CANADA
Department of Northern Affairs and National Resources
FORESTRY BRANCH

YIELD OF EVEN-AGED FULLY STOCKED SPRUCE-POPLAR STANDS IN NORTHERN ALBERTA

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Forest Research Division
Technical Note No. 18
1955

Published under the authority of
The Minister of Northern Affairs and National Resources
Ottawa, 1955

FOREWORD

The preparation of yield tables for mixed stands composed of species with widely differing growth habits presents a difficult problem, which has not yet been satisfactorily solved. This publication does not attempt to provide a fully adequate solution to the problem, as certain inherent weaknesses in the method used—particularly with respect to changes in species composition and extended extrapolation—are fully recognized. However, because of the urgent need for yield tables in this forest type, it was considered unpractical to delay their preparation until more precise techniques and additional data were available. The present tables are, however, believed to be reasonable approximations, suitable for the present stage of management in the area to which the yield tables apply.

Field work and analysis in connection with the yield tables were conducted during the period 1949 to 1951 by W. K. MacLeod, who also prepared the preliminary report on the study prior to his retirement from the staff of the Alberta District Office of the Forest Research Division. This final report was prepared for publication by A. W. Blyth, Research Forester, Alberta District Office, Forest Research Division.

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INTRODUCTION

White spruce (*Picea glauca* (Moench) Voss) is at present the most important timber tree in Alberta. It grows in association with every species found in the province, but is most commonly associated with aspen poplar (*Populus tremuloides* Michx.), and lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.). The spruce-poplar type is dominant in the Mixedwood Section of the Boreal Region, while the spruce-pine type is restricted to the East Slope Section of the Subalpine Region. Between the two regions there is a transition zone where all three species may be found growing in close association.

Although the East Slope Section was first prominent as a timber source, its present value as a watershed, game reserve, and tourist attraction outweighs that of the productive cut. In the past 20 to 25 years moreover, the centre of logging operations has moved to the north and to the east, and now (1955) is located in the Mixedwood Section.

Prior to the present study, no growth data were available for this increasingly important timber Section. However, the forest inventory at present underway in Alberta, assisted by the provision of the Canada Forestry Act, has greatly stimulated interest in growth and perpetual yield; so much so that some of the larger logging companies are seriously contemplating forest management on sustained yield principles. This study therefore undertakes to provide growth data of a factual nature, not only on the timber of the Mixedwood Section but also to assist administrators interested in forest management.

THE SPRUCE-POPLAR FORESTS

The forest cover in the Mixwood, or B. 18, Section of Alberta, as described by Halliday (14), is principally aspen—at present of little market value—among which white spruce is interspersed in scattered patches in a wide range of densities. On sandy, well-drained soils, balsam fir (*Abies balsamea* (L) Mill.) is often present and in some localities exists in almost pure stands. Black spruce (*Picea mariana* (Mill.) B.S.P.) and larch (*Larix laricina* (Du Roi) K. Koch) enter the above mixtures on poorly drained soils and on swamp margins. Lodgepole pine, jack pine (*Pinus banksiana* Lamb.), and their hybrids are found in patches or as scattered individuals and possess local importance for sawlog and railway tie production. Black poplar (*Populus balsamifera* L.) and white birch (*Betula papyrifera* Marsh.) are seldom completely absent in the hardwood portion of the spruce-poplar stands. Of these, the poplar is the most common, showing major expression on moist sites, and growing in almost pure stands on the alluvial soils of river flats and creek margins. Birch may be found locally in pure stands which have some marketable value, but such occurrences are rare. It most frequently exists as a spindly malformed tree of minor importance.

Although the species found in the Mixedwood Section occur in innumerable combinations ranging from pure stands to mixtures of a number of species, white spruce and aspen comprise 89 per cent by basal area of the stands sampled in conducting this study.

Regardless of species composition, stands in the Mixedwood Section are almost all of fire origin, and therefore are distinctly even-aged. Occasionally stands are found with two or more distinct age-classes of spruce, the younger age-class resulting from opening of the stand by windthrow or ground fire.

FIELD DATA

Before describing the sampling method, it is necessary to define several terms which appear many times in the text of this publication. They are as follows:

Total Age—The average age of the spruce dominants. This will most frequently coincide with the period elapsed since the fire or other agency which removed the previous stand.

Even-aged Stands—Stands in which the difference in ages between the youngest and oldest trees is not more than 20 years.

Dominant—Usually defined as any tree with a well-formed crown that receives full light from above and at least some light from the sides. For understory spruce the dominants were empirically selected as the tallest trees which would be dominant if no overstory were present.

Site Quality—The wood-producing capacity of an area measured, in this study, by the height growth of the dominant spruce.

Site Index—A finite measurement of the site quality on a particular area. It is based on the height attained by the average dominant spruce at 80 years.

Stocking—The degree to which an area is effectively occupied by living trees. Fully stocked stands theoretically contain as many trees per acre as can fully utilize the growing space available.

Composition—The mixture of the tree species forming the stand. Percentage composition for a particular species means the basal area for that species expressed as a percentage of the total basal area of the stand.

Tolerant Species—Those species possessing the ability to grow in the shade of and in competition with other trees. In this study the tolerant species are white spruce, black spruce, and balsam fir.

Intolerant Species—Those species with little or no ability to grow in the shade of and in competition with other trees. In this study the intolerant species are aspen poplar, black poplar, white birch, pine, and larch.

The basic data for this study consisted of 229 single examination plots established in spruce-poplar stands whose ages varied from 25 to 150 years. The geographical distribution of the plots is shown in Figure 1. All the plots were located in stands where the spruce was essentially even-aged; when the tolerant and intolerant components were combined the stands were judged to be fully stocked. It was assumed that, on the average, the younger fully-stocked stands would develop into a form corresponding to that of the older fully-stocked stands. Thus, sampling stands throughout the range of site and age-classes which had a good representation of spruce should give a close estimate of growth trends.

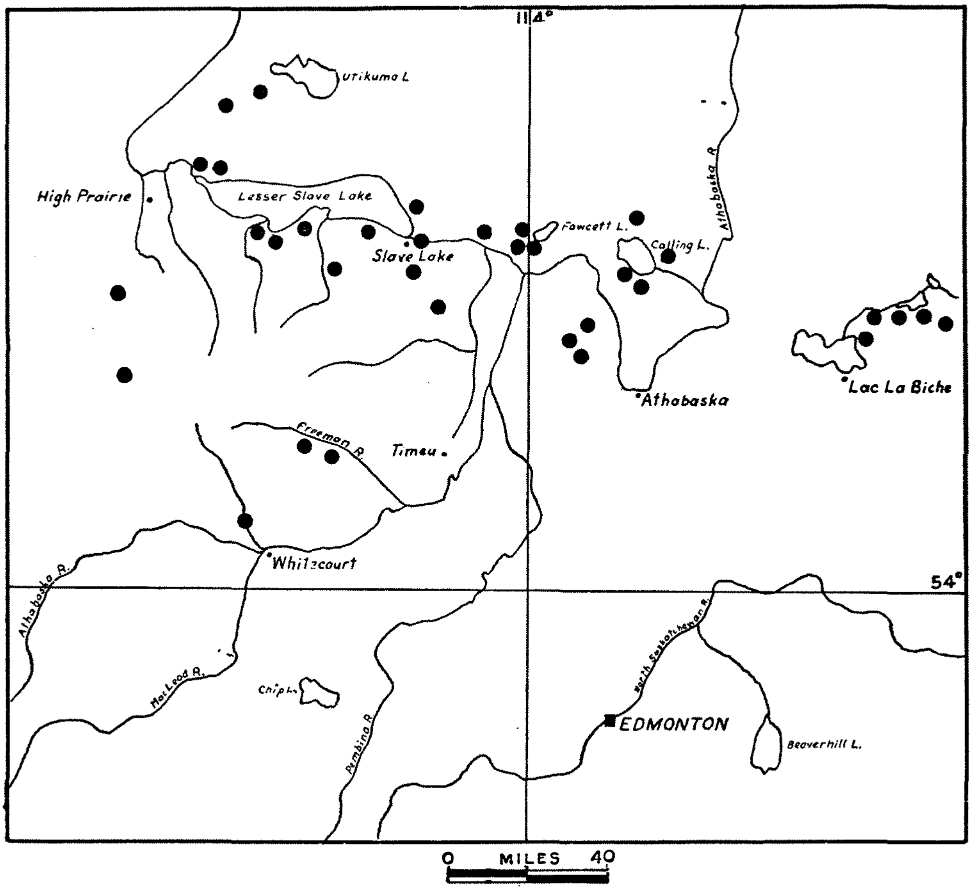

FIGURE 1.—Sample area: each dot marks the location of one or more sample plots.

Plot boundaries were surveyed with a staff compass and surveyor's chain. The plots, however, were not of uniform size, as a minimum objective of 100 trees was required on each.

A tally was taken of all the trees on each plot in one-inch diameter classes by species. Sufficient height measurements were taken to prepare height-diameter curves for aspen and for spruce on each sample plot. The heights for aspen were used for black poplar except on the occasional plot where a noticeable difference in heights existed. On plots where tolerants other than spruce were present in appreciable numbers, separate height-diameter curves were drawn for each species; otherwise their heights were read from the spruce curve.

The age of the stand was determined with an increment borer from dominant, and highest co-dominant spruce trees. These borings were taken as close to the ground line as possible and the height above the ground line was recorded so that the apparent age could be adjusted to total age by adding the number of years required for a dominant seedling to grow to the height of the boring. (See Table 1.) Intermediate and suppressed spruce were also bored to make sure that the stand was even-aged. Age counts were also taken on dominant aspen.

On each sample plot the site index was determined from the height-age relationship of the dominant spruce.

