Government of Canada
Canadian Forestry Service

Gouvernement du Canada
Service canadien des forêts

Proceedings of the 1984 Mechanized Silviculture Workshop

J.R. Gorman, compiler

Information Report NOR-X-272
Northern Forest Research Centre




PROCEEDINGS OF THE
1984 MECHANIZED SILVICULTURE WORKSHOP

February 29 to March 2, 1984, in Edmonton, Alberta

J.R. Gorman, compiler

INFORMATION REPORT NOR-X-272

NORTHERN FOREST RESEARCH CENTRE
CANADIAN FORESTRY SERVICE
1985

Catalogue No. Fo46-12/272E
ISBN 0-662-14322-1
ISSN 0704-7673

This publication is available at no charge from:

Northern Forest Research Centre
Canadian Forestry Service
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Gorman, J.R., compiler. 1985. *Proceedings of the 1984 mechanized silviculture workshop*. Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-272.

ABSTRACT

The 1984 Mechanized Silviculture Workshop was held to encourage comprehensive discussion between government and industrial users of site preparation equipment. Topics covered included types of mechanized silviculture equipment currently in use in the prairies, safety, site preparation, and procedures for equipment evaluation.

RESUME

Le but de l'atelier de 1984 était de favoriser des discussions approfondies entre les usagers gouvernementaux et industriels de matériel de préparation des terrains. On y a présenté des communications sur les types de machinerie utilisés en sylviculture dans les Prairies, sécurité, préparation des terrains, et modalités d'évaluation du matériel.

CONTENTS

NOTE

The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products imply endorsement by the Canadian Forestry Service.

WELCOMING REMARKS

A.D. Kiil
Regional Director of Forestry
Northern Forest Research Centre
Edmonton, Alberta

It is my pleasure to welcome you to the 1984 Mechanized Silviculture Workshop, sponsored by the Northern Forest Research Centre of the Canadian Forestry Service. I am particularly gratified by the large turnout, suggesting that this topic is timely and of interest to a large segment of the forestry community in the prairie provinces and indeed, all of Canada.

This interest in mechanized silviculture is not surprising. Increasingly, government agencies and industry are finding it necessary to treat and plant more of the area harvested or burned each year. The challenge is two-fold: 1) available equipment needs to be tested and evaluated to optimize its performance in specific situations, and 2) new equipment needs to be developed in response to specific site conditions and operational requirements of forest managers in Canada. The purpose of this workshop is to provide a forum for exchange of information covering current equipment usage and performance in the prairie provinces and elsewhere, to identify significant gaps in our knowledge and understanding of mechanized silviculture operations, and to point to new research needs and opportunities. In 1982 the Northern Forest Research Centre initiated a mechanization of silviculture study to develop a regional inventory and data bank entry for mechanized silviculture. Lorne Brace (Project Leader) and Ron Gorman have been largely responsible for the significant progress made in achieving study objectives and in organizing this workshop. It is apparent that this cooperative study, involving the Great Lakes Forest Research Centre and regional clients, has already generated much-needed practical information about the application of mechanized silviculture to forest management.

The program content suggests a very comprehensive coverage of the subject area, including such topics as equipment development, use, and assessment in a variety of practical situations. On behalf of the Canadian Forestry Service, I would like to express my personal appreciation to the workshop organizers, the speakers, and the participants from many government agencies and industry across Canada for their contributions and attendance. I am confident that the meeting will serve as a source of much new and interesting knowledge and awareness about mechanized silviculture.

USE AND DEVELOPMENT OF SITE PREPARATION EQUIPMENT

R.G. McMinn
Forest Ecologist
Pacific Forest Research Centre
Victoria, B.C.

INTRODUCTION

When there is a job to be done, we usually try the most readily available tool first. Choice of equipment for preparing white spruce (*Picea glauca* (Moench) Voss) sites following harvesting was no exception. The job thought necessary was removal of competing vegetation and exposure of mineral soil (Dobbs 1972). Bulldozers could do just that and they were readily available. Only when it was found that there could be unwanted "side effects", such as long delays until seedling growth became commensurate with the capability of the site, was consideration given to the development of specialized equipment. Hence my title, use and development of site preparation equipment. First we use what we have at hand. The development of specialized equipment is only considered when the tools at hand are found to be inadequate.

OBJECTIVE OF SITE PREPARATION

The objective of site preparation for forest renewal is correction of factors unfavorable to seedling survival and growth. Survival is obviously of paramount importance. Site preparation, however, is not satisfactory if survival is obtained at the expense of growth. Conditions for survival are not necessarily the same as those favoring growth. It is imperative to understand the factors influencing growth as well as those affecting survival on each specific site. Moreover, when correcting adverse conditions, we must ensure that deleterious side effects are not introduced. In moist, fertile white spruce clear-cuts, various factors are likely to have adverse effects on the survival and growth of planted seedlings (McMinn 1982). Dense competing vegetation may smother seedlings and reduce light and temperature. Soil temperature is low when surface organic matter is undisturbed. Dense vegetation may compete with seedlings for moisture and nutrients. Nutrient availability is also affected by low soil temperature reducing the rate of seedling root growth and nutrient uptake. Aeration may be poor and root growth restricted when subsurface mineral soil is compact clay.

