CONVERTING ASPEN STANDS TO WHITE SPRUCE-ASPEN MIXEDWOODS BY PLANTING AND SEEDING, MANITOBA

MANITOBA FORESTRY DEMONSTRATION AREAS

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October, 1994

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INTRODUCTION

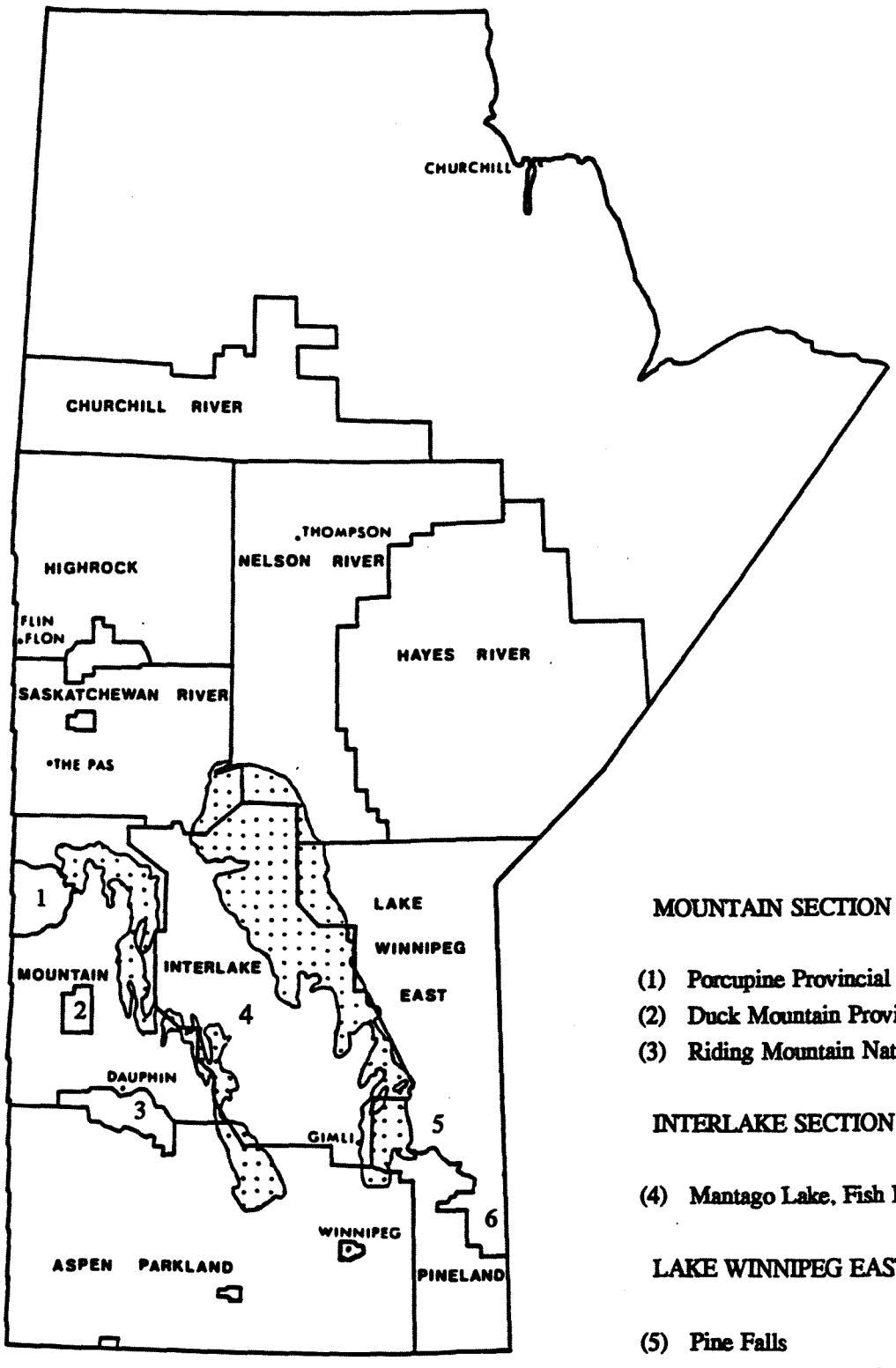
Between 1960 and 1966, 21 planting and 14 seeding trials were established to convert aspen stands to spruce-aspen mixedwoods in three Manitoba Forest Management Sections (Figure 1, Table 1). Scalped strips, varying in width from 2.0 to 3.7 m, were bulldozed in young to over mature aspen stands (Table 2) for planting and seeding. The undisturbed stands between the strips range from 2.7 to 17.7 m wide. Square 0.081 ha (1/5 acre) plots were bulldozed in one area (1a). Mineral soil exposure (B horizon) exceeded 75% on 60% of the plantations. Moisture regimes (MR) vary from dry to very moist (MR 0 - 6) according to Hills (1952) although the fresh to moderately fresh range (MR 3 - 4) occurs most frequently. All areas planted or seeded were established for research purposes except for three planted areas in the Whiteshell (11, 12 and 17) which were operational reforestation projects.

Planting

Site preparation, planting, and seedling information is shown in Table 2. The areas ranged from 0.2 to 40.5 ha in size and the number of seedlings planted per area ranged from 500 to 40 000. Seedlings varied from 8 to 22 cm in height. Seedlings were planted in slits in a single row down the center of scarified strips on 11 plantations; in two staggered rows near the strip edges on six; and in three staggered rows on four plantations. Hole as well as slit planting occurred on three areas. The first area was planted in September 1960 and the last in May, 1966 (Table 1). Spacing varied from 1.4 to 2.4 m (Table 2). Pineland Provincial Forest Nursery at Hadashville provided all planting stock.

Seeding

Seeding information is also shown in Table 2. The seed used in this study was obtained from the provincial nursery or from collections made by the Canadian Forest Service in Riding Mountain National Park. All seed was treated to prevent damping off. The fungicide, Captan 50-W, was used until mid-1963 when it was discovered that its use caused abnormal root development when treated seed was broadcast on the soil surface (Waldron and Cayford 1964). A combination of Arasan, Endrin, and aluminum flakes was used thereafter. The seeding rate



MOUNTAIN SECTION

(1) Porcupine Provincial Forest
(2) Duck Mountain Provincial Forest
(3) Riding Mountain National Park

INTERLAKE SECTION

(4) Mantago Lake, Fish Road, Beaver Creek

LAKE WINNIPEG EAST SECTION

(5) Pine Falls
(6) Whiteshell Provincial Park

Figure 1. Study areas in Manitoba's Forest Management Sections

Table 1. General location of study areas in Manitoba and dates of planting and seeding

Forest Region[1]	Forest Section[1]	Forest Management Section (prov.)	Forest Management Unit (prov.)	General Location	Area Number	Date Planted	Date Seeded	Cover Type
Boreal	Mixedwood B18.a	Mountain	14	Porcupine Prov. Forest	1	May 62	Nov. 61[2]	dense young aspen
					1a	May 62	Nov. 61	as above
					20	May 62	none	as above
			13	Duck Mtn. Prov. Forest				
				Madge Lake	2	May 62	Nov. 61	dense mature aspen
				Gill Meadow	3	May 62	Nov. 61	dense uneven-aged aspen
			15	Riding Mtn. Nat. Park	4	May 63	none	open over-mature aspen
					18	May 64	none	as above with hazel
					19	May 65	none	as above
	Manitoba Lowlands B.15	Interlake	41	Interlake				
				Fish Road	8	May 62	May 62	dense young aspen
				Fish Road	9	May 63	May 62	as above
			40	Beaver Creek	10	Sept. 62	Sept. 62[2]	open mature tA-bP
			41	Mantago Lake	16	May 64	April 64	dense young aspen
					21	May 65	May 65	as above
		Lake Winnipeg East	31	Pine Falls	5	May 62	none	young bP-bA with willow
					6	May 63	Oct. 62[2]	mod. dense young & mature tA-bP
					7	May 64	Oct. 63	as above
					22	May 65	June 65	as above with hazel
					23	May 66	May 66	recent cut-over with hazel
	Lower English River B.14		30	Whiteshell Prov. Park				
					12	Sept. 60	none	dense mature aspen
					13	none	Nov. 61	mod. dense mature aspen
					14	none	April 62	moderately dense b. ash
Great Lakes St. Lawrence	Rainy River L.12			Falcon Lake	15	May 62	none	na
	Quetico L.11			West Hawk Lake	17	Sept. 63	none	dense mature aspen

[1] Rowe, 1972.

[2] These areas were reseeded at a later date.

