Forest Research Branch

FOREST CONDITIONS ON THE LOWER PEACE RIVER

by

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Conclusions et recommandations en français

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FOREWORD

In July, 1957, a three-week forest reconnaissance survey was conducted in the Peace River lowlands of Wood Buffalo National Park, near the border of Alberta and the Northwest Territories. The party consisted of three research officers specializing respectively in forest site classification, ecology, and growth and yield.

The object was to obtain background information for forest management decisions and for defining further research needs.

Observations centred in two localities along the Peace River, the first in the vicinity of the Peace delta, mainly between the Baril and Slave Rivers; and the second at the west side of the park between the fifth meridian and Big Island. Thirty-four areas were studied in some detail in the first locality and eighteen areas in the second. Plot locations are shown on maps in Appendix 2.

General notes of ecological interest were taken during a boat journey along the entire length of the Peace River within Wood Buffalo Park and during airplane and helicopter flights over much of the fluvial and upland parts of the park.

Detailed examination of aerial photographs formed an integral part of the survey, and a photo interpretation guide is included to familiarize the reader with various geomorphic and forest features characteristic of the area.

The studies were expedited by reference to pertinent ecological literature, particularly the extensive works of Raup (1935, 1946).

FOREST CONDITIONS ON THE LOWER PEACE RIVER[1]

PART 1

REGIONAL DESCRIPTION, SITE EFFECTS AND CLASSIFICATION

by

D. S. LACATE[2]

DESCRIPTION OF THE AREA

Location

Wood Buffalo Park lies partly in northeastern Alberta and partly in the Mackenzie District of the Northwest Territories. The Peace River traverses the Park in approximately an east-west direction, close to latitude 59°N. The west boundary of the Park crosses the Peace River at longitude 114°W., and the east boundary in the south-central portion is the Slave River.

The general area selected for the reconnaissance lies within the Mackenzie Lowlands Section (B.23) of the Boreal Forest Region, as classified by Halliday (1937). A revision of this classification will result in a subdivision of this long belt (B.23), and the Peace River valley will be included in the Upper Mackenzie Section (B.23a).

Bedrock and Topography

Sedimentary rocks of the Devonian age form the base of the Palaeozoic section underlying the Peace River lowlands. "The eastern boundary of Wood Buffalo Park is roughly coincident with the contact zone between the Precambrian granites and gneisses to the east and the Palaeozic sediments to the west" (Raup 1935). The limestone and gypsum cliffs west of Peace Point represent the latter sedimentary rocks, and the rounded knolls, rising above the delta plain of the Peace and around the Quatre Fourches channel, are examples of the Precambrian rocks at their western margin.

The Peace River lowlands area is a plain composed chiefly of alluvial and glacio-lacustrine deposits of fine silts and sands. The granite hills mentioned above are the only notable relief feature.

Glacial and Post-Glacial History

The Keewatin glacier is thought to have approached the Wood Buffalo Park region from the northeast. A. E. Cameron (1922) states that: "At least three definite glacial lobes are apparent in the area. One extended up the valley of the Hay River; a second swung west, south of the Caribou Mountains, and probably sent tongues up the valleys of the Peace and Wabiskaw Rivers; while the third lay in the basin of Athabaska Lake with its tongue pointing up the valley of Athabaska River".

As the continental ice sheet receded from the area, large post-glacial lakes were formed as the waters from the Hay, Peace and Athabaska river basins were impounded against the retreating ice front. Cameron has designated four

(1) Department of Forestry, Canada, Forest Research Branch Contribution No. 659
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of these ancient lake levels, formed successively at 1,600, 1,100, 800 and 700 feet above sea level. The present level of Lake Athabaska is just under 700 feet.

Flood Plain Features

Except for the areas at the gypsum cliffs west of Peace Point, the Peace River has cut a wide valley through the extensive lacustrine deposits of the post-glacial lakes. Within the Park, the river can be regarded as being in the mature stage of development. Well-developed meanders are present. On the inner side of the meanders deposition is taking place in the slower moving

Figure 1. Close-up of the cut bank at Eldorado mill. The land type is alluvial, having stone-free soil containing a moderate amount of buried organic matter.

waters. Lateral cutting has not ceased as noted at the Eldorado mill (Figure 1). The north shore of the island north of Swanson's Mill has had its banks cut back at least 500 to 600 feet in a period of nine years (observed in the comparison of two sets of air photographs).

Many former point bar and natural levee deposits are being undercut and destroyed as the meanders migrate. It appears that, in general, the river terraces are not paired, implying that the surrounding land might have been under a continued slow uplift. This type of development has been classed as non-cyclic terraces (Cotton 1940).

Climate

The region, in general, has a northern continental climate with short, warm summers and very cold winters. The short growing season of this region can be to a large extent offset by the longer hours of daylight.

Climatic data for Fort Vermillion (the weather station used to describe B.23a, Peace River area, in the revised Forest Classification for Canada) are given in Table 1.

TABLE 1. CLIMATIC SUMMARY — LOWER PEACE RIVER

A

Location			Annual Temperature (°F.)			Jan.-July Temp.	
Station	Lat.	Long.	Ann. av. of daily max. temp.	Ann. av. of daily min. temp.	Ann. av. of daily mean temp.	Jan. av. of daily min. temp.	July av. of daily max. temp.
Fort Vermillion	58	116	40	14	27	—24	75

B

Annual Precipitation (inches)			Frost and Snow	
Average total precipitation	Average rainfall	Average snowfall	Depth of frost penetration	Maximum depth of snow on ground
12.1	8.8	33.7	95	40

C

Seasonal Data				
June, July, Aug. average of daily mean temperature	June, July, August rainfall	No. of hours sunshine June, July, Aug.	March, April, May precipitation	September, October, November precipitation
58	5.6	790	2.4	2.6

D

Growing Season Data					
No. of days having mean temp. over 42°F.	Start	End	Average of daily mean temp.	Total precipitation	Average of daily precipitation
149	May 3	Sept. 28	55	8.1	0.05

From Table 1 it can be seen that the summer rainfall (June, July and August) of 5.6 inches is quite low. An adequate description of the climate from interpretation of climatic data is difficult in an area such as this where, for instance, the relation between summer precipitation and soil moisture, expressed in terms of its significance to plant growth, is complicated by the presence of frozen ground which retains a supply of moisture close to the ground surface.

Frozen Ground Discussion

Field observations indicate that frozen ground is present throughout much of the reconnaissance area. Permafrost appears to be limited to areas in which the mean annual temperature of the atmosphere near ground level is below 32°F. The Meteorological Division of the Department of Transport considers that the southern limit of permanently frozen ground closely coincides with the annual mean isotherm of 23°F. (Jenness 1949). In the same article it is noted that several Russian investigators consider a mean annual temperature of 26°F. and even higher as the limit below which permafrost can originate. The article by Jenness (1949) also suggests "that permafrost may be less closely related to the mean temperature for the entire year than to the ratio between the winter's mean temperature combined with its length, and the corresponding mean temperature and length of the summer, winter being taken as the period of frost and summer the period of thaw". The climatic data presented above give a mean annual temperature of 27°F. for Fort Vermillion. The valley could conceivably be within the limit in which permafrost could originate; however, it is not felt that the frozen ground observed during the reconnaissance is true permafrost.

Frozen ground is a very important feature of the area. Its presence can influence the root development and the distribution of vegetation, can slow down humus formation and the maturation of soils, and can affect soil drainage. In the dry climate of the Peace River area it is possible that the presence of frozen ground, holding a moisture supply close to the surface, is necessary for good tree growth. The data in Appendix I suggest that the distribution of frozen ground in the region is related to the presence of a continuous cover of mosses.

LAND TYPES

Introduction

The soils in the Peace River lowlands have resulted from late glacial and post-glacial events. Soils, generally of medium and fine texture and derived from lacustrine and alluvial deposits, cover the area to a considerable depth. Except for the minor occurrence of river gravel bars, all the soils sampled were stone-free.

Soil drainage classes were based on (1) the depth to water tables, as expressed by glei; (2) the depth to frozen ground, and its effects on water tables; (3) the topographic position of the particular soil material under question; and (4) the soil texture. The classes established are listed in Table 2.

TABLE 2. DESCRIPTION OF DRAINAGE CLASSES

Drainage Class	Mapping Symbol	Some Characteristics
Excessively drained	1	weakly weathered profile on fine to medium sands, without a water table.
Well drained	2	very fine sands, silty sands, and silts found o elevated areas such as levees, without a water table; may be found on coarser materials with an available water table present near the surface.
	2Z*	very fine sand, and silty sands with an available water table perched on frozen ground, usually at a depth of 4-5 feet or more.
Moderately well drained	3	silty sands, and silts with an available water table at a depth of about 3-4 feet, found on elevated areas.
	3Z	very fine sands and sandy silts with an available water table perched on frozen ground, usually at a depth of 2-3 feet.
Imperfectly drained	4	very fine sands, silty sands and silts with an available water table at a depth of 1 to 2 feet, found on lower slopes and in depressions.
	4Z	silty sands, silts and silt loams, with water table perched on frozen ground, usually at a depth of 1 to 2 feet.
Poorly drained	5	silts, silt loams and clays with a water table at a depth of about a foot below the surface or at the ground surface; do not support tree cover; found in low lying areas, newly formed islands, meadows and abandoned river channels.
Verv poorly drained	6	silt loams and clays, saturated to the surface for most of the year; found in broad swampy areas and depressions.

*The drainage classes are divided into two types, one without frozen ground, and the other showing the effects of frozen ground (with symbol Z).

Above the frozen ground is a layer that thaws in the summer and freezes again in the winter. The presence of this seasonally frozen ground was indicated in several of the samples, where evidence of a perched water table was noted a fair distance above the frozen ground level at the time the sample was taken.

The area in and surrounding the Peace River valley can be divided into three major land types, based partly on their origin and partly on their topographic position or elevation in relation to the present river channel. The divisions are:

(1) *High terrace:* composed of glacio-lacustrine and deltaic deposits.

(2) *Middle terrace:* composed of glacio-lacustrine deltaic deposits that have alluvial deposits (in the form of a shallow cap) overlaying them. Included in the middle terrace are areas without an alluvial cap, and which have had the fine sand (or shallow water deposits of the post-glacial lakes) removed. As a result these areas have lacustrine silts and clays exposed at the surface.

(3) *Recent alluvial deposits:* of various origins.

High Terrace Land Type

MATERIALS

The high terraces or lacustrine flats consist of deep deposits of fine sand underlain by alternating bands of very fine sand, silt and clay (Figures 2, 3 and 4). In many areas sand dunes are associated with these high terraces. The division line between the lacustrine and deltaic deposits (which have the same range in texture as the lacustrine deposits) was not established in the field.

Figure 2. Contact of high terrace with present river channel (area is about ten miles east of Big Island.) Middle terrace is at left with spruce and aspen stand on the land type.

Figure 3. Picture of same high terrace as in Figure 2 showing the banded fine sands and silts of the lacustrine material. Trembling aspen and jack pine with an understorey of spruce are the tree species present.

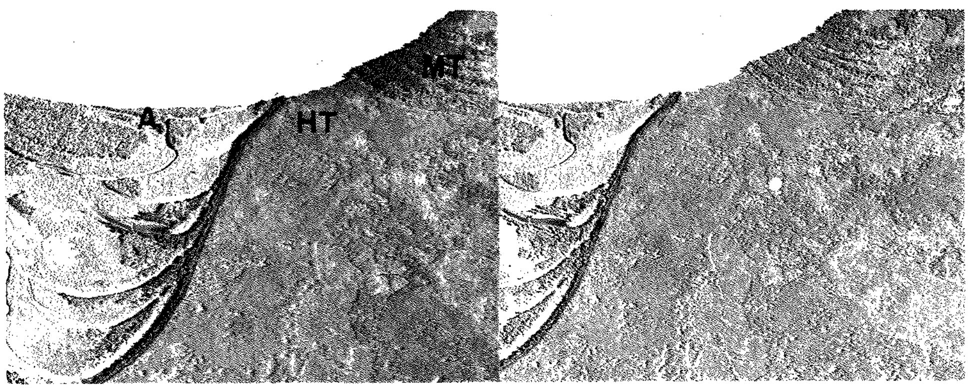

Figure 4. Stereo pair taken from aerial photographs covering the area shown in Figures 2 and 3. Symbols used are described in Appendix 4.

However, deltaic deposits were not noted west of Peace Point. Deltaic deposits, showing typical foreset beds of fine sands and silts overlain by topset beds usually of fine and very fine sands were noted in two areas, at the cut bank north of Swanson's mill and at the cut bank approximately one mile northwest of Rocky Point. Undoubtedly much of the area now covered with alluvial material is underlain by these deltaic and lacustrine deposits and it is apparent that surficial signs of these deposits have been washed away during the evolution of the valley floor.

DRAINAGE

These terraces are for the most part excessively drained. Imperfectly and poorly drained areas are evident, but are not extensive until the inland areas well back from the river are reached. Frozen ground was not encountered in any of the samples taken on this land type.

Middle Terrace Land Type

MATERIALS

In many areas an alluvial deposit of one to three feet in depth is evident as a cap over the above mentioned lacustrine and deltaic deposits. As the name implies this middle terrace land type is found at a lower relative elevation above the present river level than are the high terraces. These middle terraces are not evident along the entire length of the river, they are basically areas of land that are above the zone of frequent flooding and deposition.

Figure 5. River bank at A24, two to three feet of alluvial silt over lacustrine or deltaic fine sands and silts. The alluvium is darker than the underlying sands.

The area around and east of Rocky Point is an example of a middle terrace with an alluvial cap of 2 to 3 feet over deltaic sands and silts (Figure 5). The alluvial material ranges from a silty fine sand to almost a pure silt. Buried organic matter and wood is present in the alluvial material but is not evident in the deltaic sands directly beneath.