TABLE 1.—CORRECTION IN YEARS APPLIED TO INCREMENT BORINGS TO OBTAIN TOTAL AGE FOR SPRUCE AND ASPEN

Distance from ground level to boring	Age correction for	
	Spruce	Aspen
(inches)	(years)	(years)
2	3	1
4	5	1
6	7	2
8	8	2
10	8	2
12	9	3
18	10	3
24	10	4
30	11	4
36	12	5
42	12	5
48	13	5
54	14	5

YIELD TABLES

Plot Rejection

Since spruce-poplar is the most important type in the Mixedwood Section, it was felt that yields should be developed, initially at least, for a species association as close to this type as possible. A rather severe selection was made, and in order to be included in the analysis, plots had to be composed of:

(1) Tolerant species—mainly white spruce with less than 25 per cent balsam fir and black spruce.

(2) Intolerant species—mainly aspen with less than 25 per cent birch and 50 per cent black poplar; no pine or larch to be present.

For any plot to be usable it had to be confirmed that a poplar overstory once existed.

Since variations in the spruce yield were likely to be large, particularly in the younger ages, a test of the uniformity of this component was required. The logarithm of number of trees was plotted over average diameter and a curve fitted. Plots were discarded for which the logarithm of the number of trees was more than twice the standard deviations from the average. As was anticipated, this meant the rejection of a considerable number of young plots, leaving 127 plots for final analysis.

Determination of Site Index

The height attained by the average dominant spruce at 80 years of age was used as the index of site quality for the entire stand. Figure 2, which shows the trend of average dominant height with age for the various site classes, was developed by the method of Osborne and Schumacher (24). This method employs the standard deviation, coefficient of variation, and standard unit concept to obtain the shape of a set of curves from one average curve.

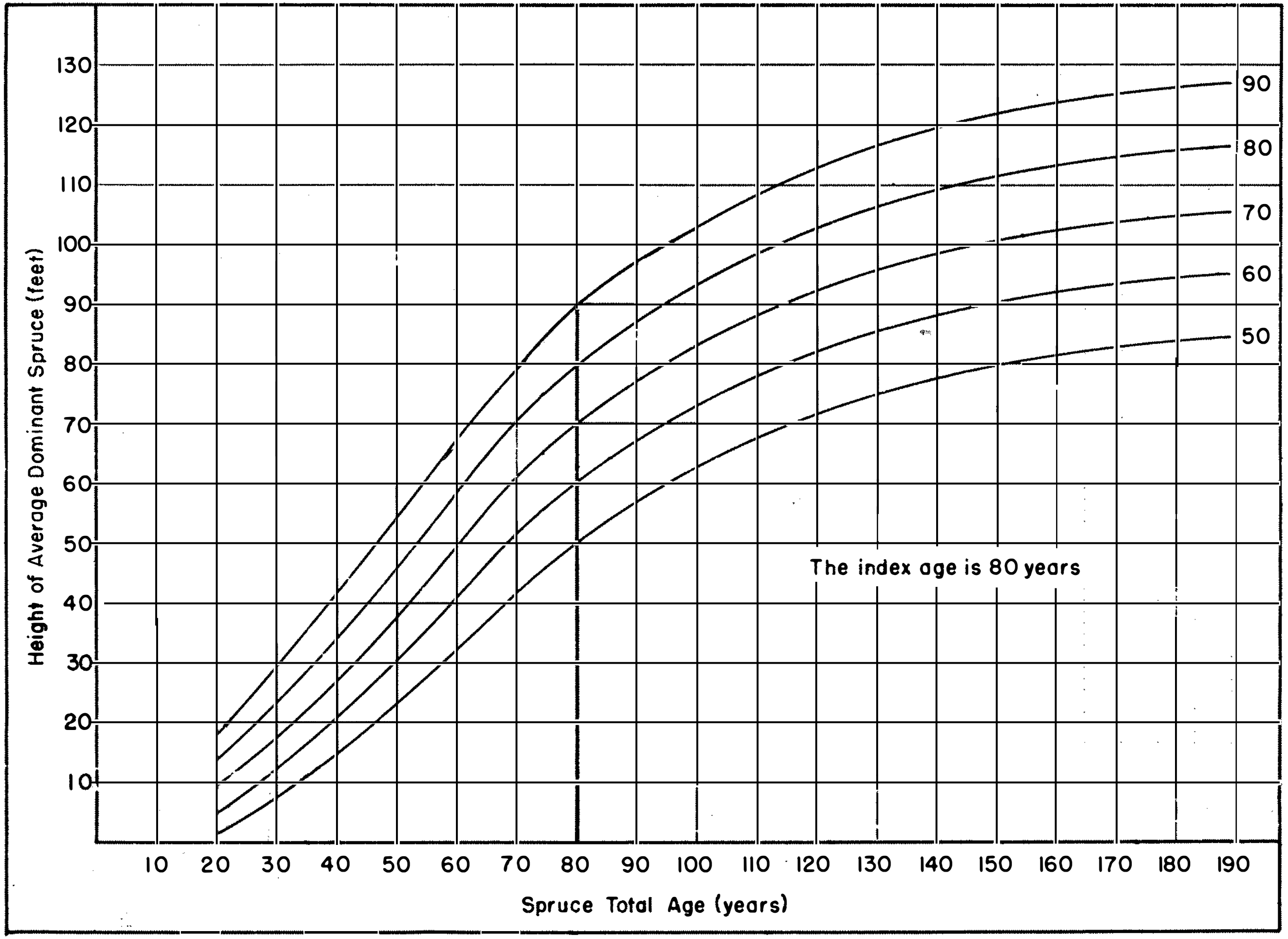

FIGURE 2.—Height of average dominant spruce, showing trend with age by site index classes.

For simplicity the following descriptive terms have been applied to each site index class:

Site Index Class—	Description
90	Excellent
80	Good
70	Medium
60	Fair
50	Poor

Determination of Plot Volumes

The height-diameter curves for each plot were used to construct plot local volume tables from the standard volume tables which are listed in Appendix I. In combination with the diameter tallies, these local tables were then used to calculate the volumes of the various species on each plot.

Construction of Yield Tables

For the tolerant (spruce) component, average curves were developed for basal area, number of trees, diameter of average tree, and total cubic volume, each plotted over age. For the intolerant (poplar) component, curves were developed for percentage composition of hardwoods, basal area, and the factor determining total volume by basal area, each plotted over spruce age.

These controlling average curves form the basic shapes, and the entire development of curves by site classes, followed the same method as previously described in the preparation of the site index curves. For extremes of sites and age-classes, the shape and direction of some portions of the curves are doubtful, although cross-checking with other values which were well defined offered a strong guide to where the curve should be drawn.

The data presented in the yield tables were read from the above-mentioned curves and all the curves are shown in Appendix II. The yield tables also give yields in merchantable cubic volume and board foot volume (Scribner Log Rule). These merchantable yields were obtained from the total cubic yields by the use of converting factors based on merchantable volume divided by total volume for each plot and curved over average diameter. Such curves are well defined and this method of volume conversion is standard procedure in yield table construction.

Yield Tables

The following yield tables are applicable to fully-stocked spruce-poplar stands. The tolerant or spruce portion of the stand is stressed, as both age and site index are based on the spruce; it is also the most important species from a utilization point of view.

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TABLE 2.—YIELD PER ACRE FOR FULLY STOCKED SPRUCE-ASPEN STANDS

POOR SITE—INDEX 50

Spruce, total age	Tolerant Softwoods, Mainly Spruce										Intolerant Hardwoods, Mainly Aspen			Entire Stand
	Height, average dominant	Number of trees	Average d.b.h.	Basal area	Volume inside bark						Basal area	Composition[3]	Volume to basal area factor[4]	Basal area
					Entire stem	Merch. stem[1]			Scribner rule[2]					
						4″+	4″−11″	12″+	7″+	12″+				
(years)	feet	no.	inches	sq. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	bd. ft.	bd. ft.	sq. ft.	%	units	sq. ft.
30	7	1,286	0·6	2	0	0	0	0	0	0	95	99	16·7	96
40	14	1,742	1·3	16	115	0	0	0	0	0	106	87	19·9	122
50	23	1,787	1·7	30	275	0	0	0	0	0	111	79	22·6	141
60	32	1,505	2·3	44	525	40	40	0	0	0	112	72	25·0	156
70	41	1,164	3·0	56	825	185	175	10	170	0	111	66	27·1	167
80	50	851	3·8	66	1,180	510	485	25	790	40	108	62	28·7	174
90	57	623	4·7	75	1,560	1,000	945	55	1,940	250	104	58	30·1	179
100	63	477	5·7	83	1,950	1,480	1,345	135	3,700	680	98	54	31·3	181
110	67	384	6·6	89	2,285	1,870	1,540	330	5,680	1,450	89	50	32·3	178
120	71	326	7·3	94	2,620	2,235	1,630	605	7,470	2,510	78	45	33·2	172
130	75	287	7·9	98	2,925	2,565	1,645	920	9,140	3,780	64	39	34·0	162
140	78	261	8·4	101	3,180	2,835	1,620	1,215	10,580	5,100	50	33	34·7	151
150	80	242	8·8	103	3,400	3,050	1,570	1,480	11,810	6,300	35	25	35·3	138

[1] 1-foot stump, 4-inch top inside bark
[2] 1-foot stump, 6-inch top inside bark
[3] hardwood composition by basal area
[4] × basal area=total cubic volume