Table 2. Area establishment information[1]

Area	Size (ha)	MR	Site Preparation: Scalp Width (m)	Soil Exposure: Mineral (%)	Humus (%)	Mixed (%)	Undist. Width (m)	Planting: Spacing (m)	Outplanting Height (cm)	Planting Method[2]	No. Rows Per Strip	Number Planted	Seeding: Seed Treatment[3]	Seed Viability (%)	Seeding Rate (kg/ha)
1	12.10	3-4	2.4	76	14	10	10.1	2.4	8	S	1	2 000	C	11	1.2
1a[4]	0.24	3-4	--[5]	100	0	0	na[6]	1.8	8	S	various	960	no seeding		
2	8.10	3-5	2.4	63	22	15	17.7	2.1	13	S	1	1 000	C	11	2.8
3	12.10	3-4	2.4	44	28	28	11.0	2.1	11	S	1	1 500	C	11	2.0
4	5.70	3-4	2.0	35	35	30	4.6	2.1	18	S	1	3 500	no seeding		
5	1.00	3-5	3.4	na	na	na	4.6	1.8	12	S	2	3 700	no seeding		
6	2.80	4-6	3.4	100	0	0	4.9	2.4	21	S&H	3	2 000	C	41	1.7
7	2.40	3-5	3.0	100	0	0	4.9	2.4	13	S&H	3	1 400	AEA	56	1.7
8	4.40	2-6	2.1	26	20	54	2.7	2.0	14	S	1	2 000	C	63	1.5
9	3.60	3-5	2.7	1	11	88	4.3	1.5	22	S	1	500	AEA	71	1.1
10	1.20	5	2.6	80	20	0	11.6	1.8	22	S	1	500	C	3	15.8
11	36.40	3-6	2.1	100	0	0	6.1	1.8	17	S	2	40 000	C	na	0.7
12	40.50	3-6	2.1	80	0	20	5.4	1.8	12	S	2	40 000	no seeding		
13	na	na	2.7	80	0	20	5.8	not planted					C	39	1.1
14	na	na	2.7	80	0	20	5.8	not planted					C	39	1.0
15	na	na	na	na	na	na	na	na	16	S	na	500	no seeding		
16	10.10	0-6	3.2	32	39	29	4.3	1.8	13	S	1	1 200	AEA	58	3.4
17	34.40	3-6	3.7	100	0	0	4.9	1.8	15	S	3	33 000	no seeding		
18	0.81	3-4	3.0	100	0	0	4.9	1.8	14	S	2	800	no seeding		
19	2.00	3-4	3.0	100	0	0	6.1	1.4	14	S	2	2 800	no seeding		
20	6.10	3-4	2.4	76	14	10	10.1	1.6	13	S	1	2 000	no seeding		
21	11.00	0-5	3.4	83	17	0	4.6	1.8	14	S	1	1 200	AEA	55	2.0
22	1.70	3-4	3.1	100	0	0	4.3	1.8	15	S&H	3	1 400	AEA	55	1.7
23	2.40	3-5	2.6	100	0	0	2.7	1.8	15	S	2	2 000	AEA	55	2.0
Totals	199.05											144 000			
Means	9.48		2.7	75.3	10.0	14.7	6.4	1.9	14.5			6 500		41	2.6

[1] From MS-226 Converting aspen stands to white spruce by planting and seeding on scalped strips, Manitoba Internal Reports
[2] Planting method: S = slit, S+H = slit and hole
[3] Seed treatment: C = Captan 50-W, AEA = Arasan, Endrin, and aluminum flakes
[4] This area consists of 5 square 0.081 ha (1/5 acre) plots
[5] Scalped plots were 28.4-m^2
[6] NA = not available or not applicable

varied from 0.7 - 15.8 kg/ha depending on the viability (3% to 71%) of the seed used. All seed was applied with a Cyclone seeder except in the Whiteshell areas where it was broadcast by hand.

Measurements

Planting and seeding measurements were taken in the spring or early summer at five years and at 17 to 23 years depending on the age of the plantation during the final measurement in 1983, 1984 or 1985. Sample plot sizes usually exceeded 10% of the entire areas planted or seeded except in the Whiteshell areas where they were smaller. Heights were measured to the end of the previous growing season.

Results

Table 3 shows survival, heights and height growth rates of planted seedlings at the 5th year and the last measurement at 17 - 23 years. Figure 2 presents the survival and height of planted seedlings at the last measurement according to moisture regime. Table 4 - 6 show the results of the seeding trials. Maps showing the location of the experimental areas are provided (Figures 3 to 8).

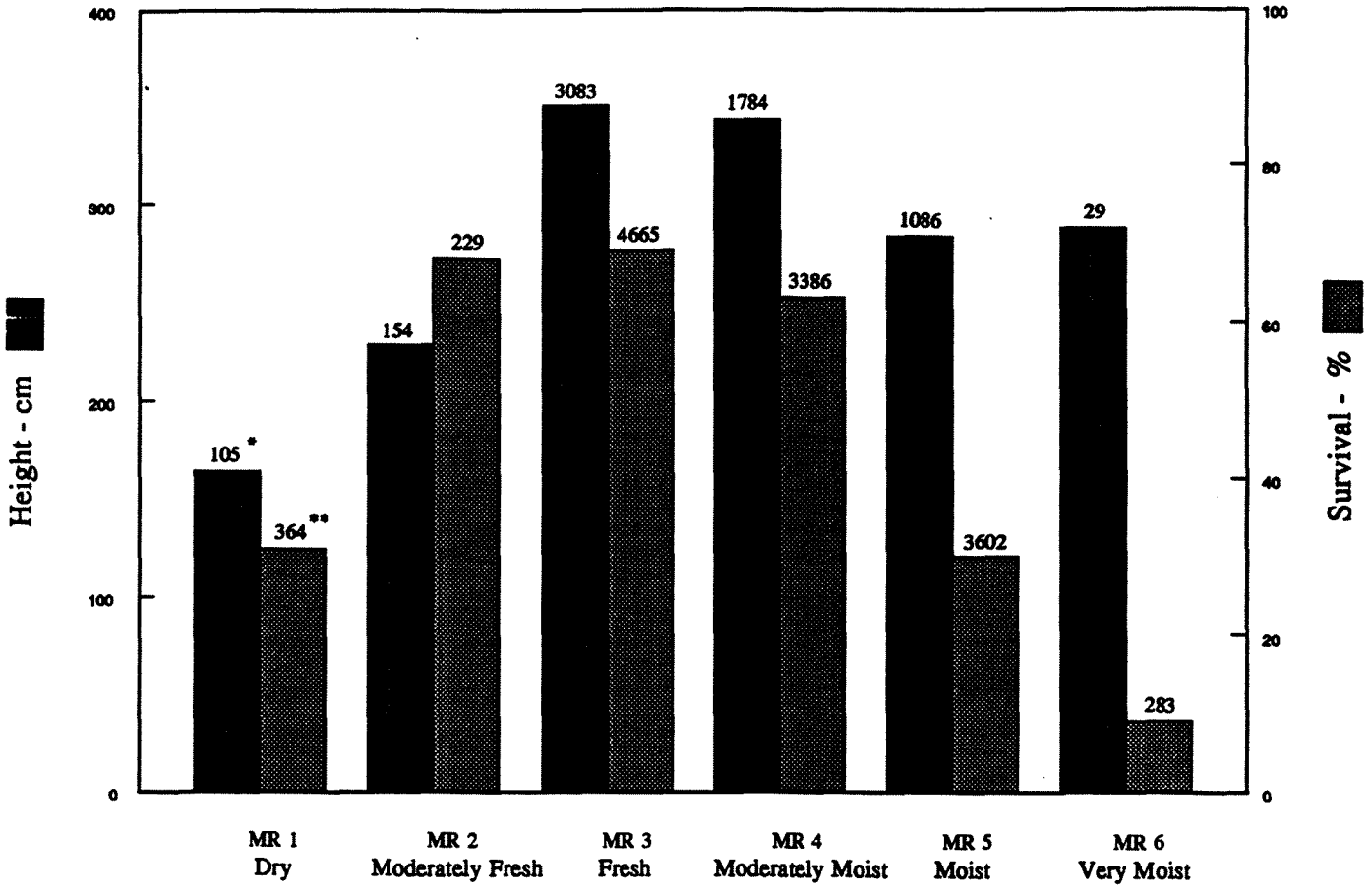
MOUNTAIN SECTION

(areas 1, 1a, 2, 3, 4, 18, 19 & 20)

The Mountain Section encompasses Duck Mountain Provincial Forest, Porcupine Provincial Forest and Riding Mountain National Park in western Manitoba. These locations refer to Forest Management Units (FMU) 13, 14 and 15 respectively. Eight planting and 4 seeding trials were established in this Section.

Porcupine Provincial Forest

Areas 1, 1a, & 20 are located on the southern boundary of the forest within 1 km of the Saskatchewan border (Figure 3). The soils are moderately well drained, have developed from moderately calcareous fine or clay textured glacial till, and are classified as Dark Grey Luvisol (Ehrlich *et al* 1959). The moisture regime are 3 and 4. Prior to site preparation the forest was a dense young aspen stand.