SITE PREPARATION ALTERNATIVES

The three basic mechanical treatment methods for preparing sites for forest renewal are as follows:

1. *Scalping* to expose mineral soil by removing surface organic matter and competing vegetation;

2. *Mixing* to incorporate chopped-up competing vegetation and surface organic matter into the mineral soil;

3. *Inverting* the surface organic matter and covering it with a cap of mineral soil.

Some of the factors relevant to machine use and development are discussed in the following pages.

Scalping

Scalping deep enough to remove plant roots reduces competing vegetation (Fig. 1). Soil temperature in cool, moist climates is increased (Fig. 2) beneficially (Fig. 3) by exposure of mineral soil. Bulldozer scarification that scrapes off surface layers, however, may leave planting spots liable to flooding, and root growth is restricted when the subsurface soil exposed is compact clay (Minore et al. 1969). Seedlings planted in exposed mineral soil may be chlorotic and slow-growing when surface organic matter is removed beyond their reach because surface organic matter is the principal source of nitrogen (Keeney 1980). Although seedling survival may be improved by scalping fine-textured soils, growth may be slow for a number of years (Table 1). Bulldozers, even though readily available, therefore would seem to be inadvisable implements for preparing fine-textured soils.

The adverse effects of scalping off surface layers with a bulldozer to control competing vegetation and expose mineral soil may be minimal or more than offset by beneficial effects when soil textures are moderately coarse (McMinn 1982). Increased soil temperature and reduced competing vegetation after scalping can result in improved seedling growth and survival (Table 2).

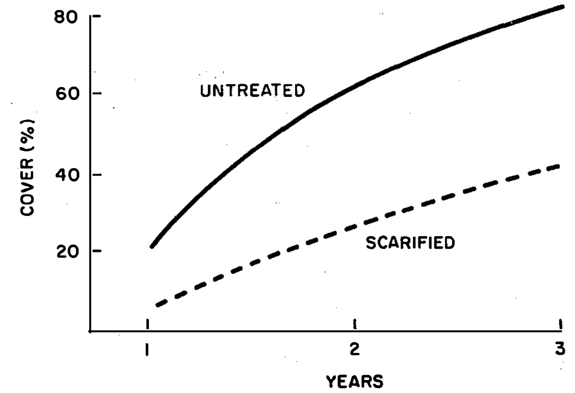

Figure 1. Change in density (% cover) of competing vegetation on untreated and bulldozer-blade scarified sites with time since clear-cutting or treatment.

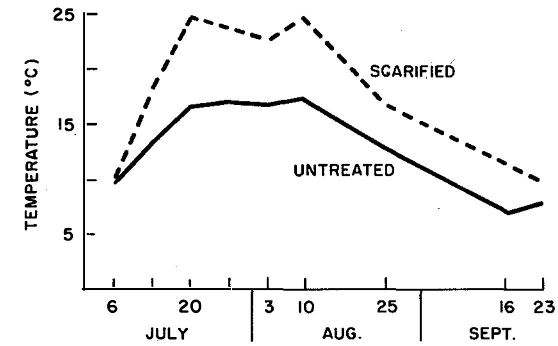

Figure 2. Seasonal change in afternoon (15:00 to 17:00) soil temperature at 5 cm depth on untreated and bulldozer-blade scarified sites (Dobbs and McMinn 1973).

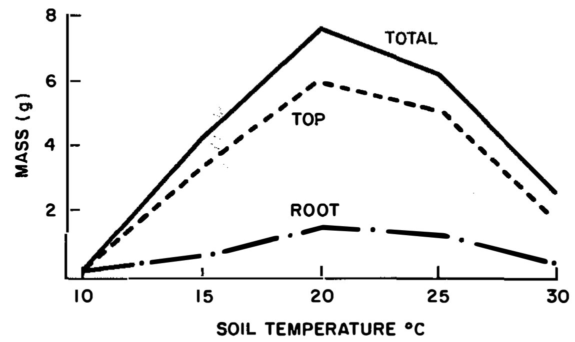

Figure 3. Dry mass of white spruce seedlings grown at various root temperatures for 17 weeks (Dobbs and McMinn 1977).

Table 1. Survival and growth after 8 growing seasons of styroplug white spruce seedlings outplanted following blade scarification and an inadequate mixing treatment in a clear-cut with dense competing vegetation and a fine-textured soil

Treatment	Survival[1] (%)	Stem volume[2] (ml)
Blade scarification	97a[3]	109a
Mixing	88a	112a

[1] Values based on 200 seedlings planted.

[2] Stem volume equals height times one-third stem area at ground line.

[3] Values in same column do not differ significantly ($p = 0.05$).

Table 2. Survival and growth after 5 growing seasons of styroplug white spruce seedlings outplanted following blade scarification and no treatment in a clear-cut with dense competing vegetation and a loamy sand soil

Treatment	Survival[1] (%)	Stem volume[2] (ml)
Blade scarification	89a[3]	40a
No treatment	40b	6b

[1] Based on 200 seedlings planted.

[2] Stem volume equals height times one-third stem area at ground line.

[3] Values in each column differ significantly ($p = 0.05$).

Scarifiers such as the Leno and the Bracke, which expose patches of soil, are suitable for moderately coarse-textured soils. Seedling roots in warm (Table 3), exposed mineral soil patches rapidly reach the nutrients of the undisturbed soil around the patch when root growth is not impeded by compact soil.