The profile at the bank at Fifth Meridian illustrates the situation where there is about 2 to 3 feet of alluvial soils over lacustrine fine sands and silts. Very little buried organic matter is present here.

A middle terrace without an alluvial cap features lacustrine deposits, mainly silts, with some admixture of clay, exposed at the surface.

DRAINAGE

The soils are usually well-drained to moderately well-drained if frozen ground is not present near the surface. If frozen ground is present the drainage is usually imperfect to moderately well-drained. The effects of different types of vegetation on the distribution of frozen ground and the depth at which it is found are discussed later. At the area illustrated in Figure 5 where the tree cover is white spruce, and a moss carpet of 4 inches is present, the depth to frozen ground was 32 inches.

Poorly drained and very poorly drained areas are found back from the river in meadow and swamp areas. Abandoned river channels and sloughs are areas also very poorly drained. These areas around Rocky Point with an alluvial cap have moderate amounts of wood and organic matter buried in the silty sand that overlies the deltaic sands. Silt loams and clays are common in the poorly drained areas visited in the vicinity of Big Island and Fifth Meridian.

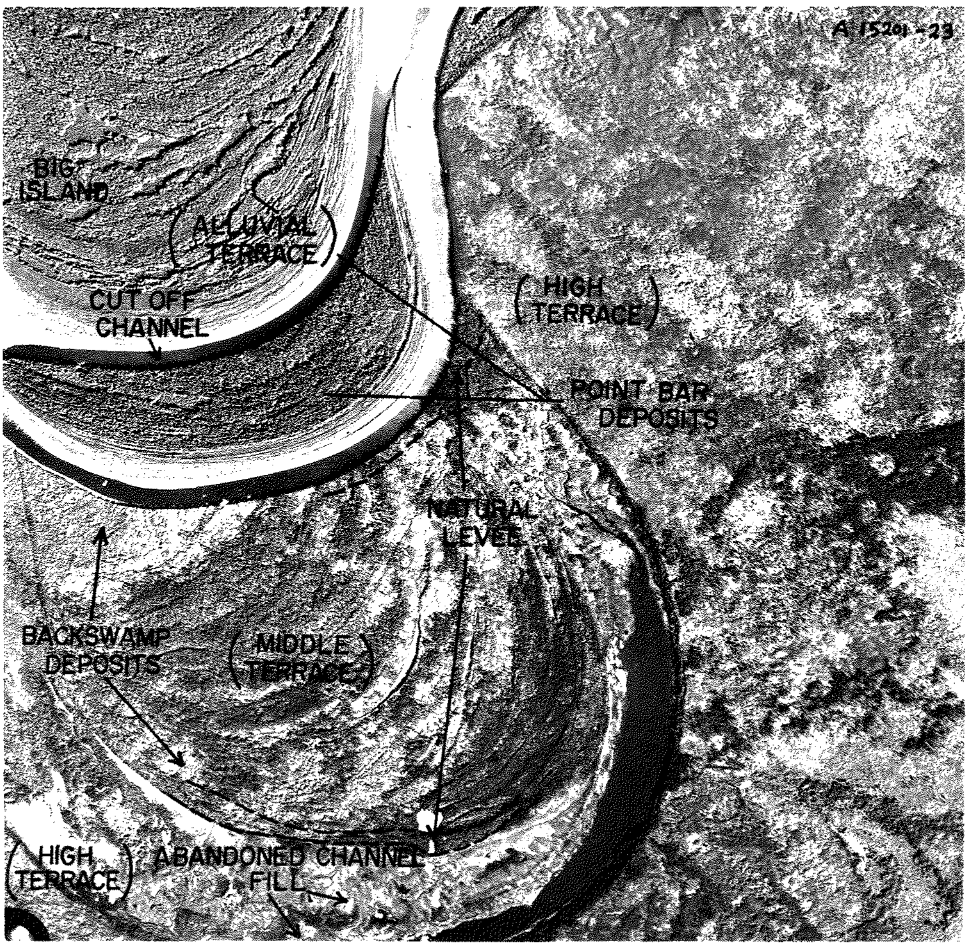

Figure 6. South of Big Island. Swinging across the bottom of the picture is an outline of an abandoned channel and an oxbow lake. The area in the centre of the picture is a middle terrace with an alluvial cap two to four feet thick (origin, point bar deposit). Backswamp deposition has occurred over some of this terrace behind the levees.

Alluvial Land Type

MATERIALS

The alluvial deposits of the Peace River can be classified as follows (the classification follows in part that of Fisk, as outlined in Principles of Geomorphology by Thornbury).

(1) Point bar deposits
(2) Abandoned channel fill
(3) Natural levee deposits
(4) Backswamp deposits.

These deposits are illustrated on the air photograph in Figure 6.

The term "point bar deposit" refers to deposits of alluvium on the inside of a meander bend. Continued deposition occurs as the meander migrates. Alternating sloughs and ridges make up the characteristic pattern common to these deposits (Figure 6). These series of ridges mark the individual accretions associated with the migration of the meander curve. A range in texture from very fine sand to almost pure silt can be found in these deposits. In the delta area around Rocky Point a great amount of organic detritus is buried in these alluvial deposits. There is much less buried organic matter in the alluvium found at Big Island and vicinity.

Deposition made in abandoned cut-off channels is called abandoned channel fill. Cut-off channels can be channels through one of the sloughs of a point bar, or they can be channels that have been cut through a meander neck (which results in a shortening of the river course). The latter type of cut-off can convert the abandoned channel into an oxbow lake. The texture of the soil in these deposits is the same as above.

Natural levees are common to all the alluvial flats along the river and can vary considerably in width. In general they are well drained and are lighter in soil texture, containing a high percentage of very fine sand and fine sand.

In the Peace River area the term backswamp deposits refers generally to deposition taking place back of the natural levees, and in most instances these layers of very fine sands and silts cover the point bar deposits, sloughs and abandoned channels mentioned above.

The alluvial soils on the bottomland areas of the Peace River are stone-free, are rich in organic matter and are moderately calcareous, but have poor vertical and horizontal drainage. Very little soil profile development is evident.

DRAINAGE

Drainage patterns on the alluvial flats are complicated by the presence of frozen ground. A carpet of moss, which develops under the white spruce stands (and not under balsam poplar or aspen stands), insulates the ground and maintains the level of the frozen ground layer close to the surface.

In most instances the natural levees are well drained. The sloughs and abandoned channels are imperfectly drained to very poorly drained as a result of their relative lower elevation above river level and because of the finer soil texture usually associated with some of these areas. Owing to the lack of coniferous tree vegetation and associated moss mat on these areas, frozen ground is not always encountered.

The ridges and higher areas found in the point bar deposits are moderately well drained or imperfectly drained, depending on the present level of the frozen ground.

The more recent accretions usually associated with the inside of the meander curve also range from moderately well drained to imperfectly drained. However, here frozen ground is not the determining factor; the presence of temporary or permanent water tables, due to the low elevation of these areas above the river, is the important feature.

PRODUCTIVITY

There is a wide range in productivity over all the sites encountered in the Peace River valley. This range is related to soil drainage and to soil origin and fertility. As a result, four productivity classes, into which various land areas may be grouped, have been set up as follows:

Productivity Class

(1) Good to Excellent
(2) Moderate
(3) Poor
(4) Very Poor

Soil origin, fertility and drainage were considered to be the chief controllers of productivity (See Table 3).

TABLE 3. PRODUCTIVITY IN RELATION TO LAND TYPE AND DRAINAGE

Productivity Class	Land Type	Drainage
1	limited to the alluvial land type	(a) Areas well drained, moderately well drained and imperfectly drained. (b) Areas moderately well drained and imperfectly drained as a result of frozen ground.
2	occurs on the middle terrace	(a) Areas excessively drained, well drained and moderately well drained. (b) Areas moderately well drained and imperfectly drained as a result of frozen ground.
3	occurs on the high terrace	Areas excessively drained and well drained.
4	can occur on all land types, examples are sand dunes, sloughs, abandoned channels, meadows and swamps	Areas excessively drained and areas poorly and very poorly drained.

A four-foot depth of alluvial material is considered to be the critical depth in determining whether an area will fall into productivity class 1 or 2. If a middle terrace should have more than four feet of alluvial soil over the lacustrine sands and silts, then it would be classed as having excellent to good productivity.

Exceptions to the above relationships may be caused by abnormal richness of the parent soil material, by the presence of a severely compacted soil, or conversely by exceptionally good rootability of the subsoil.

Subdivision of the alluvial flats into an "excellent" and a "good" class would be desirable, but until further studies are made, particularly on the effect of frozen ground and on its development, all the stands were put into one productivity class. As an example, the presence of frozen ground may well be a desirable phenomenon. Frozen ground provides a firm base under well developed spruce stands and if some roots are frozen in, good anchorage will be provided. Frozen ground also helps to retain available moisture close to the ground surface. Hence, well drained areas without frozen ground, such as natural levees, may have a lower productivity.

Similarly, the middle terrace could be subdivided on the basis of: (a) whether or not an alluvial cap is present; (b) frozen ground; and (c) the soil texture of the lacustrine materials.

CONCLUSIONS

White spruce attains its best development on the moderately well to imperfectly drained alluvial silty sands and silts where frozen ground is present. Balsam poplar has its best development on the moderately well drained to imperfectly drained alluvial soils of the same texture as above, but generally of more recent deposition. Frozen ground does not interfere with the drainage here. The proximity to the river, and the low elevation of these areas above the river, usually result in permanent water tables being situated close to the surface.

The influence of the vegetation on the distribution of soil frost is more obvious in the reconnaissance area than is the influence of soil frost on the vegetation. In the recent deposits of alluvium the frozen ground table is very deep—if present at all—under stands of balsam poplar. No moss cover is present under these stands. The frozen ground table seems to rise gradually from these younger areas of the point bar deposits to the older and higher parts where white spruce stands are well established. Here, the mosses form a moderately thick layer which protects the underlying frozen ground during the summer thaw period. As a spruce stand develops on the alluvial flats, a moss carpet develops under it, and the frozen ground table rises to or is maintained near the surface. A mature stand of white spruce that presently has only one or two feet of unfrozen ground in which to root, did not develop under such conditions. These conditions have progressed as the stand developed.

Clear cutting appears to be the silvicultural system best suited to the forests in this area since blowdown is excessive in any partly cut area. The opening up of the stand by partial cutting could result in a patchy decline of the frozen ground level. This degeneration of the firm base on which the spruce stand depended for support and anchorage could be one of the explanations for the amount of blowdown that takes place in some stands.

During logging the moss mat under the mature spruce stands should be removed or greatly disturbed, not only to aid in the re-establishment of a new stand, but, mainly to ensure a thawing of the frozen ground that is present.

In the Peace River area the frozen ground layer is not extremely thick. Hence, removal of the moss layer after cutting could "burn out" the frozen ground completely over a period of several years.

CONCLUSIONS

L'épinette blanche croît le mieux en sol sablolimoneux alluvionnaire ou vaseux, mal ou modérément bien drainés, sur pergélisol. Le peuplier baumier préfère les sols alluvionnaires assez bien ou imparfaitement drainés de même composition que les sols décrits ci-dessus, mais de formation plus récente. Evidemment, le pergélisol ne gêne en rien le ruissellement des eaux, la rivière étant toute proche et la faible élevation des régions riveraines contribuant à la formation de nappes aquifères permanentes près de la surface du sol.

Dans la région étudiée, l'influence des plantes sur la diffusion de la gelée dans le sol se fait plus nettement sentir que celle du pergélisol sur la végétation. Dans les dépôts récents d'alluvions, la couche de pergélisol se trouve à une grande profondeur et est même parfois absente, sous les peuplements de peuplier baumier. Aucun tapis de mousse ne recouvre le sol de tels peuplements. La couche de pergélisol semble de plus en plus élevée à mesure qu'on passe de ces dépôts en barre plus récents aux sols plus anciens de plus grande altitude, où des peuplements d'épinette blanche sont bien établis. A ces endroits, un tapis de mousse d'épaisseur moyenne empêche le pergélisol de dégeler en été. Au fur et à mesure qu'un peuplement d'épinette s'établit dans la plaine alluviale, un tapis de mousse se forme également, permettant au pergélisol de s'épaissir et de se maintenir près de la surface du sol. Un peuplement mûr d'épinette blanche qui n'a actuellement qu'un pied ou deux de sol dégelé pour s'enraciner, ne s'est pas établi de la façon décrite ci-dessus. Le milieu a évolué au fur et à mesure que le peuplement s'établissait.

Il semble que la coupe à blanc convienne le mieux à l'exploitation des forêts de la région, parce que les boisés bûcheronnés en partie sont excessivement vulnérables aux chablis. L'éclaircissement des peuplements par des coupes partielles pourrait causer au niveau du pergélisol des inégalités de hauteur nuisibles. L'amollissement de la base solide qui permet à l'épinette blanche de s'enraciner, est peut-être une des raisons pour lesquelles certains peuplements sont ravagés par les chablis.

En période d'exploitation, il y aurait lieu d'enlever ou de remuer la mousse qui recouvre le sol des peuplements mûrs d'épinette blanche, ce qui non seulement aiderait à la régénération d'un nouveau peuplement, mais assurerait surtout le dégel du pergélisol existant.

Dans la région riveraine de la rivière de la Paix, la couche de pergélisol n'est pas très épaisse. Par conséquent, l'enlèvement du tapis de mousse après le bûcheronnage pourrait faire disparaître le pergélisol tout à fait, au cours de plusieurs années.