* represents the number of trees measured

** represents the number of trees planted

Figure 2. Survival and height of planted white spruce seedlings according to moisture regime

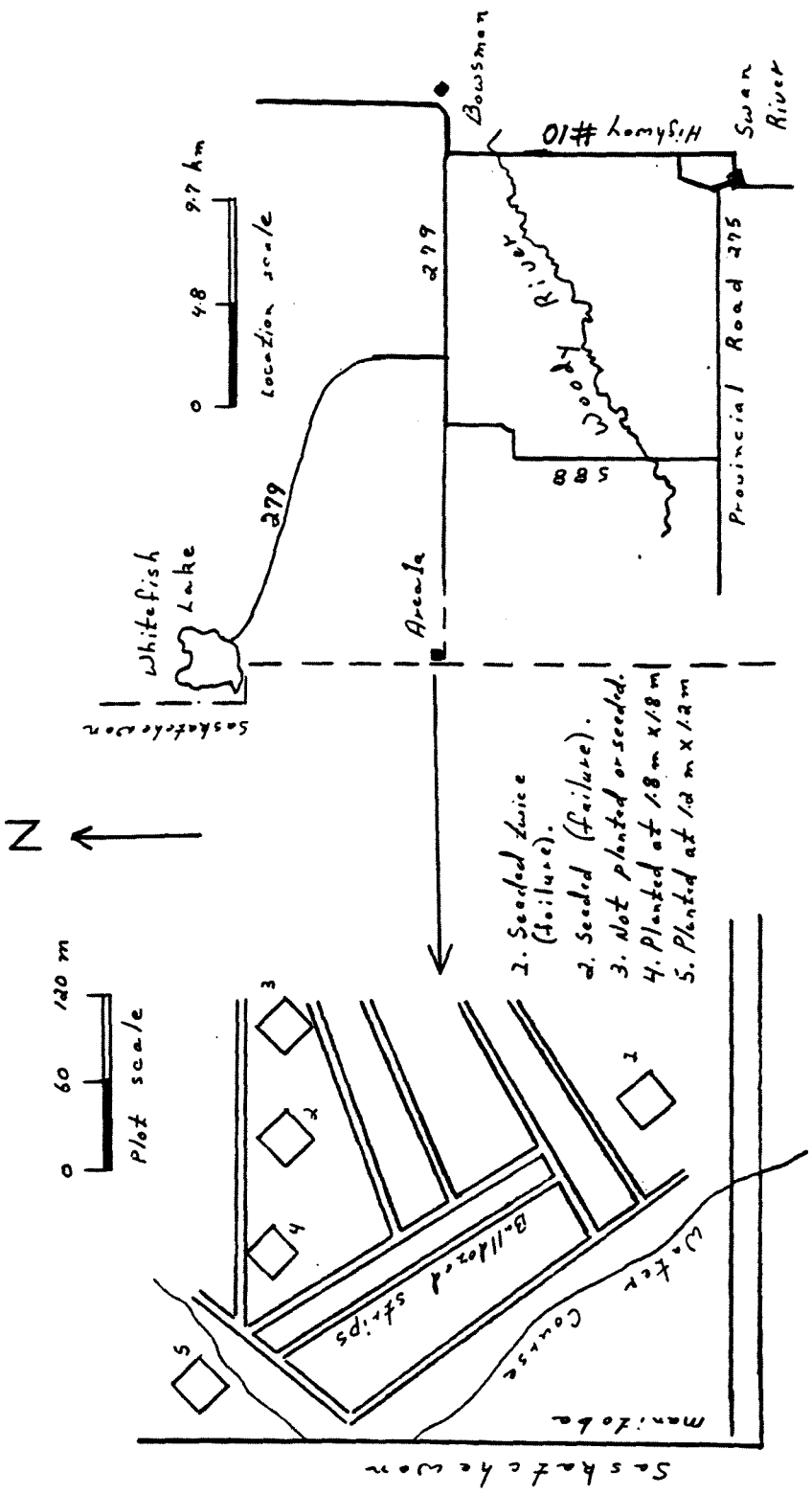


Figure 3. Aspen conversion area 1a, Porcupine Provincial Forest

Table 3. Summary of 21 planting trials in Manitoba

General Location	Area no.	Age (yrs.)	Moisture regime	Number measured at 5yr	Number measured at 17-23	Survival (%) at 5yr	Survival (%) at 17-23	Outplant height (cm)	Height (cm) at 5yr	Height (cm) at 17-23	Annual height growth (cm/yr)[1] 1st 5 yrs	Annual height growth (cm/yr)[1] overall last 3 yrs	Annual height growth (cm/yr)[1] last 3 yrs
Mountain Region	1	22	3 - 4	575	0	93	0	8	58	--[2]	10.0	--	--
	20	20	3 - 4	879	0	82	0	13	40	--	5.4	--	--
	1a[3]	23	3 - 4	--	614	--	64	8	--	223		9.3	31.8
	2[4]	22	3 - 5	439	410	89	88	13	59	455	9.2	20.1	41.4
	3[5]	22	3 - 4	402	385	82	78	11	48	505	7.4	22.5	45.1
	4	21	3 - 4	390	294	83	63	18	61	299	8.6	13.4	29.1
	4cont.	21	3 - 4	90	35	93	36	18	60	264	8.0	12.0	--
	4herb.	21	3 - 4		259		70	18	59	303	8.0	14.0	--
	18	20	3 - 4	237	218	89	82	14	55	299	8.2	14.2	32.0
	19	19	3 - 4	353	306	78	67	14	40	271	5.2	13.5	37.4
	means	21		409	278	85	55	12	52	342	7.8	15.5	36.1
	totals			2700	2227								
Interlake	8[6]	22	2 - 6	1073	0	68	burned	13	49	burned	7.2	burned	burned
	9	21	2 - 6	1073	0	68	burned	13	49	burned	7.2	burned	burned
	9	21	3 - 5	430	251	89	52	22	73	436	10.2	19.7	44.8
	10	22	5	110	0	88	3	22	52	--	6.0	nd	nd
	16[7]	20	0 - 6	562	203	71	37	13	47	177	6.8	8.2	28.8
	21[7]	19	0 - 5	298	343	67	53	14	43	266	5.8	13.3	38.4
	means	21		495	199	77	36	17	53	220	7.2	13.7	37.3
	totals			2473	797								
Pine Falls	5	21	3 - 6	414	201	70	34	12	53	300	8.2	13.7	--
	6	20	4 - 5	391	330	86	73	21	69	412	9.6	19.5	--
	7	19	3 - 5	413	293	79	56	12	41	279	5.8	14.1	--
	22	18	4	363	290	35	28	15	47	343	6.4	18.2	--
	23	17	3 - 5	492	466	95	90	15	56	343	8.2	19.3	--
	means	19		415	316	73	56	15	53	335	7.6	17	nd
	totals			2073	1580								
White-shell	11	22	3 - 6	675	429	51	32	17	58	259	8.2	11.0	27.5
	12	23	3 - 5	642	805	54	24	12	45	230	6.6	9.5	17.7
	17	19	3 - 6	586	403	67	55	15	47	307	6.4	15.4	nd
	means	21		634	546	57	37	14.7	50	265	7.1	11.9	22.6
	totals			1903	1637								
	overall means	21		463	297	73	46	14.4	52	318	7.5	15	31
	totals			9149	6241								

[1] The outplanting height of the seedlings was deducted before calculations
[2] Not measured, not applicable or not available
[3] This area consists of 5 square 0.081 ha (1/5 acre) plots
[4] Data collected in 1993 at 32 years of age revealed 86% seedling survival and 87% stocking on a 10-m^2 quadrat basis with 1270 trees/ha averaging 10.4 cm in diameter and 860 cm in height (R. Waldron, personal communication).
[5] Data collected in 1993 at 32 years of age revealed 76% seedling survival and 90% stocking on a 10-m^2 quadrat basis with 1290 trees/ha averaging 11.7 cm in diameter and 930 cm in height (R. Waldron, personal communication)
[6] This area was destroyed by fire in 1978
[7] Areas 16 and 21 were destroyed by fire in 1989

Good survival rates at 5 years were obtained on the strip areas (1 and 20) in the Porcupine Provincial Forest. Severe and repeated browsing during high hare populations destroyed the strip-planted area prior to the last measurement. The survival, height and height growth rate at 23 years on two square plots (area 1a) were 64%, 223 cm and 9.3 cm/yr respectively (Table 3). Good survival was obtained on open square plots for a number of reasons: scarification down to the B horizon removed all vegetation and their roots from the site (unfortunately the removal of the nutrient rich organic layers caused the height and height growth rate to be among the lowest of the study); at 23 years the vegetative encroachment was just beginning on the southern edges of the square plots; and with no woody or herbaceous concealment cover from predators, in particular birds of prey, hare foraging on open areas was light. Failure occurred on the strip areas because readily accessible protective shelter in the leave strips was provided.

Duck Mountain Provincial Forest

Areas 2 & 3 are located in the Duck Mountain Provincial Forest. Area 2 is 3.2 km south of the Madge Lake turn-off on Highway 83 while area 3 is on the western boundary of the Provincial Forest approximately 13 km east of San Clara (Figure 4). The dominant soil profile is an Orthic Grey Luvisol that has developed on medium-textured lacustrine deposits: the soil is well drained (Ehrlich *et al* 1959). Moisture regimes are in the fresh to moist range (MR 3 to 5). The topography of area 2 is rolling; area 3 is generally flat except for shallow depressions caused by seasonal drainage channels. The forests on areas 2 and 3, prior to site preparation, were respectively, a dense mature aspen and dense uneven-aged aspen stands.