Mixing

One of the ways to retain the fertility of surface organic matter available for uptake by seedlings is to mix the surface organic matter with the underlying mineral soil (McMinn 1984a). Favorable soil temperature regimes have been recorded following mixing (Table 3). Seedling growth in mixed treatment planting spots can be appreciably faster than in scalped or untreated areas because mixing controls competing vegetation (Table 3). If competing vegetation is poorly controlled by mixing, seedling performance may be no better than in scalped spots.

Adequate chopping up of competing plants seems to be the key to successful vegetation control by mixing. The mixing drum of the Madge Rotoclear turning at 360 rpm can effectively control competing vegetation. Howard Rotovator tines turning at 180 rpm do not seem to chop vegetation sufficiently to provide effective control. The large size (6.8 m long), weight (9525 kg), and high power requirement (275 kW; 368 hp) of the Madge, however, may limit its use for forest site preparation. Mixing implements would seem most applicable in fine-textured soils with few stones, where tine wear would be minimized.

Inverting

Covering inverted surface organic matter with a layer of mineral soil (Fig. 4) can control competing vegetation (Table 4). Analysis of needles showed that more nitrogen was taken up by spruce seedlings planted in spots prepared by inverted mounding than by seedlings in untreated or scarified patches. Soil temperature in the inverted mounds was increased as much as in exposed mineral soil (Table 4). This increase in temperature is likely to hasten decomposition of the inverted surface organic matter (Solonius 1983) and release of nutrients. Results after three growing seasons showed that the growth of seedlings was greater in mounds where the capping was deep than where it was shallow (Fig. 5). Growth trends in favor of inversion as a site preparation treatment in another experiment have been sustained for eight growing seasons (Fig. 6).

The Bracke Mounder is a towed implement developed in Sweden to produce inverted-mound planting spots operationally (Backstrom 1981). Although a trial in British Columbia during 1983 showed that high slash loadings on sites with high stumps produced irregular planting spot distribution, planting spot distribution where stumps were low was reasonably regular. Depth of mineral soil capping was less than optimum on sites with heavy clay soil. Modification of the shovel mechanism that deposits the soil capping might allow deeper penetration and greater depth of capping. The British Columbia Ministry of Forests is developing an inverted mounder that attaches directly to the prime mover.

Intermittent inverted berms formed by plowing offer an alternative to inverted mounding. Observations in the British Columbia Peace River district have shown that mineral soil covered berms remained free from competing vegetation for two growing seasons after plowing. Unfortunately no seedlings were planted on these berms for comparison with seedlings planted in the furrows. In view of the successful performance of seedlings in inverted planting spots, development of an implement to prepare intermittent inverted berms seems justified.

USE OF HIGH PERFORMANCE STOCK AS AN ALTERNATIVE TO MECHANICAL TREATMENT

Although my topic is the use and development of site preparation equipment, it seems appropriate to mention that high performance stock might eliminate the cost of mechanical treatment on some sites. Table 5 shows results from a trial comparing small stock (styroplug 2) and large stock (styroplug 8) in untreated and blade-scarified areas (McMinn 1984b). These results suggest that planting larger stock without prior site treatment may be a viable alternative to using standard stock with site preparation.

COST-EFFECTIVENESS OF SITE PREPARATION

The cost-effectiveness of site preparation is unknown until the effect of site preparation on the length of time for seedlings to reach harvestable size can be estimated. A more expensive site treatment might be more cost-effective than an initially cheaper method if length of time to rotation age is sufficiently reduced. If the growth trends shown in Figure 6 continue, the inverting treatment could well be cost-effective even if more expensive initially.

Table 3. Soil temperature during the second growing season and survival and growth after 10 growing seasons of 2 + 0 bare-root white spruce seedlings outplanted following blade scarification, a mixing treatment, and no treatment in a clear-cut with dense competing vegetation and a silty clay loam soil

Treatment	Soil temperature[1] (°C)	Survival[2] (%)	Stem volume[3] (ml)
Blade scarification	18.7	90a[4]	859a
No treatment	14.3	75b	783a
Mixing	17.1	87a	1507b

1 Average temperature 5 cm below the soil surface measured weekly June 6 – Sept. 19 during the warmest part of the day (15:00–17:00).

2 Values based on 100 seedlings planted.

3 Stem volume equals height times one-third stem area at ground line.

4 Values in each column followed by the same letter do not differ significantly (p = 0.05).

Table 4. Soil temperature, vegetation density, and foliar nitrogen content of 2 + 0 bare-root white spruce seedlings following planting in inverted mounds and in blade-scarified and untreated areas

Treatment	Soil temperature[1] (°C)	Density of vegetation[2] (% cover)	Foliar nitrogen[3] (%)
Inverted mound	23	30a[4]	1.9
Blade scarification	20	22a	0.8
No treatment	14	57b	1.3

1 Measured with a glass-bulb thermometer 5 cm below the soil surface during a warm July afternoon.

2 Percentage of ground within 50 circles 2000 cm² in area covered by vegetation.

3 Based on content of two needles of the current year from each of 15 seedlings sampled in each treatment during September of the second growing season.

