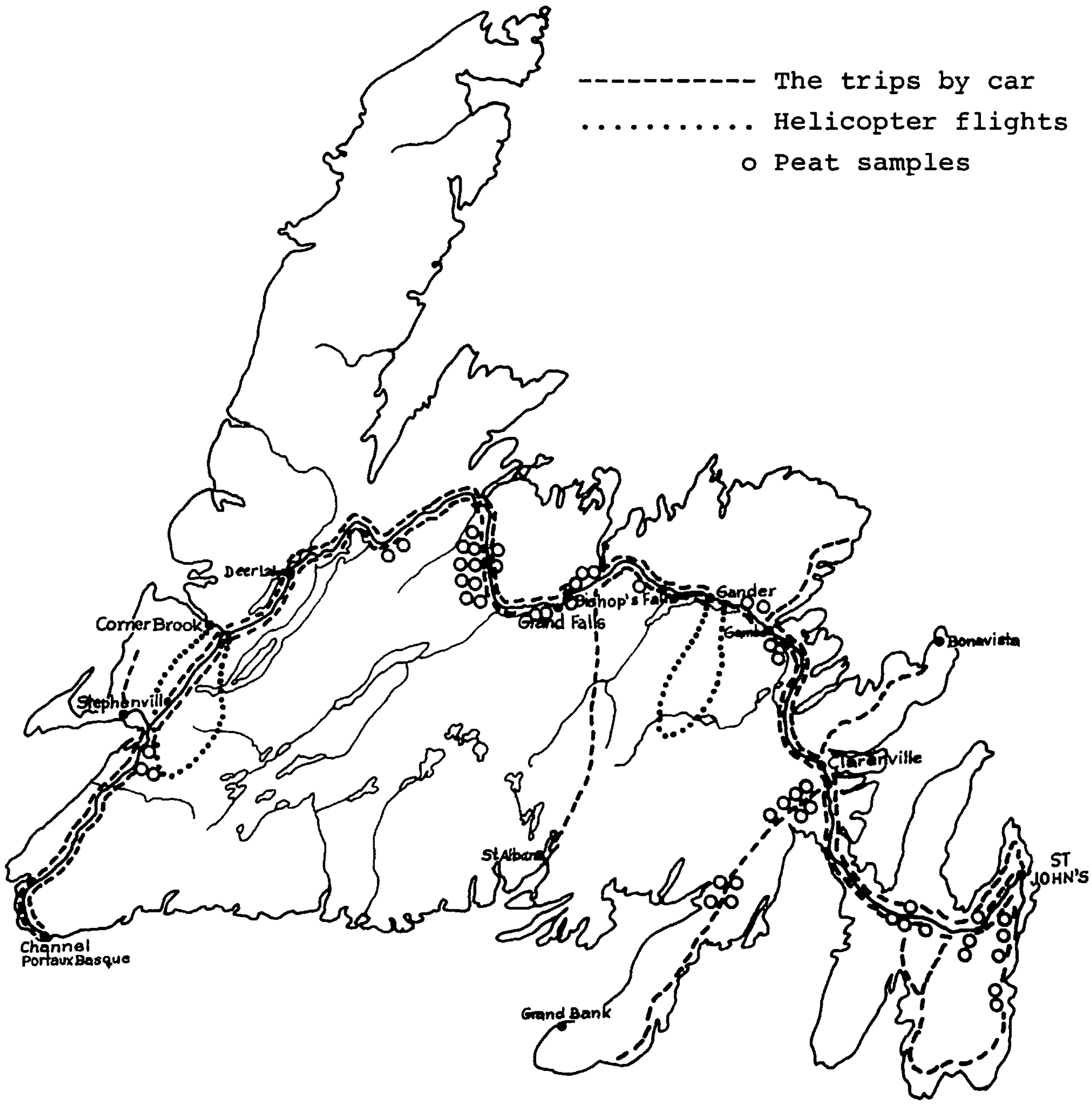

Fig. 1. Map showing the research travels and the places of peat samples.

volume were taken from each point, the first from a depth of 2-4 inches and the latter from 8 to 10 inches. The small peat samples were cut with a sharp knife from bigger ones which were dug up with a shovel. The volume of the whole samples was thus almost exactly one liter.

Some attempts were also made to study the possibilities of using aerial photographs for classification of the peatlands. Likewise efforts were also made in order to find some drained peatland areas, where measuring of the effect of drainage on tree growth could have been done. However, due to lack of time these attempts were not very productive.

To the field work I would also like to count the discussions I had with many foresters of the island and with some other people interested in the utilization of peat and peatlands for various purposes. Without these discussions it would have been difficult for me to get even that degree of familiarity with the conditions of forestry and peatlands of the island which I actually was able to obtain.

3. GENERAL ASPECTS OF PEATLANDS

3.1 The Concept Peatland and Associated Terminology

In this chapter I will introduce the concept peatland and the terms I have used in this report without going deeper into these questions. In general I have used the same concept and terms in my earlier publications (c.f. Heikurainen, 1964).

P e a t l a n d is the general term for all kinds of land formations with a peat cover or for those plant communities growing on a deep or thin peat layer which usually produce peat. Sometimes the term mire is used as a synonym. The term peatland covers all such terms as bog, fen, swamp, marsh, muskeg, etc. I am using the terms bog, fen and swamp only in the following meanings. B o g is an ombrotrophic peatland without any tree stand, f e n is a minerotrophic peatland also without any tree stand and s w a m p is a wooded peatland. The term marsh, which is in common use in Canada, I did not use because it seems to me that marsh is a term for a certain kind of terrain with ponds and a more or less gradual changing from water vegetation to the peatland vegetation surrounding the ponds.

The terms o m b r o t r o p h i c and m i n e r o t r o p h i c are used in the sense of their international meaning as follows: If the water used by the vegetation mostly comes from the surrounding mineral soils and it is therefore more or less rich in nutrients, the peatland is called minerotrophic, and if the water supply is directly and only from rainfall, we speak about ombrotrophic peatlands.

I will use the terms e u t r o p h i c, m e s o t r o p h i c and o l i g o t r o p h i c to describe the degree of nutrition of peatlands. Eutrophic means rich, mesotrophic moderate and oligotrophic poor in nutrients.

3.2. Extent of Newfoundland Peatlands

Complete statistics concerning the extent of the peatlands in Newfoundland are not available. Estimations based on maps and especially on aerial photographs have come to an amount of 2.7 mill. acres of so-called peat bogs (Rayment and Chancey, 1966). Obviously these peat bogs include only open peatlands with a fairly deep peat layer. The above-mentioned authors think that if peatlands with a thin peat layer should be included, the percentage of peatlands of the total land area would be 15. In some other papers the amount of peatland is estimated at 7.800 sq. miles or about 5 mill. acres, which means about 17 per cent of the land area. In the list of peatland types presented in the same paper nothing is said about tree-covered peatlands. It probably means that the tree-covered peatlands are not included in this area of about 5 mill. acres. Consequently, because the amount of forest-covered peatlands is fairly large, it is obvious that the whole extent of peatlands in Newfoundland is considerable larger than 5 mill. acres, maybe 6-7 mill. acres.

3.3. Some Previous Peatland Classifications

One of the earlier attempts to classify the peatlands of Newfoundland was made by Løddesøl in his report in 1955. It is very rough and can hardly be considered a real classification. Gillespie (1954) has presented a classification of peat which might be an attempt to classify peatlands, too. He talks about 1. fibrous, 2. woody and 3. sedimentary peat types, and he divides each of them into two subclasses: namely, Sphagnum peat (S-peat) and sedge peat (C-peat). The classification made by Allington (1961) is concerned with the peatlands of Central Labrador and Ungava, but not those of Newfoundland. Nevertheless, it is worth presenting here. This classification is as follows: A. string bog, B. closed strings, C. sedge meadows, D. spruce muskeg and E. tamarack swamp forest.

The classification presented by Damman (1964 a) is worth presenting particularly because it has been a very good guide for me; furthermore, the peatland types by Damman are to some extent the same I have got in my study. Damman uses the terms bog, marsh, fen and swamp, dividing the peatlands according to these terms into four main groups. Bogs he divides into three groups: Dwarf shrub bog, where especially Sphagnum fuscum and S. rubellum are dominant species of the moss layer, from the shrub layer he has mentioned particularly the Kalmia species. Oligotrophic bog is according to him an open peatland, characterized by Sphagnum fuscum, S. magellanicum and Trichophorum caespitosum. On the mesotrophic bog tall sedges are dominant. The fen peatlands Damman has divided into two groups. Mesotrophic fens are characterized by greyish green sedges and Sphagnum species and eutrophic fens by green sedges and brown mosses. Marsh - peatlands are typical around the lakes and ponds, on alder swamps Alnus rugosa is the most typical plant.

In the very comprehensive study concerning the forest types of Central Newfoundland Damman (1964 b) describes also those forest types, which in this paper are counted among the peatlands. Such types are Sphagnum - Kalmia - black spruce forests and alder swamps, which he has divided into three groups: Lycopodium - alder swamp, Carex - alder swamp and wet alder swamp.

3.4 General Features of Newfoundland Peatlands

As Pollett (1967), for instance, has stated, the peatlands of Newfoundland belong partly to the zone of raised bogs and partly to the zone of blanket bogs. The special shape of a bog is typical of the former. The middle part of it is higher than the edges, and it is always formed by very oligotrophic and ombrotrophic bog, while the edges usually have some characteristics of mesotrophic vegetation influenced by minerotrophic water. Usually, the peat layer is more than 6 feet in depth and the occurrance of flashets and ponds is common. It is typical of blanket bogs that the whole landscape, the hills, slopes and valleys, are covered by a peat layer. Usually the peat is fibrous and not very deep, seldom more than 6 feet. Relatively small bogs, seldom more than some acres in size, are also typical of the nature of the peatlands in Newfoundland. These bogs or fens are situated in valleys, and their middle parts are usually mesotrophic or eutrophic open peatland influenced by minerotrophic water, the edge parts being wooded swamps. Sometimes the wooded swamps reach quite high up the slopes.

Characteristic of the peatlands of Newfoundland are the good gradients and the many natural waterways, occurring as a consequence of this circumstance.

The lack of great, homogeneous forest-covered peatlands seems typical of Newfoundland as in other countries where the climate is maritime and the terrain uneven.

4. PEATLAND TYPES

4.1 Some Principles of Classification

A real, comprehensive peatland classification must be based on vegetation. It is of no sense here to go deep to the ideas of different plant sociological schools. I am going to explain only those principles which form a basis for the classification used in Finland and many other countries, too. This classification was established by A.K. Cajander (1913) and after him worked out by many scientists in my country.

The basic unit of this classification is the plant-community in the field. We can find on the same area, for instance, in Newfoundland a series of plant communities in which we can recognize a change from oligotrophic to eutrophic vegetation. This series is a continuum series, in this case influenced by nutrient conditions. There are many other series influenced, for instance, by water economy, temperature conditions, etc.

If we have enough material of plant-community descriptions, we can find out that in certain places of the continuum series there is more material than in some other places, or, in other words, some types of vegetation are common in nature. We can say that there are accumulations in the continuum series, and these accumulations in the continuum series are plant community types or peatland types.

The ideas presented above mean that there are possibilities to divide the continuum series into either a few or many groups, depending on the purpose of the classification. In my opinion the classification of peatlands for forestry purposes must be quite rough, for instance, because the treatments in forestry need fairly large areas. Very detailed classification leads to small units of area and it is impossible to fit practical treatments into these small units. Furthermore, a very detailed classification is always more difficult to use than a more general one.

4.2 Basis of Classification for Newfoundland

Early in the field work an idea of the kinds of continuum series that would be most common became clear to me. The most common was a continuum series probably influenced by the nutrients. It was characterized especially by changes in the moss layer. The poorest bogs were characterized by Sphagnum fuscum and S. rubellum, many times with lichens. On little more fertile bogs S. fuscum seems to decrease and S. papillosum and S. magellanicum increase, and still richer bogs seem to be characterized by S. recurvum and S. flavicomans. In the richest end of the continuum series were S. warnstorfii, S. subsecundum and brown mosses especially Campylium, Drepanocladus, Calliergon and Scorpidium species abundant. With these changes of the moss layer the amount of sedges and herbs increased. Certain shrubs occurred through the whole changing series, but some of these, e.g. Betula michauxii and Myrica gale occurred primarily in the mesotrophic and eutrophic end of the continuum series. Some bushes, such as Rosa nitida, Lonicera villosa, Spirea latifolia and Potentilla fruticosa occurred mainly in the most eutrophic end of the series.

Another series seems to be influenced mostly by the water economy; in the wet end of it the peatland was open bog or fen and in the dry end it was wooded swamp. At the same time with the increase in tree cover there were definite changes in the ground vegetation; for example, the amount of bushes increased.

Separate from these continuum series a series of well-stocked woody swamps were observed. The change from oligotrophy to mesotrophy was very clear, for instance, the abundance of Sphagnum fuscum had changed to vegetation characterized by S. magellanicum, S. recurvum and S. girgensohnii.

According to these three continuum series it seemed to be possible to describe the peatland types in the whole of Newfoundland. The vegetation descriptions were made according to these continuum series. The units for handling were the mean values of the plant coverage of several descriptions in each research area. When the mean descriptions were arranged in the continuum series it was easy to see the most common plant community types or peatland types.

4.3 Descriptions of the Peatland Types

In the following paragraphs the peatland types will be described. For each type there is a table as an appendix in which the mean coverage of plants is shown. Also the frequency of the plants is presented so that the figure means the number of research areas where the plants in question have occurred. In the end of the table there is a list of plants with a smaller coverage than 1 or with a very small frequency. Last in the tables there is a short description of the peat layer, peat kind, humification degree according to the system established by von Post and an average value of the depth of the peat layer.

First I will describe the types of open peatlands in the order of their trophy, first the most poor in nutrients, and the most rich in nutrients last. These peatland types are the following: 1. dwarf shrub bogs, 2. small sedge bogs, 3. sedge bogs, 4. herb-rich bogs, 5. Sphagnum fens and 6. brown moss fens. Thereafter I will describe those peatland types which are intermediate forms between the open peatlands and the woody peatlands. These are: 7. sedge tree swamps and 8. fen-like tree swamps. Last will be described the types of woody peatlands, namely, 9. Kalmia black spruce swamps, 10. herb-rich black spruce swamps and 11. alder swamps.

4.3.1. Open Peatland Types

1. Dwarf shrub bog (Sphagnum fuscum - Kalmia bog, cf. app. 1.). This is the most oligotrophic peatland type. Sphagnum fuscum, Cladonia sp., Rubus chamaemorus and dwarf shrubs, especially Kalmia species, Empetrum sp. and Ledum groenlandicum dominate. The peat layer is always very deep, as a rule over 6 feet, and surface peat is very undecomposed Sphagnum peat. This type is quite common and occurs in the middle parts of raised bogs.

2. Small-sedge bog (Sphagnum - Trichophorum caespitosum bog, cf. app. 2.). This type is a little more fertile with some not very demanding Sphagnum species like S. papillosum, S. magellanicum and S. rubellum as a dominant mosses, and Trichophorum caespitosum and Rhyncospora alba as so-called small sedges. The shrub layer is rather weakly developed. The peat layer is usually quite deep, over 6 feet, but it can be also very shallow. The surface peat is undecomposed sedge - Sphagnum peat, usually very fibrous. This type is the most common peatland type in Newfoundland and it occurs usually in large areas on blanket bogs.