TABLE 3.—YIELD PER ACRE FOR FULLY STOCKED SPRUCE-ASPEN STANDS

FAIR SITE—INDEX 60

Spruce, total age	Tolerant Softwoods, Mainly Spruce										Intolerant Hardwoods, Mainly Aspen			Entire Stand
	Height, average dominant	Number of trees	Average d.b.h	Basal area	Volume inside bark						Basal area	Composition[3]	Volume to basal area factor[4]	Basal area
					Entire stem	Merch. stem[1]			Scribner rule[2]					
						4 +	4″–11″	12″+	7′+	12″+				
(years)	feet	no.	inches	sq. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	bd. ft.	bd. ft.	sq. ft.	%	units	sq. ft.
30	12	1,220	1·1	8	45	0	0	0	0	0	93	92	16·7	101
40	21	1,619	1·7	27	235	0	0	0	0	0	102	79	19·9	129
50	30	1,637	2·3	47	535	40	40	0	0	0	104	69	22·6	151
60	40	1,364	2·9	63	920	185	175	10	140	0	104	62	25·0	167
70	51	1,057	3·7	77	1,385	570	540	30	840	40	102	57	27·1	179
80	60	781	4·5	87	1,845	1,120	1,060	60	2,040	240	99	53	28·7	186
90	67	576	5·5	95	2,270	1,680	1,545	135	4,090	730	95	50	30·1	190
100	73	443	6·5	102	2,695	2,195	1,830	365	6,540	1,620	90	47	31·3	192
110	77	358	7·4	108	3,080	2,640	1,885	755	8,930	3,110	82	43	32·3	190
120	81	306	8·2	112	3,445	3,055	1,835	1,220	11,200	5,090	71	38	33·2	184
130	85	270	8·9	117	3,775	3,395	1,695	1,700	13,260	7,370	60	34	34·0	177
140	88	247	9·4	120	4,045	3,675	1,580	2,095	14,880	9,360	47	28	34·7	167
150	91	230	9·8	122	4,300	3,930	1,475	2,455	16,210	10,950	34	22	35·3	156

[1] 1-foot stump, 4-inch top inside bark
[2] 1-foot stump, 6-inch top inside bark
[3] hardwood composition by basal area
[4] × basal area = total cubic volume

TABLE 4.—YIELD PER ACRE FOR FULLY STOCKED SPRUCE-ASPEN STANDS

MEDIUM SITE—INDEX 70

Spruce, total age	Tolerant Softwoods, Mainly Spruce										Intolerant Hardwoods, Mainly Aspen			Entire Stand
	Height, average dominant	Number of trees	Average d.b.h.	Basal area	Volume inside bark						Basal area	Composition[3]	Volume to basal area factor[4]	Basal area
					Entire stem	Merch. stem[1]			Scribner rule[2]					
						4"+	4"−11"	12"+	7"+	12 +				
(years)	feet	no.	inches	sq. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	bd. ft.	bd. ft.	sq. ft.	%	units	sq. ft.
30	17	1,154	1·4	13	95	0	0	0	0	0	91	87	16·7	104
40	27	1,496	2·2	39	405	25	25	0	0	0	95	71	19·9	134
50	37	1,487	2·8	64	890	160	150	10	90	0	94	59	22·6	158
60	49	1,224	3·6	83	1,445	555	525	30	790	20	94	53	25·0	177
70	60	951	4·3	97	2,030	1,145	1,085	60	1,980	200	92	49	27·1	189
80	70	710	5·2	107	2,615	1,850	1,735	115	4,170	670	90	46	28·7	197
90	77	529	6·3	116	3,145	2,530	2,165	365	7,270	1,690	86	42	30·1	202
100	83	408	7·4	123	3,625	3,110	2,220	890	10,510	3,660	80	39	31·3	203
110	88	332	8·4	128	4,050	3,600	2,060	1,540	13,480	6,480	73	36	32·3	201
120	92	284	9·3	133	4,425	4,010	1,780	2,230	16,120	9,850	64	32	33·2	197
130	95	254	9·9	137	4,740	4,330	1,570	2,760	18,120	12,800	54	28	34·0	191
140	98	233	10·5	140	4,990	4,595	1,310	3,285	19,850	15,400	43	23	34·7	183
150	101	219	10·9	142	5,210	4,820	1,155	3,665	21,100	17,300	31	18	35·3	173

[1] 1-foot stump, 4-inch top inside bark
[2] 1-foot stump, 6-inch top inside bark
[3] hardwood composition by basal area
[4] × basal area = total cubic volume

TABLE 5.—YIELD PER ACRE FOR FULLY STOCKED SPRUCE-ASPEN STANDS

GOOD SITE—INDEX 80

Spruce, total age	Tolerant Softwoods, Mainly Spruce										Intolerant Hardwoods, Mainly Aspen			Entire Stand
	Height, average dominant	Number of trees	Average d.b.h.	Basal area	Volume inside bark						Basal area	Composition[3]	Volume to basal area factor[4]	Basal area
					Entire stem	Merch. stem[1]			Scribner rule[2]					
						4″+	4″−11″	12″+	7″+	12″+				
(years)	feet	no.	inches	sq. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	bd. ft.	bd. ft.	sq. ft.	%	units	sq. ft.
30	23	1,091	1·6	16	155	0	0	0	0	0	88	83	16·7	104
40	34	1,379	2·5	49	620	75	70	5	0	0	88	64	19·9	137
50	45	1,344	3·3	79	1,280	390	370	20	480	0	85	52	22·6	164
60	58	1,091	4·1	100	2,010	1,050	995	55	1,710	150	82	45	25·0	182
70	70	845	5·0	114	2,740	1,870	1,765	105	3,980	600	79	41	27·1	193
80	80	643	6·0	125	3,445	2,695	2,385	310	7,340	1,540	76	38	28·7	201
90	87	484	7·1	133	4,060	3,435	2,600	835	11,140	3,490	71	35	30·1	204
100	93	376	8·3	140	4,565	4,040	2,395	1,645	15,000	7,020	66	32	31·3	206
110	98	307	9·3	145	4,995	4,525	2,005	2,520	18,200	11,180	60	29	32·3	205
120	102	264	10·2	150	5,370	4,920	1,595	3,325	21,000	15,590	53	26	33·2	203
130	106	238	10·9	153	5,680	5,255	1,260	3,995	23,070	18,980	45	23	34·0	198
140	109	220	11·4	156	5,945	5,520	1,060	4,460	24,710	21,320	36	19	34·7	192
150	112	208	11·8	158	6,165	5,750	940	4,810	25,970	23,060	26	14	35·3	184

[1] 1-foot stump, 4-inch top inside bark

[2] 1-foot stump, 6-inch top inside bark

[3] hardwood composition by basal area

[4] × basal area=total cubic volume

TABLE 6.—YIELD PER ACRE FOR FULLY STOCKED SPRUCE-ASPEN STANDS

EXCELLENT SITE—INDEX 90

Spruce, total age	Tolerant Softwoods, Mainly Spruce										Intolerant Hardwoods, Mainly Aspen			Entire Stand
	Height, average dominant	Number of trees	Average d.b.h.	Basal area	Volume inside bark						Basal area	Composition[3]	Volume to basal area factor[4]	Basal area
					Entire stem	Merch. stem[1]			Scribner rule[2]					
						4″+	4″−11″	12″+	7″+	12″+				
(years)	feet	no.	inches	sq. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	bd. ft.	bd. ft.	sq. ft.	%	units	sq. ft.
30	29	1,038	2·0	23	255	5	5	0	0	0	82	78	16·7	105
40	42	1,281	2·9	59	880	180	170	10	130	0	79	57	19·9	138
50	54	1,224	3·7	92	1,710	705	665	40	1,040	50	74	45	22·6	166
60	67	978	4·7	114	2,570	1,650	1,560	90	3,100	420	70	38	25·0	184
70	79	764	5·6	129	3,445	2,580	2,360	220	6,300	1,190	66	34	27·1	195
80	90	587	6·6	140	4,265	3,495	2,875	620	10,590	2,780	62	31	28·7	202
90	97	446	7·8	149	4,950	4,315	2,835	1,480	15,260	6,090	57	28	30·1	206
100	103	349	9·0	155	5,490	4,950	2,405	2,545	19,480	11,110	53	25	31·3	208
110	108	286	10·2	161	5,925	5,425	1,760	3,665	23,110	17,200	47	22	32·3	208
120	112	247	11·2	166	6,305	5,840	1,225	4,615	25,980	21,800	41	20	33·2	207
130	116	224	11·8	170	6,615	6,175	1,005	5,170	27,880	24,750	34	17	34·0	204
140	120	209	12·4	173	6,870	6,445	785	5,660	29,480	26,900	27	13	34·7	200
150	122	200	12·8	175	7,085	6,670	645	6,025	30,700	28,540	19	10	35·3	194

[1] 1-foot stump, 4-inch top inside bark

[2] 1-foot stump, 6-inch top inside bark

[3] hardwood composition by basal area

[4] × basal area = total cubic volume

Correction for Stocking

Duerr and Gevorkiantz (9) have suggested a method of obtaining growth curves for degrees of stocking above or below the average by means of the proper use of the coefficient of variation and age. For the tolerant portion of each plot, volume differences were determined between actual and tabular values, as estimated from age and site. The standard deviation was then computed for each age-class and expressed as a percentage of the volume for the average age and site index of the class. These percentages or coefficients of variation were then plotted over age. (See Figure 10 in Appendix II. Table 7 is a tabular presentation of Figure 10.)

TABLE 7

TABLE 7.—COEFFICIENT OF VARIATION OF VOLUME, THE EFFECT OF SITE BEING REMOVED

Spruce Total Age	Coefficient of Variation
(years)	(per cent)
50	48·8
60	43·1
70	39·6
80	37·1
90	35·3
100	33·9
110	32·5
120	31·1
130	29·7
140	28·3
150	26·9

The coefficient of variation decreases with age even though the method of developing volumes for each site class was designed to take into account the original variation of volume with advancing age. The degree of stocking of the spruce is the only variable to which this trend can be readily attributed. It suggests that volumes above and below the average do not respond according to any fixed percentage with respect to the yield values.

As the entire spruce portion of a stand does not reach measurable size until 40 to 50 years of age (See Figure 3 in Appendix II), to obtain corrections for stocking, the data in Table 7 is concerned only with stands 50 years of age and older.