4 Values in each column followed by the same letter do not differ significantly (p = 0.05).

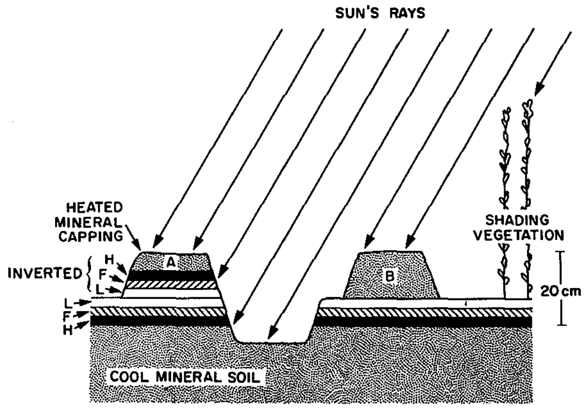

Figure 4. A: mound consisting of inverted surface organic layer capped by mineral soil; when the mineral soil capping is warmed by the sun, heat is transferred to the inverted H layer, which speeds decomposition releasing nitrogen to seedling roots at the interface between the mineral capping and the inverted surface organic matter. B: mound of mineral soil placed directly on undisturbed surface organic matter, which acts as an insulating blanket reducing heat transfer to the H layer and underlying mineral soil.

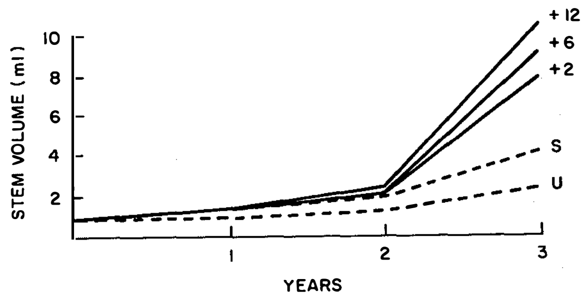

Figure 5. Stem volume for the first three growing seasons of white spruce seedlings planted in inverted mounds with various depths of mineral soil capping, scarified patches, and untreated areas (+12, +6, +2 = depth of mineral soil capping on mounds, in cm; S = scalped; U = untreated).

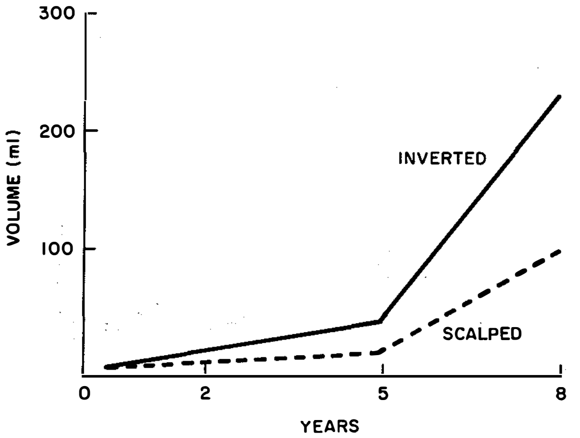

Figure 6. Stem volume (height times one-third stem area at ground line) of styroplug white spruce outplanted following inverting and scalping treatments in a clearcut with dense competing vegetation and a fine-textured soil.

Evaluation of potential benefits should not be based on too short a time period following outplanting. Figure 7 shows that termination of measurements after the fifth growing season would have indicated that mixing and clipping treatments produced the same result. After 10 growing seasons, trees in the clipping treatment plots were substantially larger than trees in the mixing treatment plots (McMinn 1984a).

It would seem advisable when initiating site preparation trials to use an experimental design that accommodates measurements over a long enough period to model effect of growth rate on estimated length of time to harvestable size. Side-by-side test rows are inadequate for this purpose because trees in a good treatment row flanked by poor treatments would not have the competition characteristic of a closed stand after stand closure should have taken place. "Mini-stands" consisting of a core of measurement trees with a buffer surrounding (Fig. 8) could provide the necessary data. Such an experimental design is not appreciably more difficult (or costly) to install than the traditional row comparison.

CONCLUSIONS

Knowledge of the factors leading to good or poor seedling performance is essential if we are to lower cost per established, free-to-grow seedling or perhaps even more important, if site preparation is to be cost-effective in terms of length of time required for seedlings to reach harvestable size. The development of inverted mounding demonstrated that knowledge of the relevant factors can lead to improved methods. The task, of course, is not complete until operational implements are fully developed and in use. Is the continued use of equipment poorly suited to the job justified when experimental results show that more-effective equipment should be developed?

Table 5. Vegetation cover during the second growing season and survival and growth after 10 growing seasons of styroplug white spruce planted in blade-scarified and untreated plots with dense competing vegetation and a fine-textured soil

	Treatment	Density of vegetation[1] (% cover)	Survival[2] (%)	Stem volume[3] (ml)
Plug 2	Untreated	63[4]	93a	516a
	Blade-scarified	25b	97a	722a
Plug 8	Untreated	63a	96a	1288b
	Blade-scarified	25b	98a	803c

[1] Pecentage of ground within 25 circles 2000 cm^2 in area covered by vegetation.

[2] Based on 200 seedlings planted.

[3] Stem volume equals height times one-third stem area at ground line.

[4] Values in each column followed by the same letter do not differ significantly ($p = 0.05$).

REFERENCES

Backstrom, P.O. 1981. Site preparation and direct seeding in Swedish forestry. Pages 208-216 *in* Forest regeneration: the Proceedings of the Symposium on Engineering Systems for Forest Regeneration. Am. Soc. Agric. Eng., Ste. Joseph, MI.

Dobbs, R.C. 1972. Regeneration of white and Engelmann spruce. Environ. Can., Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C. Inf. Rep. BC-X-69.