PART 2

FLORISTIC ASSOCIATIONS, FOREST HISTORY AND STRUCTURE

by

K. W. HORTON[1]

GENERAL DESCRIPTION OF THE REGION

A comprehensive description of the conditions in the park as a whole is available in the extensive writings of Raup (1935, 1946). Raup conducted phytogeographical studies in the region for several seasons and developed a broad ecological classification. Many of the vegetative associations which he classified are outside the scope of this report, having no bearing on commercial forestry. Prairie formations and various kinds of aquatic vegetation are, among others, in this category. Some forest associations, those of the muskeg conditions, of the granite hills and the high plateaux have no commercial prospects under present circumstances because of low productivity and inaccessibility.

Three major forest associations described by Raup in his 1946 paper are relevant to the present study. They were termed the Flood Plain White Spruce Forest, the Upland Mesophytic White Spruce Forest, and the Jack Pine Forest. It is the first that is of chief interest at present. The other associations approach close enough to the river to be of economic use in some localities but in the main they occur in inaccessible upland reaches.

Its name concisely describes the Flood Plain White Spruce Forest. Situated on low terraces along the major rivers at elevations around 700 feet above sea level, this forest is characteristically of mature white spruce. An admixture of balsam poplar is common and zones of willow and alder are prevalent, but succession to pure white spruce is evident everywhere. Fluvial action has been the controlling ecological factor, constantly changing the environment and consequently the vegetation through deposition and erosion. This is markedly noticeable from the air. The meanderings of the great sediment-laden rivers over the years have produced fantastically complex site patterns in the flood plains. Local drainage systems superimposed on the basic alluvial patterns have added to the complexity. A closer view, however, reveals that the vegetation changes, though very frequent, are clear cut and easily defined, thus simplifying classification.

Such is not the case in the upland conditions. Heterogeneity prevails there —poorly defined sites and vegetation types, many transitional in nature. The geomorphology of this region varies widely. There are extensive plains of lacustrine soils originating from the last two post-glacial lake levels which closely corresponded with the present 1,100-foot and 800-foot contours. Rolling morainic areas and stabilized sand dunes provide local relief. It is on the sandy areas that Raup's Jack Pine Forest usually occurs. Extensive muskegs of bog, birch and sphagnum or, where less saturated, black spruce and tamarack, occur in poorly drained locations. On the mesic or well-drained site is a mixed upland forest of aspen, white birch, balsam poplar and white spruce which, if undisturbed by fire, will succeed to pure white spruce, the Upland Mesophytic Spruce Forest of Raup. Fire, however, has been so prevalent in the past that this climax association is relatively uncommon.

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This, then, is a general description of the conditions under investigation. As already suggested, the focus will be on the flood plain or alluvial lowland forest which is of immediate commercial interest, rather than on the upland forests. The terms lowland and upland are rather ambiguous in this relatively flat region. Lowland in this report will refer to alluvial areas, terraces varying in height above the present river level, with a distinct alluvial cap over the lacustrine deposits. In the field, most samples of this condition were termed Site I, highest in productivity, although a few cases on older alluvial deposits (middle terraces) were tentatively classified Site II because of a relatively shallow alluvial cap. However, later analysis indicated that there were no appreciable differences in forest structure and yield within a broad practical classification, so that the whole condition has been classed Site I, subject to further study.

Uplands will refer generally to all non-alluvial conditions, from old eroded terraces near the rivers to the higher plains and moraines beyond. Most of the sampling was confined to high sandy terraces adjoining the Peace River. This condition was tentatively termed Site III in productivity but it is recognized that such a category does not apply at large in the uplands. Pending further investigation, the richer mesic conditions will be assigned Site II, the drier sand plains and dunes Site III and the unproductive muskegs Site IV.

The ecology of each of these sites will be dealt with next. Quantitative data on the timber of Site I and Site II-III will be found in Part 3 of this report, and detailed descriptions of the soils are given in Part 1.

ALLUVIAL LOWLANDS

Development of Associations

The evolution of the alluvial lowland condition begins with fresh river deposits which vary from fine sands to silts depending on the strength of the current which is mainly controlled by the local configurations of the river. On the sandy material a stand of sandbar willow *(Salix interior)* will develop in the first season, extending by suckers from an existent strip on the previous year's deposition. On finer material an *Equisetum hyemale* association usually pioneers.

As the bank builds up periodically, the willow thickens. Gradually other Salix species, such as *Salix lutea* and *Salix planifolia* appear, then ***Alnus*** *tenuifolia* and balsam poplar invade from inland sources, succeeding the willows.

Meanwhile a poplar trunk may be deposited by high water among the shrubs and suckering may occur directly. In this case the shrubs will be shaded out from the first. A dense understorey of *Equisetum pratense* develops and, as the poplar overstorey ages and thins out, a continuous shrub layer of *Salix bebbiana, Alnus tenuifolia, Rosa acicularis, Viburnum edule* and *Cornus stolonifera* evolves. Scattered white spruce may seed in on the poplar deadfalls and some poplar reproduction may develop through suckering from established trees.

Raup postulated that the present extensive spruce stands of the region developed through this succession and his view has subsequently been upheld. But, according to the present study this is not usually the case. Before the sere can be completed to climax white spruce, history shows that fire occurs, resulting in a return to the Bebbs willow—alder—poplar cover with a spruce understorey, its density depending on seed source proximity. The river bank succession therefore holds mainly for the most recent alluvial deposits.

If sedimentation alters the course of the river causing an abandoned channel which eventually becomes a slough, the succession takes a somewhat different course. First come the aquatic and slough-shore associations described thoroughly by Raup (1935). Grading back from the slough are distinct meadow *(Carex-Calamagrostis)* and shrub *(Salix-Alnus)* associations identifiable with successively drier moisture regimes, often on successively higher terraces. The meadows in general occupy wet moisture regimes 6 to 8*, and the shrub vegetation moist areas. Their relative positions and dominant component species are shown in Appendix 3. Comparable shrub associations occur on depressional topography of other than abandoned channel origin.

These non-forest associations are not permanent. Numerous cases were found of meadow encroaching slough-shore, of shrubs invading meadow, and of balsam poplar or occasionally spruce invading shrub sites. However, such succession is very slow, quite limited, and is in all probability completely overridden by periodic burning or flooding. Fire would result in a maintenance of the existing pioneer vegetation of each association; flooding, with its resultant sedimentation and terrace build-up, would improve the moisture regime, allowing succession to the next stage. Changes in local drainage patterns, hence vegetation, could be brought about by erosion through bank undercutting or, conversely, by levee build-up.

The top stage is, of course, the spruce-poplar forest association of the alluvial terraces and levees which vary in moisture regime from 2 to 4. This is Forest Site I, the condition of foremost interest to commercial forestry. Its ecology will be dealt with next in some detail.

The Forest Association—Site I

Stand Origin

The idea of a fire origin for the existing timber of the lowlands is expected to cause controversy, being opposed to past opinion. However, there is evidence that most of the productive stands owe their structure to fire history. First, several young burns of traceable extent from several to many acres were found adjoining the rivers. Noteworthy examples of various ages are: 3 years old at Trident Creek, 20 years old at Fifth Meridian Warden Station, 25 years old just south of Big Island, and 40 years old on the northern end of Scow Island.

Second, all maturing stands (less than 140 years old) sampled showed definite fire signs in the form of charcoal in the humus, burnt snags, or fire scars along adjoining older age-class boundaries. Moreover, all were even-aged and contained remnants of pioneer species, willow, birch or poplars, structures which indicate fire origin.

Third, in the overmature stands, charcoal was discovered in at least one case (along a bull-dozed road through the 220 year-old Eldorado timber berth), and in almost all samples the canopy largely was even-aged. In the one exception encountered, on Scow Island, excessive blowdown in a shallow-rooting condition could account for the age irregularities present.

Fourth, evidence that fire was effective long before the establishment of the oldest existing stand was discovered in the alluvial cap. Charcoal was present in humus bands at various depths, particularly at the Fifth Meridian station.

* Moisture regime classification follows Hills (1952).

Stand Succession

Succession in the forest is thus apparently based on fire. The generalized details of the various stages follow:

Stage 1 — (origin)	Fire completely destroys the vegetative cover, leaving residual patches of spruce and poplar timber locally.
Stage 2 — (young)	A scrub type composed of willow, balsam poplar, aspen, white birch and alder in varying amounts evolves. A white spruce understorey becomes established, varying in density according to the proximity of a residual seed source; if adjoining, it may be practically a pure canopy from the beginning. Pure aspen or poplar with a spruce understorey is a more common variant or type.
Stage 3 — (maturing)	White spruce forms a more or less complete canopy often with remnant dominant balsam poplars. Later in this stage the poplar becomes very decadent (dead tops are usual and trees are impossible to age by the annual rings after 150 years). Meanwhile, where the spruce overstorey is lesser stocked, a variable tall shrub layer of of alder, dogwood, etc. develops along with scattered spruce reproduction, rooted on deadwood.
Stage 4 — (over-mature)	Remnant poplars die before 200 years and the spruce thins out naturally. Windthrow or breakage depletes the spruce canopy, encouraging luxuriant shrub growth (alder predominating) and further spruce reproduction. White birch, sprouting from old stumps, may occur locally as an intermediate component.

Lesser Vegetation

A descriptive analysis of the lesser vegetation of the lowland forest association is given in Table 4. The flora of 30 stands were assessed in the field according to Braun-Blanquet's combined scale of abundance and cover. These data have been separated into two broad stand age groups with the species tabulated to show relative constancy (frequency from stand to stand) and cover value according to three layers.

There are several noteworthy points regarding the floristic structure. First, the mesophytic nature of the whole list is evident. Yet the composition is relatively simple, only about four species regularly predominating in each layer. This may indicate uniformity of site. The prominence of tall shrubs, particularly in the older stands, is the most remarkable feature of this association. Grasses are practically absent, tall herbs quite sparse, and the feather mosses moderate in abundance compared with other spruce associations in Alberta. This is largely due to the strong competition provided by the shrubs and by *Equisetum pratense* which can be extremely dense.

Stand Age Structure

Detailed age structure information is required to formulate harvesting policies. The sample on which the present observations are based is small but the consistency encountered in age structures strengthens the applicability.

Fire has occurred less frequently and less extensively in these lowlands than in most conditions to be found in boreal regions and certainly less than in the adjoining uplands. Local topography is doubtless the primary cause of this; the river meanders, the numerous old channels and sloughs, and the abrupt high banks provide fairly effective local firebreaks, allowing many stands to develop past maturity.

TABLE 4. LESSER FLORA OF THE ALLUVIAL LOWLANDS SPRUCE FOREST

Species	Maturing Stands (12)		Over-maturing Stands (18)	
	Constancy	Cover Value	Constancy	Cover Value
Shrub Layer				
Cornus stolonifera	a	1	a	2-3
Rosa acicularis	a	2	a	2
Viburnum edule	a	2	a	1-2
Alnus tenuifolia	c	1	a	3-4
Ribes lacustre	c	+	c	+
Ribes triste	s	+	s	+
Shepherdia canadensis	s	+	c	+ -3
Amelanchier florida	s	+	c	+
Symphoricarpos albus	s	+	s	+
Lonicera glaucescens	s	+	s	+
Rubus idaeus	o		s	1
Herb Layer				
Equisetum pratense	c	1	a	4
Cornus canadensis	a	1-2	a	1
Rubus pubescens	a	1	a	2
Linnaea borealis	a	1	c	1
Mitella nuda	a	1	a	1
Fragaria glauca	c	1-2	s	+
Mertensia paniculata	c	+	s	+ -1
Pyrola asarifolia	c	+ -1	s	+
Pyrola secunda	s	+	s	+
Galium boreale	s	+	s	+ -1
Aralia nudicaulis	s	+	s	+ -1
Vicia americana	s	+	s	+
Geocaulon lividum	o		s	2
Elymus innovatus	o		s	+
Epilobium angustifolium	o		s	+
Viola spp.	o		s	+
Actaea rubra	o		s	+
Maianthemum canadense	s	+	o	
Lathyrus ochroleucus	s	+	o	
Osmorhiza obtusa	s	+	o	
Moss Layer				
Hylocomium splendens	a	3	c	3
Calliergonella schreberi	c	1	s	2
Hypnum crista-castrensis	c	1	s	2
Hypnum arcuatum	c	+	c	2
Rhytidiadelphus sp.	o		s	1
Mnium sp.	o		s	+
Peltigera spp.	s	1	o	
Cladonia spp.	s	1	o	

Key

Constancy (general distribution)
o—absent
s—scattered—present in less than 1/3 of stands
c—common—present in 1/3 - 2/3 of stands
a—abundant—present in over 2/3 of stands

Cover Value (local average)
(Braun-Blanquet's combined scale of abundance and cover degree)
+—sparse—cover degree insignificant
1—plentiful but small cover degree
2—numerous—covering at least 1/20 of area
3—any number of individuals covering ¼—½ of area
4—any number of individuals covering ½—¾ of area
5—covering more than ¾ of area

It is probably safe to say that the majority of the timbered area contains overmature stands ranging from 160 to 240 years old. No older trees were encountered, yet there is little doubt that the spruce can grow beyond this age, since some of the 240-year-old trees bored were quite vigorous. Younger stands are by no means infrequent and are often quite extensive. Several ranging from 70 to 120 years were sampled. Below that age class the present sample was sparse. The stands at this stage are usually dominated by poplar, although occasional pure spruce types occur, as exemplified by a 40-year stand on Scow Island. An over-all assessment of relative age class distributions and of the extent of productive young stands is needed.

In most stands the canopy is characteristically even-aged. Where lesser stocked, the actual age of canopy trees will be in a broader range and scattered single or patches of younger trees may occur. Where fully stocked, a quite narrow age range exists in the total population.