3. Sedge bog (Sphagnum - Carex oligosperma bog, cf. app. 3.) This type is quite similar to the previous one, but some more demanding mosses and sedges like Sphagnum recurvum and especially Carex oligosperma implies that this type is a little more fertile than the previous one. Also some herbs like Aster nemoralis and shrubs like Betula michauxii and Myrica gale are becoming new dominant species. The peat layer is usually quite shallow and the surface peat is medium decomposed sedge-Sphagnum peat. This type is perhaps as common as the previous one and it occurs together with it in the same areas.

4. Herb-rich sedge bog (Sphagnum recurvum - Carex - Herbacae bog, cf. app. 4.). This is clearly more fertile than the types described before. In the moss layer Sphagnum recurvum is especially characteristic, and even some mesotrophic brown mosses are present. Many sedges for instance, C. exilis, C. rostrata, C. michauxiana and C. livida are abundant. Also the share of herbs is great, especially Smilacina trifoliata, Solidago uliginosa, Aster nemoralis and in many cases also Sanquisorba canadensis are abundant. Especially Rosa nitida and Lonicera villosa are characteristic. Among shrubs, especially Myrica gale is to be mentioned. The peat layer is usually quite shallow and the surface peat is medium - well decomposed Sphagnum - sedge peat. This type seems to be fairly common, but it is seldom found in very large areas.

5. Sphagnum fen (Sphagnum warnstorfii fen, cf. app. 5.). This type seems to be quite rich, it is characterized by many demanding mosses and herbs. Especially Sphagnum warnstorfii and S. flavicomans should be mentioned, also some brown mosses like Campylium stellatum are quite common. Carex lasiocarpa, C. rostrata, Trichophorum caespitosum and T. alba are the most common sedges. Among the herbs Sanquisorba canadensis and Selaginella selaginoides[1] are above all worth mentioning because these are quite demanding. Naturally, the less demanding herbs like Solidago uliginosa and Aster nemoralis are also very common. Shrubs are not very abundant, but Potentilla fruticosa, Rosa nitida, Lonicera villosa and Myrica gale are almost always present. The peat layer is usually quite shallow and the surface peat medium decomposed eutrophic Sphagnum - sedge peat. This type is fairly common in some districts of Newfoundland.

6. Brown-moss fen (Campylium stellatum - Trichophorum fen, cf. app. 6). This peatland type is probably as rich as the previous one, and these two types are otherwise similar, but the share of brown-mosses is much higher in brown-moss fen. Especially Campylium stellatum is abundant. Among sedges Trichophorum species are very common and characteristic. The peat layer is usually shallow and the surface peat medium decomposed brown-moss peat. This type is as common as Sphagnum fen, many times both occur in the same areas, the former on the drier part and the latter on the wetter part.

These were the types of open peat lands. Naturally, it would be possible to divide open peat lands into more groups or types than

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1) Selaginella selaginoides is naturally not a herb, but it is usually counted to the field layer with the herbs.

I have presented and, on the other hand, it would be possible to put some of foregoing types together, too. In my material - which was somewhat limited - I found these accumulations in the continuum series of open peatlands, which seems to me be influenced mainly by nutrient relations.

4.3.2. Intermediate Types

7. Sedge tree swamp (Carex - Picea mariana - Larix laricina swamp, cf. app. 7.). This type has much the same ground vegetation as a herb-rich bog, but there is a sparse tree stand with black spruce and larch, many times with balsam fir. As a rule the tree stand is scattered and sparse, the volume is usually under 20 cu. m. per hectare and the trees seldom reach a height of more than 20 feet.

The most common species in the moss layer are Sphagnum recurvum and S. magellanicum and in the field layer many sedges like Carex interior, C. lasiocarpa and Trichophorum caespitosum. Among the grasses and herbs Calamagrostis canadensis, Aster nemoralis, Solidago uliginosa and Smilacina trifoliata are the most common species. Bushes like Rosa nitida and Spirea latifolia are characteristic. The shrub layer is fairly well developed, especially Myrica gale and Chamaedaphne calyculata are dominant.

The peat layer is always quite shallow and the surface peat well decomposed woody - Sphagnum - sedge peat. Sedge tree swamp is a common peatland type and it occurs usually on the edges of open peatlands, but seldom forming very large areas.

8. Fen-like tree swamp (Sphagnum warnstorfii - Picea mariana - Larix laricina swamp, cf. app. 8.). Usually black spruce is the dominant tree species, but sometimes also Larix laricina. Abies balsamaea is always present, but usually only a few small trees on an acre. The volume of the tree stand is small, seldom over 30 cu.m. per hectare and the height of the trees usually does not exceed 20 feet.

The ground vegetation is much like that of Sphagnum fen with Sphagnum warnstorfii, S. recurvum and Campylium stellatum in the moss layer. Carex interior and sometimes C. lasiocarpa are abundant and so is also Trichophorum caespitosum. Among the herbs especially Sanguisorba canadensis is worth mentioning. Myrica gale, Ledum groenlandicum and Chamaedaphne calyculata are dominant in the shrub layer. The peat layer is always quite shallow with well decomposed woody - brown moss - sedge peat in the top layer.

This type is quite common in the same areas as the fens, but large areas of fen-like tree swamps are rare.

I think that [illegible] land types should lead to additional subtypes. The diversity of the vegetation descriptions (cf. app. 7. and 8.) indicates that the variety of vegetation attributed to these types perhaps is great enough for more types. On the other hand, the extent of these swamps is not very great and so it is perhaps unnecessary to have too many types.

4.3.3. Wooded Peatland Types

Among the forest-covered peatlands there seems to be two which I would call real tree swamp types without any relations to the open peatlands: namely, *Kalmia* black spruce swamp and herb-rich black spruce swamp. Maybe also alder swamp could be included in this group, although it is very different from the previous ones.

9. *Kalmia black spruce* swamp (*Kalmia* - *Picea mariana* swamp, cf. app. 9.). The tree stand of *Kalmia* black spruce swamp is quite dense but the trees are small and their growth rate very low. Black spruce is clearly the dominant tree species and only seldom are there some scattered small larches.

In the moss layer *Sphagnum fuscum*, *S. rubellum*, *Pleurozium shreberi*, *Hylocomium splendens* and *Cladonia* species are abundant Grasses and herbs are nearly missing, but shrubs are very well developed. Especially *Kalmia* species, *Chamaedaphne calyculata* and *Ledum groenlandicum* are abundant, sometimes also *Rhododendron canadense*.

The peat layer is usually about 2 feet, and the surface peat is woody *Sphagnum* peat and low or medium decomposed. In some areas this kind of swamp type is fairly common and occurs many times over large areas. This type seems to be the same as the *Sphagnum* - *Kalmia* - black spruce forest described by Damman (1964 b).

10. *Herb-rich black spruce swamp* (*Sphagnum* - *Cornus* - *Picea mariana* swamp, cf. app. 10). The tree stand of this swamp type is usually relatively well stocked and the volume can sometimes be about 100 cu.m. per hectare, but it can also be quite small. The height of the trees can be about 40 feet, but usually it is only 15-30-feet. Black spruce is always the dominant tree species and larch and balsam fir are nearly always present.

Sphagnum recurvum, *S. magellanicum* and feathermosses are abundant in the moss layer. *Carex interior* and *C. trisperma* are common. Herbs like Cornus species, Smilacina trifoliata, Coptis trifoliata, etc. are very characteristic. Also shrubs like Ledum groenlandicum, Kalmia angustifolia and Gaultheria hispidula are characteristic and abundant.

The peat layer is not very deep, but can be up to 5 feet and the surface peat is medium - well decomposed woody - sedge - Sphagnum peat. Herb-rich black spruce swamp is quite a common swamp type in the wooded regions of Newfoundland and it seems to be related with some real forest types (cf. Damman 1964 b).

11. Alder swamp (Alnus - Herbaceae swamp). Alder swamps are fairly common, but they occur almost exclusively along rivers and brooks or in other places where the overflow from year to year has an important influence, Due to this, its value for forest drainage may be very small. For that reason I did not describe it more closely. Besides, it is quite well described by Damman (1964 b). The three vegetation descriptions I made, agree with those made by Damman.

The tree stand is almost pure Alnus rugosa, which is very dense, but only in bush form. Some scattered black spruce and balsam fir occur. The moss layer is usually scarce with Calliergon, Rhytidiadelphus and Mnium species. The herb layer is very strong with many species like Myosotis, Calium, Thalictrum, Aster and Rubus species. The shrub layer is almost missing. The peat layer is usually very thin and highly decomposed.

5. EVALUATION OF PEATLAND TYPES FOR FORESTRY

5.1. Some Principles For Evaluating Forestry Capability

Under natural conditions peatlands are usually treeless or covered only by scattered tree growth. Their site quality, from the point of view of forestry, is low or even nil, but their potential site quality, i.e., their capability of growing trees after ditching, might even reach a high level.

In this connection, it is not my purpose to discuss the determination of the capability of peatlands for forestry utilization more closely. I would only like to refer to my earlier publications (for instance, Heikurainen, 1964).

It is not possible to calculate exactly the potential site quality of the peatland types of Newfoundland, because the only adequate way to do it is to measure the tree growth after ditching; however, drained peatlands bearing tree stands are very rare in Newfoundland. Thus, we have to try to evaluate the potential site

T o t a l m a g n e s i u m d e t e r m i n a t i o n was similar to total calcium determination.

pH - m e a s u r e m e n t s were made from fresh material and three measurements were made from each sample.

O v e n - d r y w e i g h t was determined keeping the whole sample (1 liter) at 110°C for 24 hours.

5.2.2. Results

The results are presented as percentage of the oven-dry weight of peat and in kilograms per hectare in a 20-cm surface-peat layer. These methods of expressing the results of analysis are the same as those in common use in Europe.

The figures in the text are arithmetic mean values and the primary materials are presented in the appendix (App. 11). When calculating the mean values some primary results, which are very exceptional, were disregarded; these figures are in parentheses in the appendices.

To make comparison of the results with those of Finnish peatlands possible, the variation of nutrient content in Finnish peatlands is presented in the tables below. A more detailed comparison of these peatland types is given in the next chapter.

Table 1. Nutrient contents, pH and oven-dry weight of surface peat of different peatland types.

Peatland type	N	P	Ca	K	Mg	pH	Oven-dry weight gms. per liter
	per cent of oven-dry peat						
Dwarf shrub bog	0.64	0.026	0.15	0.035	0.106	3.41	70
Small sedge bog	1.19	0.028	0.08	0.023	0.106	3.72	87
Sedge bog	1.54	0.046	0.07	0.027	0.043	3.89	105
Herb-rich sedge bog	1.99	0.083	-	0.05[illegible]	0.030	4.55	101
Sphagnum fen	2.13	0.066	0.15	0.033	0.037	4.51	93
Brown-moss fen	2.01	0.092	0.24	0.054	0.121	5.16	162
Sedge tree swamp	1.49	0.094	0.36	0.081	0.110	4.82	101
Fen-like tree swamp	1.83	0.078	0.44	0.046	0.116	5.20	109
Kalmia black spruce swamp	0.33	0.023	0.12	0.036	0.090	3.45	72
Herb-rich black spruce swamp	1.00	0.067	0.17	0.042	0.116	4.00	100
Variation in peatlands of Finland	1.2-2.4	0.025-0.100	0.25-1.35	0.015-0.070	0.03-0.15	3.5-5.5	60-300

Table 2. Nutrient amounts of the surface peat of different peatland types.

Peatland types	N	P	Ca	K	Mg
	kilograms per hectare in a 20 cm deep surface peat				
Dwarf shrub bog	920	37	200	49	143
Small sedge bog	2170	50	143	39	187
Sedge bog	3430	93	148	49	79
Herb-rich sedge bog	4030	162	-	103	62
Sphagnum fen	4430	126	523	57	76
Brown-moss fen	6560	320	752	182	404
Sedge tree swamp	2980	195	767	177	230
Fen-like tree swamp	4190	175	957	99	244
Kalmia black spruce swamp	470	32	178	50	131
Herb-rich black spruce swamp	2000	130	317	81	228
Variation in peatlands of Finland	2000-7000	50-275	500-3500	30-200	50-300

There is reason to examine two different things in the tables; (1) the relationship between the nutrient conditions and peatland types and (2) the comparison of nutrient conditions of peatlands with the Finnish ones.

The relationship between nutrient conditions and peatland types can be seen clearly in acidity, nitrogen and phosphorus. The poor open bogs, dwarf shrub bog, small sedge bog and to some extent also sedge bog are very acid and poor in nitrogen and phosphorus, and it is worth mentioning that dwarf shrub bog is in this sense the poorest and sedge bog the most fertile. Herb-rich bog and the fen types are much better than the previous types, but the differences between these fertile peatland types are not clear. Also the intermediate types, sedge tree swamp and fen-like tree swamp are very fertile with regard to pH, nitrogen and phosphorus, and the last type the best of all. *Kalmia* black spruce swamp is at the same level as dwarf shrub bog, the content of nitrogen is even smaller than in dwarf shrub bog. Herb-rich black spruce swamp is a medium peatland types except for the nitrogen content, which is fairly low.

The relationship between the calcium, magnesium and potassium content, and the peatland type is very vague. In general open bog types are very poor in potassium, and wooded swamp types fairly rich.

The comparison of the nutrient conditions with the Finnish ones indicates that the variation of nutrient conditions is about the same in Newfoundland as in Finland, except for the calcium content which is much lower in Newfoundland than in Finland. It seems to me, that the determination of calcium is not reliable, the great variation in the results and the lack of correlation between calcium and pH indicates this. In general it is necessary to point out, that because of the great dispersion of the results of determination, the reliability is weak. The number of samples should be much greater.

5.3. Comparison Newfoundland and Finnish Peatland Types

Before I compare the peatland types of Newfoundland with the Finnish ones, it might be necessary to present the system used in Finland for describing the potential site quality of peatlands. The number of peatland types is 28 and each type has a certain index of potential site quality. The scale is from 0 to 10, and the index 10 refers to the most fertile sites and 0 to the poorest. The indexes are relative figures, but because the most fertile soils in Finland produce about 10 cu.m. per hectare a year (~1.6 cords per acre in a year) as a medium growth, the figures are roughly the same as the mean annual increment in cu.m. per hectare. Because Finland reaches about 1100 kilometers (~684 miles) from south to the north, and, on the northern latitudes of Finland (60° - 70°), the growth rate depends very much on the location of the growing place, the index of certain peatland types decreases towards the north. For classifying this decrease, the country is divided into five zones and each peatland type is given a certain index in each zone.

The differences in the climate of different parts of Newfoundland are marked (cf. The Canada Inventory, Report No. 3, 1966) and these regional differences may have some influence on the potential site quality, but because this matter is not studied closely in this connection, I had to consider Newfoundland as one entity in this sense.[1] It is worth mentioning that the idea of dividing the forests of Labrador into zones made by Wilton (1965) probably does not suit Newfoundland conditions.

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1) The Northern Peninsula of Newfoundland is not included in this report.

At the same time as I compare the peatland types in Newfoundland with those of Finland, I will make comparisons according to the nutrient analyses.

D w a r f s h r u b b o g is very much like *Sphagnum fuscum* bog in Finland. The similarity is fairly great, and also the nutrient content is about the same, as can be seen from the table below:

	pH	N %	P %	K %
Dwarf shrub bog (Nfld)	3.41	0.64	0.026	0.035
Sphagnum fuscum bog (Fld)	3.40	0.90	0.035	0.020

Because the calcium and magnesium determinations are very unreliable, I have not included them here, besides the importance of these nutrients in general is more theoretical. *Sphagnum fuscum* bog in Finland has shown very poor productivity and its psq-index is only 1.[1]

S m a l l s e d g e b o g has also a corresponding peatland type in Finland. The similarity is as great as it can be between two types located so far from each other. As can be seen from the table, the nutrient content of these two types are quite the same.

	pH	N%	P%	K %
Small sedge bog (Nfld)	3.72	1.19	0.028	0.023
Small sedge bog (Fld)	3.80	1.40	0.035	0.025

In my country the small sedge bog has the index of psq 2.