If the stocking of the tolerant portion of the stand varies from normal, the following example illustrates how the coefficient of variation is used to make an adjustment in yield. The stocking of a stand (s) is defined as the actual total cubic volume divided by its normal yield table volume. Considering a 60-year-old stand whose stocking is (s), then the difference from normal stocking is $(1-s)$. At 60 years of age, from Table 7, this difference is associated with a coefficient of variation of 43·1 per cent. At 70 years of age the coefficient of variation is 39·6 per cent. At 70 years, therefore, the stocking difference from normal is $(1-s)\frac{39\cdot6}{43\cdot1}$. The stocking at 70 years is, therefore, $1-(1-s)\frac{39\cdot6}{43\cdot1}$, or as expressed in formula form:

$$S = 1-(1-s)\frac{CV_2}{CV_1}$$

where (S) is the future stocking, (s) is the present stocking, and (CV_1) and (CV_2) are the present and future coefficients of variation respectively.

APPLICATION OF YIELD TABLES

For any timber cruise to which the yield tables are to be applied, the diameter tallies should be grouped under the broad classifications of tolerant and intolerant species. In conjunction with the diameter tallies, height, age, and site determinations should be made at frequent and usually predetermined intervals. Heights, throughout the range of diameters of each species, should be measured using an instrument such as an Abney hand level in conjunction with a tape or chain. An ocular estimate of heights is unsatisfactory. Stand age should be determined by boring dominant spruce as close to ground line as possible, and the ring counts should be adjusted to total age according to Table 1. When age is determined, care should be taken to avoid veterans or relics of former stands. The occasional intermediate and suppressed spruce should be bored to determine if the stand is definitely even-aged. Additional borings should be taken when there appears to be a change in age-class in order to define stand boundaries. Site determination should be made by obtaining the height-age relationship of 6 to 10 dominant spruce. The average height and age is used to obtain the site index from Figure 2. The site determination should be made in the field, where with increasing experience site boundaries can be determined by eye and sketched on a map. River valleys, creek bottoms, side hills, and swamp margins are useful guides in mapping the extent of a particular site.

On the completion of the timber cruise enough data should be available to map completely the major age and site divisions. In each division the average total cubic volume per acre can be computed for each species and for the tolerant and intolerant components separately. The tolerant volume divided by the yield table volume for the same age and site index will give the stocking of the tolerant portion of the stand. The stocking at any future age can be determined from the previously derived stocking formula. Multiplying the tabular yields at the same future age by this new stocking value will give the tolerant yield to be expected at that age.

In general, the best spruce sites are also best for poplar, but sites for the two species may vary widely on the same area. Also, since the amount of rot and its advance with age is extremely variable and unpredictable, greater refinement of the growth prediction for the intolerant component than is described here was deemed unpractical.

Poplar growth may be estimated only in total cubic feet. The intolerant total cubic volume is first computed and then divided by the yield table intolerant volume for the same age, *but always for medium site.* This stocking figure is used to correct the basal area read from the table for any future age. Poplar basal areas may be converted to total cubic volume by applying the converting factors in the yield tables. If the poplar age is found to vary greatly from the spruce age (more than plus or minus 10 years) then its actual age in reading from the yield tables should be used.

The following is an example of the use of the yield tables:

EXAMPLE

Spruce Age is 84 years; site index is 70.

	Tolerant Species	Intolerant Species	Entire Stand
Actual Total Volume	2,290 cu. ft.	3,016 cu. ft.	5,306 cu. ft.
Yield Table Total Volume	2,827 cu. ft.	2,578 cu. ft. (88 x 29·3)	5,405 cu. ft.
Stocking	0·81	1·17	0·98

An estimate is desired of the spruce yield in basal area, total cubic volume and board foot volume for trees 7 inches d.b.h. plus, at an age of 140 years.

The spruce stocking value at 140 years is calculated from the formula:

$$S=1-(1-s)\frac{CV_2}{CV_1}$$

where S = stocking at 140 years

s = present stocking at 84 years

CV_1 = coefficient of variation at 84 years
CV_2 = coefficient of variation at 140 years
} from Table 7

Substituting in equation:

$$S=1-(1-\cdot 81)\frac{28\cdot 3}{36\cdot 4}$$

$$=1-\ \cdot 15$$

$$=0\cdot 85$$

	Tolerant Species	Intolerant Species	Entire Stand
YIELD TABLE VALUES AT 140 YEARS			
Basal Area	140 sq. ft.	43 sq. ft.	183 sq. ft.
Total Cubic Volume	4,990 cu. ft.	1,492 cu. ft. (43 x 34·7)	6,482 cu. ft.
Board Foot Volume 7″+	19, 850 bd. ft.		
YIELD VALUES AT 140 YEARS (yield table values multiplied by 0·85 for tolerants and 1·17 for intolerants)			
Basal Area	119 sq. ft.	50 sq. ft.	169 sq. ft.
Total Cubic Volume	4,241 cu. ft.	1,746 cu. ft.	5,987 cu. ft.
Board Foot Volume, 7″+	16,870 bd. ft.	—	—

These yields per acre can readily be applied to the total area by multiplying by the number of acres.

INCREMENT AND ROTATION

The mean and periodic annual increments per acre for the tolerant (spruce) component of fully-stocked spruce-poplar stands are given in Table 8.

TABLE 8.—MEAN AND PERIODIC ANNUAL INCREMENTS PER ACRE

in terms of
(1) Total cubic feet, all trees,
(2) Merchantable cubic feet, all trees 4″ d.b.h. plus,
(3) Board feet, Scribner rule, all trees 7″ d.b.h. plus,

(1) TOTAL CUBIC FEET

Site Index Class

Total Age (years)	50		60		70		80		90	
	m.a.i.	p.a.i.	m.a.i.	p.a.i.	m.a.i.	p.a.i.	m.a.i.	p.a.i.	m.a.i.	p.a.i.
30	0	5·0	1·5	12·5	3·2	19·0	5·2	31·5	8·5	47·5
40	2·9	14·0	5·9	24·0	10·1	41·0	15·5	57·5	22·0	73·0
50	5·5	20·5	10·7	35·0	17·8	53·0	25·6	71·5	34·2	87·0
60	8·7	27·5	15·3	43·0	24·1	57·0	33·5	72·5	42·8	86·5
70	11·8	32·5	19·8	46·5	29·0	59·5	39·1	72·5	49·2	86·5
80	14·8	37·0	23·1	44·0	32·7	56·5	43·1	66·5	53·3	76·0
90	17·3	39·0	25·2	43·5	34·9	50·0	45·1	55·5	55·0	60·5
100	19·5	37·0	26·9	40·5	36·2	45·5	45·6	46·5	54·9	48·0
110	20·8	33·5	28·0	38·0	36·8	40·0	45·4	41·0	53·9	41·0
120	21·8	31·0	28·7	35·0	36·9	34·5	44·7	34·0	52·5	34·5
130	22·5	28·0	29·0	29·0	36·5	28·5	43·7	28·5	50·9	28·5
140	22·7	24·5	28·9	26·0	35·6	23·0	42·5	23·5	49·1	23·0
150	22·7	....	28·7	....	34·7	....	41·1	....	47·2	....

(2) MERCHANTABLE CUBIC FEET

Site Index Class

Total Age (years)	50		60		70		80		90	
	m.a.i.	p.a.i.	m.a.i.	p.a.i.	m.a.i.	p.a.i.	m.a.i.	p.a.i.	m.a.i.	p.a.i.
30	0	0	0	0	0	0	0	0	0·2	5·0
40	0	0	0	0	0·6	7·5	1·9	17·5	4·5	33·5
50	0	1·0	0·8	9·0	3·2	24·5	7·8	48·5	14·1	79·0
60	0·7	9·5	3·1	25·0	9·2	51·0	17·5	77·5	27·5	91·5
70	2·6	22·0	8·1	49·0	16·4	66·0	26·7	84·0	36·9	98·5
80	6·4	42·0	14·0	56·0	23·1	71·0	33·7	78·0	43·7	86·0
90	11·1	50·0	18·7	54·5	28·1	63·0	38·2	68·5	48·0	72·5
100	14·8	43·0	22·0	48·5	31·1	54·0	40·4	54·5	49·5	55·0
110	17·0	39·5	24·0	42·5	32·7	45·0	41·1	44·0	49·3	44·5
120	18·6	33·0	25·5	38·0	33·4	35·5	41·0	36·5	48·6	36·5
130	19·7	29·5	26·1	31·0	33·3	29·5	40·4	29·0	47·5	30·5
140	20·2	24·5	26·2	25·5	32·8	24·0	39·4	24·0	46·0	23·0
150	20·3	....	26·2	....	32·1	....	38·3	....	44·5	....

(3) Board Feet, Scribner Rule

Site Index Class

Total Age (years)	50		60		70		80		90	
	m.a.i.	p.a.i.	m.a.i.	p.a.i.	m.a.i.	p.a.i.	m.a.i.	p.a.i.	m.a.i.	p.a.i.
30	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	3	45
50	0	0	0	0	2	37	10	86	21	151
60	0	4	2	43	13	89	28	170	52	260
70	2	39	12	94	28	169	57	288	90	385
80	10	82	26	161	52	265	92	356	132	455
90	22	155	45	232	81	330	124	400	169	447
100	37	185	65	250	105	310	150	349	195	391
110	52	198	81	227	123	292	165	307	210	327
120	62	169	93	224	134	221	175	243	216	239
130	70	159	102	182	139	188	177	185	214	175
140	76	129	106	144	142	150	176	139	211	136
150	79	....	108	....	141	....	173	....	205	....

A stand cut at the age where the periodic annual increment and the mean annual increment are the same will yield the maximum volume return per year of growth. This is the same age at which the mean annual increment culminates. Rotation ages computed on this basis for various products growing on the different sites are shown in Table 9. Rate of growth for different products is, however, only one of a number of factors which must be considered in fixing the rotation age. The financial return and the silvicultural features of the forest must also be considered.