Dobbs, R.C.; McMinn, R.G. 1973. The effects of site preparation on summer soil temperature in spruce-fir cutovers in the British Columbia Interior. Can. For. Serv. Bi-Month. Res. Notes 29:6-7.

Dobbs, R.C.; McMinn, R.G. 1977. Effects of scalping on soil temperature and growth of white spruce seedlings. *In* T.A. Black et al., editors. Energy, water and the physical environment. Sixth Soil Science Workshop, Vancouver, B.C.

Keeney, D.R. 1980. Prediction of soil nitrogen availability in forest ecosystems: a literature review. For. Sci. 26:159-171.

McMinn, R.G. 1982. Ecology of site preparation to improve performance of planted white spruce in northern latitudes. Pages 25-32 *in* M. Murray, editor. Forest regeneration at high latitudes: experiences from northern British Columbia. Proceedings of a Third International Workshop, Prince George, British Columbia, Aug. 29-Sept. 1, 1981. Sch. Agric. Land Resour. Manage., Univ. Alaska and U.S. For. Serv., Pac. Northwest For. Range Exp. Stn. Misc. Rep. 82-1.

McMinn, R.G. 1984a. Effect on white spruce and lodgepole pine seedling performance of surface organic matter availability following various methods of site preparation. Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C. File Rep. PC 48-111.

McMinn, R.G. 1984b. Stock size versus site preparation as forest renewal strategies. Environ. Can., Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C. File Rep. PC 48-111. 4 p.

Minore, D.; Smith, C.E.; Wollard, R.F. 1969. Effects of high soil density on seedling root growth of several northwestern tree species. USDA For. Serv., Res. Note PNW 112.

Salonius, P.O. 1983. Effects of organic-mineral soil mixtures and increasing soil temperature on the respiration of coniferous raw humus material. Can. J. For. Res. 13:102-107.

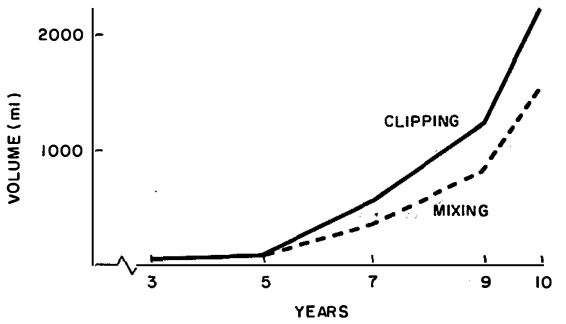

Figure 7. Stem volume (height times one-third stem area at ground line) of 2 + 0 bareroot white spruce outplanted following mixing and clipping treatments (competing vegetation clipped three times during each of the first two growing seasons) in a clear-cut with dense competing vegetation and a fine-textured soil.

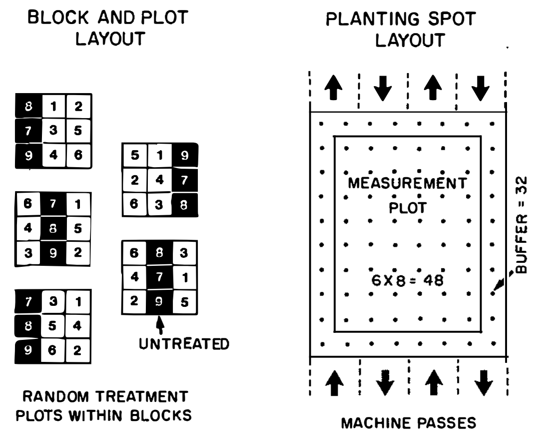

Figure 8. Experimental design for comparing mounding implement with other mechanical treatments, standard and large stock with no treatment and herbicide treatment (1. inverted mound with ± 6-cm cap; 2. inverted mound with ± 14-cm cap; 3. inverted mound with ± 20-cm cap; 4. Bracke hump; 5. Bracke scalped patch; 6. blade scarified; 7. untreated; 9. herbicide treated: all with standard stock: 8. untreated planted with large stock).

SILVICULTURAL EQUIPMENT USED BY THE ALBERTA FOREST SERVICE

C. Bamsey
Silviculture Forester
Alberta Forest Service
Edmonton, Alberta

This paper is presented primarily to introduce the reader to the types of site preparation treatments the Alberta Forest Service (AFS) conducts on forested lands to establish acceptable stocking levels. Before discussing the various machines in use today, it may be worthwhile to sketch the present assignment of reforestation responsibilities in the province and the scope of the programs involved.

The AFS is the division of the provincial Department of Energy and Natural Resources that is charged with the management of Alberta's forest lands in such a way as to ensure a perpetual supply of benefits while maintaining a forest environment of high quality. The government is ultimately responsible for ensuring that all cutover public lands are adequately reforested; however, the cost of reforestation on harvested forest land is borne by the forest industry. The responsibility for carrying out the reforestation work is shared as follows:

1. holders of forest management agreements (FMAs) do their own reforestation;

2. timber quota holders may elect, when issued a new timber license, to do the reforestation themselves, or pay a set levy and turn the responsibility over to the AFS;

3. smaller timber dispositions (sold as temporary permits) are reforested by the AFS.

In addition to the above quota and non-quota categories, the AFS has also undertaken reforestation and afforestation projects under the Maintaining Our Forests (MOF) program. These activities are designed to compensate for reductions in the productive forest land base by other forest users and are currently funded through the Alberta Heritage Savings Trust Fund.