S e d g e b o g in Newfoundland does not have a comparable peatland type in Finland, but in my opinion it seems to be between small sedge bog and normal sedge bog in Finland. Also the nutrient analyses point to this, as can be seen from the table below:

	pH	N %	P %	K %
Sedge bog (Nfld)	3.89	1.54	0.046	0.027
Normal sedge bog (Fld)	4.60	1.60	0.060	0.030

The former has the index of psq 2 and the latter 5. I am willing to give the psq-index 3-4 to the sedge bogs of Newfoundland.

H e r b - r i c h s e d g e b o g has a related peatland type in Finland with the same name. The psq-index is 6-7. It seems to me that the Finnish type is a little more fertile, or, in other words, herb-rich sedge bog in Newfoundland will be

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1) psq = potential site quality.

situated between the Finnish normal sedge bog and herb-rich sedge bog, and so the psq-index 6 would be suitable. The comparisons of the nutrient contents show the same, as follows:

	pH	N %	P %	K %
Herb-rich sedge bog (Nfld)	4.55	1.99	0.083	0.053
Herb-rich sedge bog (Fld)	5.00	2.30	0.070	0.035

S p h a g n u m f e n is very much the same as Finnish Sphagnum warnstorfii - fen and also brown-moss fen has a corresponding peatland type in Finland. Also the figures showing the nutrient contents are quite close to each other, as can be seen from the table below:

	pH	N %	P %	K %
Sphagnum fen (Nfld)	4.51	2.13	0.066	0.033
Brown-moss fen (Nfld)	5.16	2.01	0.092	0.054
Fen-types (Fld)	5.50	2.50	0.065	0.035

Both these peatland types in Finland are given the same psq-index, namely 6.

For s e d g e t r e e s w a m p it seems to be difficult to find a comparable peatland type in Finland. In fact, these are four peatland types, which are related to the sedge tree swamp; namely normal sedge pine swamp with the psq-index 5, herb-rich sedge swamp with the psq-index 6-7 and comparable spruce swamp with the psq-indexes 7 and 9. The reason for this is that the sedge tree swamp seems to be less fertile than the Finnish herb-rich swamp types, but more fertile than the Finnish normal swamp types, as follows:

	pH	N %	P %	K %
Sedge tree swamp (Nfld)	4.82	1.49	0.094	0.081
Normal sedge pine swamp (Fld)	4.50	1.40	0.060	0.045
Herb-rich sedge pine swamp (Fld)	4.90	1.60	0.070	0.050
Normal sedge spruce swamp (Fld)	4.60	1.90	0.070	0.050
Herb-rich sedge spruce swamp (Fld)	5.00	2.10	0.075	0.060

Another difficulty is the question of tree species. I believe that the psq-index for sedge tree swamp should be 7.

F e n - l i k e t r e e s w a m p may be comparable with the Finnish fen-like pine swamp and fen-like spruce swamp, see the table below.

	pH	N %	P %	K %
Fen-like tree swamp (Nfld)	5.20	1.83	0.078	0.046
Fen-like pine swamp (Fld)	5.50	1.80	0.065	0.045
Fen-like spruce swamp (Fld)	5.70	2.20	0.070	0.045

Both of them have the psq-index 7-8, and I think this is suitable for fen-like tree swamp in Newfoundland.

Kalmia black spruce swamp is a very strange peatland type from the Finnish point of view. The comparison must be based only on the nature of vegetation and according to this questionable comparison it might be about the same as Finnish *Sphagnum fuscum* pine swamp with the psq-index 1-2. Also the nutrient conditions of these two comparable swamp types are quite close to each other.

	pH	N%	P %	K %
Kalmia black spruce swamp (Nfld)	3.45	0.33	0.023	0.036
Sphagnum fuscum pine swamp (Fld)	3.40	0.60	0.030	0.020

Herb-rich black spruce swamp is also very difficult to compare with Finnish peatland types. However, I think this is somewhat similar to the Finnish normal spruce swamp, which has many similarities in the vegetation, for instance, *Sphagnum girgensohnii* and feather mosses. The psq-index of normal spruce swamp is 7-8.

Nutrient conditions are fairly similar, except that the Finnish spruce swamp seems to be richer in nitrogen, as is seen in the following tabulation:

	pH	N %	P %	K %
Herb-rich black spruce swamp (Nfld)	4.00	1.00	0.067	0.042
Normal spruce swamp (Fld)	4.30	1.90	0.075	0.045

Alder swamp is, no doubt, a very fertile swamp type, and it has many connections with Finnish grove-like spruce swamp with a thin peat layer. Its psq-index is 10 and I have the impression that alder swamp is fertile enough to have the same psq-index. However, there are many practical difficulties in using alder swamps for forestry purposes.

Table 3. The psq-indexes of Newfoundland peatland types and the related Finnish types.

Peatland types: Newfoundland	Peatland types: Finland	Potential site quality index
1. Dwarf shrub bog	Sphagnum fuscum bog	1
2. Small sedge bog	Small sedge bog	2
3. Sedge bog	Small sedge bog and normal sedge bog	3-4
4. Herb-rich sedge bog	Herb-rich sedge bog	6
5. Sphagnum fen	Sphagnum warnstorfii fen	6
6. Brown-moss fen	Bryales fen	6
7. Sedge tree swamp	Sedge pine swamps and sedge spruce swamps	7
8. Fen-like tree swamp	Fen-like pine swamp and fen-like spruce swamp	7-8
9. Kalmia black spruce swamp	Sphagnum fuscum pine swamp	1-2
10. Herb-rich black spruce swamp	Normal spruce swamp	7-8
11. Alder swamp	Grove-like spruce swamp	10

5.4. Forest Capability of Peatland Types

The potential site quality indexes presented in the previous section have been collected in table 3. I would like to point out that the the psq-indexes show the tree growth after ditching, but without fertilizing. The index is a relative value and it does not indicate the increment itself in some units. Such an estimation indeed is not yet possible in Newfoundland. However, to get some impression of the indexes and to help the user of that system, it is perhaps necessary to try to find out what the comparable increment of the psq-indexes might be. If we assume that the highest index 10 corresponds to the best sites in Newfoundland, where according to studies by Bajzak (1962) and van Nostrand (1964), the mean annual growth is a little under 1 cord per acre, we can state that the peatlands with the psq-index 10 might have a mean annual growth after ditching of 1 cord per acre and the peatlands with psq-index 5 of 0.5 cord per acre and so forth.

The tree growth is one of the factors which has an influence on the profitableness of forest drainage. But there are many other factors, such as costs, prices of wood, rotation time, etc. In general it is very difficult to calculate the profitableness of forest drainage mainly because of the long time period between input and output. We will return to that subject later, but in the following I will describe some factors which influence the profitableness, or maybe it is better to say, the capability of peatland types for forest drainage.

Open peatland types need effective ditching, afforestation and almost always some kind of fertilizing in order to be converted to productive forest land. I suppose that only fen types and herb-rich bogs are able to grow forest without adding nutrients, this is also to be seen from the fairly high psq-indexes of these types. But also on these types according to experiences in Finland, the lack of potassium or phosphorous can cause a stagnation in the tree growth some decades after ditching. Therefore, it is necessary to have PK-fertilizing also on these types, but maybe only once. I consider these types suitable for forest drainage but not very economical because the costs of effective ditching (cf. p. 54) and afforestation will be quite high.

The other open peatland types are very poor in nutrients, and they will need probably NPK-fertilizing only at the time of afforestation and for the second time maybe after 20 years[1]. The content of nitrogen is perhaps so high in the sedge bog that the second fertilizing can be only PK-fertilizing. I think that the costs to grow forest on dwarf shrub bogs and small sedge bogs will be too high to consider these types capable for forest drainage, but I am willing to consider sedge bogs capable for forest drainage although not very economical.

The two intermediate peatland types, sedge tree swamp and fen-like tree swamp are quite fertile sites and the psq-indexes are high, too. Fertilizing is hardly necessary, and in my mind, ditching should not be as dense and expensive as on open peatlands

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[1] So far we do not know exactly how many times fertilizing on poor peatlands is to be repeated, but according to experiences in Finland, the effect of the first fertilizing on peatlands will be over after 20 years.

(cf. p. 54). Sometimes, especially on sedge tree swamp, the tree stand is dense enough and capable of recovering after ditching. In these cases swamps are very suitable for forest drainage. If the tree stand on virgin swamp is not dense enough, it is necessary to have regeneration after drainage. According to my experiences there are usually plenty of seedlings on the swamps and regeneration is very easy; it needs only removal of the old trees. Thus, also in these cases, we do not need any artificial regeneration, and the undertaking of drainage will be quite economical. The only disadvantage is the fairly small size of these swamps; the planning of ditching requires more careful work and the use of ditching machines is not as economical as on open peatlands with large areas.

The dense tree stand on Kalmia black spruce swamp and herb-rich black spruce swamp is a common feature of these swamp types, and it is obvious that in some cases the tree stand is capable of recovering after drainage, but in most cases it is necessary to have a regeneration. I think that only clear-cutting is needed for reforestation. The nutrient content of Kalmia black spruce swamp is very low and without fertilizing tree growth will not be sufficient. In my opinion NPK-fertilizing is needed and the costs to grow trees on this peatland type will be quite high. I would only consider cases where the tree stand is capable of recovery as economically satisfactory for drainage.

Herb-rich black spruce swamp, on the contrary, is a medium rich swamp type and should not need any fertilizing to grow forest after drainage, and because the growth rate after drainage will be quite high I am sure that herb-rich black spruce swamp is a relatively economical subject for forest drainage even when reforestation is necessary.

Alder swamp is a very fertile swamp, but because it usually is located along water ways with a periodic overflow, the use of this swamp for forest drainage is only seldom possible. If so, artificial regeneration is inevitable. Also the possible difficulties for regeneration due to dense alder bush must be taken into consideration. These facts mean that alder swamp is not so capable of forest drainage as it seems to be according to the high psq-index.

5.5. General Consideration on Selection of Peatlands for Forestry

In the previous section we have discussed the forest drainage capability of several peatland types in relation to their fertility. In this connection the influence of the tree stand of virgin peatlands on the forest-drainage capability has also been discussed. In addition to these facts it is necessary to point out the following things which influence the forest-drainage capability of peatlands.

1. The number of rimpis or flashets decreases the capability. It is typical of peatlands in Newfoundland, especially of blanket bogs, that there are often many rimpis, sometimes even deep ones, which may have even a size of small ponds. It is clear that such ponds are not suitable for forest drainage but also smaller and lower rimpis have some decreasing influence on the capability of forest drainage. There are difficulties in ditching them and the typical construction of rimpi peat will cause difficulties in afforestation. If the proportion of rimpis is very great, over 30 per cent for instance, the peatland in question is not capable of forest drainage.

A great number of rimpis is common especially on small sedge bogs and sedge bogs, and on other open bogs, and there are often rimpis on intermediate swamp types as well.

2. The hummocks of *Sphagnum fuscum* also decrease the forest drainage capability of peatlands. We can say that such a hummock is a small part of dwarf shrub bog with a low content of nutrients and with the unfavorable physical characteristics of that peatland type. The more hummocks present, the more the forest drainage capability decreases.

The occurrence of *Sphagnum fuscum* hummocks is not very common in Newfoundland, but sometimes, for instance fen types have plenty of such hummocks.

3. Thin peat layer, more exactly the peat depth being less than 1.5 feet, is usually considered to increase the capability of peatland for forest drainage if the ground soil is clay, till, fine sand or some other such finely divided soil, but if it is gravel which is poor in fine material or more coarse soil, this characteristic may have even a decreasing influence on the forest drainage capability. This is naturally the case if there is a bedrock under the thin peat layer.

Thin peat layer is common for all tree swamps, sometimes also for open peatlands occurring on blanket bogs.

4. All those factors which increase the costs, such as ditching, afforestation, and fertilizing costs, have a decreasing influence on the profitableness of forest drainage. Sometimes the drainage costs and drainage difficulties

might be so great that ditching is impossible in practice and thus the peatland is not capable of forest drainage although the psq-index might be very high. A good example for that is alder swamp.

Some open bogs, as small sedge bog and sedge bog, occur in very great areas. Usually other types, especially those which are capable of forest drainage, occur in comparably small areas (from 1 to 10 acres) mixed with others, for instance with peatland types not capable of forest drainage. Thus the drainage area will include many kinds of peatland types and this fact will bring a new view point to the selection of peatland types for forest drainage. It means that small peatland areas, not capable of forest drainage, surrounded by better peatland areas should for practical reason be drained and, on the contrary, small peatland areas, capable of forest drainage but surrounded by large poor peatlands should be left outside drainage.

6. POTENTIAL OF PEATLAND FORESTRY IN NEWFOUNDLAND

6.1. Tree Growth Conditions in Newfoundland

6.1.1. Climate

One way to get some conception of the growing conditions in Newfoundland is to compare climatical data of Newfoundland with Finnish ones.

Newfoundland is situated between 46° 35' N and 51° 30' and Finland between 60° and 70° N latitude. It means that Newfoundland is a much more southern country than Finland. In spite of this, the temperature conditions are close to each other, as can be seen from the following table.[1]

	Nfld	Fld
Mean annual temperature, °F	37-40	32-41
Mean temperature in July, °F	57-60	56-65
Mean temperature in February, °F	16-26	8-22
Duration of growing season, days	150	125-175
Beginning of growing season	10-15 May	25 April - 20 May

1) The explanation for this in Finland is the warm Gulf Stream and the cold Labrador Current in Newfoundland, as is very well known.