Excellent survival, heights and height growth rates for both areas were obtained at 5 and 17 - 23 years. The survival rate, height and height growth rate at 22 years for areas 2 and 3 were respectively 88%, 455 cm, 41.4 cm/yr and 78%, 505 cm, 45.1 cm/yr (Table 3). Good results were attributed to excellent site conditions and lack of browsing. Data collected in 1993 (see footnotes, 4 and 5 of Table 3) indicate an average survival of 81% with trees averaging 11 cm dbh and 900 cm in height.

Seeding trials were also established in both Duck Mountain areas. An assessment after one year revealed no seedlings; reseeding was ruled out due to heavy aspen leaf cover on the seedbed. The failure was attributed to the use of Captan, poor seed quality, and to smothering by aspen leaves. An examination of the seeded strips at 22 years (Table 4) revealed that the

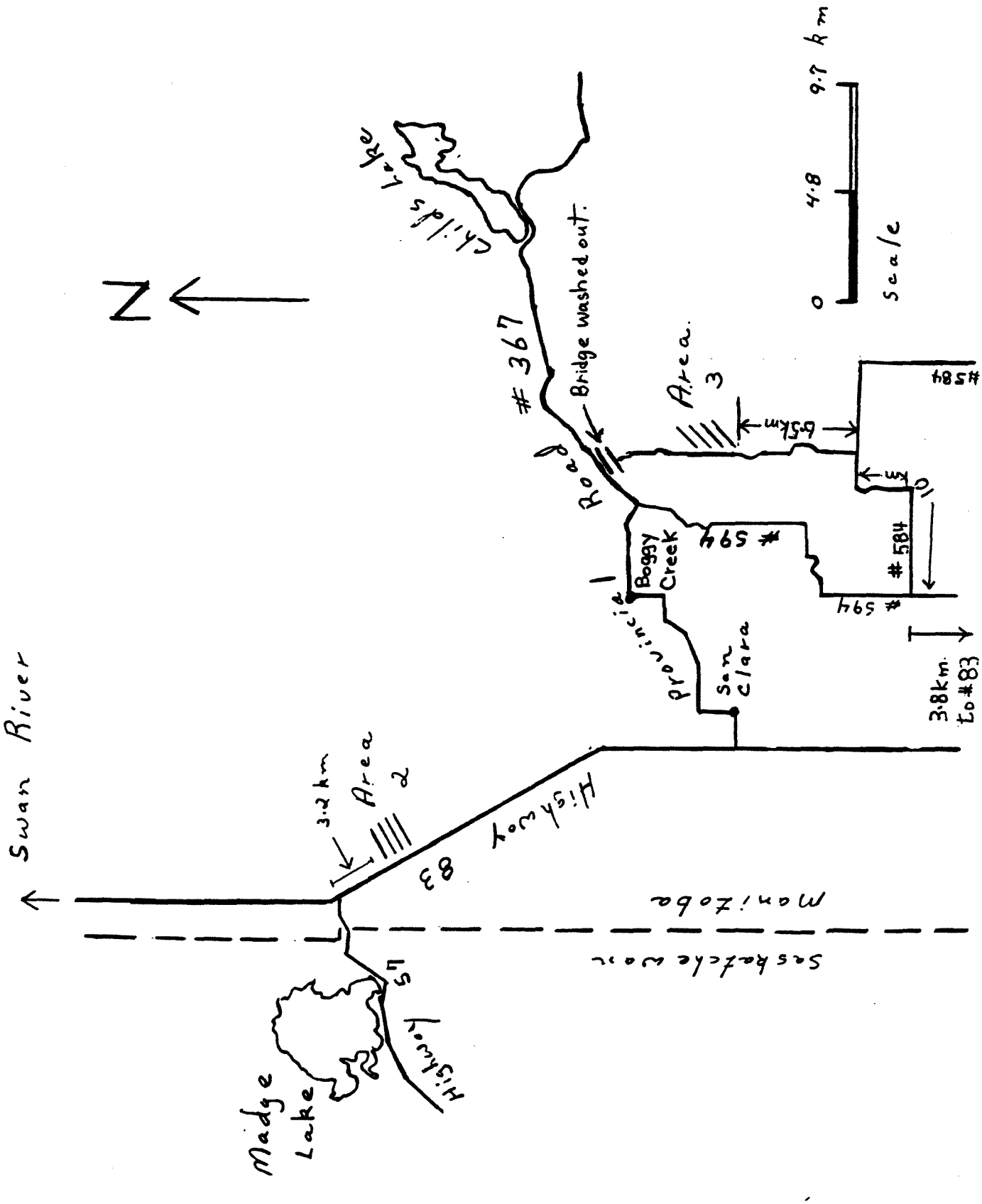


Figure 4. Aspen conversion area 2, Madge Lake and area 3, Gill Meadow, Duck Mountain Provincial Forest

Table 4. Stocking, height and height growth of seeded white spruce on 14 areas in Manitoba

General Location	Area no.	Age at last measure (yrs)	Moisture (%)	No.quads stocked[1]	Stocking (%)		No. stems /ha		Height (cm)		Annual height growth (cm/yr)		
					5 yrs	17-23 yrs	5 yrs	17-23 yrs	5 yrs	17-23 yrs	5 yrs	all	last 3 yrs
Mountain Region													
	1[2]	22	3-4	0	0	--[3]	0	--	0	--	--	--	--
	reseeded	20	3-4	0	--	--	--	--	--	--	--	--	--
	2[4]	22	3-5	49	16	19	1 549	2 104	8	180	1.3	8.2	--
	3[5]	22	3-4	30	na	15	na	1 985	na	210	na	9.5	--
	mean	22	3-4			18		2 045		195		8.9	
Pine Falls													
	6	20	3	19	67	17	45 000	750	9	63	1.8	3.2	--
	7	19	3-5	73	61	46	39 000	2 227	18	92	3.6	4.8	--
	22	18	4	67	70	65	25 000	16 800	18	128	3.6	7.1	--
	23	17	3-5	66	79	69	50 000	21 100	14	168	2.8	9.9	--
	mean	19	3-5		69	49	40 000	10 220	14.8	113	3.0	6.3	
Interlake Region													
	8[6]	22	2-6	0	71	0	41 000	--	17	--	3.4	--	--
	9	21	3-5	51	61	23	40 000	3 345	20	165	4.0	7.9	23.0
	10[7]	22	5	0	28	0	7 200	--	7	--	1.1	--	--
	16[8]	20	0-6	136	42	58	8 600	8 600	12	129	2.4	6.5	31.6
	21	19	0-6	488	63	60	7 900	11 900	10	115	2.0	6.1	19.0
	mean	20	0-6		53	47	21 000	7 950	13.2	136	2.6	6.8	24.7
Whiteshell Region													
	13[9]	23	3-5	0	44[10]	--	6 000	--	18	--	--	--	--
	14	23	3-5	0	--	--	--	--	--	--	--	--	--
	Overall mean					31		5 735		114		7.0	24.7

[1] The quadrat size for the 19 year measurement of 21 was 4-m^2 (1/1 000 acre): all other were 1-m^2 (1/4 000 acre).
[2] Failure due to poor seed and smothering by aspen leaves.
[3] Not applicable or not measured.
[4] Data collected in 1993 at 32 years of age revealed 72% stocking on a 10-m^2 quadrat basis with 1 950 seedlings per ha averaging 4.8 cm in diameter and 480 cm in height (R.Waldron,personal communication).
[5] Data collected in 1993 at 32 years of age revealed 70% stocking on a 10-m^2 quadrat basis with 2 620 seedlings per ha averaging 4.6 cm in diameter and 460 cm in height (R.Waldron, personal communication).
[6] Destroyed by forest fire 1977.
[7] Destroyed by seasonal flooding.
[8] Area 16 and 21 were destroyed by forest fire in 1989.
[9] Destroyed by land clearing.
[10] 5th year values are for both areas 13 and 14.

stocking rate was less than 20% and density approximately 2 000 stems/ha. Seedling heights were approximately 2 m. The seedlings were in part, attributed to natural seeding from parent white spruce. Seedbeds remained receptive to natural seeding for many years as a result of the 1961 scarification. Data collected in 1993 (see footnotes, 4 and 5 of Table 4) indicate the current stocking based on 10-m^2 plots is 71%.

Riding Mountain National Park

Areas 4, 18 and 19 border the game line road between townships 20 and 21, less than 1 km west of Highway 10 in Riding Mountain National Park (Figure 5). These areas were established in three successive years beginning in 1963. The topography of the area is rolling and the soils have developed on moderately calcareous till parent material. Soils are clay-loam in texture and moisture regimes are fresh and moderately moist (MR 3 - 4). Prior to site preparation the forest was an over-mature aspen stand with a dense understorey of beaked hazel.
At five years, survival ranged from 78 to 89% and height from 40 to 61 cm. At the last measurement, at age 19 to 21, survival ranged from 63 to 82% and heights were 299, 299, and 271 cm (Table 3) respectively. Browsing by elk might be partially responsible for the height uniformity.