TABLE 9.—ROTATION AGE BY SITE INDEX CLASSES FOR MAXIMUM PRODUCTION OF VARIOUS PRODUCTS

(Age to the nearest 5th year)

When Product Desired and Part of Stand is:	Site Index Classes				
	50	60	70	80	90
	Rotation Age in Years				
Total cubic feet, entire stand	....	....	75	....	....
Total cubic feet, poplar portion of stand	....	....	30	....	....
Total cubic feet, spruce portion of stand	145	130	115	100	95
Merchantable cubic feet, spruce portion, trees 4" plus	(150)	140	125	115	105
Board feet, Scribner rule, spruce portion, trees 7" plus	(170)	(160)	140	130	125
Board feet, Scribner rule, spruce portion, trees 12" plus	....	(165)	(160)	(150)	135

Bracketed figures are extrapolated.

The 75-year rotation indicated for a fully-stocked mixedwood stand is more a matter of interest than of importance as the values of spruce and poplar lumber show a very wide spread. The rotation age of 30 years for the poplar is misleading as this age is obtained from borings made on spruce trees which on the average are somewhat younger than the poplar; so that from a poplar age standpoint, a rotation age of 40 years would be more appropriate. The lengthy rotation ages for spruce are somewhat discouraging especially from a management viewpoint. They do not, of course, preclude intermediate cuttings aimed at stand improvement. If, however, an intermediate cut results in almost complete removal of the stand, then considerable economic loss can be expected if the cutting is permitted at too early an age.

DISCUSSION

The field and office methods used in this study are essentially those outlined by Bruce and Schumacher (5). All the plots were established where the spruce was even-aged and the stands, as a whole, were judged to be fully stocked. That full stocking *can* be determined is confirmed by the basal area data. The total basal area on average and better sites between the ages of 80 and 130 years is consistently near 200 square feet per acre. This is true even though the average diameter varies from 6 to 12 inches. From 60 to 80 years full stocking is still easily recognizable; below 60 years, however, full stocking is not so apparent because of the two-storied appearance of the stand and also because many of the spruce are not of measurable size. To overcome the difficulty in selecting fully-stocked young stands a larger sample was measured. As the range of conditions in young stands is very great, it was essential in selecting a plot that the young spruce were evenly distributed beneath the poplar. The averages of such data were considered as representative of the older stands at this younger age.

The averages of spruce volume for each age-class showed considerable variance from one age to another, but the general volume trend throughout the range of ages was reasonably well defined. A comparison of actual and tabular spruce volumes on the basis of age gave a correlation index of 0·845; a comparison on the basis of age and site index increased the correlation index to 0·883.

The yield tables which have been prepared are applicable only to fully-stocked stands. Adjustments in yield can be made when the stocking of either the tolerant or intolerant components varies from normal, but when the stocking of the entire stand is above or below normal the problem of adjusting yield remains to be solved by future studies.

SUMMARY

Yield tables were prepared from data collected on 127 temporary sample plots established in spruce-poplar stands in the Mixedwood Section of the Boreal Forest Region of Alberta. These tables show yields for the tolerant (spruce) and intolerant (poplar) components of the stand by site index and age-classes, and as presented here are for fully-stocked stands. To predict yields for spruce when the stocking of that species is not normal, an adjustment is made based on the degree of stocking and the coefficients of variation at present and future ages. To predict future yields for poplar when the stocking varies from normal, an adjustment is made on the basis of the present degree of stocking.

The tables were necessarily complicated in their construction by the presence of two components, spruce and poplar, whose growth characteristics are so different; throughout, however, the spruce component is emphasized. Both stand age and site index were determined from the spruce, even though the poplar age and site may vary slightly. The spruce component is emphasized because this species is the most important economically, and is moreover the only one at present being utilized.

APPENDIX I—VOLUME TABLES

The volume tables used for each species are listed in Table 10. With the exception of those for aspen and black poplar, all the tables have been previously published. The aspen tables and their correction for application to black poplar were prepared as part of this yield table and are published herein. (See Tables 11 and 12.)

TABLE 10.

Species Common Name	Species Scientific Name	Source of Volume Table Employed
White spruce	*Picea glauca* (Moench Voss)	Blyth, A. W. 1952. White Spruce Standard Volume Tables for the Boreal and Sub-Alpine Regions of Alberta. Dept. Resources and Development, Forestry Branch, Silv. Leaf. No. 60.
Black spruce	*Picea mariana* (Mill.) B.S.P.	Same as for white spruce.
Balsam fir	*Abies balsamea* (L.) Mill	Dom. Form-Class Volume Tables, 1948, Form-class 65.
Lodgepole pine	*Pinus contorta* Dougl. var. *latifolia* Engelm.	Dom. Form-Class Volume Tables, 1948, Form-class 65.
Jack pine	*Pinus banksiana* Lamb	Dom. Form-Class Volume Tables, 1948, Form-class 70.
Larch	*Larix laricina* (Du Roi) K. Koch	University of Minnesota, Tech. Bulletin No. 39, 1934. Table No. 139.
Aspen poplar	*Populus tremuloides* Michx	See this publication.
Black poplar	*Populus balsamifera* L.	See this publication.
Birch	*Betula papyrifera* Marsh	Dom. Form-Class Volume Tables, 1948, Table No. 182.
Alder	*Alnus tenuifolia* Nutt	Same as for black poplar.

TABLE 11.—TOTAL CUBIC VOLUME[1] FOR ASPEN (POPULUS TREMULOIDES MICHX.) AND BLACK POPLAR (POPULUS BALSAMIFERA L.)[2] IN THE BOREAL FOREST REGION OF ALBERTA

Cubic Feet

Diameter Breast Height	Total Height of Tree in Feet: 10	20	30	40	50	60	70	80	90	100	110	Number of Trees
	Total Volume (Stump and top included)											
1	0·04	0·06	0·07									2
2	0·13	0·21	0·29	0·37	0·45							4
3	0·28	0·47	0·66	0·85	1·04							9
4		0·85	1·19	1·53	1·87	2·21						13
5		1·36	1·90	2·44	2·98	3·52						13
6			2·75	3·55	4·35	5·15	5·95					6
7				4·86	5·97	7·09	8·20	9·31				9
8				6·38	7·84	9·30	10·76	12·22	13·7			10
9				8·10	10·00	11·8	13·6	15·5	17·3			5
10					12·3	14·5	16·7	18·9	21·1			6
11					14·8	17·4	20·0	22·6	25·2			8
12					17·5	20·5	23·6	26·7	29·8	32·9		5
13					20·4	24·0	27·6	31·2	34·8	38·4		7
14					23·5	27·8	31·9	36·0	40·1	44·2		8
15					26·9	31·6	36·3	41·1	45·8	50·5		7
16					30·3	35·6	40·9	46·3	51·6	56·9	62·2	11
17						40·1	46·1	52·2	58·2	64·2	70·2	11
18						44·6	51·3	58·1	64·8	71·5	78·2	8
19						49·5	56·9	64·4	71·9	79·3	86·7	5
20						54·7	62·9	71·0	79·2	87·3	95·5	4
21							68·8	77·6	86·5	95·3	104·2	6
22							74·7	84·2	93·8	103·3	112·9	4
23								90·8	101·1	111·3	121·6	1
24								97·4	108·4	119·3	130·3	—
25								104·0	115·7	127·3	139·0	2
26								110·6	123·0	135·3	147·7	1
27								117·2	130·3	143·3	156·4	—

[1] Table prepared by adjusting aspen volume table, page 196, Dominion Form-Class Volume Tables, 1948.
[2] For black poplar multiply tabular volumes by 0·842; basis, 46 trees.
Heavy line indicates range of basic data.

Aspen: Aggregate difference = Table 0·267 per cent high
Average deviation = ± 6·15 per cent

Black poplar: Aggregate difference = Table 0·023 per cent low
Average deviation = ± 6·09 per cent

TABLE 12.—MERCHANTABLE CUBIC VOLUME[1] FOR ASPEN (POPULUS TREMULOIDES MICHX.) AND BLACK POPLAR (POPULUS BALSAMIFERA L.) IN THE BOREAL FOREST REGION OF ALBERTA

Scribner Log Rule

Diameter Breast Height	Total Height of Tree in Feet							Number of Trees
	50	60	70	80	90	100	110	
	Merchantable Volume (Stump height 1·0 feet; Top diameter 6 inches I.B. Log length 16·3 feet)							
7	2	4	7	9				3
8	11	16	21	26	31			9
9	21	29	37	45	53			5
10	32	43	54	66	77			6
11	42	57	71	86	100			8
12		72	91	109	128			5
13		88	111	134	157	180		7
14		104	133	163	192	221		8
15		120	156	191	226	262		7
16		136	178	219	261	302		11
17		152	200	248	295	342	390	11
18		169	223	277	330	384	438	8
19		185	245	305	365	424	484	5
20		201	267	333	399	465	531	4
21			290	362	434	506	578	6
22			312	390	468	546	624	4
23				419	503	588	672	1
24				447	538	628	718	—
25				476	572	669	765	2
26				504	606	709	812	1
27					641	750	858	—
28						791	906	—

[1] Table prepared by multi-curvilinear methods.
[2] For black poplar multiply tabular volumes by 0·787; basis, 46 trees.
Heavy line indicates range of basic data.