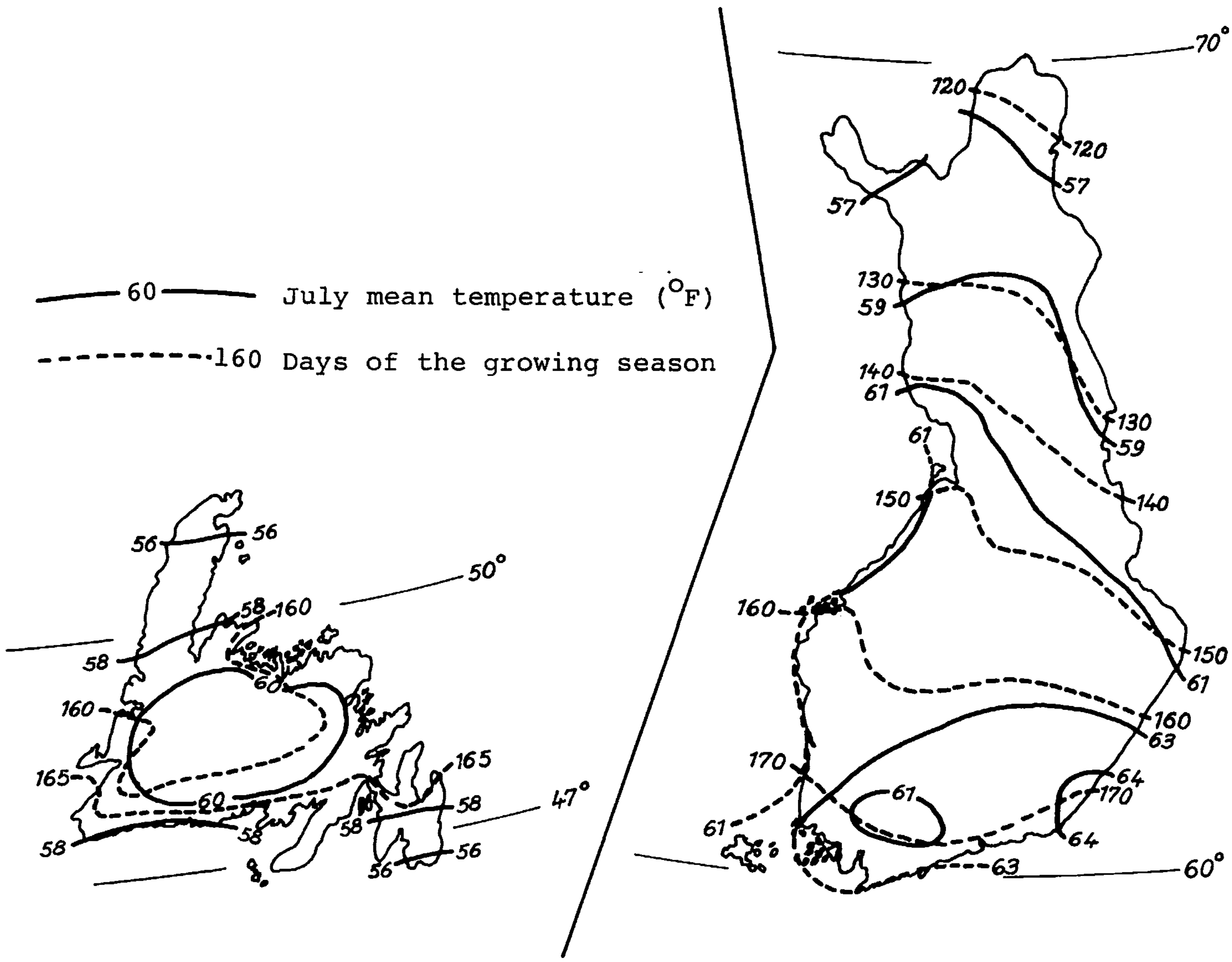


Fig. 2. Comparison of some climate conditions in Newfoundland and Finland.

Because Finland is a fairly long shaped country in a northern direction, the variation of temperature conditions is much greater than in Newfoundland (excluding the Northern Peninsula). But the most important data, the mean temperature in July and the duration of the growing season in the middle part of Newfoundland are quite the same as those in Middle Finland (Kainuu) (cf. Fig. 2).

Precipitation is much higher in Newfoundland than in Finland and also precipitation during the summer months is higher. Although evapotranspiration in Newfoundland is greater than in Finland, the moisture surplus in Newfoundland is more than twice as much as in Finland. The comparison of these water balance conditions are to be seen in the following table.

	Nfld	Fld
Annual precipitation, inches	36-55	20-27
Precipitation in June and July, inches	3.0	2.0-2.6
Evapotranspiration, inches	18-19.5	6-14
Moisture surplus	25-30	8-16

Wind speed in Newfoundland is much higher than in Finland, especially this is true in the winter, the summer conditions are more similar to each other, as can be seen from the following table.

	Nfld	Fld
Mean annual wind speed, MPH	10-15	5-11
Mean wind speed in January, MPH	15-20	6-13
Mean wind speed in July, MPH	7-14	5-10

According to this examination we can state that regarding the temperature conditions during the growing season, Newfoundland seems to be quite comparable to Middle Finland (Kainuu). Hpwever, the precipitation is much higher and the wind much stronger.

5.1.2. Tree Growth

There are many difficulties in comparing the development of tree stands in Newfoundland and in Finland. The tree species are different, the fertility of sites perhaps is not comparable and the measuring methods in both countries are not equal. In spite of these difficulties I have tried to make some comparisons. In Figures 3 and 4 there are some curves showing the height development of trees in both of those countries according to studies by Ilvessalo (1920, 1937 and 1967) in Finland and by Bajzak (1962) and van Nostrand (1964) in Newfoundland. Without going deep into the problems concerning this matter, I will only state that the curves from Finland are for pine (*Pinus silvestris*) and from Newfoundland for black spruce (*Picea mariana*) and balsam fir (*Abies balsamaea*). The sites are of average quality.

The curves show, that the height development of black spruce and balsam fir is situated between the curves showing the height development of pine in Middle Finland, perhaps it is a little lower, but obviously better than height development in North Finland and clearly lower than in South Finland.

The growth charts for black spruce and balsam fir in Newfoundland and those for pine in Finland can be seen in Figure 5. We can notice that the growth charts in the two best height site index classes are situated between the curves of South Finland and Middle Finland, perhaps closer to the last ones. Only the curves of the lowest height site index are at the same level with the curves of North Finland. Thus this comparison strengthens the conclusions drawn above, and we can state that, as far as a comparison between Newfoundland and Finland is possible, the tree growing conditions in Newfoundland may correspond to those in Middle Finland.

In Finland we consider Middle Finland (Kainuu) quite favourable for forest drainage, and the forest drainage activity is very wide even in North Finland, where the tree growing conditions seem to be more extreme than in Newfoundland. Thus, I do not see any biological reason, why it should not be possible to start forest drainage in Newfoundland. But it is necessary to point out, that the climate conditions seem to have some unfavourable aspects, like a high precipitation and strong winds, which may have some harmful effect on the forest growth on drained areas.

6.2 Review of Peatland Forestry in Finland

6.2.1. Historical

The total area of peatlands in Finland is 9.7 million ha (24 million acres), comprising 32 per cent of the entire land area of the country. For a long time 65 to 75 per cent of our exports has been forest products; hence, it is not surprising that serious attention has been paid to the utilization of peatlands in Finland for the production of wood.

Some drainage work for forestry purposes was done in Finland as early as in the 19th centry, but it was not until 1909 that a systematic forest drainage program was started. By 1940 about 800,000 ha (2 million acres) of swamp had been drained; all of

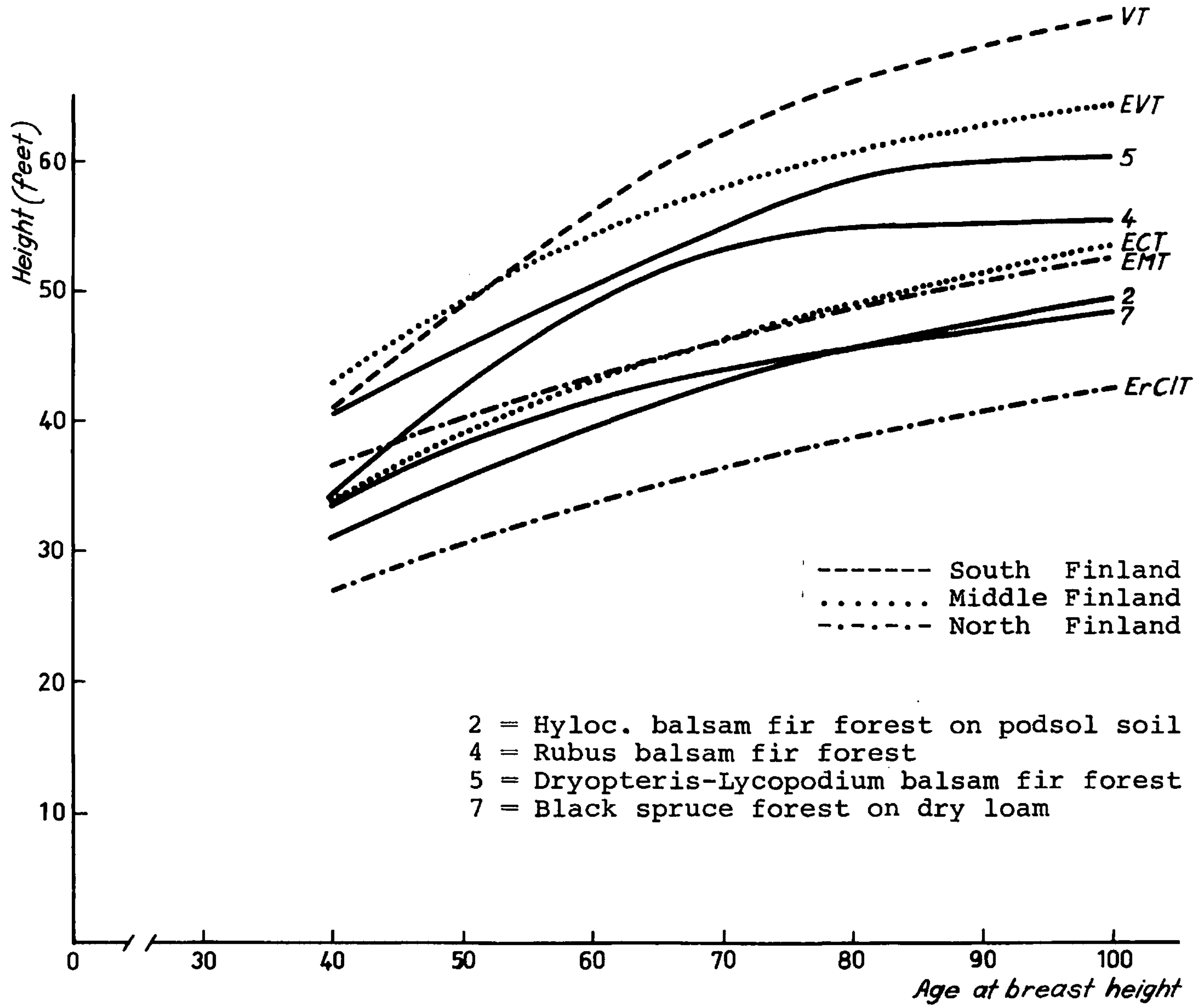


Fig. 3. The height development of trees in Newfoundland (according to Bajzak) and in Finland (according to Ilvessalo).

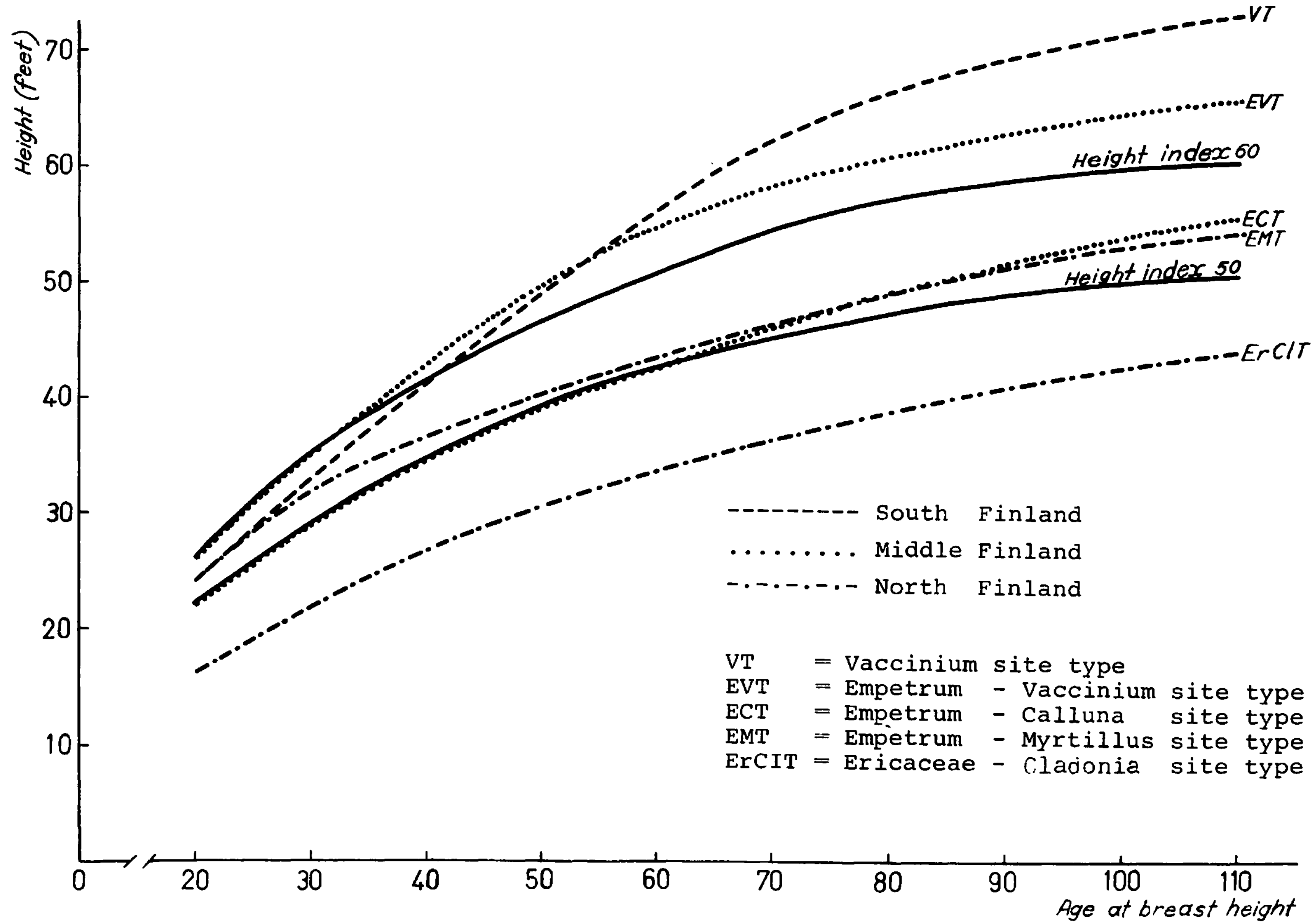


Fig. 4. The height development of trees in Newfoundland (according to Nostrand) and in Finland (according to Ilvessalo).