In 1964 excessive competition from lesser vegetation and aspen suckers threatened the survival and vigour of the seedlings on area 4. To reduce the competition, a portion of area 4, (area 4 - 1), was treated with a herbicide mixture consisting of an aqueous solution of 2,4,5-T, 76% acid equivalent (ae), and 2,4-D (80% ae) at the rate of 0.6 kg/ha of each chemical. The herbicide was applied using "Solo" mist blowers on July 28, 1965. Five control strips were not sprayed (approximately 0.4 ha). The survival of the herbicided seedlings was double that of the control at age 21 (72% vs 36%) but height was unaffected.

INTERLAKE SECTION
(areas 8, 9, 10, and 16)

The Interlake Section lies between Manitoba's largest lakes: Lake Winnipeg on the east and Lakes Manitoba and Winnipegosis on the west. Five planting and seeding trials were established in this Section (Figure 6). Four areas (8, 9, 16 and 21) are located in FMU 41 and one (area 10) is in FMU 40. The browse control repellent Tat-go was applied on areas 8 and 10 in October 1962 and in July 1963 on area 9. Herbiciding with 2,4,5-T (80% ae at 3 000 ppm applied to the dripping point) was carried out on area 8 in the summers of

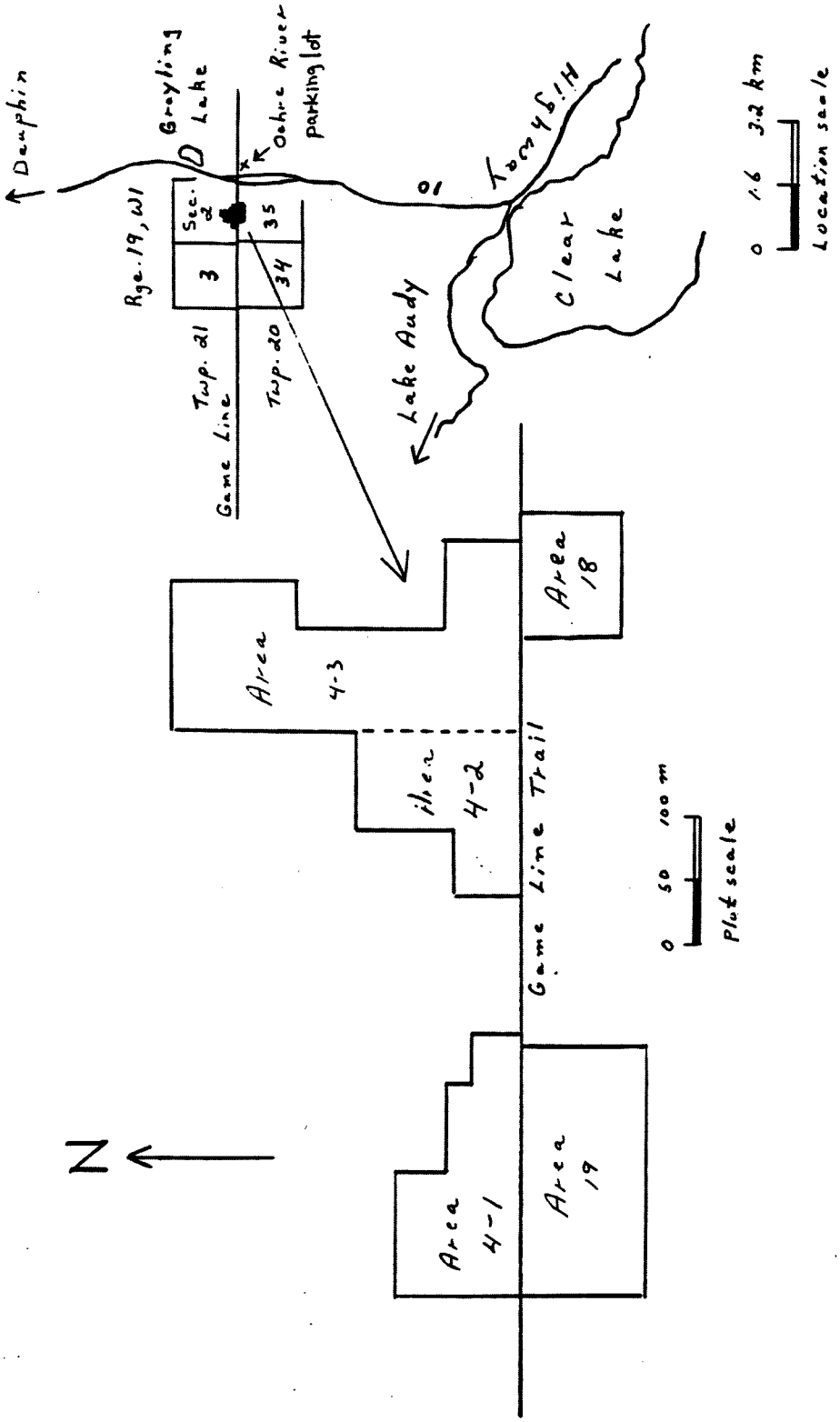


Figure 5. Aspen conversion areas 4, 18, 19, Riding Mountain National Park

1963 and 1964 and on area 9 in mid summer 1964. All areas except area 10 were also aerially herbicided (a mixture of 2,4-D and 2,4,5-T; 1.1 kg ae /ha of each chemical was sprayed at the rate of 44.9 L /ha) in August 1965. Control plots were not established for browse or chemical control, consequently the effects on survival and growth cannot be ascertained. Walker (1967) reported that white spruce was unaffected by the herbicide and that "a good leaf kill on young aspen trees and suckers and an excellent leaf kill on hazel, willow and lesser vegetation" were obtained. The objectives of the herbiciding were met.

Fish Road

Area 8 was destroyed by a forest fire in 1977.

Area 8 is located 19 km east of Hodgson on Highway 325 (Figure 6). The topography of the area is flat. The soils of the study area vary from moderately fresh (MR 2) to very moist (MR 6) and are clay-loam in texture. The forest was a dense young aspen stand. Five year results (Table 3) for area 8, measured in 1967, show the survival rate was 68% and height was 49 cm.

Area 9 is located across the road (south) from area 8. Stand, soil and site conditions are similar to area 8. Seedling performance at 5 years was best on MR 3 followed by MR 4 then by MR 5 combined with MR 6. After 21 years the pattern is the same: survival 54%, 55% and 40% (mean 52%), heights 508, 425 and 331 cm (mean 436 cm) and height growth rates 51.6, 40.8 and 38.7 cm/yr based on the last 3 years of growth (mean 44.8 cm/yr) (Table 3). The mean survival rate would be 80% if saplings removed from the plantation for ornamental plantings (7%) and those destroyed by the fire of 1977 (21%) were included in the rate. Good survival, heights, and height growth rates, on fresh to moderately moist sites were obtained because winter scarification did not remove the nutrient rich organic horizons. Mineral soil exposure on this area was only 1%. The current practice of winter shear-blading after logging produces similar seedbeds. Because of the rich site and minimal exposure of mineral soil, vegetative ingress was heavy. Herbiciding may have ameliorated the competition problem.

On area 9 at five years the seeded strips were stocked (61%) with an abundance of seedlings (40 000/ha based on 1-m^2 square quadrats, (Table 4). The mean height was 20 cm. At 21 years the stocking, seedling density and mean height were 23%, 3 345 stems/ha, and 165 cm respectively. Annual height growth rate averaged 7.9 cm for 21 years; this increased to 23.0