In the case of white spruce the highlights of stand age structure are as follows:

> The age range of canopy trees can vary to 50 years depending on initial stocking, but usually it is less than 20 years. By maturity, and particularly later, the spruce stands are thus even-aged for practical purposes.
>
> In the lighter stocked stands, occasional younger spruce often became established and, at the over-mature stage, these are present as intermediate crown-class trees.
>
> Spruce advance growth is practically absent in stands under 140 years old. It occurs scattered in the openings of some old stands but is itself usually quite old, ranging up to 100 years.
>
> Recent natural reproduction is scattered through most old stands, being generally rooted in or alongside deadwood. In the usually well-stocked younger stands it is seldom present.
>
> Thus in the decadent stands, particularly in blowdown areas, natural reproduction would ensure some degree of spruce in the next generation. Abundant alder and other shrubs, though undoubtedly providing stiff competition, do not preclude spruce seedlings; they may, in fact, have a nurse-crop effect.

In poplar stands the canopy is typically even-aged in a narrow range. If the initial poplar canopy itself is not complete, willow and alder fill in to prevent a wide age spread. An intermediate poplar understorey is thus a rarity but young suckers may be found locally, near younger age-class boundaries.

White birch is initially even-aged. In several thrifty stands sampled, the birch had died out before 100 years, stand age. The presence of scattered intermediate birch in certain old spruce stands is probably explained by sprouting. Young sprouts were observed in a few cases.

UPLANDS

The upland sites are much more diverse physiographically than the lowland and the concrete sampling was very meagre, being practically confined to sandy conditions. Only broad, tentative ecological observations can therefore be made.

Unproductive Associations—Site IV

The very general site classification presented was derived by a process of elimination. First, the non-forested sites peculiar to the region, the salt plain and the prairie formations for example, were eliminated from consideration. The frequent muskeg and semi-muskeg conditions were distinct enough, being characterized by typical bog vegetation, black spruce and tamarack dominating. They were grouped as Site IV, considered to be unproductive. In both his papers, Raup gives examples of floristic detail on these various unproductive conditions.

Xeric Forest Association—Site III

Dry and relatively coarse sand areas, often stabilized dunes and adjoining plains which support a predominantly jack pine forest type, provided an obvious class termed Site III in productivity. The driest side of the site, moisture regime O, usually on dunes, is often characterized by a slow-growing pure jack pine forest, but where moisture conditions improve, (grading into Site II), an admixture of aspen, white birch and white spruce is common. Owing to its high, unusually exposed position, the site is particularly vulnerable to fire, so that younger stands prevail. Light fires have often resulted in poorly stocked, two-aged or irregular-aged stands, adding to the complexity of the cover typing. Succession seldom progresses far in these circumstances, but occasional stands may be found exhibiting various stages of succession from jack pine and aspen to white spruce. Raup reported seeing many such examples in the higher uplands toward the Caribou Mountains, and he describes the floristics of the final stage, a park-like white spruce forest.

Mesic Forest Association—Site II

The remainder of the forested uplands, from old eroded river terraces to higher plains, have been categorized as Site II subject to further investigation. This is the mesic upland condition involving mainly moisture regimes 2 to 4 on relatively flat topography. Existing forest cover has been conditioned by fire history similar to that described for Site III. However, light burning with its resulting irregularity in stand age structures, has probably been more common on Site II, considering the predominance of aspen rather than the more combustible jack pine. Virtually all the species of the region occur on this site, usually in mixture, but aspen is the most characteristic and ubiquitous, white spruce and balsam poplar being somewhat less so. On drier areas jack pine may be present, and on the fresher moisture regimes, black spruce and tamarack may occur.

General succession on Site II would take the following course:

Stage 1 — (origin) Fire occurs, leaving residual timber patches locally.

Stage 2 — (young) A "scrub" cover develops, composed generally of aspen, willow, white birch, white spruce and balsam poplar with, locally, alder, tamarack, black spruce or jack pine. It is often a simple aspen type with a white spruce understorey.

Stage 3 — (maturing) The shrub and infrequent species and much of the aspen die out by about 100 years, leaving a white spruce—decadent poplar type. Lesser vegetation is sparse when the canopy is complete. After 100 years the white spruce rapidly dominates the canopy. Usually fire strikes by this time, reverting the sere to Stage 1.

Stage 4 — (mature) By 150 years all of the poplar has died and the cover is pure spruce, even-aged. Decay is common beyond this age, resulting in wind breakage, and scattered natural reproduction in the openings. Poplar suckers may intrude here from adjoining younger stands. This stage would be comparable to Raup's Upland Mesophytic White Spruce Forest, held to be the climax association.

ILLUSTRATIONS

Figures 7 to 13 inclusive show different stages in the different kinds of forest. In addition, a schematic profile of the conditions described in this report is presented in Appendix 3. It integrates landforms, moisture regimes and vegetative associations and shows the relative positions of the classified forest sites and non-productive formations. In actuality the profile is probably never so simple, as the representative air photo in Appendix 4 shows. Various levels of alluvial terrace would usually be present, separated by numerous old channels. Moreover, the inexorable undercutting of the river at certain points would slice progressively through the whole profile, so that any of the associations might be present on today's river bank.

Figure 7. Maturing stage: willow, birch and some poplar dead, white spruce predominating.

Figure 8. The pure poplar type, overmature at 150 years.

Figure 9. The pure spruce type, overmature at 200 years.

Figure 10. The maturing stage: white spruce over-topping aspen at 100 years.

Figure 11. The maturing stage: a dense stand of pure white spruce.

Figure 12. Maturing jack pine—white spruce—aspen stand on a high sand terrace. Moisture regime I, Site III.

Figure 13. Stunted fire-scarred jack pine on a sand dune. Moisture regime 0, Site III.

PART 3

GROWTH AND YIELD OF SPRUCE AND SPRUCE-POPLAR STANDS

by

A. W. BLYTH[1]

INTRODUCTION

This report is confined mainly to the study of growth and yield in the forests of the Peace River area of Wood Buffalo National Park. An attempt is made to analyze the data and present the results in a form which can be applied in improving the regulation and management of an area which has only recently been exploited commercially.

The spruce forests of the lower Peace River are one of the largest continuous blocks of mature softwood in the Province of Alberta. At the present time it is extremely doubtful if the entire area is economically operable; however, if northern development in Alberta and Saskatchewan continues at the present rate it is imperative that regulations provide for the best recovery and the renewal of a considerable timber resource.

No attempt is made to describe in detail such factors as stand origin, development, succession, etc. as these features have been adequately covered in Parts 1 and 2. It must be stressed, however, that even-aged stands predominate in the Peace River valley and the majority of the stands are of fire origin.

SAMPLING PLAN

Sampling for growth and yield purposes was conducted in the same stands, and in conjunction with the soil sampling, site classification, and ecological observation work.

Due to the preponderance of mature and overmature timber, some difficulty was encountered in obtaining a sample including all age classes. It was deemed necessary to obtain such data in order to adequately describe the trend of growth with advancing age, and some age classes were sampled which represent only a minor portion of the area. Due to the limitations of access and time, the field work was restricted to areas immediately adjacent to the river. It is felt, however, that these are the only areas which are presently operable.

The stands sampled were chosen directly from air photographs, and the actual sample plot location was picked as being representative of average stand conditions in respect to density. No attempt was made to pursue the normal or fully stocked concepts.

In general the pure spruce and spruce-poplar mixtures were stressed in the sampling plan. Further, the sampling was more intense on the alluvial lowlands than on the high terraces. These policies were adopted in the field as it was fairly obvious that the predominantly softwood stands are the most extensive and most valuable. and the alluvial lowlands are the most pro-

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ductive and most accessible areas. For comparison purposes it would, of course, have been desirable to obtain equivalent quantities of information for the alluvial pure poplar stands and for the stands of the higher terraces. Some sampling was done in these areas but the time element precluded any extensive work.

DATA RECORDED

All sample plots were four chains in length and either ¼ or ½ chain in width. The smaller plot size, 1/10 of an acre in area, was used in the young dense stands, the larger 1/5-acre plot in the mature and overmature stands. On each plot species were tallied by one-inch diameter classes. The heights of a minimum of two dominant trees on or close to the plot were measured, and the ages of the same trees were recorded at a height of one foot above ground level. Additional ages were also taken over the range of diameter classes. Sufficient heights were measured to permit the preparation of a height/diameter curve for each sample plot.

For a number of stands, sample plot data were obtained from an inventory survey party. This procedure greatly expedited the sampling, but it was necessary to obtain additional height/age and height/diameter data for these stands. The use of the inventory plots, all of which were located on the alluvial lowlands, greatly strengthened the sample for that particular site.

Table 5 presents the distribution of the samples by 10-year age classes and for two broad site classes.

Of the total 62 samples, 28 were established by the research party and 34 by the inventory party. It is obvious from the quantity and distribution of the data in Table 5 that an analysis of growth and yield can be carried out only for the spruce and spruce-poplar data on the alluvial lowlands.

TABLE 5. DISTRIBUTION OF SAMPLES BY AGE, SITE AND SPECIES

Age Class	Site I (Alluvial Lowlands)		Site II (Higher Terraces)
	Spruce and Spruce-Poplar	Pure Poplar	All Species
40	1		1
50			
60			
70	1		
80	1		
90	3		
100	3	1	2
110	11	1	
120	1		1
130			
140	1		
150		1	
160	6		
170	9		
180	1		1
190	3		
200			
210	5		
220	5		
230			
240	3		
Totals	54	3	5

ANALYSIS OF DATA

Site Classes

In Part 1, Lacate has recognized four productivity classes. A study of growth and yield is not directly concerned with the fourth class covering areas of excessive or extremely poor drainage, both of which are non-productive sites. For the purpose of growth comparisons, and because of the lack of data, it has been found necessary to consolidate the sample plot material into two site classes. These classes as compared to Lacate's are as follows:

Productivity Class (Lacate)	*Land Type*	*Site Class*
1	Alluvial	I
2	Middle Terrace	II
3	High Terrace	II
4	Dunes, sloughs, meadows, etc.	non-productive

There are exceptions to the above regrouping. Three sample plots were classified as middle terrace by Lacate due to the absence of a minimum 4-foot alluvial cap. On the basis of landform (as visible on the photographs), stand structure, and ecological information, these plots have been placed in Site Class I. This is not a contradiction of Lacate's work but merely an expedient towards the establishment of a site classification which can readily be applied to the Peace River area by a photo-interpreter. The land area can be divided, with few exceptions, into two site classes on the basis of landform as visible from the photographs. All areas exhibiting recent river action as characterized by the banded appearance of the land and the forest cover are Site I. All other areas which do not demonstrate this pattern are Site II. Non-productive areas are, of course, interspersed within the general boundaries of the two sites.

Dominant Height

The solid line of Figure 14 presents the dominant height/age relationship for spruce on Site I. This curve is based on the measurement of 66 dominant trees. The broken line is the spruce dominant height curve for Site II. The latter curve is based on the measurement of only 18 trees, however, it is presented for comparison purposes. Only the Site I data are plotted.

Plot Volumes

By standard methods a local volume table was compiled for the spruce portion of each sample plot. The standard volume table utilized was that of Forest Research Division S. and M. 57-3, "Standard Volume Tables for White Spruce on Alluvial Soils in Wood Buffalo National Park". The plot volumes of all other species were compiled utilizing the local volume tables prepared for forest inventory purposes.

In the samples in the spruce and spruce-poplar stands of Site I, the volumes of spruce and poplar have been combined, and the yields presented are gross yields of the two species. On first appraisal this step could be severely criticized, however, in Alberta both spruce and poplar are merchantable species, the former as lumber and the latter as lumber and plywood. Any assessment of site productivity must therefore consider the volumes of both species in any stand. The quantity of poplar, however, shows little correlation with age, and it is felt that the presence or absence of the species is merely a matter of chance, depending on how densely the spruce seeds in after fire. In very

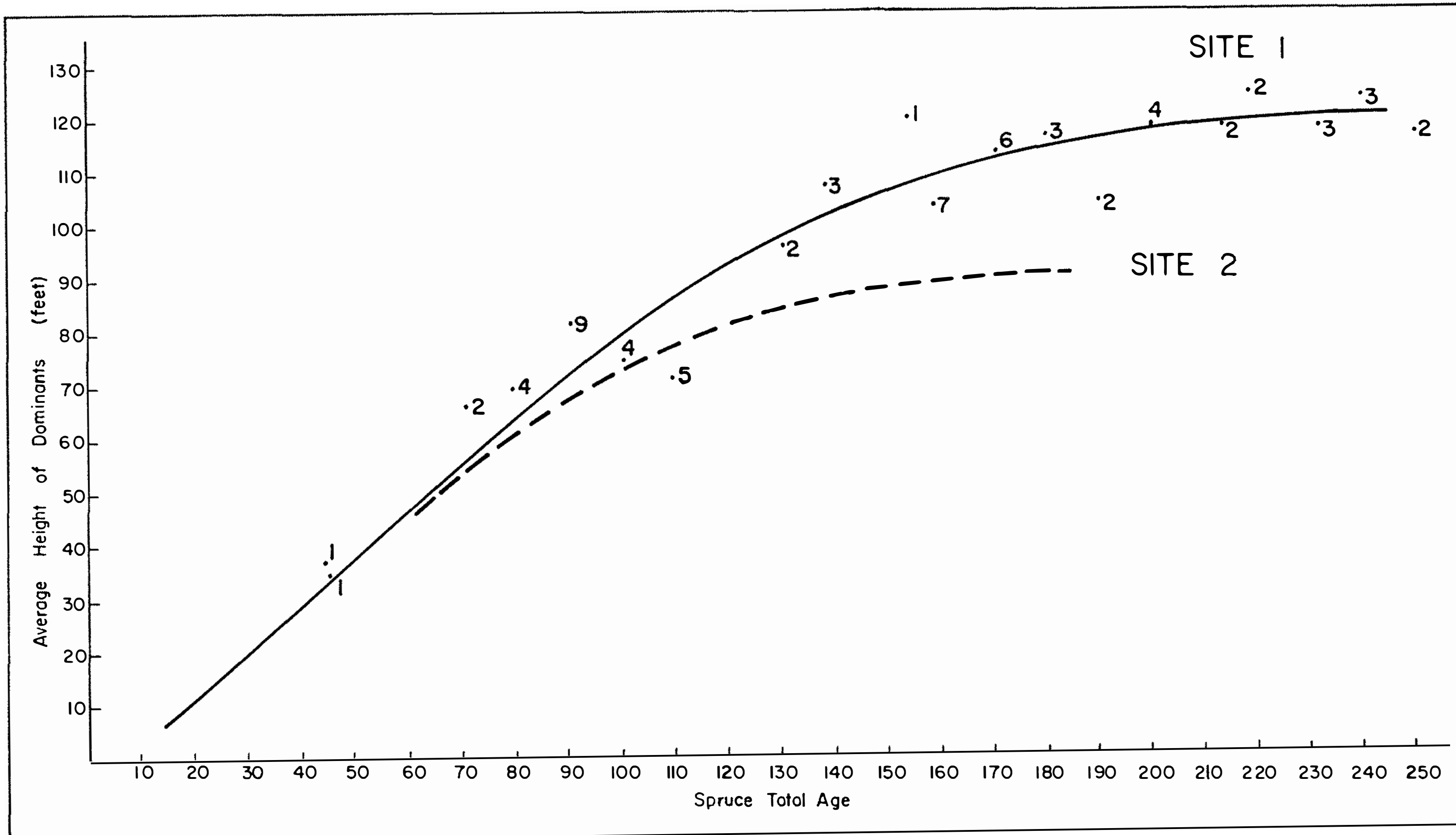

Figure 14. Height of dominant spruce, showing trend with age for two site classes.

young stands, poplar is almost always present; however, its presence at an age of over 40 years is controlled by its inability to compete with spruce under moderate or full stocking of the latter species.