These three sources of AFS responsibility include lands throughout the province with a wide variety of sites and conditions. Silviculture foresters in each of the ten regional forests (together with district ranger staff and the Reforestation and Reclamation Branch in Edmonton) plan and implement reforestation work in their respective areas. Tables 1 and 2 summarize the work completed by each forest in the 1982–83 fiscal year.

Six main reforestation systems are prescribed following harvesting based on prior knowledge or on postharvest surveys (Table 3). These combinations of natural regeneration and treatments are the main first treatments used; however, clearing, piling, or chemical application may also be prescribed as a first treatment.

Regeneration surveys are normally performed 4-6 years after disturbance when relying on natural seeding, 3 years after planting, and 4 years following broadcast seeding. The quota and non-quota figures for 1980 and 1981 show that an average unit is surveyed 1.51 times at a total cost of $29.04 per ha per survey before it reaches the satisfactorily restocked (SR) status.

Scarification is currently prescribed as a first treatment on about 61% of cutover areas reforested by the AFS, plus about 85% of areas cleared under the MOF program. This treatment covered a total of 11 117 ha in 1981 and 18 086 ha in 1982. The range of sites ad conditions encountered over this area warrants having available a variety of proven machinery, as well as selecting and testing new products that appear to have potential.

The AFS has purchased five types of scarifiers that have proven capabilities on selected sites. The process of determining on which sites each machine will work effectively is a long one. In 1982 the AFS began establishing permanent monitoring plots on areas treated by each machine. Stocking, growth, competition, and various other microsite parameters are measured in years 1, 2, 4, and 8 after treatment. The data are to be used not only to determine the most effective scarification type, but also to confirm or refine present conceptions of aerial seeding rates, natural ingress, planting spot selection, competition dynamics, etc. by repeated observation of individual plants and microsites over a 10-year period.

The following section briefly describes each piece of equipment the CFS currently uses on a regular basis, as well as the two pieces tested during 1983. Average direct costs per hectare are based on projects completed in 1980 and 1981 on cutovers (except where noted) and include access, transportation, prime mover, and repair costs. The advantages and diasadvantages are based on personal observation and opinion.

Table 1. Reforestation work by the Alberta Forest Service, 1982-83

Forest	Site preparation: Mechanical (ha)	Site preparation: Chemical (ha)	Seeding (ha)	Cone collection: Pine (hL)	Cone collection: Spruce (hL)	Seeding/planting, Conventional: Area (ha)	Seeding/planting, Conventional: No. of trees	Seeding/planting, Container: Area (ha)	Seeding/planting, Container: No. of trees	Thinning
Athabasca	—	—	—	—	—	—	—	289	382 092	—
Bow/Crow	709	—	176	1 217	286	801	760 105	319	425 600	—
Edson	724	—	144	306	7	89	200 364	243	432 702	399
Footner Lake	1 059	—	292	—	919	372	608 331	245	344 537	—
Grande Prairie	904	—	304	1 754	—	62	69 100	—	—	—
Lac La Biche	696	—	41	—	290	156	201 277	—	—	—
Peace River	201	—	411	112	318	—	—	847	1 176 350	55
Rocky/Clear-water	904	—	353	1 653	16	111	125 657	98	121 687	—
Slave Lake	2 173	—	1 491	12 360	3 383	557	710 286	684	825 454	—
Whitecourt	761	—	—	98	—	511	816 000	14	3 232	89
Total	8 131	—	3 212	17 500	5 219	2 659	3 491 120	2 739	3 711 654	543

Table 2. Maintaining Our Forests reforestation work program by forest activity, 1982-83

Forest	Stocking surveys: Aerial recon.	Stocking surveys: Ground recon.	Stocking surveys: Ground inten-sive	Site preparation: Land clearing	Site preparation: Scarifi-cation	Planting, Conventional: Area (ha)	Planting, Conventional: No. of trees	Planting, Container: Area (ha)	Planting, Container: No. of trees	Cone collection: Pine (hL)	Cone collection: Spruce (hL)	Seeding: Aerial (ha)	Seeding: Hand (ha)	Thinning (ha)
Footner Lake	110 000	—	—	1 660.0	—	—	—	880.0	1 588 496	—	620.0	—	—	—
Lac La Biche	27 000	181	698	1 971.1	2 035.4	—	—	1 857.0	3 008 980	—	241.0	30.2	—	—
Peace River	4 400	—	401	3 452.0	4 819.0	—	—	2 608.0	3 165 120	—	148.1	—	—	70.5
Slave Lake	14 000	2 629	1 821	3 007.7	3 101.0	142.4	225 183	1 119.1	1 586 218	—	—	—	—	—
Whitecourt	—	—	—	—	—	—	—	—	—	—	—	—	—	115.0
Rocky	—	—	—	—	—	—	—	—	—	—	—	—	—	236.0
Edson	—	—	—	—	—	—	—	—	—	—	—	—	—	280.1
Total	155 400	2 810	2 920	10 090.8	9 955.4	142.4	225 183	6 464.1	9 348 814	—	1 009.1	30.2	—	701.6

Source: Alberta Department of Energy and Natural Resources. 1983. *Annual Report: March 31, 1983*. Edmonton, Alberta.