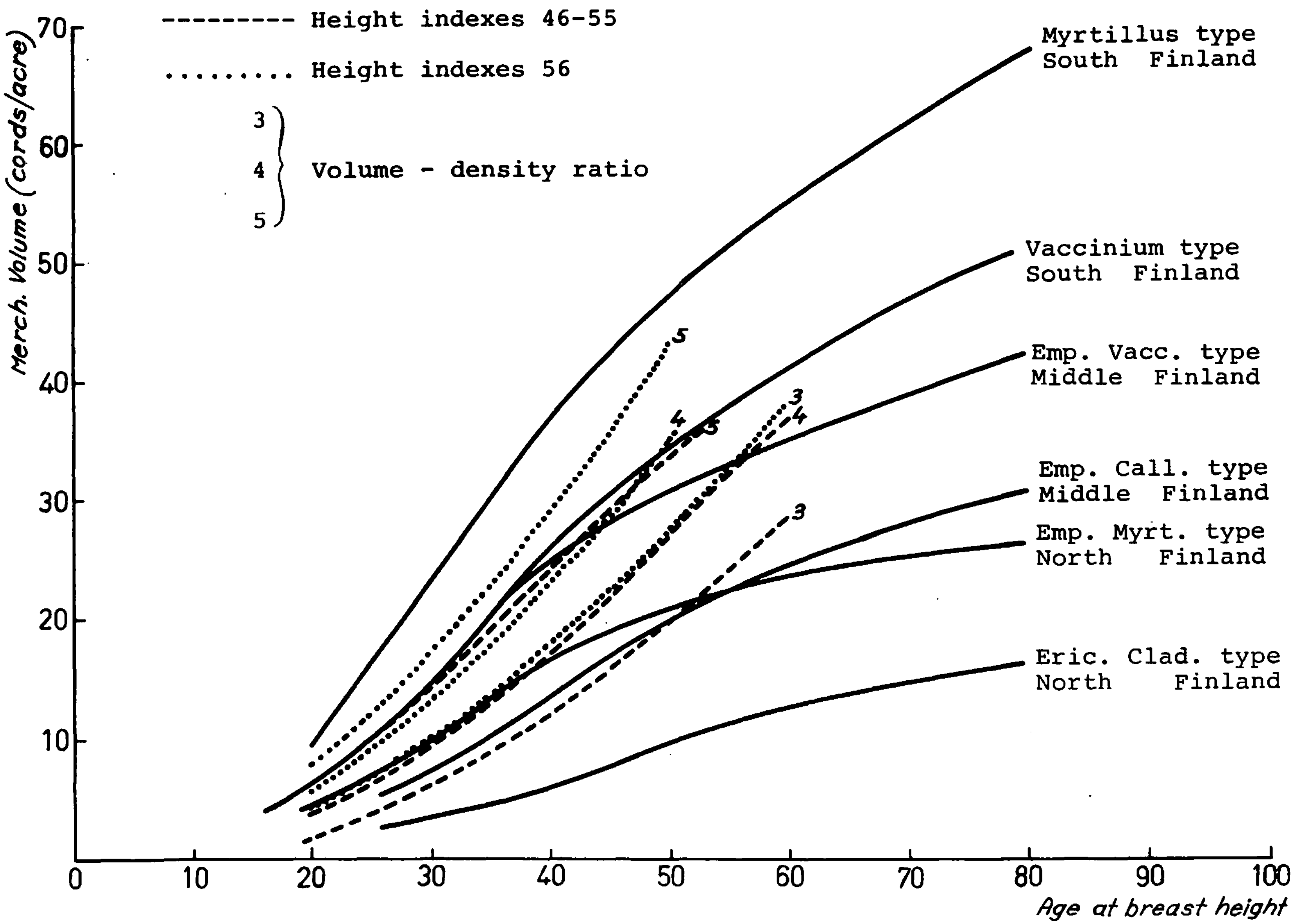


Fig. 5. The volume development of stands in Newfoundland (according to Nostrand) and in Finland (according to Ilvessalo).

this work was done manually. Then because of the war, drainage projects were at a nearly complete standstill for a period of ten years, but since the early 1950's, work has been continued more effectively than before. By the end of 1967, about 3 million ha (7.4 million acres) of peatland had been drained for forest production and about 650,000 km (about 400,000 miles) of forest ditches had been dug. The increasing extent of drainage is well illustrated by the following table covering the last seven years:

Year	Length of ditches dug annually km	miles	Area of forest land drained annually hectares	acres
1961	24,000	14,[illegible]00	120,000	297,000
1962	30,000	18,600	144,000	356,000
1963	33,000	20,500	158,000	390,000
1964	36,000	22,400	175,000	432,000
1965	45,000	28,000	215,000	531,000
1966	52,000	32,300	247,000	610,000
1967	60,000	37,300	286,000	707,000

These drained areas are divided into different ownership groups as follows: private about 65, state 20 and companies 15 per cent corresponding to about the same percentage of forest land under different ownership. The state and companies are doing their drainage work at their own costs and using their own personnel and machines. For drainage work in private forests there is a special organization, the so-called forest improvement staff paid by the government. This forest improvement staff (about 60 forest officers, 120 foresters and about 300 forest foremen and office workers) takes care of some other forest improvement works, too, like building forest roads, and seeding and planting of underproductive forest land, but about 65 per cent of their staff is used for forest drainage work. This forest improvement staff makes drainage plans and directs the ditching work without any costs for the land owners. Also the work costs are supported by the government so that it is possible for private land owners to get loans with a low interest (3 per cent) and also in some cases to get grants up to 60 per cent of the work costs.

The whole investment for forest drainage was in 1967 about 40 million FM (about 10 million Canadian dollars), and the government's share of it was about 65 per cent.

According to my studies, the need for additonal forest drainage in Finland is still about 4.5 million ha (about 11 million acres). The best estimates suggest that the necessary drainage work could be completed in about 15 years and according to the national plans the annual drainage capacity will be increased to the amount of 355,000 ha (877,000 acres) in the near future,

6.2.2. Current Activites

Ditching has been mechanized completely during the past fifteen years. About one half of the ditches are dug by ploughing. Many different plough types are used ranging in weight from 4 to 7 tons. The ploughs are drawn by winches mounted on 16-22-ton crawler tractors. Power excavators (backhoes) are used in smaller drainage areas. They have a hydraulic excavating device driven by a medium heavy or heavy farm tractor or a powerful forest tractor. Other ditchers, especially the rotary type, have also been experimented with success in the last few years.

In general drainage intensity today is reflected in the depth of ditches, which ranges from 60 to 90 cm (24-35 inches), and in ditch spacing which ranges from 30 to 60 m (100-200 feet). It is quite obvious that the trend is towards shallower ditches and closer spacings. In the last few years a new ditching method has gained increasing favour, especially on open peatlands. This method involves very shallow ditches at close spacings, and provides also good site preparation for subsequent afforestation. About 35 to 45 centimeter (14-18 inches) ditches 4 to 5 meters (13-16 feet) apart from each other are made with rather light ploughs or rotary ditchers drawn by agricultural tractors. This method has been introduced in our country from Great Britain where it has been in use for many years. It seems to be suitable also under our climatic conditions, but requires treeless, snag-free peat and quite extensive areas.

It is characteristic of the utilization of Finnish peatlands for forestry purposes that the bulk of the area to be drained carries forest. According to my calculations, only about 30 per cent of the area consists of open peatlands requiring afforestation in connection with ditching. Either Norway Spruce (*Picea excelsa*) or Scotch pine (*Pinus silvestris*) is used in afforestation depending on the fertility of the site. Spruce is usually planted, pine seeded or planted. Drained peatlands are usually very easy to afforest. Both in direct seeding and in planting the seed grain or the plant is placed usually on the peat surface, only in few cases it is necessary to use the turf-planting method. (cf. Zehetmayr 1954).

About 70 per cent of the whole area to be drained consists of forest-growing swamps, where regeneration can be carried out naturally or the existing tree stands can be grown further after drainage. Studies show that the capacity of trees to respond to drainage is the greater, the smaller and younger they are. Therefore, in practical improvement cuttings made just before or after ditching it makes sense to remove the largest trees and leave the smaller ones, with greater capacity to recover, to form the main growing stock.

6.2.3. Results

That growth after drainage depends both on the peatland type and on the climate of the specific location in question has been well-established after much study, and is very well known (cf. also p. 29). As examples showing the tree growth after drainage I will take four peatland types, s p r u c e s w a m p w i t h h e r b s , which may be similar in regard to fertility with alder swamps in Newfoundland, n o r m a l s p r u c e s w a m p, which is comparable with herb-rich black spruce swamp in Newfoundland, n o r m a l s e d g e p i n e s w a m p , which is close to the sedge tree swamp in Newfoundland and p i n e s w a m p w i t h s h r u b u n d e r s t o r y , which is perhaps a little like Kalmia black spruce swamp but not so extremely poor.

Data from these four very common peatland types in the middle part of Finland, where the growing conditions seen to be comparable to those of Newfoundland (cf. p. 41), are in the table 4 to illustrate growth attained in stands of different volumes 20 to 25 years after ditching.

Table 4. The increment in some Finnish peatland types 20 to 25 years after ditching in stands of different volumes. The figures refer to all the stem wood.

Volume per ha (per acre)		Annual growth per ha (per acre)							
		1. Spruce swamp with herbs		2. Normal spruce swamp		3. Normal sedge pine swamp		4. Pine swamp with shrub understory	
cu.m	(cu. ft.)	cu.m	(cu.ft.)	Cu.m	(cu.ft.)	cu.m	(cu.ft.)	cu.m	(cu.ft.)
40	571	3.9	56	2.8	40	3.0	43	1.6	23
60	857	5.3	76	3.6	51	4.0	57	1.8	26
80	1143	6.5	93	4.3	61	4.7	67	1.9	27
100	1429	7.5	107	4.9	70	5.0	71	2.0	29
120	1714	8.2	117	5.5	79	5.1	73	2.1	30
140	2000	8.5	121	5.8	83	5.2	74	-	
160	2286	8.6	123	5.9	84	-		-	

Table 5. shows other examples from measurements concerning the volume and the increment of these peatland types made in 1967 from areas in South Finland drained in the year 1935. Thus, the figures describe tree stands about 32 years after ditching. The figures showing the situation before ditching are average figures obtained from the national forest inventory.

Fertilizing peat soils for forestry purposes is quite new. It has been done on a practical scale only during the present decade, but now fertilizing is rapidly becoming very extensive. Up to now peatland fertilizing has been usually done with mixed

Table 5. The volume and annual growth in some peatland types in South Finland before ditching and 32 years after that. The figures refer to all the stem wood.

Peatland types	1.	2.	3.	4.
Number of sample areas	10	34	17	29
32 years after ditching				
Volume, cu.m per ha	220	170	146	85
cu.ft. per acre	3143	2086	2086	900
Increment, cu.m per ha	9.6	6.4	5.3	2.5
cu.ft. per acre	137	84	76	36
On the undrained peatlands				
Volume, cu.m per ha	60	70	15	35
cu.ft. per acre	857	1000	214	500
Increment, cu.m per ha	2.3	2.6	0.7	1.2
cu.ft. per acre	33	37	10	17

NPK-fertilizer, where the N - P_2O_5 - K_2O -proportion is 14 - 18 - 10. Separate fertilizing with N, P and K is also very commonly used. This kind of full-fertilizing is used on poor peatland types and the amount of fertilizers is usually 100 kg per hectare (about 90 lb per acre) of N, P_2O_5 and K_2O. The peatlands rich in nitrogen have been recommended to be fertilized only with PK.

In connection with planting or seeding we use so-called spot fertilization, putting a small amount of fertilizer close to the seedling or seeding point. Most common application is 30 g. (about 1 ounce) or NPK-mixture, as mentioned above.

Broadcast application of fertilizers is made today with machines, mostly with centrifugal or blowing equipment installed on tractors. Also use of air planes is becoming more common, and in the near future broadcasting of fertilizers by air plane seems to be the most effective method, especially in difficult terrain.

There is perhaps no sense to explain the results of fertilizing here. I only would like to say that the results have been very promising. For persons who are more interested in results of fertilizing obtained on peatlands, refer to my paper (Heikurainen, 1967).

I think that fertilizing problems and solutions of them will be the same in Newfoundland. Forest growing on peatlands will need fertilizing in most cases, but so far we do not have any experience about response of black spruce and balsam fir to fertilizing.

A widely held opinion in Finland is that by utilizing the peatlands intensively in the forest management program, it will be possible to influence the forest balance of the whole country to a very marked degree. According to my own study of the situation, the increase both in growth an in removal - assuming the necessary drainage program will be completed in 15 years - is anticipated to be approximately as shown by the table below:

Year	1968	1978	1988	1998
	Million cu. metres (cu.ft.) per annum			
Increasing in growth	3.7 (131)	6.0 (212)	8.8 (311)	10.7 (378)
Increasing in removal	1.2 (42)	2.1 (74)	3.6 (127)	7.0 (247)

After thirty to forty years the increase in growth and cut, on an average, is about ten million cubic metres (353 million cu.ft.) per annum. This increase represents nearly twenty-five per cent of the present growth of the entire forest resources of the country. Although this increase may appear to be relatively large, it is worth remembering that the anticipated stimulus from fertilizing and from employment of better drainage methods is not included in the above estimates. Some estimates have shown that the increase in growth and cut can be about fifteen million cubic metres (530 million cu.ft.) per annum if using fertilizing connected with drainage on a fairly great scale.

It is maybe a little naive to estimate what should be the increase in growth and cut in Newfoundland if using peatlands on a great scale for forest growth, but assuming that the whole drained area will be about 25 per cent of that in Finland (cf. peatland area in Newfoundland p. 10) we will get about 130 million cu.ft. as an annual increase.

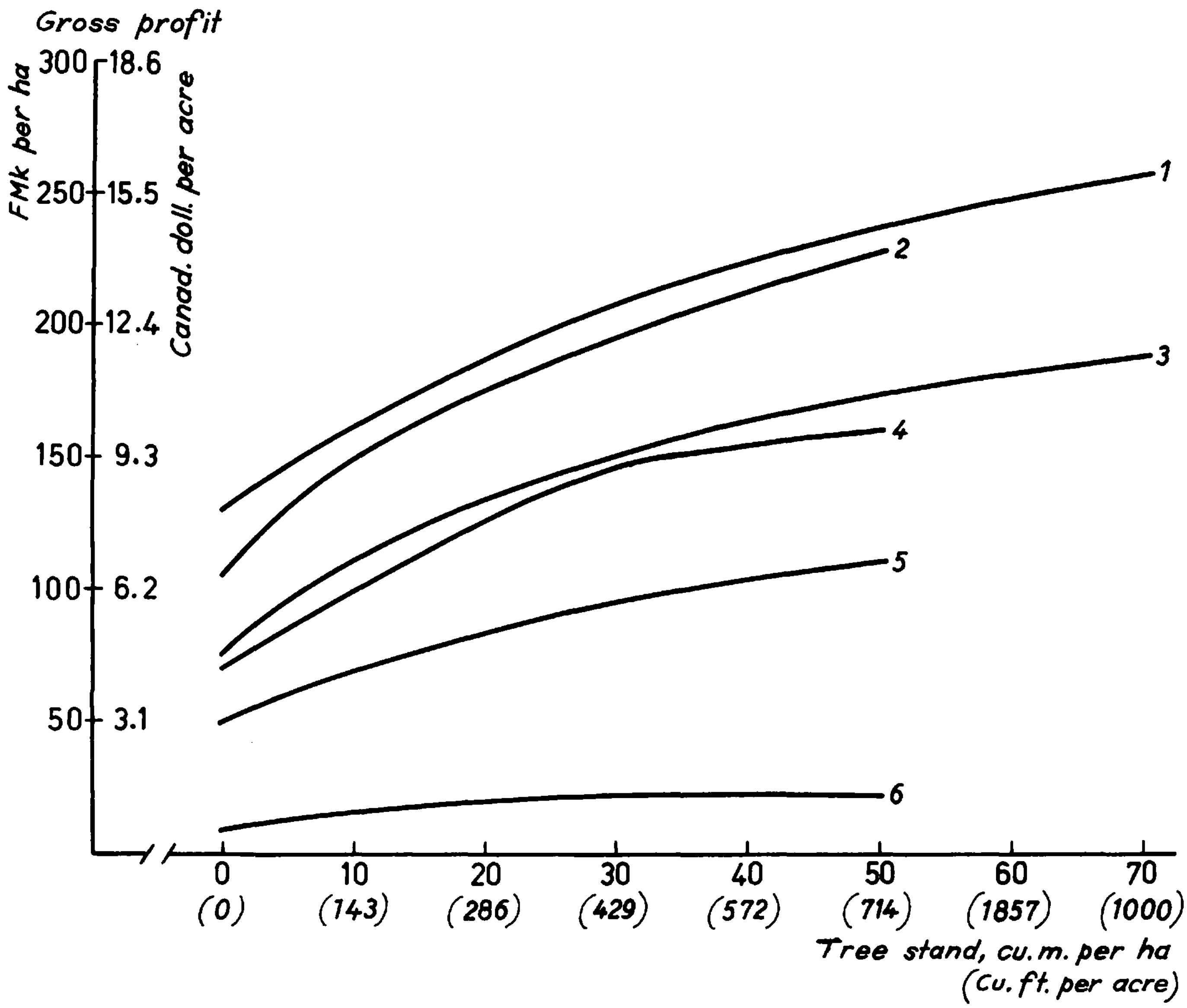
6.2.4 Costs and Benefits

There is a great variation in stand increment and removal, drainage costs, and stumpage prices between different parts of Finland. Accordingly, the economic rent obtainable from equal investments on forest drainage may be highly dependent on the location. To get some conception of the costs and profitableness of forest drainage I will refer to the calculation made by Keltikangas and Seppälä (1966). The authors have made calculations, mainly on the basis of average figures taken from published statistics and earlier studies, to measure the profitableness of forest drainage undertakings. The main principle of calculation was to compare the input and output discounted to the same point of time. The rate of discount was five per cent.