Table 6 shows by age classes the percentage of poplar by volume in the spruce-poplar plots of Site I.

TABLE 6. PERCENTAGE OF POPLAR BY VOLUME, SPRUCE AND SPRUCE-POPLAR PLOTS OF SITE I.

Age Class	No. of Samples	Percentage of Plot Volumes consisting of poplar
40	1	0.0
70	1	16.7
80	1	14.2
90	3	7.0
100	3	5.1
110	11	15.9
120	1	0.0
140	1	1.0
160	6	0.1
170	8	2.4
180	1	0.0
190	3	0.0
210	5	11.7
220	3	1.4
240	3	0.0
	Total 51	
	Average 6.8%	

It is felt that the combining of species volumes under the conditions demonstrated in Table 6 will introduce little error in assessing the gross productivity of Site I.

Yield Curves

For Site I, curves were developed for basal area, average diameter, number of trees, merchantable cubic foot volume, each plotted over total age. These curves are presented in Figures 15 to 19 inclusive. It should be mentioned that 3 sample plots were discarded in the analysis. Two of these were located in an area of excessive blowdown, and on the third an obvious error was made in the recording of the data. The significance of the yield curves is, of course, questionable when one considers that they are based on only 51 sample plots. It is felt, however, that the trends demonstrated are sufficiently accurate for the degree of management which is liable to be practised in the area in the immediate future. The average values for the various age classes have been plotted on the yield curves to demonstrate the variation present in the data.

Figure 15 shows that basal area per acre culminates at an age of approximately 160 years. The basal areas in the Peace River stands are low; much lower, in fact, than those of lodgepole pine in the B.19, or spruce-aspen in the B.18, both of which culminate at a level of approximately 200 square feet on average site conditions. Over 180 years there is some tendency for basal area to decline, which is understandable if one considers that such stands are overmature and approaching decadence.

Number of trees per acre plotted over age is shown in Figure 16. The low number of trees in the mature and overmature stands (140 years plus) is reflected in the high average stand diameters shown in Figure 17. Poplar

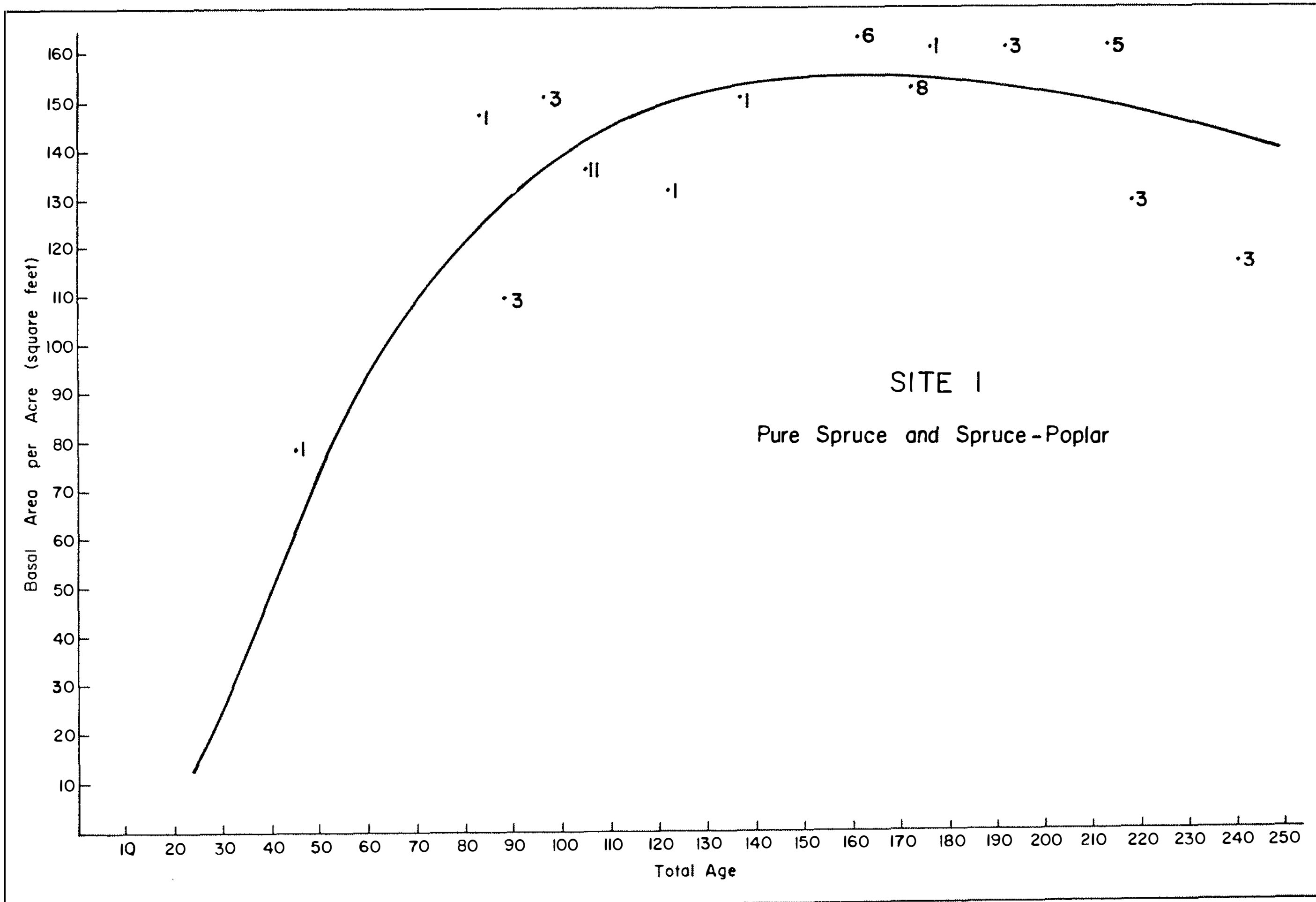

Figure 15. Site I basal area per acre, showing trend with age.

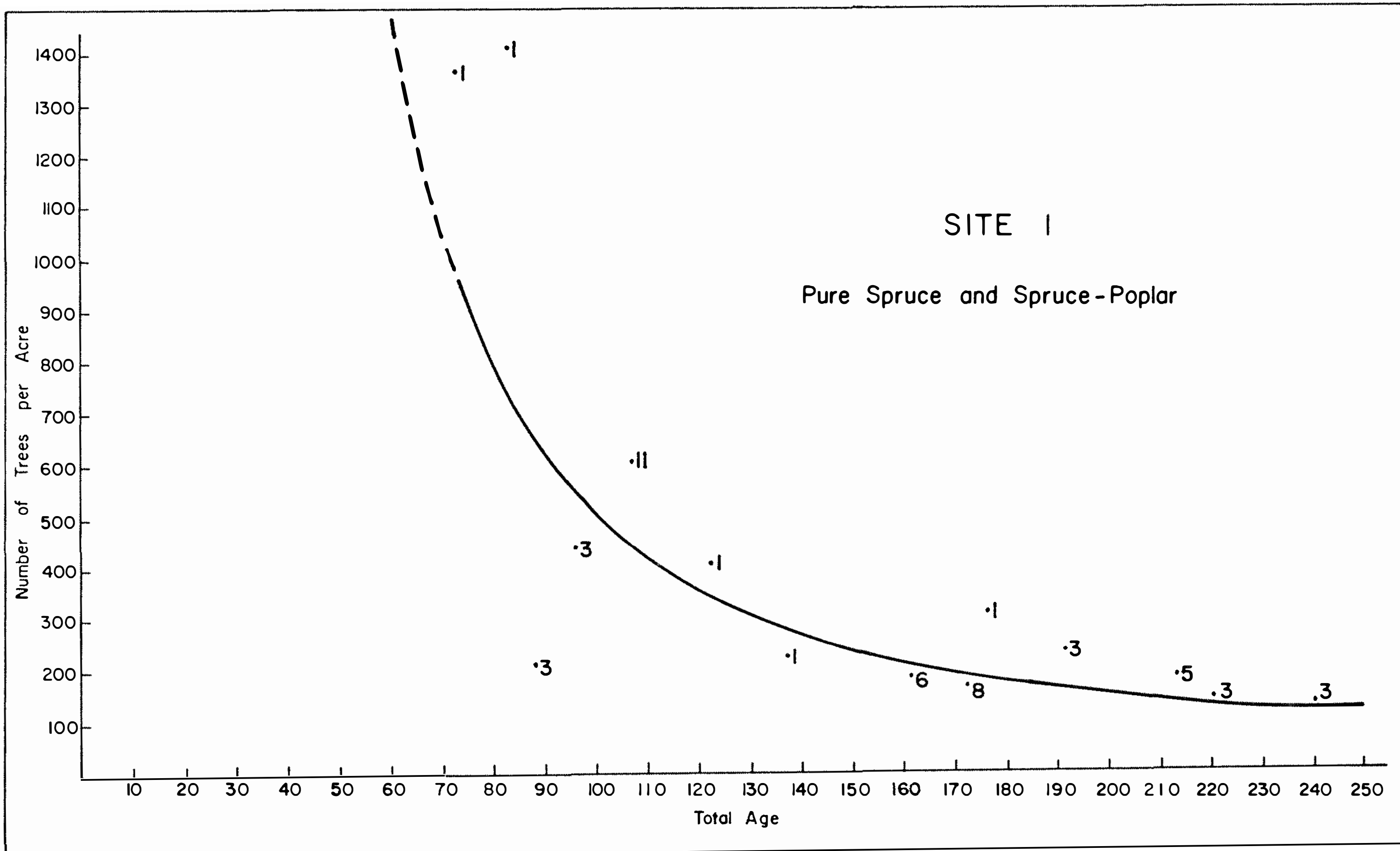

Figure 16. Site I number of trees per acre, showing trend with age.

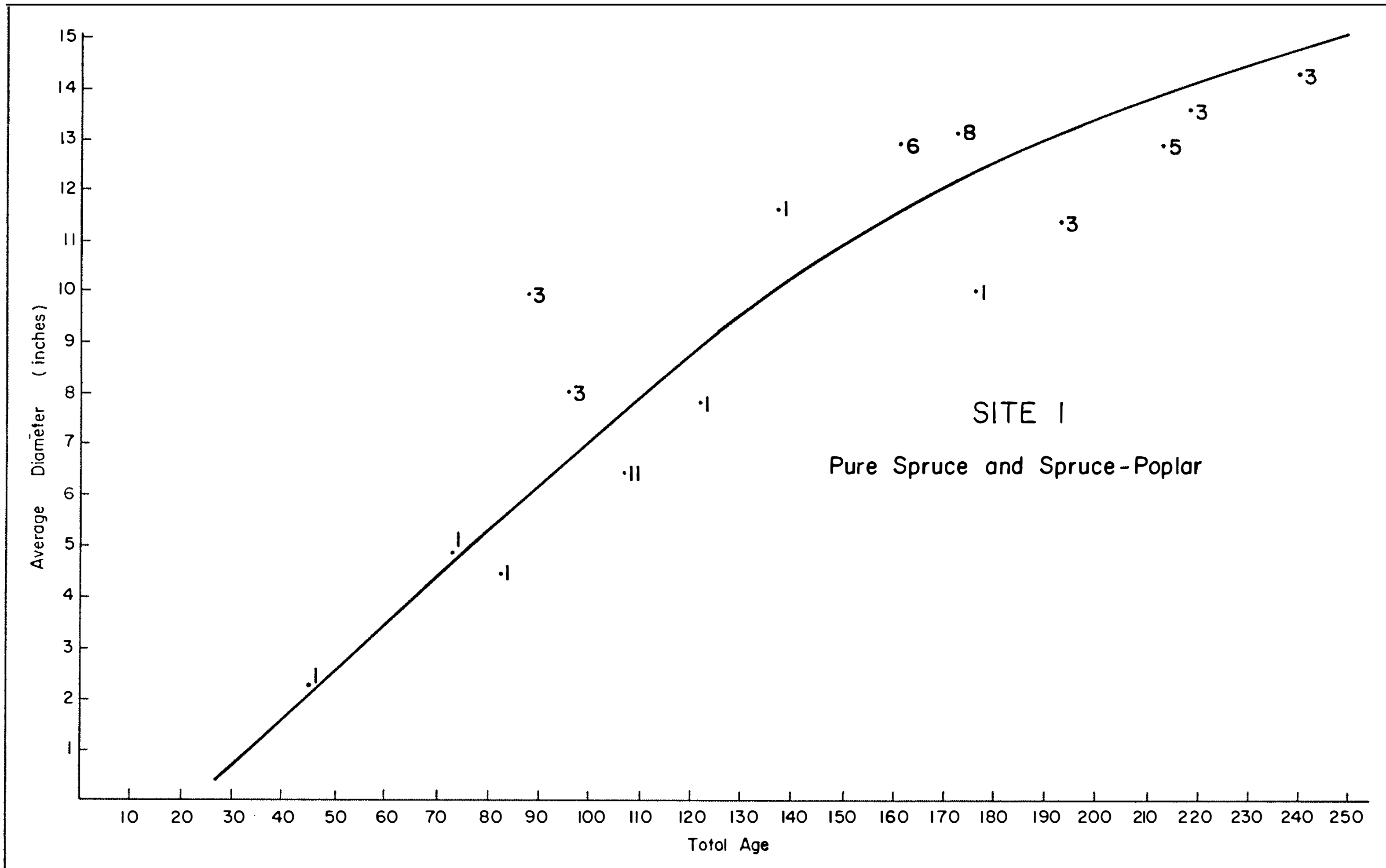

Figure 17. Site I average stand diameter showing trend with age.