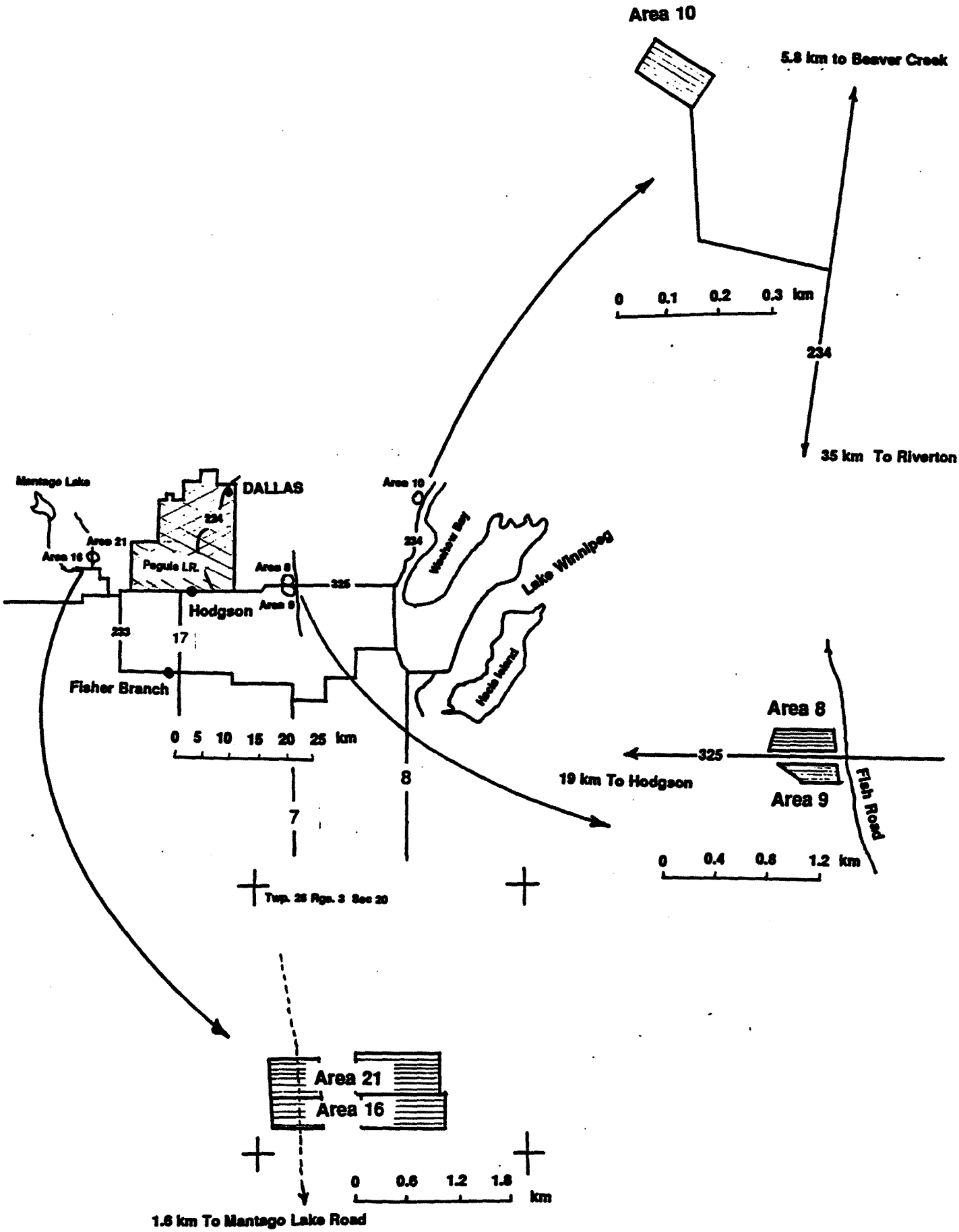


Figure 6. Aspen conversion areas 8, 9, 10, 16, 21, Interlake

cm based on the last 3 years of growth. The major cause of mortality since the 5th year measurement was the fire of 1977. Seedling distribution remains a problem as some of the quadrats examined are densely stocked and contain up to 16 saplings per square meter.

Beaver Creek

Area 10 is located approximately 6 km south of Beaver Creek (Figure 6) settlement which is approximately 35 km north of Riverton on Highway 234. The topography of the area is generally flat and the soils of the area are clay in texture, and although rated as moist (MR 5) sites during the summer, are prone to spring flooding. The forest was a mature open trembling aspen -balsam poplar stand from which merchantable white spruce had been removed.

The survival and height of planted seedlings after 5 years (Table 3) were 88% and 52 cm. Thirty percent of the seedlings were browsed. After 21 growing seasons the plantation was a failure due to severe browsing. Approximately 5 to 10% of the dead saplings still standing resembled sticks (usually less than 1 m tall) with branches browsed off to the stem.

Seeding took place in September 1962. Poor stocking (5%, based on 1-m^2 quadrats, Table 4) necessitated reseeding in April 1963. In spring 1969, five years after seeding, the stocking was 28% with 7 200 seedlings /ha (Table 4). In April 1984 there were no seedlings.

The failure of the seeding trials is due to a combination of reasons: deep scarification had produced seedbeds that were below the forest floor and subject to seasonal flooding (both seeding and planting were delayed from spring to the fall of 1963 due to standing water), the use of Captan 50-W, the poor quality of the seed, abundant leaves on the seeded strip, and browsing.

Mantago Lake

Plantations on **areas 16 and 21** were destroyed (since the last measurement) by a forest fire in 1989.

Areas 16 and 21 are located south of Mantago Lake on the Mantago ridge, approximately 40 km north of Fisher Branch (Figure 6). The site is in a transition zone between prairie and

forest; the landform, soil, and sites are very complex. Soil textures vary from roughly stratified coarse sand and gravel on beach ridges, and range from medium to fine-textured loam to clay-loam on stone free beach and lacustrine deposits. Calcareousness ranges from weak to strong. Moisture regimes vary from very dry (MR 0) on ridge tops to very moist (MR 6) on the lacustrine flat (Cayford and Jameson 1965).

The area was initially burned in 1948. When the study was initiated the vegetation was characterized by either a grass cover (on the ridge) or by a young trembling aspen stand with sporadic occurrences of white spruce and jack pine.

Other studies were established on the ridge and various species of trees were planted. (Cayford et al 1967, Cayford and Jameson 1965).

The survival rate, height, and height growth rate of area 16 at five years were 71%, 47 cm, and 6.8 cm/yr (Table 3) respectively. At 20 years these values were 37%, 177 cm, and 8.2 cm/yr. During the three years prior to the last measurement the growth rate improved to 28.8 cm/yr.

Poor results at the last measurement were attributed to a number of reasons. The most productive and the largest portion of the plantation was destroyed by a land clearing project. The results therefore, are influenced by site conditions on the remaining portion of the area which is on a ridge that is wind-swept, nutritionally poor, and rapidly drained. Also, a stubble-burning fire in the spring of 1984 reduced survival by 7%.

The stocking and height of seedlings on the seeded portion of area 16 (Table 4) at five years were 42% and 12 cm; at 20 years they were 58%, and 129 cm. Seedling density remained the same at 8 600 stems/ha. The annual growth rate for 20 years was 6.5 cm/yr. The use of different quadrat sizes for the two assessments (4-m^2 or 1/1000 acre in 1984, and 1-m^2 or 1/4000 acre in 1969) and the loss of the moist portion of the strip due to land clearing make these results difficult to assess.

Area 21 is adjacent to area 16 and occupies the same topographic positions on the dry beach ridge and the moderately dry to very moist lacustrine flat. Strips were prepared in March 1965, but heavy snow and frozen ground prevented adequate exposure of mineral soil. The area was re-scarified in spring 1965. Land clearing did not affect this area.

The survival at five years (Table 3), 67% decreased to 53% at 19 years. During this time mean height increased from 43 cm to 266 cm. Annual height growth rate increased from 5.8 cm for the first five years, to 13.3 cm for the 19-year average and to 38.4 cm based on the last three seasons of growth.

Seeding on area 21 took place on two strips in May 1965. The quadrat size for the 5 and 19 year assessments was 4-m^2. The stocking percent (Tables 5 and 6) was the same at 5 (63%) and 19 (60%) years while seedling density and mean height increased from 7 900 to 11 900 stems/ha and 10 to 115 cm respectively. The annual height growth rate increased from 2 cm for the first five years to 6.1 cm for the 19-year average and to 19 cm based on the last three years of growth.

In addition to scarification with a straight blade, one of the strips on this area was ploughed with a Middlebuster fire-line plough. Tables 5 and 6 show the effect of the plough at 5 and 19 years after seeding. Generally, the effect of the plough was positive for stocking and negative for height growth while the stocking was improved on the ridge and decreased on the flat. Increased moisture at the bottom of the ploughed trench on the ridge may have improved stocking while less nutrients in the trench may have reduced growth on both ridge and flat.

In a related study (Cayford and Jameson 1965, Walker 1966) on the same location 1 320 seedlings were planted, half each on the bottom of the ploughed trench and on the up-turned promontory. Results at 19 years showed that in the trenches, survival and heights were lower (55 vs 68%), (248 vs 266 cm) than on the created ridge.

LAKE WINNIPEG EAST SECTION

(Pine Falls areas 5, 6, 7, 22 and 23; Whiteshell Provincial Park areas 11, 12, 13, 14, 15 and 17)

The Lake Winnipeg East Forest Management Section is located east of Lake Winnipeg. Five areas were established in Forest Management Unit 31 near Pine Falls and 6 in the Whiteshell Provincial Park in Unit 30.

Table 5. Stocking, height, and height growth of white spruce seeded in spring, 1965 at Mantago Lake and measured in spring 1970, at 5 years of age, area 21

Moisture regime	0 + 1			2 to 6			0 to 6
Site treatment	S[1]	S+P[2]	S,S+P	S	S+P	S,S+P	S,S+P
No. quadrats examined	137	137	274	269	265	534	808
No. quadrats stocked	51	78	129	190	188	378	507
Stocking (%)	37	57	47	71	71	71	63
No. stems/ha[3]	2 700	3 000	2 900	13 200	7 400	10 300	7 900
Height (cm)	8	9	9	12	9	10	10
Annual height,growth(cm/a)							
1965 - 1969	1.6	1.8	1.8	2.4	1.8	2.0	2.0

[1] Scarified with a buldozer and straight blade
[2] Scarified with a straight blade and ploughed with a Middlebuster fireline plough
[3] Based on quadrat size of 4 square meters (1 milacre)

Table 6. Stocking, height, and height growth of white spruce seeded in spring, 1965 at Mantago Lake and measured in spring, 1984 at 19 years of age, area 21

Moisture regime	0 + 1			2 to 6			0 to 6
Site treatment	S[1]	S+P[2]	S,S+P	S	S+P	S,S+P	S,S+P
No. quadrats examined	137	137	274	269	265	534	808
No. quadrats stocked	52	55	107	170	211	381	488
Stocking (%)	38	40	39	63	80	71	60
No. stems/ha[3]	4 700	5 500	5 100	17 000	11 200	13 800	11 900
Height (cm)	96	88	92	134	111	121	115
Annual height growth(cm/a)							
1965 - 1983	5.1	4.6	4.8	7.1	5.8	6.4	6.1
1981 - 1983	--	--	--	--	--	--	19.0

[1] Scarified with a buldozer and straight blade
[2] Scarified with a straight blade and ploughed with a Middlebuster fireline plough
[3] Based on quadrat size of 4 square meters (1 milacre)

Pine Falls

Areas 5, 6, 7, 22 and 23 are located approximately 5 km north of Highway 11 on Highway 304 (Figure 7) on the Abitibi-Price Inc. Forest Management Lease. The five plantations are within 2 km of each other on the Manigotagan road. One area was established each year beginning in 1962. The soils of the area consist of Gleysols, Gleyed Dark Grey Luvisols and similar soils which have developed under conditions of excess moisture as indicated by soil mottling. The parent material consists of weakly to strongly calcareous loamy to silty lacustrine sediments. The sites vary from fresh to very moist (MR 3 - 6). The stands on moist sites consisted mainly of young aspen and black ash with some willows. On fresh sites, stands were young to mature aspen-balsam poplar with inclusions of black ash and Manitoba maple.