The costs are divided into two groups, ditching costs and costs after ditching. The former depend on many things, but approximately ditching costs are about 120 FMk per hectare (about 12 Canad. dollars per acre) in South Finland and about 80 FMk (about 8 Canad. dollars per acre) in North Finland. The costs after drainage consist of selecting cuttings in the seedling stand and maintenance of ditches. When discounted to the point of the ditching time, these costs have been 55-100 FMk per hectare (about 5.5-10 Canad. dollars per acre). Thus the whole input for forest drainage varies from 130 to 220 FMk per hectare (13-22 Canad. dollars per acre).

The removal, also that from the selecting cuttings, depends on many things previously discussed (cf. p. 48). The stumpage prices, vary very much depending on the haulage location, the tree species, and assortments, for instance in South Finland the sawlogs 1.45 FMk (0.36 Canad. dollars) per cu.ft., spruce pulpwood 16.50 FMk per cu. metre (about 10.50 Canad. dollars per cord), and pine pulpwood 12.00 FMk per cu. metre (about 7.65 Canad. dollars per cord). After multiplying the volume of the removals by the stumpage prices, the products are discounted to the time of drainage and the added income is called gross profit, calculated per hectare. To get the net profit we have to subtract the whole sum of costs from the gross profit. For instance, if the gross profit is 300 and the costs 160 we get 140 as a net profit.

Figure 6 shows the results as a gross profit of drainage on some peatland types in Middle Finland. The comparable peatland types in Newfoundland are marked in parentheses. From the picture we can see that the gross profit of wooded swamps are functions of the volume of the tree stand at the time of drainage. The reason for this is that the discounting time period is the shorter the greater the tree stand capable of growing after ditching. On open peatlands this time period is always equal to the rotation of the stand. The bog types in Finland which are com-



1. Herb-rich spruce swamp
   (Alder swamp)

2. Fen-like pine swamp
   (Fen-like tree swamp)

3. Normal spruce swamp
   (Herb-rich black spruce swamp)

4. Normal sedge pine swamp
   (Sedge tree swamp)

5. Pine-spruce swamp

6. Pine swamp shrubs in understory
   (Kalmia black spruce swamp)

Fig. 6. The gross profit of forest drainage undertakings in some Finnish peatland types.

parable to bog types in Newfoundland might have a gross profit as follows: Small sedge bog about 10, sedge bog about 60, herb-rich sedge bog and fen types about 110 FMk per hectare. In this connection it is necessary to state that on these peatlands the afforestation costs must be added to the other costs and the sum of costs will be twice as much.

After that I would like to point out that it is difficult to say whether the profits mentioned above are equal to those of Newfoundland. And lastly it is necessary to point out that, in general, the calculation of the absolute amount of the profit and net profit is very questionable. These calculations are made mainly to get the relative benefits, from drainage of the different peatland types.

6.3. Suggested Drainage Methods for Newfoundland

As was told before, the ditches used in Finland are mainly 2-3 feet deep and nearly semicircle in cross section. The main ditches are usually needed due to a small gradient of terrain. These main ditches are larger than other ditches, usually they are measured according to the water amount fitting into the ditch. The drainage ditches or so-called lateral ditches are used about 250 m per hectare, it means at a distance of about 100 to 150 feet. Especially on open swamps we use so-called shallow ditches, about 1-1.5 feet deep and at 6.5 or 13 feet distances in addition to the lateral ditches. These shallow ditches are made by different types of planting ploughs or rotary ditchers.

I think that about the same methods should be suitable also in Newfoundland, but more intensive drainage should be needed in Newfoundland due to the more humid climate. Taking the experiences in Scotland and Norway into consideration, where the climate is more like that in Newfoundland, I came to the conclusion that spacing can be for example 85-110 feet. Also the experiments made by the Agricultural Experimental Farm in Newfoundland indicate that this kind of spacing perhaps is sufficient.

Main ditches are seldom required in Newfoundland because of very good slopes and many natural water ways. Maybe it is sometimes necessary to clean these waterways in some places where the slope is small and the cross section of the natural drainage channel is not large enough.

Naturally, the drainage system must be fitted separately for each case, but it seems to me that it is possible to separate two different drainage systems, one for open bogs and fens and another for tree swamps. As an appendix (12 and 13) there are two examples showing the main features of these two systems. The first one is characterized by shallow ditches together with ordinary drainage ditches. The shallow ditches would be made by planting ploughs about 1 foot deep so that the furrows from the ditches can be used for planting. The distance of the shallow ditches depends on the planting distance, and 12-13 feet should be suitable, if using double-furrow ploughs.

The whole drainage system ought to be quite systematic with long, straight ditch lines bevelling the contour lines. The shallow ditches can be in a right angle the drainage ditches or also differing from that direction, but very long shallow ditches are not effective. I think that in most cases it is better to make the shallow ditches first and after that the drainage ditches.

Another drainage system must be used on forested swamps, and it consists only of ordinary drainage ditches. The ditch net depends very much on the form and size of the drainage area, on slopes, location of the water way, etc. Here it is possible to explain only some principles, which are important when planning a ditch net. Perhaps the most important is the direction of ditches. Theoretically, the most effective ditch has the same direction as the contour lines, but because it is necessary to have a gradient in the ditch, the ditch line must cut the contour line so that the gradient is more than 0.3 per cent. The gradient steeper than 2 per cent should be avoided because of the erosion effect of fast running water. Another important view point is to have trap ditches. In Finland practice has proved that a trap ditch is always needed when water is flowing into the swamp from surrounding uplands, and this situation is very common in Newfoundland. General advice for the planning of a ditch net on swamps is that the drainage system should be systematic with clear strips. An irregular system has many disadvantages, it needs more ditch length per acre, it is more difficult to dig, etc.

Speaking about the depth and form of drainage ditches, I consider that a depth of 2-2.5 feet should be suitable on swamps, espec lly when the peat layer is shallow; on open bogs and fens the ditches can be a little deeper, but not more than 3 feet. Especially on swamps, on which the peat is well decomposed, ditches should be made quite wide with a nearly semicircle cross section. On open bogs, if the peat is fibrous and undecomposed, the side slope can be steeper. Very narrow ditches which are commonly used for agricultural drainage in Newfoundland are not durable enough for forest drainage.

6.4. Suggested Drainage Equipment

I would like to divide these proposals into two groups: 1) Machinery which is necessary for establishing research trials and beginning of forest drainage activity on a "pilot plant scale", 2) machinery which is necessary for large-scale forest drainage in the future.

For the first purpose the machines should be available in Newfoundland or at least in the U.S.A. During my visit I saw many machines available already in Newfoundland. Ditching on open peatlands with deep peat can be done using the disc-ditcher, which is in common use for agricultural drainage in Newfoundland. If making some changes, for instance in cutting blades and the angle of the disc, this machine can be very useful for digging drainage ditches on open peatlands where the peat layer is more than three feet.

Planting ploughs are also available in Newfoundland. The Parkgate plough works very well, but it is a one-furrow plough and it would be more economical to have a double-furrow plough. I think that the Cuthbertson plough mounted to a double furrow plough should be suitable. For both ploughs (A 40 hp International T5 with extended crawlers) is satisfactory as a power machine.

On open peatlands with shallow peat another machine making drainage ditches is probably needed. The disc-ditcher is not durable in mineral soil. In Finland, Sweden and Norway different types of backhoes are in common use, and I think that these machines should be useful for that purpose also in Newfoundland. There are many combinations of hydraulic excavating devices and power tractors which are suitable and also available in Newfoundland, for instance Wain-Roy by International and Hyster by Caterpillar and many others which are made in the U.S.A. are used successfully also in Finland. The most important requirement for excavating devices are durability, fastness and that the power arm swings through 180°. The rending power should be over 13,000 lbs and the maximum lift over 4000 lbs.

The scoop should be formed specially for forest ditches. I do not know whether such scoops are available in Newfoundland, but it would be easy to produce them or to buy them for instance from Finland.

Medium heavy or heavy farm tractors or forest tractors are suitable power machines, but they need so-called whole or half tracks in order to be movable enough in peatland terrain. Maybe the Maskeck tractor is also suitable as a power machine on open peatlands, but I suppose not on tree swamps.

The most important requirement for power machines is at least 65 horsepower, and the distance of the machine bottom from the soil at least 15 inches. The last requirement is not necessary on open peatlands, but on tree swamps this requirement is important.

The ditching work on tree swamps needs a heavy plough or a backhoe. Because the heavy Cuthbertson plough which would be available in Newfoundland does not suit for tree swamps, I think that a backhoe is the only equipment for forest drainage in the beginning.

If we think about machinery for large scale forest drainage in Newfoundland, a heavy ditching plough such as a type of the Lokomo-plough in Finland, should be valuable. This type of plough is very effective and should suit for all kind of peatlands in Newfoundland. Because it is quite heavy, about 6.5 tons, and needs a heavy power tractor, for instance, Caterpillar D6, Serie C or Allis-Chalmers HD 11, it may have some difficulties to move on some peatlands. The surface presser with 36 inches crawlers is about 300-550 g. per sq. cm. (4.3-7.9 lbs per sq. in.). In Finland these caterpillars are very movable nearly on all kinds of peatlands, and in my opinion the peat and surface structure of peatlands in Newfoundland are as good as in Finland to permit moving of such machines. We have to remember that experience from agricultural fields in peatlands is not comparable, because the surface structure on them is broken.

Naturally there are many other machines useful for forest ditching and some of these perhaps are available in Newfoundland even now. For instance, the Ridder and the Ritscher introduced in the paper "Machines for marshland ditching" might be quite handy on open peatlands with deep peat. Such machines are coming into very common use for forest ditching in Finland.

7. SOME RECOMMENDED RESEARCH PROBLEMS

It is very clear that the forest drainage on a great scale in Newfoundland must be based on research. The suggestions I have made before are more or less uncertain, because of the lack of research work in Newfoundland, and because methods or solutions which are suitable in some conditions might not be right in some other conditions.

In my opinion based on the experiences I had in Newfoundland I consider the following research problems the most important and urgent.

1. T h e i n f l u e n c e o f d i f f e r e n t s p a c i n g o n t h e w a t e r e c o n o m y o f t h e s o i l. The fastest method to get adequate information should be to measure ground water level influenced by different ditch spacing. Naturally the ditch depth has some influence, too, but according to many results got in different countries, the ditch spacing has a much greater influence on water economy of soil than ditch depth.

Because the drainage influence depends on the character of different kinds of peat, it is necessary to have trials in different peatland types, for instance on a small sedge bog, a fen, a sedge tree swamp and a herb-rich black spruce swamp. I think that the series of 30, 60 and 120 feet of spacing should be informative, three or four replications should be necessary, too.

2. C a p a b i l i t y o f d i f f e r e n t t r e e s p e c i e s t o i n c r e a s e g r o w t h a f t e r d r a i n a g e. During my short visit I took some borings to obtain an answer to that question. I got good evidence that black spruce, balsam fir and tamarack have increased the growth rate due to drainage, but to get reliable information these measurements are far from satisfactory. Although there are very few drained areas in Newfoundland I am sure that careful searching will provide material enough for that purpose.

3. T h e a f f o r e s t a t i o n t r i a l s should have a very great importance in Newfoundland because the share of open peatlands in forest drainage will be great. It is quite obvious, that the so-called turf planting method, it means planting on turf and using fertilizers in that connection, is the best method. But the details of that method are worth testing. There are many alternatives in regard to seedling material, planting places, etc. And as a control it should be necessary to test other methods. For instance planting in an unprepared surface, seeding on turf and on surface, etc., should be tested.

4. T h e t r e e s p e c i e s t r i a l s are very necessary in Newfoundland. In that connection I would like to refer to the papers of Nickerson (1961) and Nickerson et. al (1964) in which Sitka spruce and Scotch pine have proved quite promising. It is quite possible that the domestic tree species in Newfoundland, black spruce and balsam fir are not the most suitable tree species for peatland afforestation.

5. F e r t i l i z i n g t r i a l s in connection with afforestation was mentioned before but also fertilizing of growing stands on real tree swamps should be realized. It is quite possible that even very scanty black spruce stands on peat soils will recover with fertilizing in addition to ditching. Because the capability to recover seems to be depending on the age and size

of the trees (cf. Heikurainen and Kuusela, 1962) it would be necessary to have series of trials of different stages of stands. The most reliable results will be got with factorial layout of P, K and N combinations.

It is very easy to find suitable areas for these trials in Newfoundland, and many of the trials mentioned before can be combined with each other and so the amount of sample areas will be reasonable.

6. Studying of the water economy of some forest types. Although this aim is outside my task, I have made some observations concerning the water economy of forests in general, and I got the impression that some forest types have excessive water preventing the forest growth and it would be possible to increase forest growth with ditching. To get sufficient information about this, it would be necessary to measure ground water depth and fluctuations of water table during, for instance, two growing seasons in some forest types, for instance, in Sphagnum - Kalmia - black spruce forest and Carex-balsam fir forest (Damman 1964 b).

The establishing of the experiment areas mentioned before will give a lot of experiences how to make practical drainage work. But I think that it would be useful to start practical drainage work at the same time in some small areas. This forest drainage work on a "pilot plant scale" would give much experience as to arranging the work, machinery and many other technical details.

8. CONCLUSION

To make final conclusions concerning the possibilities of using peatlands in Newfoundland for forestry purposes is too demanding a task for me. But, I hope the thoughts presented above will help to solve the problem whether it is reasonable to start forest drainage activity, and if so, how to start forest drainage work in Newfoundland.

It is naturally impossible for me to decide whether it is necessary and profitable to use peatlands for forest growth in Newfoundland. But, no doubt, there are good possibilities for that. Certainly, there are also quite great differences between the different peatland sites to be selected for forest drainage in regard to the benefit of the undertaking. The most economical sites would be the fertile forest-covered swamps in areas protected against the wind and the less economical ones would be the poor open bogs.

I suppose that the classification which I have drawn up could be useful. According to these peatland types, it is easy to select those most economical for drainage, and also otherwise, the peatland types must be the basis for the treatment which is required for conversion of these unproductive sites into productive forests. But I know that the information I have given on the peatland types of Newfoundland is of a preliminary nature. To learn enough about these basic things for using the peatlands for forestry purposes more detailed study is needed.

Nearly all other thoughts I have presented in my report are more or less based on comparison with the conditions prevailing in Finland, where forest drainage activity is very extensive and based on experience and research work done during more than one half century.

There are many similarities between Newfoundland and Finland in regard to the possibilities of using peatlands for forest growth, but also differences. It seems to me that conditions in Newfoundland are comparable to those in Middle Finland where forest drainage is practiced successfully on a great scale. The proportion of open peatlands, however, is much greater in Newfoundland and the kind of peatlands is less economical for forest drainage. The precipitation in Newfoundland is much higher and it requires more effective ditching, also the hard wind conditions can diminish the possibilities for forest drainage in Newfoundland. But there are some advantages in Newfoundland, too, in comparison with Finland. Gradient conditions are very good and the need of expensive main ditches is small; the land-ownership conditions are also ideal for planning great drainage areas, contrary to Finland where the bulk of forest land is divided into small private forests which causes a great deal of extra work in ditch planning. Otherwise, in regard to technical problems, I think that the solutions used in my country are useful also in Newfoundland.