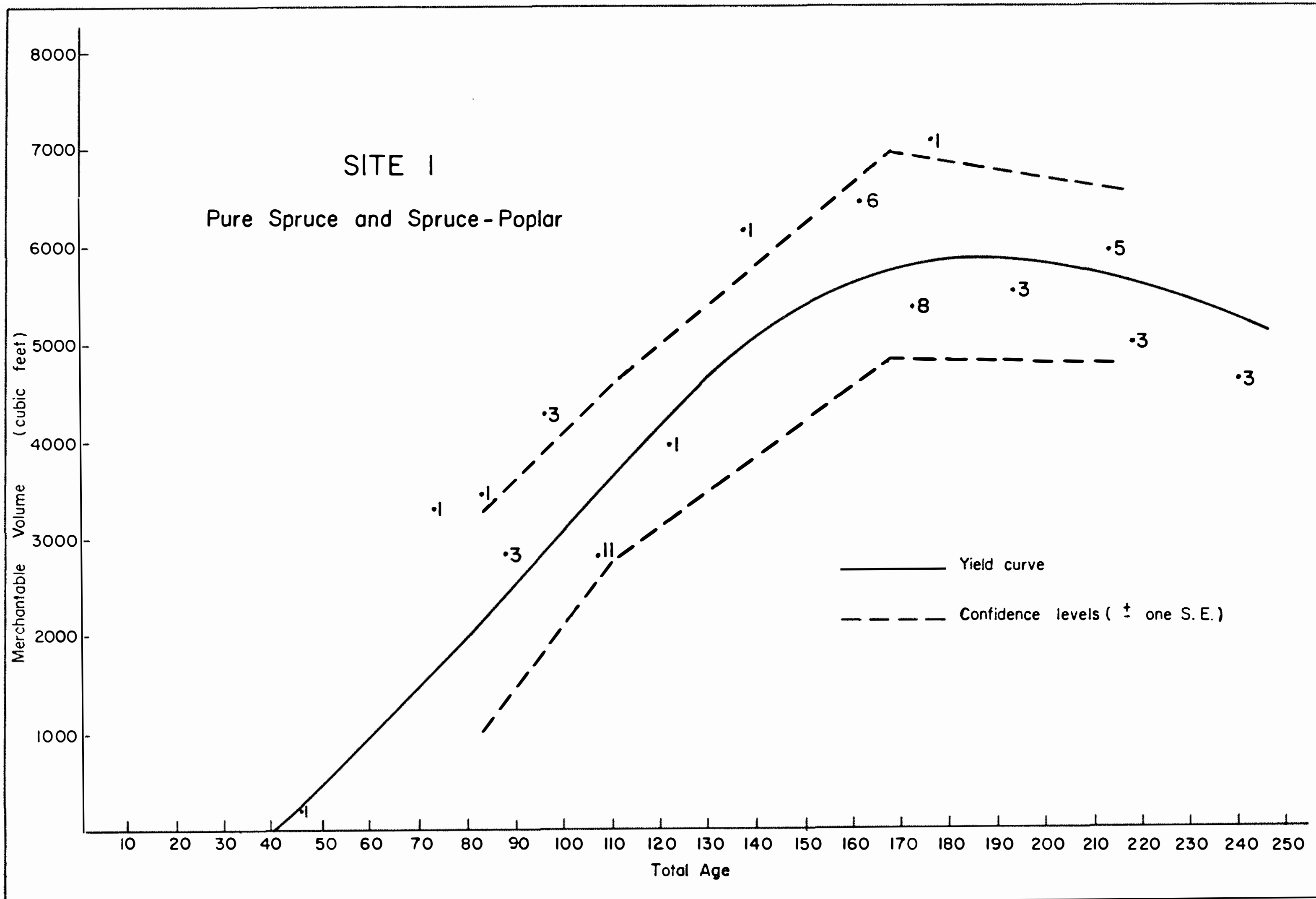

Figure 18. Site I yield per acre in merchantable cubic feet, showing trend with age. Spruce and poplar 4″ +.

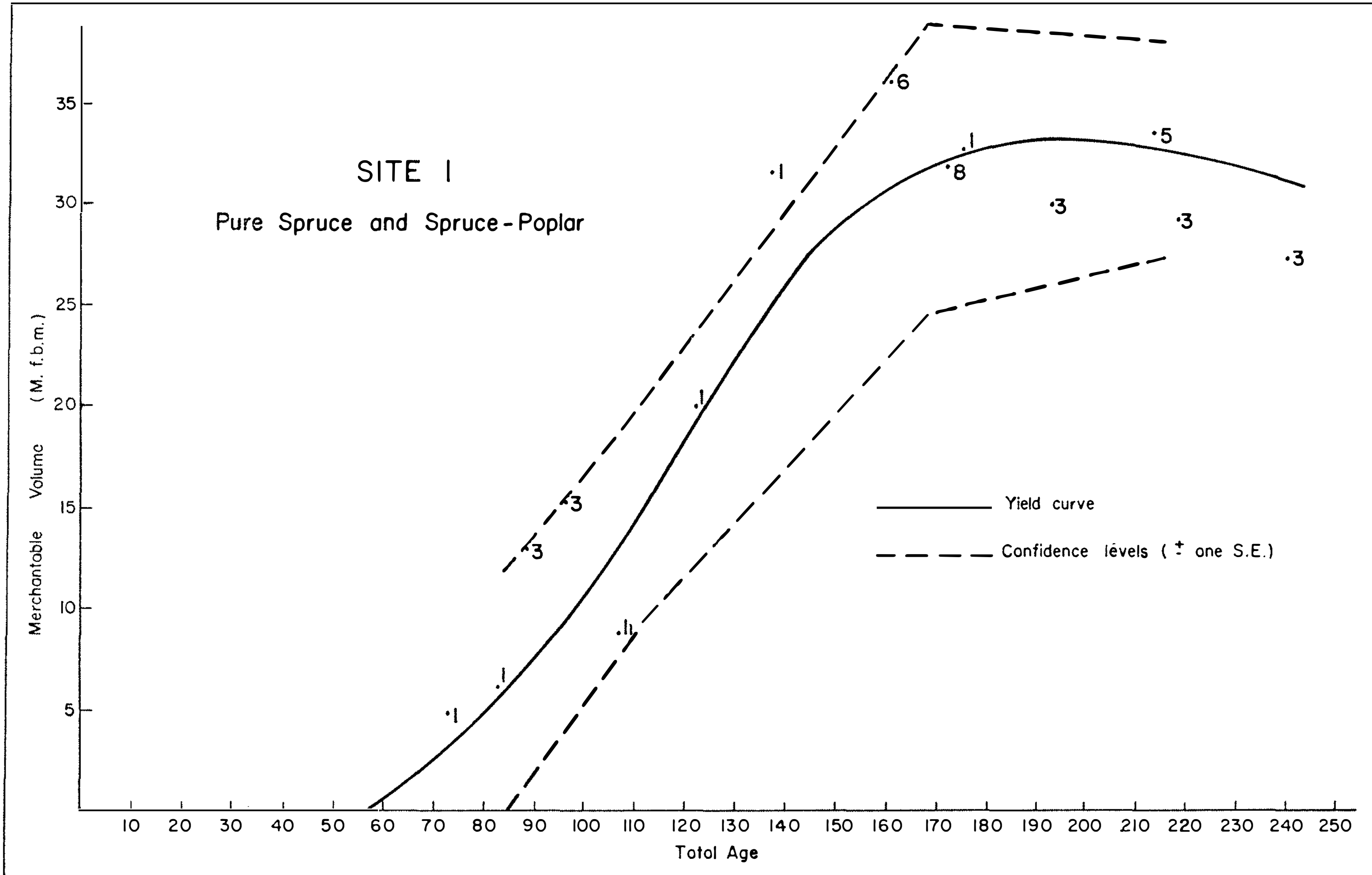

Figure 19. Site I yield per acre in board feet, showing trend with age. Spruce and poplar 8″ +.

and spruce have, however, quite different growth rates, and the validity of Figure 17 could be questioned insofar as it can be applied to spruce alone. A check was made of the individual sample plots and, while poplar grows much faster than spruce, its proportion in the stands is so low that its effect on average stand diameter is very slight. The average diameter curve, drawn for both species, is not more than 0.2 inches higher than that which could be constructed for the spruce alone.

Figures 18 and 19 present the merchantable cubic foot and board foot yields per acre for Site I, the alluvial lowlands. Both curves culminate at an age of approximately 190 years. The slight downward trend above 180 years is felt to be clear evidence of over-maturity and decadence. By pivoting a straight edge about the origin and determining the point of tangency of each curve it can be seen that a rotation age of 140-145 years is obtained for cubic foot production, and 150-155 years for board feet. The similarity of the two rotation ages is indicative of high average stand diameters, most of the trees being 8″+ in diameter.

The standard errors of estimate for Figures 18 and 19 are ± 1031 cubic feet and ± 6210 f.b.m. respectively. For both curves, confidence levels of ± one S.E. are shown; these are based on the calculation of the S.E. for four broad age classes.

For convenience the yield information derived from the foregoing graphical analyses is presented in Table 7.

TABLE 7. YIELD PER ACRE, SPRUCE AND SPRUCE-POPLAR, AVERAGE STOCKING SITE I, ALLUVIAL LOWLANDS

Total Age (years)	Spruce Dominant Height (feet)	Number of Trees (number)	Average d.b.h. (inches)	Basal Area (sq. ft.)	Volume 4″ + (cu. ft.)	Volume 8″ + (f.b.m.)	Mean Annual Increment 4″ + (cu. ft.)	Mean Annual Increment 8″ + (f.b.m.)
30	19	—	0.7	26	—	—	—	—
40	28	3000+	1.6	53	—	—	—	—
50	37	2235	2.5	76	460	—	9.2	—
60	46	1515	3.4	95	950	600	15.8	13
70	55	1070	4.3	111	1470	2500	21.0	36
80	64	800	5.3	123	2000	4700	25.0	59
90	72	630	6.2	132	2560	7400	28.4	82
100	80	510	7.1	140	3110	10500	31.1	105
110	86	420	7.9	146	3670	14200	33.4	129
120	92	350	8.8	150	4200	18300	35.0	152
130	98	310	9.5	153	4680	22600	36.0	174
140	102	270	10.3	155	5090	26200	36.4	187
150	106	240	10.9	156	5430	29000	36.2	193
160	110	215	11.5	156	5660	30900	35.4	193
170	112	195	12.1	156	5820	32100	34.2	189
180	114	180	12.6	156	5880	32800	32.7	182
190	116	165	13.0	155	5890	33200	31.0	175
200	117	155	13.4	153	5850	33200	29.2	166
210	118	145	13.8	151	5760	32900	27.4	157
220	119	135	14.2	149	5630	32500	25.6	148
230	120	130	14.5	147	5450	32000	23.7	139
240	120	125	14.8	144	5220	31400	21.8	131

Growth and Yield on Site II, the Middle and High Terraces

A graphical analysis of the samples located on the middle and high terraces (Site II) is not possible due to the limited data. General comparisons can be made, however, between the growth and yield of Site II and that of Site I.

For the Site II samples, the values of the dependent variables were expressed as a percentage of those of the yield table for Site I at the same ages. Table 8 is a summary of the results obtained.

TABLE 8. COMPARISON OF GROWTH AND YIELD, SITE II vs SITE I AT EQUIVALENT AGES

Variable	Site II as a percentage of Site I
Dominant height	82%
Trees per Acre	192%
Average Diameter	72%
B.A. per Acre	108%
Volume per Acre (cu. ft.)	96%
Volume per Acre (f.b.m.)	65%

The data presented in Table 8 is recognized as a very crude assessment of the potential of Site II. Observation, however, does lend strength to some of the stand characteristics demonstrated. In general the stands on Site II are much more densely stocked, age for age, than those of Site I. This high stocking has a considerable effect on average diameter with the result that the board foot volumes are low. It should be remembered that the board foot volume is made up only from those trees 8″ +, and the per acre values are extremely sensitive to a slight decrease in average diameter.