Table 3. Treatments prescribed for cutovers

Treatment	Average total cost per hectare[1] ($)	% area[2]
1. Leave for natural regeneration	—	31
2. Plant only	403.60	7
3. Seed only	106.83	1
4. Scarify and leave for natural regeneration	205.50	18
5. Scarify and plant	609.10	10
6. Scarify and seed	312.33	33

[1] Average of 1980 and 1981 quota and non-quota total costs, including seed and planting stock.
[2] % area treated is based on the period 1966–75.

Ripper Plow

Model	Craig-Simpson (C & S)
Quantity owned by AFS	Nine
Season used	November to April
Sites prescribed	1. Winter access only 2. Deep duff, moist spruce
Objectives of treatment	1. Expose mineral soil for seeding 2. Break root mat for planting
Usual prime mover	Crawler tractor (Cat D8K)
Approximate purchase cost	$5250
Average direct cost	$262/ha
(1980 + 1981) range	$222–$383/ha

Advantages:

- Can scarify under heavy frost during winter season when access is good
- Exposes sufficient mineral soil for successful direct seeding (if used properly)
- Mixes soil and duff that may promote growth
- Usually only requires annual maintenance
- Can be transported in three-quarter-ton pickup

Disadvantages:

- Creates poor planting spot due to flooding in the trench and drying out of the berm with very little gradient between
- Depth control is difficult because it is mounted directly on tractor
- Tractor loses use of winch
- Grass competition may be promoted by the mixing effect
- Ripper hydraulics are somewhat slow to raise or lower the plow

Mounding Bracke

Quantity owned by AFS	None; tested during 1983 on rental
Season used	April to November (suitable for use on frost-free soil only)
Sites prescribed	Wet, deep duff, heavy slash spruce-aspen cutover
Objectives of treatment	Create elevated planting spots
Usual prime mover	Widepad D6D (30-in. shoe) with V-Plow
Aprroximate purchase cost	$65 000 (1983)
Average direct cost	$163/ha
(1980 + 1981) range	$159–$176/ha

Advantages:

- Automatic shutoffs to protect components from loss of fluid damage
- Easy controls
- Replaceable shovel cutting edges
- Easy hookup and can be released and winched through wet spots
- Many satisfactory mounds are achieved on difficult sites
- Planting spots are not subject to flooding
- Production was 0.55 ha/hr on a very difficult site

Disadvantages:

- Extra motor required for hydraulics
- Shovels may pile soil on debris, creating a poor planting site
- Mounds require 1–2 years to stabilize and may further erode
- High level of expertise required for trouble shooting and repair
- Mounds are spread flat on very soft ground because the mattocks pull the rear of the unit down
- Forward speed must be regulated to achieve desired mound

Anchor Chain Drags

Model	4-Anchor Chain c/w V-Bar
Quantity owned by AFS	Three
Model	7-Anchor Chain c/w V-Bar
Quantity owned by AFS	Five
Season used	March to October (frost-free period)
Sites prescribed	1. Stands with lodgepole pine component greater than 20% 2. Shallow duff 3. Slopes sensitive to erosion 4. Burned areas

Objectives of treatment	1. Prepare seedbed by exposing mineral soil 2. Lower cones to aid in breaking resin bond 3. Reduce slash hazard 4. Distribute cone-bearing slash
Usual prime mover	Skidder or crawler tractor (D6-D8 range)
Approximate purchase cost	Custom built; prices vary
Average direct cost	$219/ha
(1980 + 1981) range	$208–$300/ha (AFS costs are inflated by high transportation costs to and between scarification sites.)

Advantages:

- Economical
- Very effective for *Pinus contorta* regeneration
- Winch control allows prime mover to cross soft spots uninhibited
- Aesthetically pleasing treatment
- Significantly reduces slash fire hazard

Disadvantages:

- Awkward to load and unload
- Sometimes 7-chain drags get badly tangled
- Grass invasion is sometimes severe

Brush Rake or Modified Dozer Blade

Model	Various
Quantity owned by AFS	None; hired on hourly basis
Season used	All seasons
Sites prescribed	1. Wide range, but mainly mixedwood with coarse textured soils 2. Areas with limited summer operability
Objectives of treatment	1. Mineral soil exposure for natural seeding or broadcast seedings 2. Grass suppression
Usual prime mover	Crawler tractor (D7-D8 range)
Approximate purchase cost	—
Average direct cost	$215/ha
(1980 + 1981) range	$116–$381/ha

Advantages:

- Can hire equipment on a moment's notice or when conditions are best
- Operable with light frost in ground
- Exposes up to 90% of mineral soil

- Effective with good growth on coarse soils
- Can contend with heavy slash and stumps
- Excellent grass and brush suppression for a number of years

Disadvantages:

- Many seedlings show poor growth
- Nutrients are piled up too far from tree
- Piles are unsightly
- Erosion may be serious unless random pattern used
- Little stocking control

Leno Patch Scarifier

Model	81
Quantity owned by AFS	One
Season used	March to October (frost-free period)
Sites prescribed	1. Mixedwood cutovers (dry) 2. Partially stocked areas requiring fill-in planting
Objectives of treatment	1. Reduce competition for subsequent planted stock 2. Create scalp where duff is moderately deep
Usual prime mover	Skidder
Approximate purchase cost	$24 750 (1982)
Average direct cost	$124/ha
(1980 + 1981) range	—

Advantages:

- Excellent maneuverability around residuals
- Good scalp quality
- Easily mounted and transported
- Economical if skidder access is good
- Quickly lifted over obstacles

Disadvantages:

- Aspen suckers are not inhibited, and may be promoted
- Patch spacing is inconsistent