Before starting forest drainage activity in practice it is very important to get more information on many biological, silvicultural and technical questions; therefore, intensive research activity for some years is required before starting practical drainage work on a large scale.

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App.1

Dwarf shrub bog (Sphagnum fuscum - Kalmia bog)

Together 14 research areas

	Cover %	Frequency
Sphagnum fuscum	37	14
" rubellum	5	8
Dicranum sp.	Δ	3
Polytrichum sp.	5	10
Cladonia sp.	41	13
Trichophorum caespitosum	8	10
Rubus chamaemorus	17	13
Sarracenia purpurea	1	7
Kalmia angustifolia	27	14
" polifolia	3	12
Chamaedaphne calyculata	3	12
Empetrum sp.	18	11
Ledum groenlandicum	6	13
Andromeda glaucophylla	1	5
Vaccinium oxycoccos coll.	1	3

Sphagnum magellanicum, S. cuspidatum, Arctostaphylos sp., Myrica gale, Lycopodium sp., Rhododendron purpurea, Picea mariana (shrub-like).

Peat layer: Sphagnum peat, humific. 2-3, depth as a rule over 6 feet.

S m a ll s e d g e b o g (Sphagnum - Trichophorum caespitosum bog) Together 16 research areas.

	Cover %	Frequency
Sphagnum papillosum	14	8
" magellanicum	10	13
" rubellum	22	15
" Pylaesii	4	7
" fuscum	13	13
" cuspidatum	6	9
Dicranum sp.	1	3
Cladonia sp.	14	12
Cetraria sp.	1	2
Trichophorum caespitosum	34	16
Rhynchospora alba	7	11
Carex oligosperma	5	6
Calamagrostis inexpansa	1	5
Sarracenia purpurea	1	8
Solidago uliginosa	1	5
Rubus chamaemorus	1	6
Kalmia angustifolia	5	11
" polifolia	2	15
Chamaedaphne calyculata	3	14
Ledum groenlandicum	1	11
Vaccinium oxycoccos coll.	4	14
Andromeda glaucophylla	2	11
Empetrum sp.	1	5
Gaylussacia dumosa	2	5

Sphagnum imbricatum, S. recurvum, S. flavicomans, Rhacomitrium lanuginosum, Scheuchzeria palustris, Eriophorum spissum, E. virginicum, Aster nemoralis, Lycopodium sp., Coptis trifolia, Vaccinium angustifolium, Betula michauxii.

Peat layer: Sedge - Sphagnum peat, humific. 3-4, depth usually over 6 feet, sometimes shallower.

S e d g e b o g (Sphagnum - Carex oligosperma bog)
Together 13 research areas

	Cover %	Frequency
Sphagnum papillosum	29	12
" magellanicum	22	12
" rubellum	12	12
" Pylaesii	3	6
" recurvum	5	6
" fuscum	3	4
Carex oligosperma	18	13
Trichophorum caespitosum	23	13
Rhynchospora alba	4	7
Calamagrostis inexpansa	4	9
Solidago uliginosa	1	6
Aster nemoralis	2	6
Chamaedaphne calyculata	2	9
Betula michauxii	2	8
Myrica gale	2	4
Andromeda claucophylla	2	13
Kalmia angustifolia	1	7
" polifolia	1	9
Vaccinium oxycoccos coll.	2	7
Ledum groenlandicum	1	6

Sphagnum flavicomans, S. balticum, S. tenellum, Dicranum sp., Cladonia sp., Cetraria sp., Carex lasiocarpa, C. exilis, C. pauciflora, C. canescens, C. michauxiana, Eriophorum angustifolium, Scheuchzeria palustris, Sarracenia purpurea, Smilacina trifolia, Lonicera villosa, Empetrum sp., Pyrus floribunda.

Peat layer: Sedge - Sphagnum peat, humific. 4-6, depth from 1 to 6 feet, seldom over 6 feet.

H e r b - r i c h s e d g e b o g (Sphagnum recurvum - Carex - Herb . bog) Together 8 research areas

	Cover %	Frequency
Sphagnum recurvum	34	8
" magellanicum	11	6
" papillosum	11	5
" imbricatum	10	4
" rubellum	18	6
Carex exilis	6	7
" rostrata	16	6
" livida	1	3
" michauxiana	14	5
" oligosperma	5	4
" lasiocarpa	9	3
Eriophorum angustifolium	3	3
" Tenellum	1	3
Trichophorum caespitosum	10	7
" alpinum	1	4
Rhynchospora alba	2	4
Calamagrostis inexpana	10	8
Smilacina trifoliata	4	5
Solidago uliginosa	6	8
Aster nemoralis	4	8
Rosa nitida	1	6
Lonicera villosa	1	5
Chamaedaphne calyculata	3	7
Myrica gale	7	8
Kalmia polifolia	2	5
Ledum groenlandicum	2	6
Vaccinium oxycoccos coll.	2	8
Andromeda claucophylla	1	4

Sphagnum flavicomans, Drepanocladus sp., Calliergon sp., Aulacomnium palustre, Polytrichum commune, Carex pauciflora, Muhlenbergia glomerata, Viola sp., Sarracenia purpurea, Sanquisorba canadensis, Epilobium palustre, Spiraea latifolia, Larix laricina (Shrub-like).

Peat layer: Sphagnum - sedge peat, humific. 5-7, depth usually 2-4 feet.

S p h a g n u m f e n (Sphagnum warnstorfii fen)
Together 10 research areas

	Cover %	Frequency
Sphagnum warnstorfii	32	10
" flavicomans	20	9
" subsecundum	2	3
" recurvum	3	4
" papillosum	7	6
Campylium stellatum	9	7
Carex lasiocarpa	17	8
" livida	2	3
" oligosperma	2	7
" rostrata	8	6
Trichophorum caespitosum	27	8
" alpinum	2	7
Rhynchospora alba	5	4
Calamagrostis inexpansa	2	4
Muhlenbergia glomerata	2	5
Selaginella selaginoides	1	7
Solidago uliginosa	2	10
Aster nemoralis	2	9
Sanquisorba canadensis	1	7
Viola sp.	1	5
Sarracenia purpurea	1	4
Potentilla fruticosa	3	4
Myrica gale	6	10
Chamaedaphne calyculata	3	9
Betula michauxii	1	5
Kalmia angustifolia	1	4
Vaccinium oxycoccos coll.	1	4
Ledum groenlandicum	1	4

Drepanocladus sp., Calliergon sp., Scorpidium scorpioides, Carex michauxiana, C. exilis, Eriophorum viridi-carinatum, E. virginicum, E. angustifolium, Scheuchzeria palustris, Juncus canadensis, Smilacina trifoliata, Thalictrum sp., Rosa nitida, Lonicera villosa, Andromeda glaucophylla, Kalmia polifolia.

Peat layer: Eutrophic Sphagnum - sedge peat, humific. 4-6, depth 1, 5-5 feet.

B r o w n - m o s s f e n (Campylium stellatum - Trichophorum fen) Together 13 research areas

	Cover %	Frequency
Sphagnum warnstorfii	7	8
" flavicomans	9	9
Campylium stellatum	38	13
Drepanocladus sp.	5	6
Scorpidium scorpiodies	2	3
Carex lasiocarpa	8	7
" livida	6	8
" michauxiana	1	4
Trichophorum caespitosum	43	11
" alpinum	2	10
Rhynchospora alba	3	7
Calamagrostis inexpansa	1	4
" canadensis	2	9
Solidago uliginosa	2	13
Smilacina trifoliata	3	3
Aster nemoralis	2	12
Thalictrum sp.	1	4
Sanquisorba canadensis	3	13
Viola sp.	1	6
Potentilla fruticosa	7	11
Rosa nitida	1	3
Myrica gale	8	12
Chamaedaphne calyculata	1	8
Andromeda glaucophylla	1	3
Kalmia angustifolia	1	7
" polifolia	1	4
Vaccinium oxycoccos coll.	1	5

Sphagnum subsecundum, S. recurvum, S. papillosum, Calliergon sp., Thomenthypnum nitens, Carex oligosperma, C. trisperma, C. nigra, C. flava, C. vaginata, C. exilis, C. interior, C. magellanica, Eriophorum tenellum, E. angustifolium, Juncus canadensis, J. effusus, Selaginella selaginoides, Aster punicens, Habenaria sp., Lonicera villosa, Betula michauxii, Ledum groenlandicum, Juniperus horizontalis.

Peat layer: Bryales - sedge peat, humific. 4-6, depth 1,5-5 feet.

S e d g e t r e e s w a m p (Carex - Picea mariana - Larix laricina swamp) Together 12 research areas

	Volume, cu.ft. per acre	Height, feet	Tree species per cent of volume	Frequency
Picea mariana	170 (70-290)	14 (9-20)	46	12
Larix laricina			44	12
Abies balsamaea			10	9

	Cover %	Frequency
Sphagnum recurvum	37	12
" magellanicum	17	7
" palustre	5	6
Carex interior	11	7
" lasiocarpa	10	3
" michauxiana	2	3
" pauciflora	4	5
" rostrata	6	4
Eriophorum virginium	5	6
Trichophorum caespitosum	10	6
Calamagrostis canadensis	8	7
Glyceria sp.	2	4
Juncus canadensis	3	6
Sanquisorba canadensis	3	6
Aster nemoralis	7	12
Viola sp.	1	4
Solidago uliginosa	2	7
Smilacina trifoliata	4	6
Cornus canadensis	2	4
" suecica	1	3
Rosa nitida	2	11
Viburnum cassinoides	1	4
Spiraea latifolia	1	3
Lonicera villosa	1	5
Myrica gale	10	8
Kalmia angustifolia	2	7
" polifolia	1	6
Chamaedaphne calyculata	12	10
Vaccinium oxycoccos coll.	1	6
Ledum groenlandicum	2	10
Gaultheria hispidula	1	7

Alnus rugosa, Betula papyrifera, Taxus baccata, Sphagnum rubellum, S. subsecundum, S. cuspidatum, S. girgensohnii, Pleurozium schreberi, Hylocomium splendens, Ptilium crista-castrensis, Calliergon sp., Campylium stellatum, Carex oligosperma, C. flava, C. magellanicum C. nigra, C. trisperma, Calamagrostis inexpansa, Eriophorum spissum, E. angustifolium, Sarracenia purpurea, Iris versicolor, Rubus acaulis, Trientalis sp., Nemopanthus mucronata, Rhododendron canadense.

Peat layer: woody - Sphagnum - sedge peat, humific. 6-7, depth 1-4 feet.

F e n - l i k e t r e e s w a m p (Sphagnum warnstorfii - Picea mariana - Larix laricina swamp) Together 8 research areas

	Volume, cu.ft. per acre	Height feet	Tree species per cent of volume	Frequency
Picea mariana	230 (70-430)	15 (10-23)	65	8
Larix laricina			26	8
Abies balsamaea			9	8

	Cover %	Frequency
Sphagnum warnstorfii	41	8
" recurvum	9	8
" flavicomans	5	3
Campylium stellatum	9	6
Carex interior	22	4
" flava	1	3
" michauxiana	1	4
" lasiocarpa	10	3
Eriophorum angustifolium	2	5
Trichophorum caespitosum	9	5
" alpinum	2	3
Calamagrostis canadensis	3	5
Muhlenbergia glomerata	8	6
Aster nemoralis	2	7
Sanquisorba canadensis	15	8
Smilacina trifoliata	2	3
Solidago uliginosa	3	5
Rosa nitida	1	4
Myrica gale	20	5
Ledum groenlandicum	6	8
Chamaedaphne calyculata	7	5
Linnaea borealis	2	3

Sphagnum palustre, S. magellanicum, S. fuscum, Rhytidiadelphus sp., Drepanocladus intermedius, Scorpidium scorpioides, Pleurozium schreberi, Carex rostrata, C. oligosperma. C. exilis, Eriophorum virginium. Calamagrostis inexpansa, Juncus canadensis, Rubus acaulis, Aster punicens, Pirola sp., Thalictrum sp., Viola sp., Cornus canadensis, C. suecica, Sarr cenia purpurea, Vaccinium angustifolia, V. oxycoccos coll., Rhododendron canadense, Lonicera villosa, Gaultheria hispidula, Kalmia angustifolia, K. Polifolia.

Peat layer: woody - Bryales - sedge peat, humific. 6-7, depth 1-3 feet.

K a l m i a b l a c k s p r u c e s w a m p (Kalmia - Picea mariana swamp) Together 4 research areas

	Volume, cu. ft. per acre	Height, feet	Tree species per cent of volume	Frequency
Picea mariana)	260(140-290)	15 (10-20)	100	4
Larix laricina)				2

	Cover %	Frequency
Sphagnum fuscum	35	4
" rubellum	11	4
" recurvum	2	1
Pleurozium schreberi	20	4
Hylocomium splendens	16	3
Dicranum sp.	3	3
Cladonia sp.	25	4
Polytrichum sp.	1	2
Rubus chamaemorus	3	3
Smilacina trifolia	2	2
Kalmia angustifolia	40	4
" polifolia	7	4
Chamaedaphne calyculata	18	4
Ledum groenlandicum	15	4
Vaccinium angustifolia	1	2
" oxycoccos coll.	1	2
Rhododendron canadense	10	3

Coptis trifolia

Peat layer: woody - Sphagnum peat, humific. 3-5, depth usually 2 feet.

Herb-rich black spruce swamp (Sphagnum - Cornus - Picea mariana swamp) Together 12 research areas

	Volume, cu. ft. per acre	Height, feet	Tree species per cent of volume	Frequency 12
Picea mariana)			80	12
Larix laricina)	570 (290-1140)	26 (13-37)	10	8
Abies balsamaea)			10	9

	Cover %	Frequency
Sphagnum recurvum	29	12
" magellanicum	26	9
" girgensohnii	12	8
Pleurozium schreberi	12	10
Hylocomium splendens	11	9
Dicranum sp.	1	4
Carex interior	14	8
" trisperma	15	7
Calamagrostis canadensis	1	4
Smilacina trifoliata	7	10
Cornus canadensis	16	12
" suecica	6	6
Coptis trifolia	2	6
Aster nemoralis	1	5
Clintonia borealis	6	8
Rubus chamaemorus	1	4
Linnaea borealis	2	8
Vaccinium angustifolia	1	6
Ledum groenlandicum	13	10
Kalmia angustifolia	8	7
Chamaedaphne calyculata	5	5
Myrica gale	1	4
Gaultheria hispidula	6	9
Rhododendron canadense	4	4
Nemopanthus mucronata	2	6
Alnus rugosa	2	4

S. papillosum, S. centrale, S. robustum, Polytrichum commune, Bazzania trilobata, Carex pauciflora, C. magellanica, Eriophorum virginicum, Solidago uliginosa, Petasites sp., Thalictrum sp., Paris sp., Sanquisorba canadensis, Rubus acaulis, Rosa nitida, Vaccinium idaea, Kalmia polifolia.

Peat layer: woody - sedge - Sphagnum peat, humific. 5-7, depth usually 2-5 feet.