Aspen: Aggregate difference = Table 0·126 per cent high
Average deviation = ± 12·65 per cent

Black poplar: Aggregate difference = Table 0·029 per cent low
Average deviation = ± 14·84 per cent

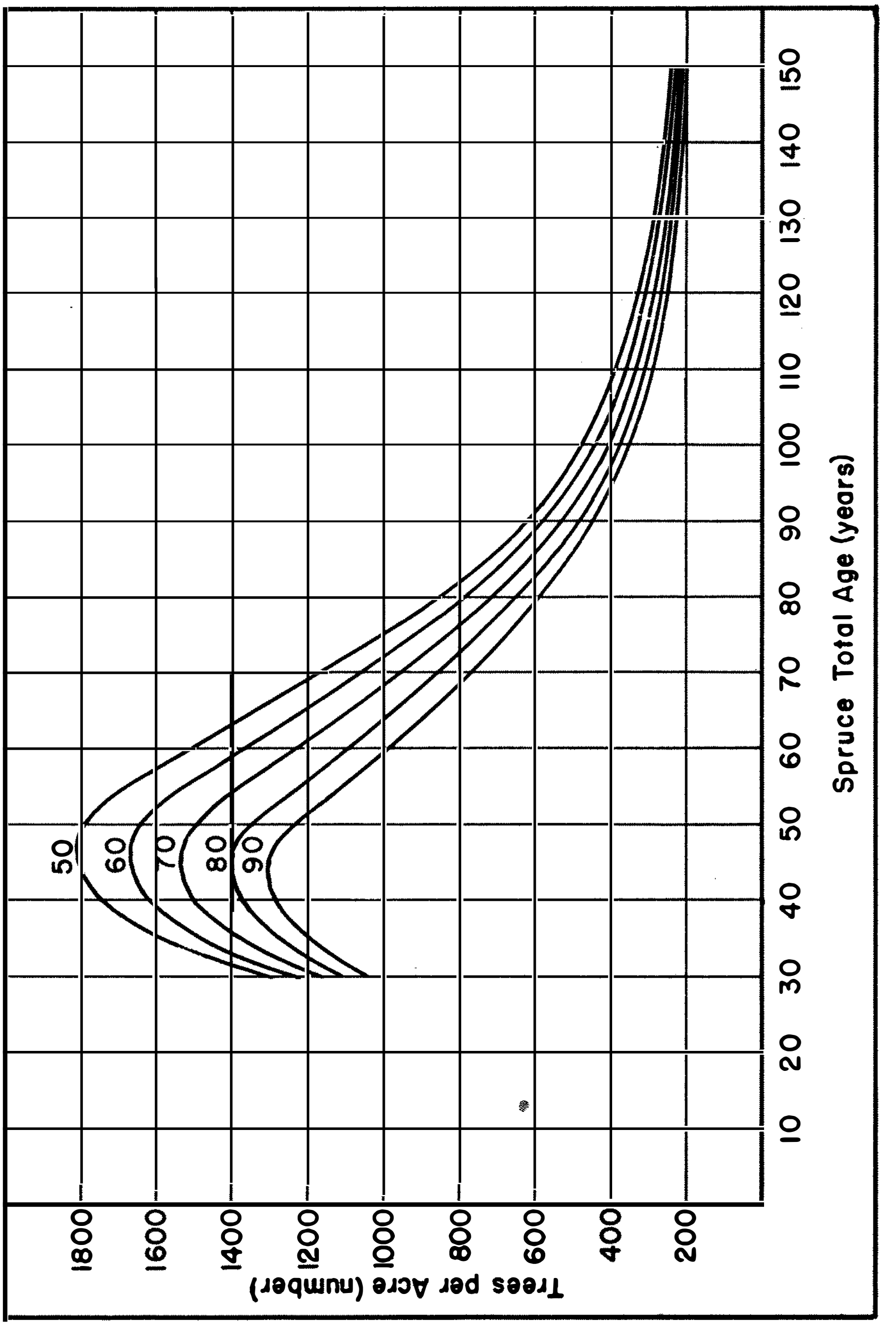

FIGURE 3.—Number of tolerant trees per acre (over 0·6" d.b.h.) showing trend with age by site index classes.

Figure 3 shows that there is a rapid increase in number of trees per acre between 30 and 45 years. This increase results from ingrowth and the number of measurable trees increases by almost one-third in 15 years. The highest mortality occurs between 50 and 70 years. This is confirmed by the large number of standing dead trees on the plots sampled in this age group.

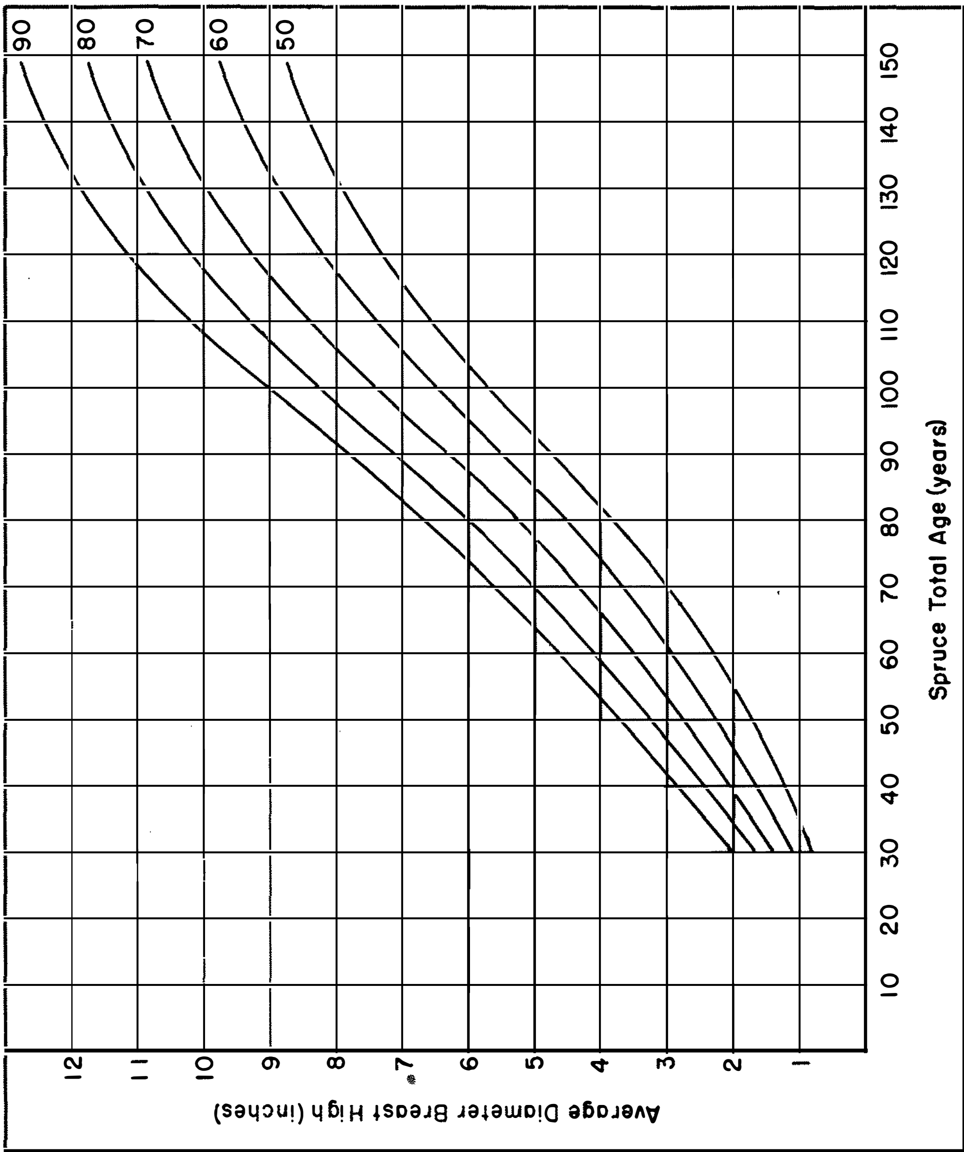

FIGURE 4.—Average diameter of tolerant portion, showing trend with age by site index classes.

From Figure 4 it is seen that even in the older stands the average diameter of the spruce trees is small. On medium sites at an age of 130 years the average diameter is only 10 inches and average growth per decade has been 0·8 inch.

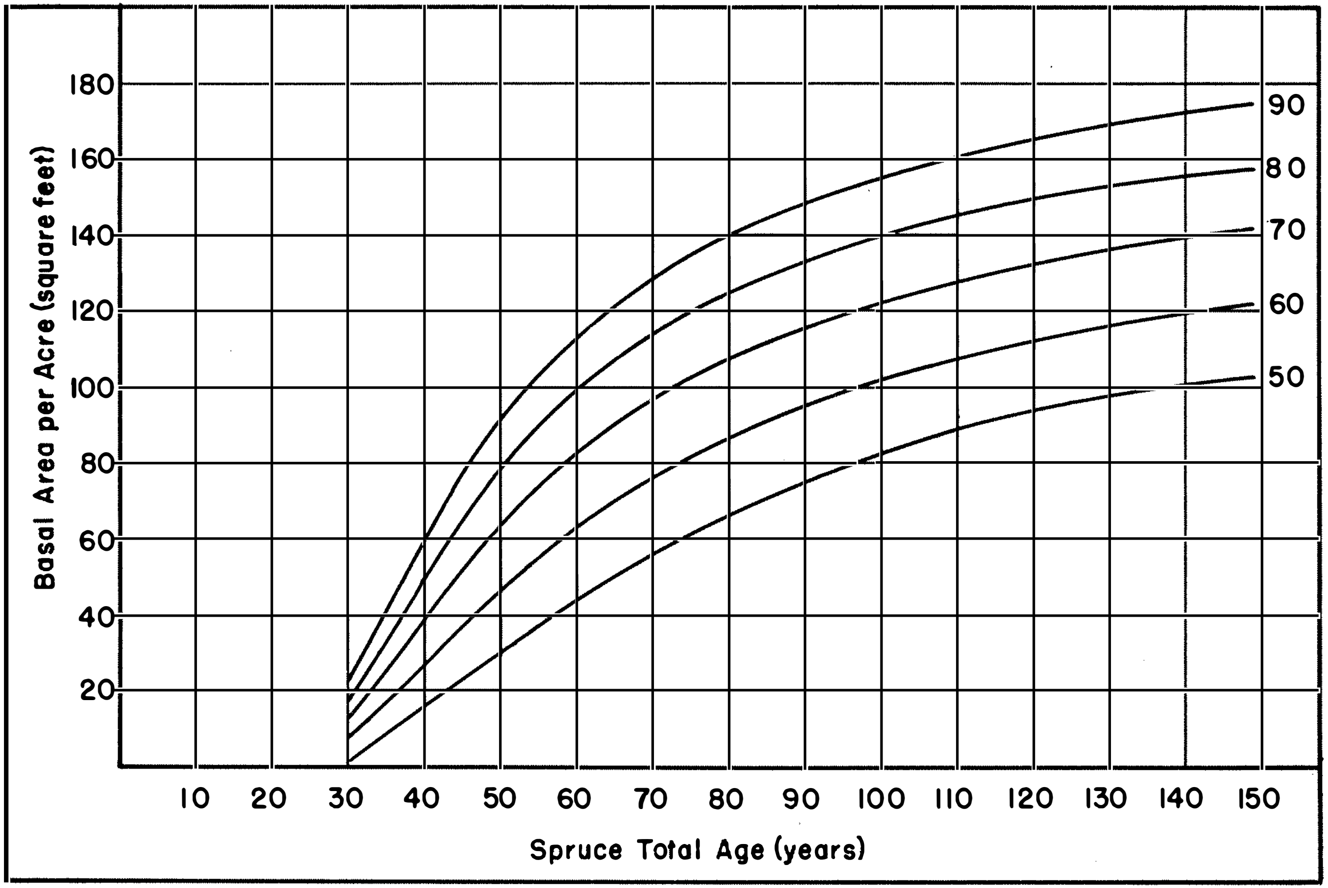

FIGURE 5.—Basal area per acre for tolerant portion, showing trend with age by site index classes.