Growth and Yield of Pure Poplar on Site I

Any discussion of growth and yield in pure poplar stands must also take into account pathological considerations. This species is subject to a much greater incidence of decay than spruce, in fact on most areas it was impossible to obtain ages due to decay. Individual poplar trees occasionally exist in spruce stands at an age of over 200 years; however, they are almost invariably subject to heart rot and in addition demonstrate considerable top dieback.

The oldest stand of pure poplar sampled was approximately 150 years of age. It had a very high volume of 37,000 f.b.m. per acre and an average diameter of 18.7 inches. The volume was, however, made up of only 60 trees per acre and it was evident that the stand was very overmature. Owing to dieback and heart rot the recoverable volume from this stand would approximate only 50 per cent of the gross figure.

Throughout the Peace River area pure poplar stands older than 100 years show distinct signs of breaking up and in many cases have a well established understorey of the same species. On the basis of observational data the writer would recommend a board foot rotation age for poplar of approximately 100 years.

SOME ASPECTS OF FOREST MANAGEMENT IN THE PEACE RIVER AREA

The Effects of Fire

Forest management in Wood Buffalo Park will be difficult to institute as few locations demonstrate such an imbalance in the area distribution of age classes. Considering the Site I alluvial lowlands, the majority of the timbered area is presently supporting mature or overmature stands. The high proportion of old timber on this site can be attributed only to a remarkable fire history.

In contrast to the lowlands, the middle and high terraces have been subject to repeated fires, many of recent origin. This condition is demonstrated on the air photographs and is confirmed on the ground where there is extensive evidence of burn and reburn. Because of fire, the terraces presently support little mature timber and it is improbable that these areas will produce a cut for many years.

On flying from Rocky Point to Fifth Meridian, the writer had the opportunity to observe the effect of a lightning strike in a lowland spruce-poplar stand. About half-an-hour prior to take-off, lightning was observed to strike upstream from Rocky Point. On flying over the area a poplar "snag" was observed to be burning with the flames gradually climbing the tree trunk. This fire was extinguished by rainfall, rendering suppression action unnecessary. The incident served to indicate, however, what is probably the main cause of fire in the area and if extreme hazard conditions had existed the fire might have denuded a large area of mature timber.

The Effect of Over-maturity

The cubic foot and board foot yield curves for Site I demonstrate that there is an actual decline in the volume of pure spruce and spruce-poplar stands at ages over 200 years. In terms of increment such stands are very overmature. What must be stressed, however, is that logging should be confined to these overmature areas for a number of years. The theoretical board foot rotation age of 150 to 160 years has little immediate application. Stands of this age can be held in reserve for 40 to 50 years if necessary with little economic loss. The harvesting of the overmature stands in the meantime will result in the salvage of material which would otherwise be lost. It is most strongly recommended that logging be confined to stands over 180 years of age until such time as this timber is liquidated. Under no conditions should current operations be allowed in stands 160 years of age or less.

Logging Operations

Current logging operations along the Peace River demonstrate a tendency to confine cutting to areas immediately adjacent to the river. This "creaming" policy is natural from the point of view of cheap logging; however, in many areas overmature stands extend some distance back from the river. Road access on the alluvial lowlands presents few difficulties in the summer and certainly none in the winter. It is recommended that future operations should not be confined to the river itself, and that any cutting plans should take into consideration all the overmature timber in a particular area even though some stands may be two miles from the river.

In laying out cut boundaries it is recommended that straight line boundaries be used wherever possible in lieu of stand boundaries. Laying out operations on a stand boundary basis results in mature timber being purposely excluded due to lower than average volumes, blowdown being present, or patchy nature of the timber.

Recommended Cutting Method

Clear cutting is recommended as the only practical method of harvesting the overmature timber. Any form of partial cutting should be discouraged, since the result would be excessive loss from blowdown. In addition the amount of spruce advance growth is probably inadequate for stand renewal. In recommending any cutting method the most pertinent question to be considered is regeneration following logging. To formulate the best management plans without solving the regeneration problem is a wasted effort. The problem in the Peace River area is not solved, and certainly any future research work must be geared towards obtaining a practical solution.

The field work conducted during the summer of 1957 provided a clue that the obtaining of satisfactory regeneration in the area may not be too difficult. A total of 240 milliacre quadrats were established in blocks of 20 in the oldest cut- over areas. These quadrats were assessed for stocking only. On the basis of the individual blocks the stocking to spruce varied from 10 to 70 per cent with an over-all average of 32 per cent. Current year germinates were not included in the assessment and although the cut-over area is heavily invaded by tall shrubs, the spruce seedlings growing beneath this underbrush are quite thrifty in appearance. The area examined was subject to very little scarification and, indeed, spruce seedlings were seldom found on the logging roads. There is some indication that the dense underbush may prevent excessive drying-out of the seedbed. While 32 per cent stocking is not indicative of successful regeneration, neither can it be interpreted as failure.

The regeneration present on the cut-over examined is in part attributable to the excellent seed source. Residual trees are fairly numerous and the distance to the marginal timber not excessive. Cutting plans must take into account seed source and a form of strip clear cutting is recommended. Strips are specifically proposed with the layout at right angles to the prevailing winds. A strip 10 chains in width is not considered excessive in size and the border timber should be reserved for a minimum of five years, or preferably until satisfactory regeneration is demonstrated by stocking surveys.

Some areas of recent logging have received excellent unintentional scarification. It is most strongly recommended that a regeneration comparison be made between these areas and areas which have not been scarified.

A small regeneration sample of 40 miliacres was tallied on the Indian Mission cutting area. This area, comprising only a few acres, has been handlogged for firewood for several years. The stocking to spruce averaged 17 per cent.

Clear cutting in the pure poplar type will not present the regeneration problem encountered in the spruce stands. Poplar under practically any conditions will regenerate by suckering; this is amply demonstrated by the invasion of the species on recent alluvial deposits. It is entirely possible that in logged spruce-poplar stands, poplar will become the most prevalent regenerating species. Such a condition is not detrimental, providing there is also sufficient spruce to form full stocking at a later age. Indeed, some of the finest mature spruce stands on the Peace River are those of low stocking to spruce which have succeeded from a predominantly poplar type.

RECOMMENDATIONS FOR FUTURE RESEARCH AND INTERIM SILVICULTURAL AND MANAGEMENT PROCEDURES

Throughout this report a number of recommendations have been made. For clarity these recommendations along with suggestions for future research are summarized as follows:

1. The Peace River forests are liable to become increasingly important as northern development continues. For this reason current exploitation should be regulated to obtain maximum recovery in the mature stands and at the same time guarantee renewal of these stands by satisfactory regeneration.

2. The obtaining of satisfactory spruce regeneration is one of the most important problems facing management in the Peace River area. There is a possibility that spruce regeneration can be obtained without resorting to scarification. In time there will be an excellent opportunity to compare stocking on recently logged scarified and non-scarified areas. Although planned mechanical scarification warrants future consideration, the formation of any definite policy regarding scarification should await the results of this comparison.

3. The layout of future cutting areas should include mature timber up to two miles from the river. The present policy of only cutting stands immediately adjacent to the river is, in effect, a "high-grading" of the area. Some form of clear cutting is recommended due to the over-maturity of much of the timber and the even-aged nature of the stands. Strip clear cutting is specifically recommended for large blocks of mature timber with a strip width not exceeding 10 chains. Cutting block boundaries should be delineated as straight lines rather than follow stand boundaries, and should include patchy timber, areas of partial blowdown, and open-stocked stands.

4. The basic ecological pattern of the alluvial lowlands has been described. However, the uplands present a more varied environmental scene and certainly require additional investigation. Research beyond the classification level seems at present scarcely warranted in the uplands, considering their inaccessibility.

5. There remain many particular problems of practical interest in the lowlands. The frozen ground problem, which may hold the key to a more intensive site classification and to the control of future yields as well, will need further investigation. Field data should be taken over several "thaw" seasons, from May to September or October. Where frozen ground is present, disturbances such as fire and cutting can alter the soil drainage pattern; for example, an imperfectly drained site may become well drained with the removal of the ground frost table. All stages of the frozen ground cycle should be investigated and a key to the pattern of changes that take place should be prepared. An investigation of frozen ground might well be combined with a rooting study of both white spruce and balsam poplar according to age and soil characteristics.

6. Within each land type unit outlined in this report, the physical and chemical properties of the soils need to be investigated and described in greater detail.

7. For broad mangement purposes the area may be divided into two sites, Site I, the alluvial lowlands, and Site II the higher terraces. A board foot rotation age of 150-155 years is indicated for the Site I spruce and spruce-poplar stands. Board foot volume begins to decline at approximately 190 years. The recently mature stands can be held in reserve for at least 40 years with little volume loss. Such a procedure is recommended until all stands presently 180 years or older are liquidated.
8. A rotation age for poplar is difficult to ascertain without pathological data. Stands at 150 years are definitely decadent. Observational data points to an approximate rotation age of 100 years.
9. Present observations lead to the conclusion that the pioneer species, willow, birch, and aspen, which disappear long before the spruce rotation age, have little effect on the ultimate spruce yields.

RECOMMANDATIONS EN PRÉVISION DE NOUVELLES RECHERCHES ÉVENTUELLES, ET MÉTHODES DE SYLVICULTURE ET D'AMÉNAGEMENT PROVISOIRES

Le présent rapport offre plusieurs recommandations. Pour plus de clarté, ces recommandations et les propositions connexes peuvent se résumer comme suit:

1. Les forêts du bassin de la rivière de la Paix pourraient bien acquérir de plus en plus d'importance, au fur et à mesure que l'aménagement des régions septentrionales se poursuit. Par conséquent, il y aurait lieu de réglementer l'exploitation courante afin d'obtenir un volume ligneux maximum des peuplements surannés tout en assurant la repousse de ces peuplements grâce à une régénération convenable.
2. Une bonne régénération des peuplements d'épinette est d'importance capitale dans la région de la rivière de la Paix. Il est probable qu'on puisse assurer la bonne régénération de ces peuplements sans devoir recourir au scarifiage. Avec le temps, on aura de très bonnes occasions de comparer la repousse des peuplements récemment exploités et scarifiés à celle des peuplements non scarifiés. Bien que le scarifiage mécanique possède certains mérites indéniables, il y aurait lieu d'attendre les résultats de la comparaison mentionnée ci-dessus avant d'adopter une ligne de conduite définie au sujet du scarifiage.
3. Les aires de coupe devraient comprendre les arbres d'âge mûr jusqu'à deux milles de distance de la rivière. La méthode actuelle de coupe, qui consiste à n'exploiter que les peuplements en bordure de la rivière, constitue en fait une sorte de pillage des forêts de la région. La coupe rase est recommandable en certains endroits où une bonne proportion des arbres sur pied sont surannés et où les peuplements sont plutôt équiennes. La coupe à blanc par bandes de 10 chaînes au plus est à recommander pour certains peuplements surannés de grande étendue. Les limites des coupes devraient être en lignes droites au lieu de suivre la bordure des peuplements; elles devraient comprendre tous les peuplements, y compris les peuplements clairsemés, les aires parsemées de chablis et les peuplements ouverts.
4. L'écologie générale des basses terres alluvialles a été précisée. Toutefois, pour ce qui est des terres hautes, leur écologie est beaucoup plus compliquée et exige sans aucun doute des recherches supplémentaires. La

recherche au delà du classement n'est certes pas de mise pour le moment dans le cas des terres hautes, vu leur inaccessibilité.

5. Pour ce qui est des basses terres, il reste encore un grand nombre de questions d'intérêt pratique à résoudre. La question du pergélisol, qui pourrait donner la clef d'un classement plus judicieux des types forestiers et celle de la réglementation du rendement futur, mérite qu'on l'étudie davantage. Il y aurait lieu de recueillir sur place les données relatives au dégel pendant plusieurs saisons, entre mai et septembre ou octobre. Là où le sol reste gelé en permanence, le feu ou l'abattage des arbres peuvent modifier l'écoulement des eaux; par exemple un endroit mal drainé pourrait très bien se drainer parfaitement si le pergélisol cessait d'y exister. On devrait étudier toutes les phases du cycle du pergélisol, afin de pouvoir définir les changements cycliques consécutifs qui se produisent. L'étude du pergélisol devrait accompagner celle du processus d'enracinement de l'épinette blanche et du peuplier baumier, selon leur âge et les caractéristiques du sol.

6. Dans tous les types forestiers esquissés dans le présent rapport, il y aurait lieu d'étudier et de décrire dans le détail les propriétés chimiques et physiques des sols.

7. Aux fins d'aménagement en général, la région de la rivière de la Paix pourrait être répartie en deux types, soit le type I qui comprendrait les basses terres et le type II qui comprendrait les terrasses plus élevées. Il y aurait lieu de fixer l'âge d'exploitation des peuplements d'épinette et des peuplements mixtes d'épinette et de peuplier du type I entre 150 et 155 ans, selon le volume de bois en p.m.p. Ce volume en p.m.p. commence à diminuer chez les sujets âgés d'environ 190 ans. Les peuplements qui viennent d'arriver à maturité peuvent être gardés en réserve au moins pendant une quarantaine d'années, la perte en volume étant assez restreinte. Ce procédé est recommandé aussi longtemps que les peuplements actuellement âgés de 180 ans ou plus ne seront pas liquidés.

8. Sans données pathologiques, il est difficile de fixer l'âge d'exploitation des peuplements de peuplier. Ces peuplements sont nettement en train de se détériorer à 150 ans. Les données recueillies à la suite d'observations indiquent que leur âge d'exploitation devrait être fixé à environ 100 ans.

9. D'après des observations courantes, les essences d'origine, saules, bouleaux, peupliers faux-trembles, qui disparaissent longtemps avant que les épinettes n'atteignent l'âge d'exploitation, influent très peu sur le rendement final des peuplements d'épinette. Toutefois, les peupliers baumiers, à cause de leur longévité, doivent probablement entrer en ligne de compte dans cet ordre d'idées.