The best survival and growth rates occurred on fresh to moderately moist sites that were not subjected to flooding (Tables 3 and 4). The survival rate on area 23 (MR 3 - 4) was 90% (Table 3). Planting did not occur on MR 5 on area 23 due to standing water at planting time in spring 1966. Area 22 (MR 4) was planted in spring 1965; the low survival rate (28%) was due to flooding in the first year. Eighty percent of the seedlings that were healthy at five years exhibit good height and growth rates at the last measurement at age 18. Area 5 did have a good survival rate at year 5 (70%) but declined to 34% at 22 years due to wet conditions and competition. Area 6, with a 21-year survival rate of 73% had the tallest trees (412 cm) and the best growth rates (19.5 cm/yr) of the Pine Falls plantations. The survival and growth rate on area 7 also were reduced due to wet conditions (MR 5 and 6) and seasonal flooding.

The planting method, either slit or hole, was tested on areas 6, 7 and 22. The different planting methods had no significant effects. Similar results were obtained on another planting study on rock-ridge sites also on the Abitibi-Price Inc. lease (Ball 1990a).

One half of the planted strips on area 7 were black spruce. The survival, height and growth rate after 19 years were 43%, 288 cm and 14.0 cm/yr.

Approximately one third of the strips in areas 6, 7, 22 and 23 were seeded. Stocking at 19 years ranged from 17% to 69% based on 1-m^2 plots and the number or stems/ha ranged from 750 to 21 000 (Table 4). Fresh to moderately moist site conditions and a lack of flooding

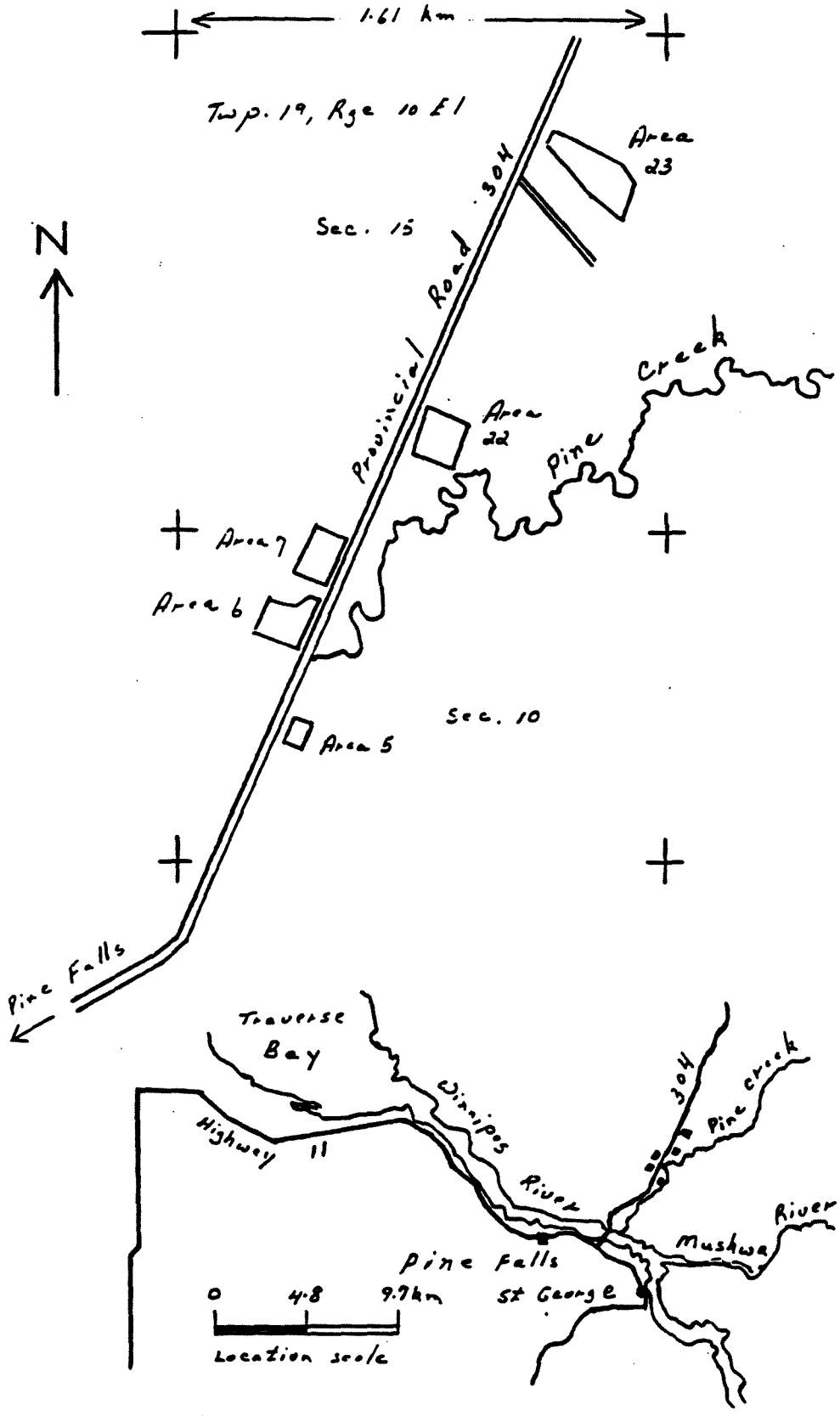


Figure 7. Aspen conversion areas 5, 6, 7, 22, 23, Pine Falls

produced the best results (areas 22 and 23). Natural seeding over the years from parent trees in areas 6 and 7 has contributed to and improved the survival recorded on the wet sites at the last measurement. These strips were also subjected to seasonal flooding from a nearby creek. The highest stocking density (21 000 stems/ha) and the best height growth rate (9.9 cm/yr after 17 years) in this study occurred on area 23 probably due to very light residual overstory.

Whiteshell Provincial Park

Areas 11, 12, 13, 14, 15, and 17 are located in the Whiteshell Provincial Park: areas 11, 12, 13, 14 and 15 are in the Nutimik Lake vicinity and area 17 is near West Hawk Lake. Most of these areas were established in black ash-balsam poplar stands that inhabit moist to wet areas. These conditions are unfavourable for early survival and growth of spruce seedlings but are ideal for aggressive herbs and shrubs. Consequently numerous refill plantings, mechanical and chemical release and repellent treatments were attempted to improve the stocking on these areas. These treatments achieved limited success and made the determination of survival and growth of originally planted stock impossible on areas 11 and 12. In spite of this, measurements were made of existing saplings. Results at the last measurement show the survival rate and height of areas 11 and 12 at age 22 and 23 years were respectively 32%, 259 cm and 24%, 230 cm (Table 3). These saplings occupied the most favourable portions of the plantations. Natural regeneration from residual trees also occurred on these sites. Areas 13 and 14 were destroyed by the creation of a landfill site. The combined five year results of seeding on these two areas was a stocking of 44% with 6 000 stems/ha, and an average height of 18 cm. Area 15 was not relocated.

Area 17 is located on Highway 307 approximately 16 km west of West Hawk Lake townsite and 1 to 2 km east of Hanson's Creek (Figure 8). The topography of the area is rolling and the soils are clay-loam textured. The moisture regime on the mature aspen stand prior to site preparation ranged from fresh (MR 3) to very moist (MR 6).
Area 17 was herbicided in 1965 with Green Cross low volatile Brush Killer "64", and in 1970 with Green Cross Brush Killer "276". A manual white spruce release project was carried out in 1972. Control plots were not established for any treatment, hence treatment effectiveness can not be ascertained. The survival rate on this plantation decreased from 67% at age 5 to 55% at age 19 in 1983 (Table 3). The survival rate is greater than 83% if the data from the very moist sites are not included.