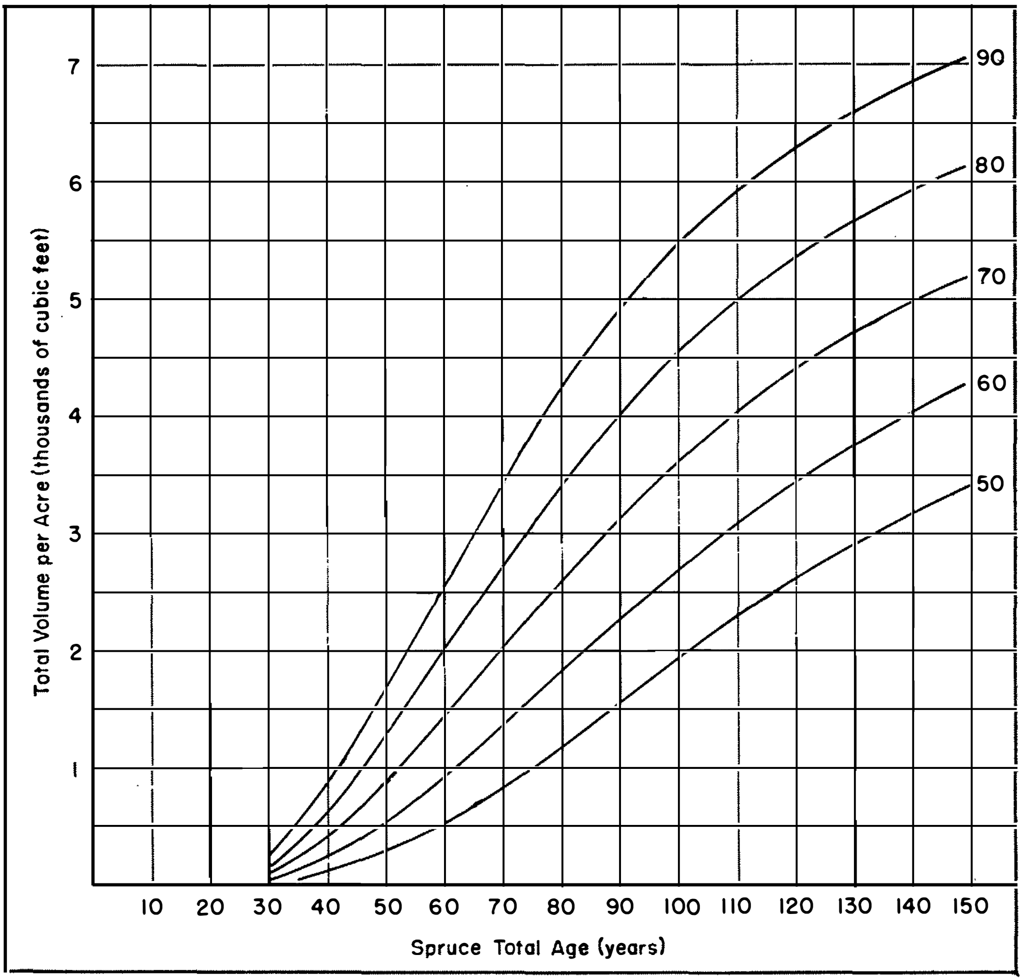

FIGURE 6.—Total volume per acre in cubic feet for tolerant portion, showing trend with age by site index classes.

Though the cubic foot volumes shown in Figure 6 are not large it must be kept in mind that there is poplar associated with the spruce at any age and on any site.

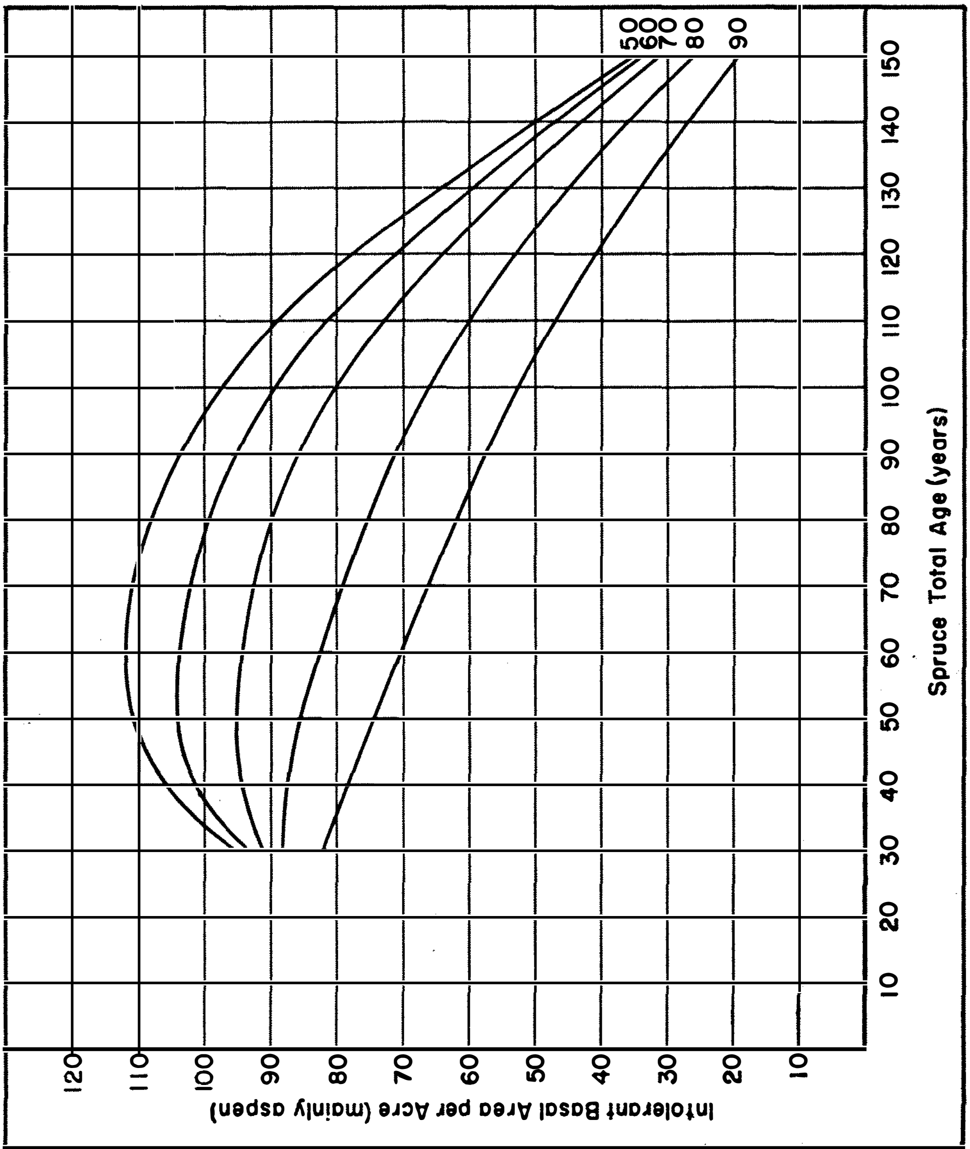

FIGURE 7.—Basal area per acre for intolerant portion, showing trend with age by site index classes.