APPENDIX 1

Frozen Ground Samples

(Mission cut, Quatre Fourches, samples taken on July 9, 1957)

In Stand			In Cut-over (cut at least 2-3 years old)			In Cut-over (clearing and roads)		
Sample No.	Depth to frozen ground	Thickness of moss layer	Sample No.	Depth to frozen ground	Thickness of moss layer	Sample No.	Depth to frozen ground	Thickness of moss layer
1.	30″	4-6″	1.	30″	4-6″	1. road	not reached at 48″	nil
2.	26	4-6	2.	24	4-6			
3.	20	4	3.	20	4-6	2. road	not reached at 40″	nil
4.	32	4-6	4.	26	4-6			
5.	6	10-12	5.	26	4-6	3. clearing (camp)	not reached at 48″	nil
6.	4	10-12						
7.	18	6				4. road	not reached at 48″	nil

In the stand, frozen ground was reached at depths between 2 and 3 feet below the surface. One low-lying area with a thick moss layer had frozen ground at less than one foot below mineral surface. In the cut-over areas where the method of extraction of the wood did not greatly disturb the moss carpet, frozen ground was encountered at 2 to 3 feet below mineral surface. On the roads and clearings where the moss cover had been removed, frozen ground was not encountered at a depth of 4 feet.

APPENDIX 2

Plot locations—Fifth Meridian Area
—Lower Peace River

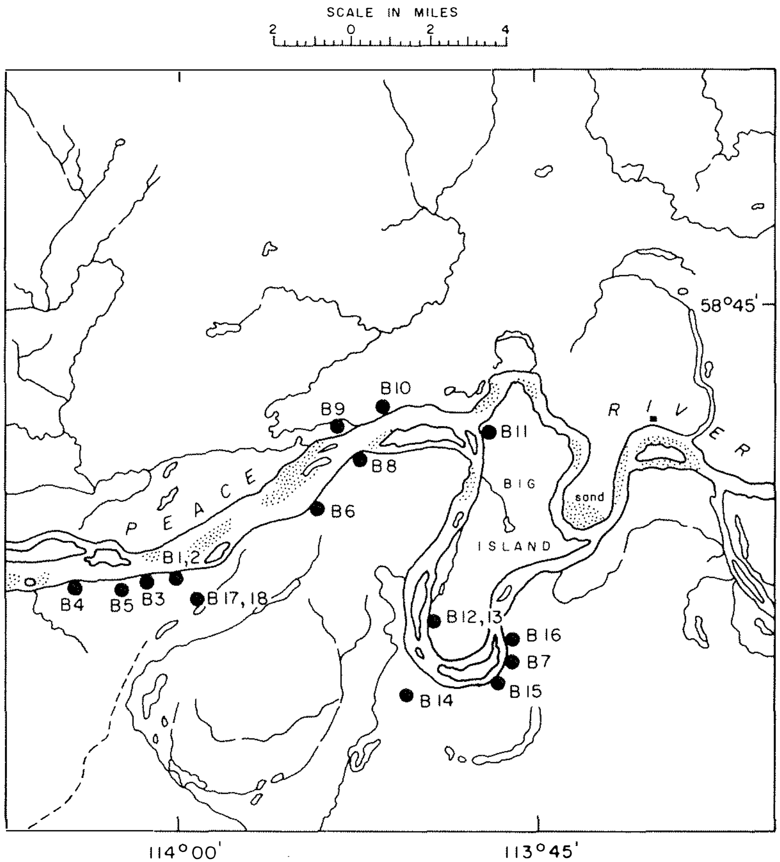

Figure 1. Plot locations Fifth Meridian area.

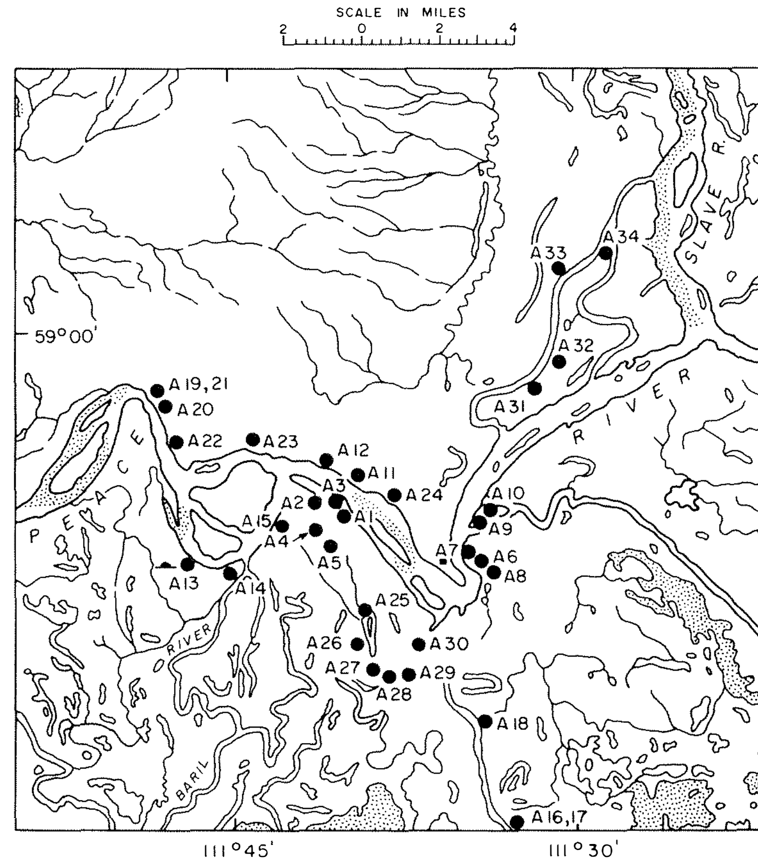

Figure 2. Plot locations Lower Peace River area.

APPENDIX 3

Schematic profile of ecological conditions

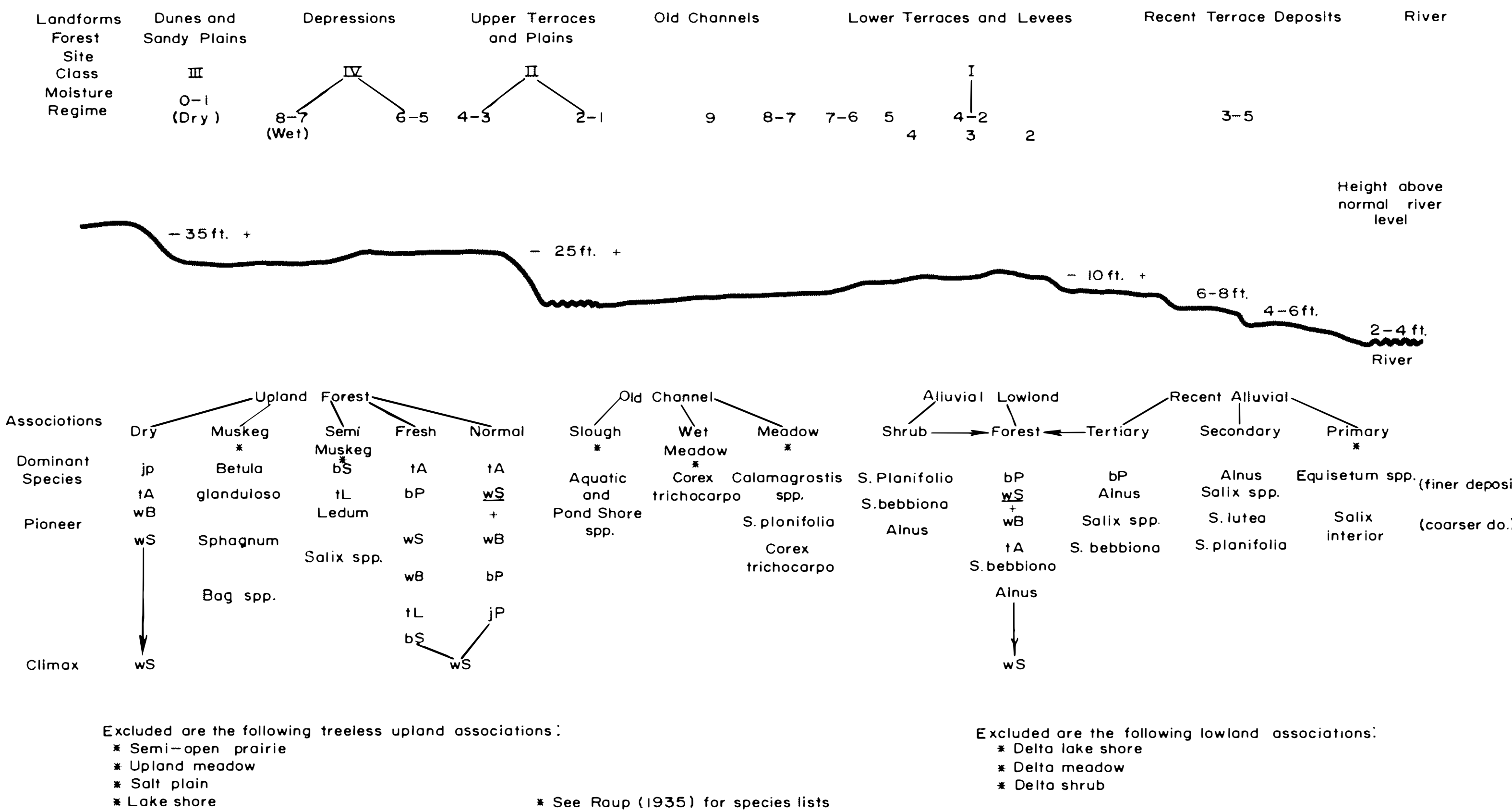

Figure 1. Schematic profile of conditions adjoining the Peace River in Wood Buffalo National Park.

APPENDIX 4

Aerial Photographic Interpretation

Figure 1. Aerial photograph A15297-54.

APPENDIX 4

Aerial Photographic Interpretation

Figure 2. Aerial photograph A15297-53.

Discussion

Land type boundaries are outlined as follows:
(See Figure 1):

Symbol	*Land Type*
A	alluvial
MT	middle terrace
HT	high terrace

Aerial photograph number A15297-53 has been partly mapped in detail using the following symbols (See Figure 2):

DRAINAGE

Symbol	*Drainage class*
1	Excessively drained
2, 2Z*	Well drained
3, 3Z	Moderately well drained
4, 4Z	Imperfectly drained
5	Poorly drained
6	Very poorly drained

*Z denotes drainage affected by frozen ground. See Table 1 in Part I of the report for more detailed description.

SOIL TEXTURE

Symbol	*Texture*
S	medium fine sand, sometimes loamy
VFS	very fine sand (included in this class is silty fine sands, and sandy silts)
Si	silt
Sil	silt loam
C	clays and clay loams

As the scale of 50 chains=1″, many poorly drained areas were too small to map out. Symbols have been left out in some cases. Most of the long narrow areas without symbols are in the 5 and 6 drainage class.

Characteristics of Land Types

HIGH TERRACE

The areas designated as high terraces are not the product of river deposition. The high terraces outline the outermost margins of the river valley. Alluvial depositional scars are not evident on the areas.

The high terraces have been burned repeatedly and many fire lines are present. Trembling aspen, birch and jack pine are the tree species usually established on these areas. Some white spruce is present, but extensive stands are rarely seen on these lacustrine deposits.

Other important identifying features are the sand dunes which are often associated with the high terrace and are not seen on the middle terrace. (See top of air photo— Figure 1).

Middle Terrace

As defined, the middle terrace includes a lacustrine area that has undergone some erosional actions and on occasion some depositional actions during the development of the river valley. If the alluvial cap, that may be present, is less than four feet thick, the area is considered to be a middle terrace, and if it is more than four feet thick the area is included with the alluvial land type.

Dealing first with the middle terrace without the alluvial cap, an important feature is the lack of the alluvial scar pattern. In general the middle terrace surface resembles the high terrace except that it is at a lower elevation. The lacustrine sand deposits have, in most cases, been washed away, silts and clays are frequently present at the surface.

These terraces have also been burned repeatedly, and trembling aspen, white spruce, and birch are established as mixed or pure stands. Jack pine is not often seen on the middle terrace. White spruce may be found in pure stands if the drainage is not too excessive.

The middle terrace with the alluvial cap is quite distinctive in its appearance as compared to the previous areas described, and difficulty will arise only in distinguishing this type from the alluvial flats. The alluvial pattern of alternating ridges and sloughs is evident but is not as pronounced nor as regular as it is on the alluvial landtype. Figure 1 shows the stages from the high terrace to the alluvial flat. The north shore shows the change from the middle terrace with a weak alluvial pattern to the alluvial flat with a more pronounced elevational difference in the ridge and slough linear pattern.

The majority of the stands are of fire origin, and white spruce in pure stands or in mixtures with balsam poplar and trembling aspen are established. Jack pine is not found on these areas. Tamarack occurs in small patches around the Eldorado area.

Alluvial Land Type

The alluvial flats are the terraces that have resulted from river erosion and subsequent river deposition. They are at the lowest elevation above the present river level. The well-drained, moderately well-drained, and some imperfectly drained sites on this land type are the most productive sites in the river valley. The individual accretions on the inside of a meander bend result in the distinctive pattern of somewhat parallel ridges and sloughs as shown in Figures 1 and 2. In some instances this pattern may be obscured by backswamp and natural levee deposits. The general level of the alluvial flat seems to be deeply "etched" by the slough pattern.

Pure stands and mixed stands of white spruce and balsam poplar are found on these areas. The stands for the most part are of fire origin. Trembling aspen is sometimes associated with the spruce on the well-drained sites.

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