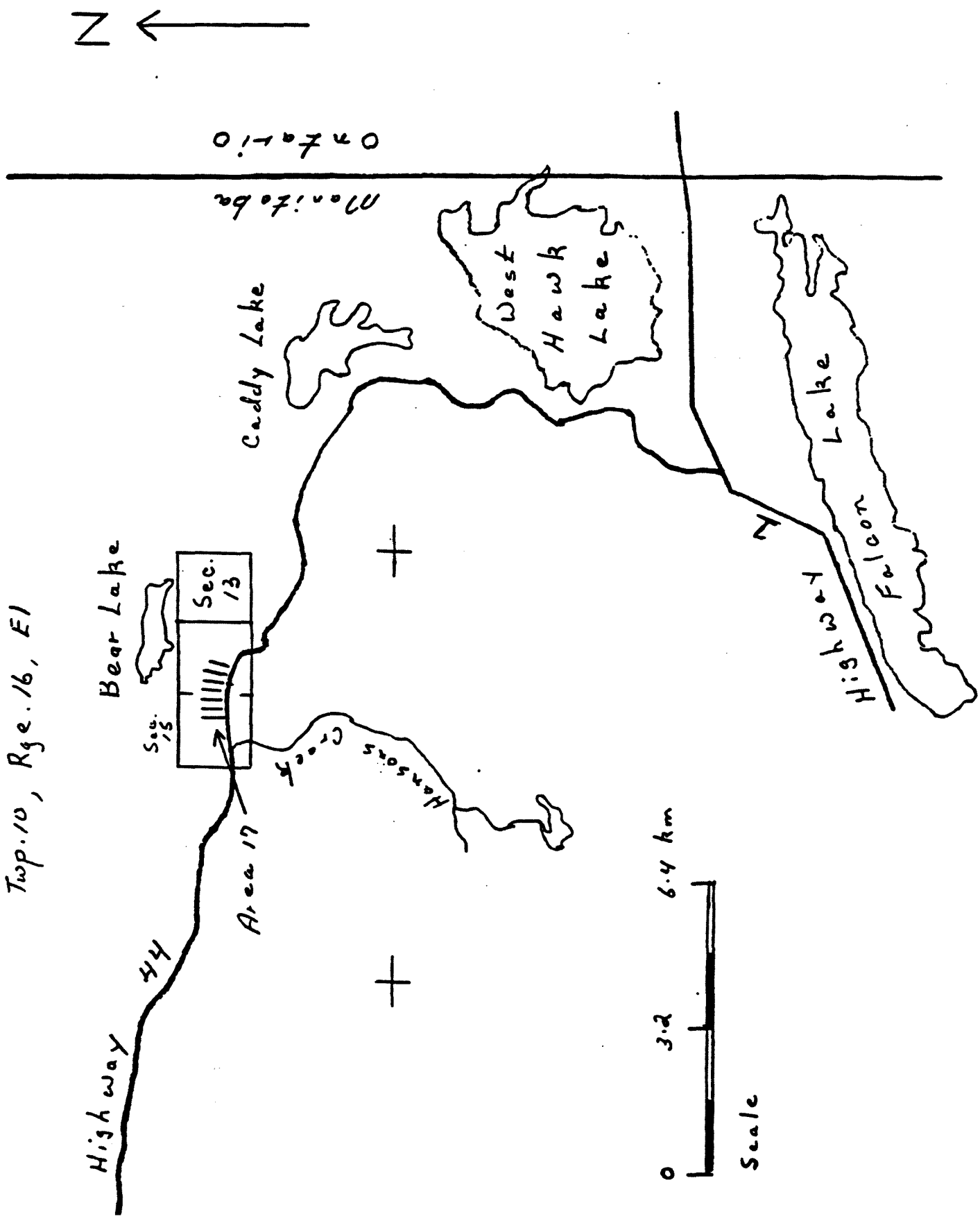


Figure 8. Aspen conversion area 17, West Hawk Lake, Whiteshell Provincial Park

Three rows of seedlings were planted on each scarified strip in this area. Height growth at 19 years of trees on the edges of the strips (south 366 cm, north 332 cm) was greater (p=0.01) than those in the center (281 cm). It is suggested that the roots of saplings on the edges of the strips were able to utilize the nutrients in the undisturbed forest floor beside the scarified strip a few years sooner than those in the center row resulting in superior performance. The saplings on the southern edge of the strip were also statistically taller (p=0.10) than those on the northern edge. The reason for this is unclear, but it may be due to strip orientation NW to SE and beneficial early shading for seedlings on the southern edge.
Stand tending programs in 1965, 1970 and 1972 have benefited survival and height growth in this area.

IMPACT OF SOIL MOISTURE REGIME

(All sections)

In this study, planting on scarified strips proved successful in introducing white spruce into aspen stands. Overall survival of planted white spruce proved best on scalped strips prepared on upland sites (MR 2-4) where there was no excessive moisture or seasonal flooding; where vegetative and overstory competition was relatively light; and where hare and ungulate browsing damage was minimal (Figure 2). Very moist sites (MR 6) exhibited the lowest survival rate.

On the other hand, seedling growth proved best on the fresh to very moist (MR 3 to 6) sites and poorest on the very dry (MR 0) site.

Similar results were obtained on the seeded strips although seedling mortality has been very high and growth extremely slow relative to the planted stock.

CONCLUSIONS AND RECOMMENDATIONS

1. The method of site preparation used in this study should be considered on upland sites prior to planting or seeding where use of herbicides in vegetation management is precluded. Winter shear-blading followed by herbiciding and planting (Ball and Dyck 1991) is a good alternative to summer scarification with a straight blade down to the B horizon. The nutrient rich organic layers and bulk density of the soil are undisturbed and the application of herbicides accomplishes the same objective (ie reduced

vegetative competition) as deep scarification but with less objectional side effects such as reduced growth rates (Ball 1990b).

2. Very moist to wet sites are indicated by the presence of moisture-loving plants such as black ash, Manitoba maple, alders and willows. These conditions are unfavourable for early survival and growth of planted and seeded white spruce but are ideal for aggressive herbs and shrubs. Scarification with a straight blade, followed by planting or seeding on these areas, or on sites subject to seasonal flooding, should be avoided. Deep scarification using a bulldozer on level sites, where the organic layer is thick, creates water catchment areas and is not recommended.

3. Seedlings planted near the edges of scarified strips in plantations (eg area 17) with three rows per strip were able to use the nutrients in the undisturbed forest floor beside the strip sooner than those in the center row resulting in greater height growth. The lower bulk density of the soil in the undisturbed area also has a positive influence on seedling growth (Corns 1988) .

4. Herbiciding improved planting survival by 100% (treated 72% vs untreated 36%) 17 years after treatment in Riding Mountain National Park (area 4 - 1) but height was unaffected. The use of herbicides in vegetation management is a recommended procedure in increasing plantation survival.

5. The planting stock provided by Pineland Provincial Forest Nursery was of good quality and was not a factor in the poor performance of any plantation. Five year survival was generally excellent and any survival losses thereafter were due to browsing, fire, excess moisture, and poor site conditions. Hare browsing was decreased in Porcupine Provincial Forest by planting in square 0.081 ha (1/5 acre) open patches. Survival on open patches was 64%; on the adjacent strip area it was nil. Planting seedlings in open patches rather than in strips prepared in aspen stands during high hare populations is recommended (Radvanyi 1987).

6. Sites chosen for scarification and seeding require more care in selection than areas for planting. Seedlings originating from seed are subject to flooding, fire, browsing and other problems for a longer period of time than planted seedlings simply because these seedlings are small for a longer period of time.

7. White spruce parent trees standing in the vicinity of scarified strips continue to assist in regeneration many years after scarification and in some cases after initial broadcast seeding was considered a failure. Leaving a few trees as a seed source at logging would help fill in unstocked patches in plantations.

8. In this study height growth appears to be unaffected by spacing of planted seedlings (1.4 to 2.4 m). Lower branches at all spacings are beginning to overlap and may reduce the growth rate in the future. Planted seedlings outperformed seedlings originating from seed in height by 179% and current growth rate by 26%. However, the mean height of seedlings (210 cm) from seed on a rich site, (area 3) were taller than the mean height of planted seedlings (176 cm) on a poor site, area 16.

9. Seeding can produce excessive numbers of seedlings. This problem diminishes through competition and natural selection as time progresses. The survivors have small lateral branches and at maturity will make excellent saw lumber.

10. In this study insufficient data exist to recommend spring over fall planting or the reverse.

11. Vandalism, or the removal of saplings for private ornamental replanting, or for Christmas trees caused losses on highly visible plantations that were beside major roads.

ACKNOWLEDGEMENTS

The author wishes to thank those agencies and individuals who established the white spruce plantings and seedlings described in this report: Porcupine and Duck Mountain Provincial Forests - Manitoba Department of Natural Resources, Klaus Vogel; Interlake Region (Fish Road, Beaver Creek, and Mantago Lake) - Canadian Forest Service, George Hennessey, and Norman Walker; Riding Mountain National Park, - Canadian Forest Service, Murray Pratt; Pine Falls - Manitoba Paper Company, Con Howe; and Whiteshell Provincial Park, Manitoba Department of Natural Resources, John Bissinger. Manuscript reviewers included R.M. Waldron, H.J. Johnson, J.Ball, N. Walker, I. Corns and D. Pronger. Special thanks go to Ross Waldron for initiating the project (MS-226) on which the report is based.

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