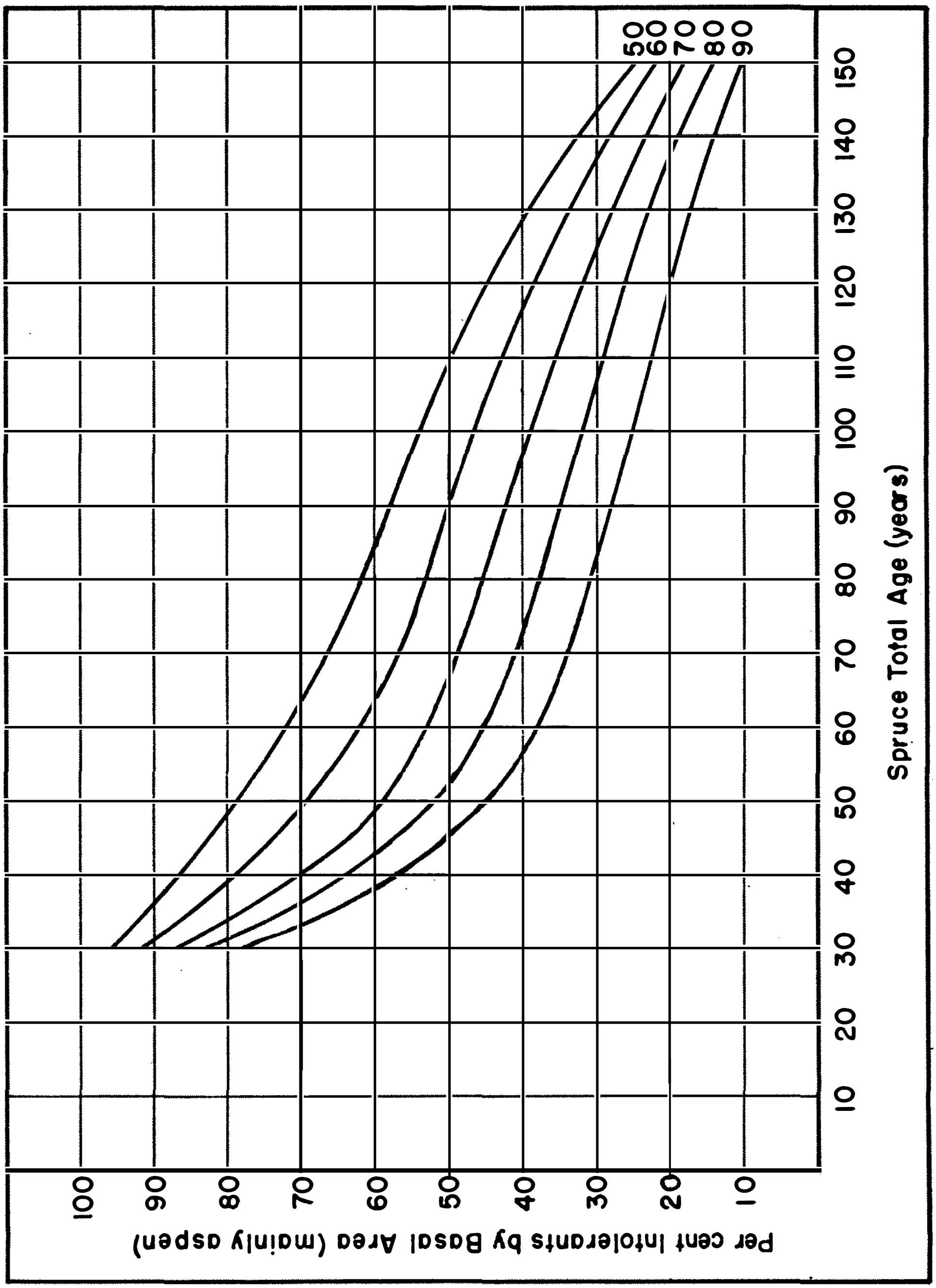

FIGURE 8.—Per cent composition by basal area for intolerant portion, showing trend with age by site index classes.

The steepness of the curves in Figure 8 between the ages of 30 and 50 years is dependent on the large number of spruce which suddenly become of measurable size and thus greatly decrease the ratio of intolerant to tolerant basal area.

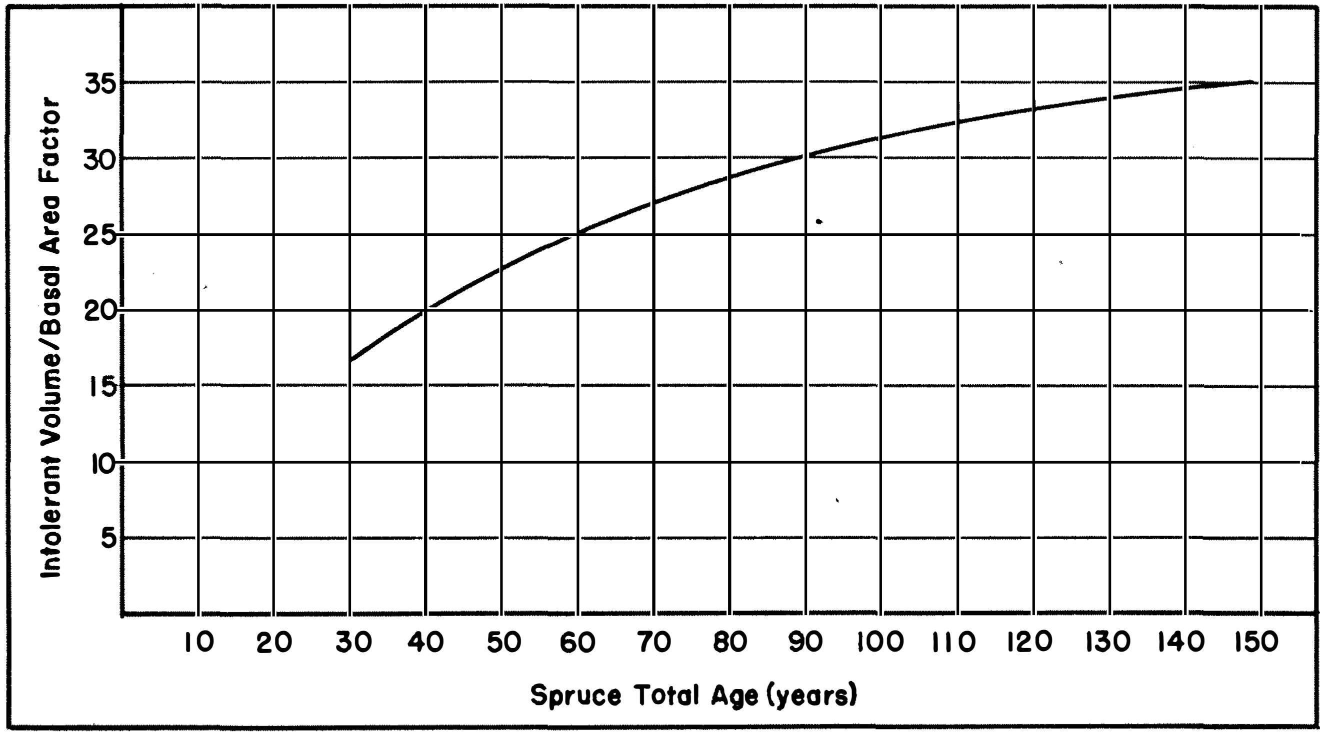

FIGURE 9.—The ratio of intolerant total cubic volume to intolerant basal area, showing trend with age.

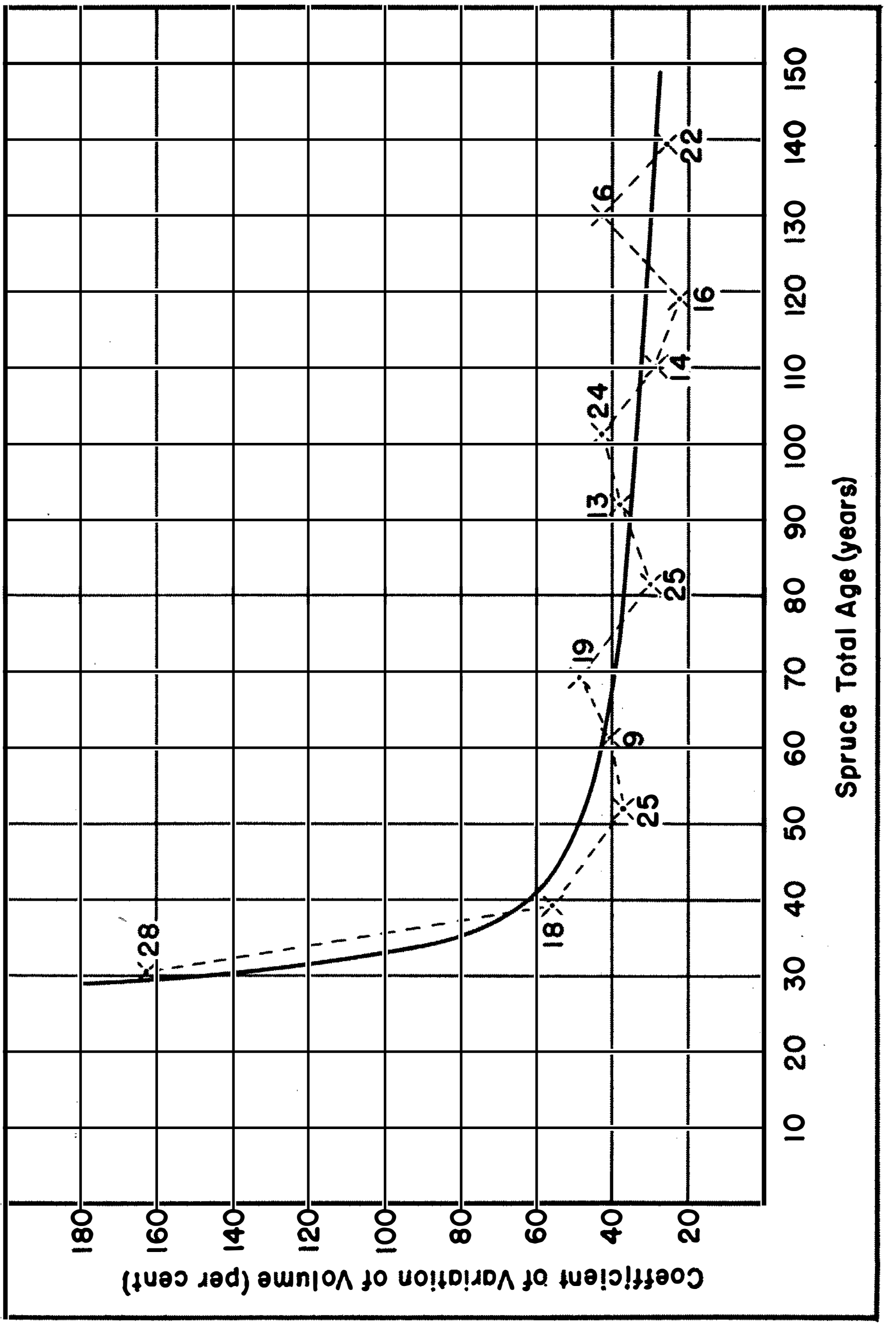

FIGURE 10.—The coefficient of variation of volume, the effect of site being removed, showing trend with age.

The high value of the coefficient of variation at 30 years, shown in Figure 10, is attributed to the variable slowness of the young spruce in reaching measurable size. In applying corrections for tolerant under-stocking or over-stocking, the trend of this curve is considered only for stands 50 years and older.

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EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1955