Chemical analysis of peat samples

Sample	N %	P %	Ca %	K %	Mg %	Oven-dry weight gms. per liter	pH
			Dwarf shrub bog				
I/1	0.4400	0.0170	0.1480	0.0370	0.1450	56.0	3.43
I/2	0.7994	0.0299	0.0918	0.0429	0.0948	80.0	3.35
I/3	0.5697	0.0199	0.1431	0.0378	0.0894	73.4	3.45
I/4	0.9594	0.0333	0.1451	0.0363	0.0814	74.4	3.30
I/5	0.4399	0.0309	0.1955	0.0219	0.1177	63.9	3.50
			Small sedge bog				
II/1	1.2200	0.0298	0.0895	0.0288	0.1134	78.8	3.59
II/2	0.7494	(0.0110)	0.0868	0.0190	0.1217	80.3	3.55
II/3	1.4688	0.0287	0.0743	0.0208	0.1129	107.2	3.97
II/4	1.7191	0.0297	0.0823	0.0188	0.1110	103.3	3.95
II/5	0.7899	0.0229	0.0819	0.0269	0.0708	63.3	3.55
			Sedge bog				
III/1	1.2900	0.0308	0.0755	0.0288	(0.1213)	87.2	3.60
III/2	1.7796	0.0390	0.0180	0.0160	0.0280	157.3	3.75
III/3	1.8196	0.0449	0.0849	0.0130	0.0250	146.0	3.95
III/4	1.7295	0.0625	0.0943	0.0417	0.0536	82.6	4.27
III/5	1.0659	0.0529	(0.2257)	0.0350	0.0639	52.3	3.89

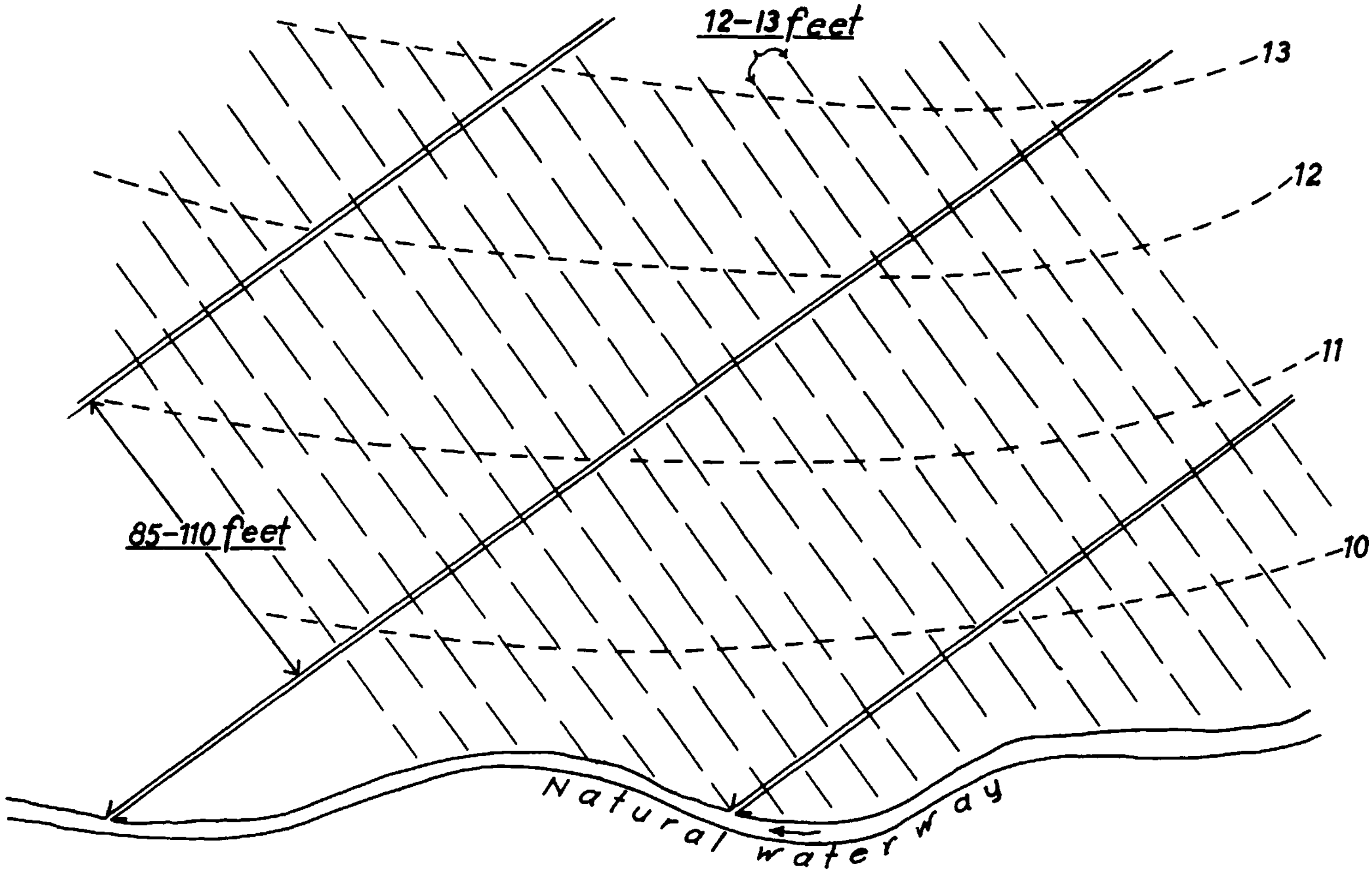
cont'd.

	Herb-rich sedge bog						
IV/1	1.8081	0.0816	0.0129	0.0418	0.0209	83.5	4.69
IV/2	2.0983	0.0877	0.0030	0.0389	0.0249	82.9	4.11
IV/3	2.1221	0.0560	(0.1029)	0.0210	0.0330	146.3	4.29
IV/4	1.7996	0.0852	0.0208	0.0852	(0.0832)	103.8	4.69
IV/5	2.1334	0.1040	0.0040	0.0792	0.0406	90.7	4.95
	Sphagnum bog						
V/1	(1.3196)	0.0464	(0.0168)	0.0513	(0.0829)	61.7	4.10
V/2	2.1889	0.0689	0.0479	0.0260	0.0230	110.0	4.12
V/3	1.7395	0.0666	0.1489	0.0294	0.0451	94.9	4.64
V/4	2.4668	0.0808	0.2494	0.0249	0.0439	104.8	5.18
	Brown-moss fen						
VI/1	2.0683	0.1406	(0.8080)	0.1377	0.1077	179.8	5.85
VI/2	2.3181	0.0847	0.2253	0.0279	0.0439	173.7	5.10
VI/3	2.6095	0.0708	0.1666	0.0279	(0.0279)	157.0	4.78
VI/4	1.5598	0.0697	0.2747	(0.1815)	0.2316	183.6	4.83
VI/5	1.4893	(0.0059)	0.3065	0.0208	0.0999	113.2	5.25
	Sedge tree swamp						
IX/1	1.8792	0.0889	0.1358	0.0958	0.0819	75.8	4.15
IX/2	1.6092	0.1425	(0.0030)	0.0831	(0.0228)	112.5	4.91
IX/3	1.3500	0.0636	0.6058	0.1092	0.1927	131.5	5.55
IX/4	1.3300	0.0443	0.3246	0.0364	0.1161	77.1	4.40
IX/5	1.2997	0.1298	(0.0040)	(0.1882)	0.0495	109.2	5.08

cont'd.

	Fen-like tree swamp						
X/1	(1.0589)	0.0478	0.2492	0.0508	0.1355	95.5	3.90
X/2	1.8989	0.0828	0.5284	0.0508	0.0957	118.5	5.85
X/3	1.6400	0.0577	0.6867	0.0398	0.1174	105.4	5.65
X/4	1.9494	0.1234	0.2764	0.0405	(0.0454)	118.0	5.38
	Kalmia black spruce swamp						
VII/1	0.2997	0.0170	0.1250	0.0240	0.0970	78.0	3.45
VII/2	0.3599	0.0287	0.1207	0.0475	0.0831	66.4	3.45
	Herb-rich black spruce swamp						
VIII/1	1.3979	0.0950	(0.0090)	0.0690	0.0350	92.3	3.89
VIII/2	0.9598	0.0649	0.0270	0.0220	0.0819	114.3	4.03
VIII/3	0.8393	(0.0270)	0.1565	0.0399	0.1645	113.8	3.80
VIII/4	0.8198	0.0417	0.3375	0.0357	0.1817	79.0	4.28

Proposal for ditching system in open bogs and fens

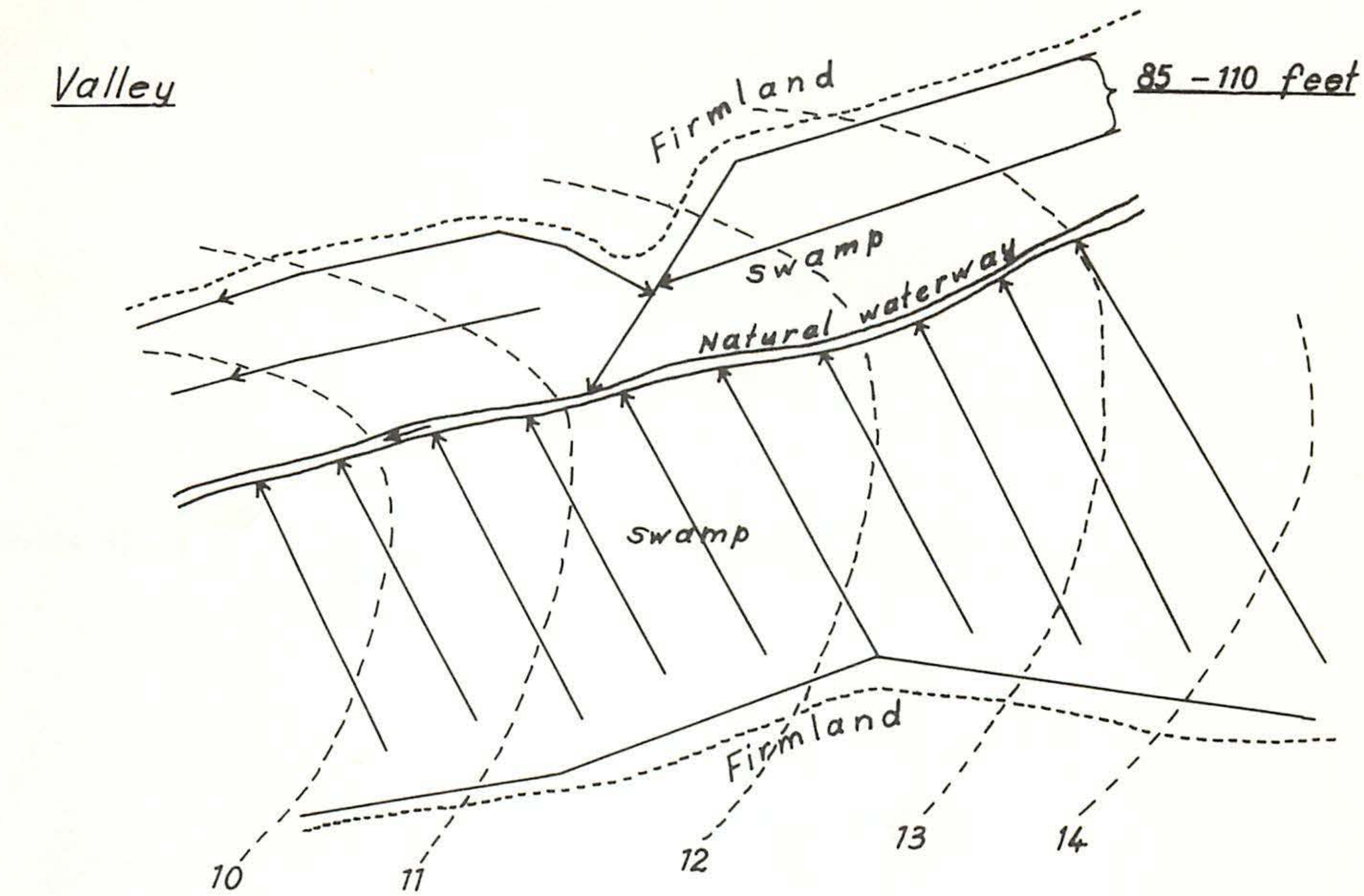


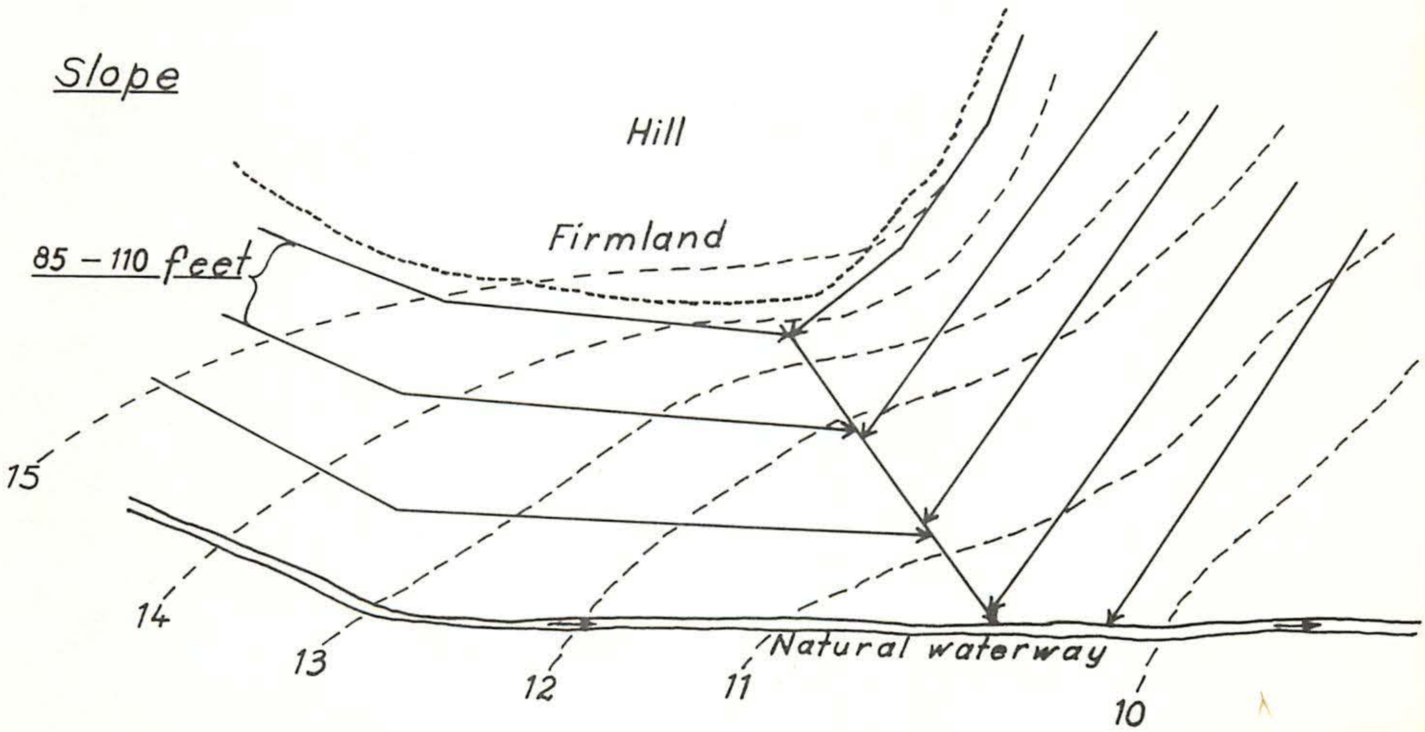
10 Contour line

Shallow ditch made by planting plough, depth in feet, on both sides planting turfs.

Ordinary drainage ditch (lateral-ditch), made by ditchingplough, type of Lokomo, or by power excavator (back hoe) with special designal scoop, depth 2,5-3,0 feet, with almost semicircle as a cross section .

Proposal for ditching system in tree swamps





All ditches are made by ditchingplough, type of Lokomo, or by power excavator (back hoe), depth 2,5 feet, with almost semicircle as a cross section.