Marttiini Plow

Model	KLM 180 and 240
Quantity owned by AFS	Five
Season used	April to November
Sites prescribed	1. Light stumps or cleared areas 2. Deep duff and wet sites 3. Areas of high grass competition
Objectives of treatment	1. Reduce grass and aspen competition 2. Create planting spot
Usual prime mover	Crawler tractor (D7-D8 range)
Approximate purchase cost	$28 000 (1979)
Average direct cost	$125/ha (1981 MOF); $85/ha (1983 MOF)

Advantages:

- Wide scarified trench reduces competition very well
- Easy walking for planters
- Creates good elevated planting site on berms if left to settle prior to planting

Disadvantages:

- Depth control is difficult to maintain as tips and cutting edges wear
- Trenches subject to flooding
- Grass topples from berm onto planted stock
- Hydraulics continually need repacking and replacement of hoses
- Retreatment on fail areas is difficult
- Does not handle slash or large stumps

Bracke Patch Scarifier

Quantity owned by AFS	10
Season used	March to October
Sites prescribed	Wide range, from dry pine to moist spruce
Objectives of treatment	1. Create planting spot 2. Reduce vegetative competition
Usual prime mover	Skidder or crawler tractor (D6)
Approximate purchase cost	$35 000 (1982)
Average direct cost	$135/ha ($48/ha on cleared MOF in 1981)
(1980 + 1981) range	$29-$185/ha

Advantages:

- Low annual maintenance
- High availability
- Repairs are mainly mechanical
- Replaceable wear teeth
- Excellent service from distributor
- Simple hookup to tractor or skidder
- Negotiates stumps and slash well
- Versatile and effective on many different sites
- Consistent spacing
- Good treatment for fill-in planting

Disadvantages:

- Not too effective on fine textured wet soils because of flooding in the bottom of patch, erosion of side walls, and drying of material pushed out of scalp
- Limited competition suppression
- Must be loaded with gin-pole truck
- Skids on moist grassy sites
- Seeders plug up

Donaren Powered Disk Trencher

Model	180D
Quantity owned by AFS	None; tested in 1983
Season used	April to November
Sites prescribed	1. Cutovers with light slash 2. Cleared aspen conversion
Objectives of treatment	1. Create planting spots 2. Duff removal to inhibit grass and brush competition
Usual prime mover	Forwarder-carrier or skidder
Approximate purchase cost	$55 300 (1983)
Average direct cost	$106/ha — primarily on cleared areas, 1983
(1980 + 1981) range	$75–$460/ha

Advantages:

- Easy to transport block to block
- Negotiates undulations in terrain very well, rides over slash and stumps
- On cleared sites, gives a near-continuous strip of consistent quality

- With properly trained and motivated operator, this machine has good potential on the lighter-textured soils, particularly if logging utilization standards were improved and slash loads on the cutover areas were reduced

Disadvantages:

- Overwidth and awkward to load when not attached to prime mover
- Skidder as prime mover has limited summer mobility on many sites
- Forwarder-carriers not available in Alberta; crawler tractor hookup unknown
- Special mounting adaptations required (suited to owner-operator)
- Does not negotiate slash greater than 3 in. diameter
- Underpowered disk rotation and disk motor seals easily blown by reversing
- Slow to lift arms (one at a time)
- Electronic controls are very sensitive to moisture
- Repairs require mechanical, hydraulic, and electronic expertise
- No distributor in western Canada

In addition to the scarification equipment mentioned, the AFS has developed an aerial seeder that has proven invaluable in carrying out the seeding program. It consists of the following three main components:

1. an aluminum hopper with a capacity of 135 kg of seed that fits inside the rear seat space of a Bell 206 Jet Ranger helicopter,
2. an auger (distributor) with adjustable metering control that fits below the hopper inside the aircraft, and
3. a slinger that connects to the distributor by a flexible hose and mounts underneath the aircraft.

Approximately 3000 ha per year have been seeded using this machine in the past three years, and plans for March 1984 include 7000 ha. A new disk-type slinger has been added this year and if it proves satisfactory, construction plans will be drafted and made available to interested parties at cost.

There is currently heavy competition for AFS planting, thinning, clearing, and scarification contracts, but few firms are interested in developing specialized site preparation equipment. While the list of machines available for use today is expanding, most machines have been designed elsewhere and adapted for Alberta conditions. Until the specific needs have been identified, and a specialized "silviculture industry" emerges, the AFS will continue to sponsor trials of new equipment, and in some cases develop "problem site" machines as required.

SILVICULTURAL EQUIPMENT USED IN MANITOBA

G. Peterson
Forester
Manitoba Department of Natural Resources
Winnipeg, Manitoba

INTRODUCTION

The scope of this paper will be limited to silviculture equipment used for reforestation and stand tending. Nursery equipment, which is an important part of silviculture in Canada, is a whole subject in itself and could not be covered adequately here.

In the past in Manitoba, as elsewhere, a wide variety of agriculture plows, fire plows, and assorted dozer blades, such as V blades, CFS, and C & H blades, were used. As cutover size increased, wheeled-skidders became a quicker and less expensive prime mover than crawler tractors. A problem with most blades was their inability to mix soil and humus for better seeding or planting sites. Another problem was the generally slow pace of agriculture equipment (compared to new equipment), and its frailty when dealing with solid stumps, rocks, and heavy logging slash.

Shear-blading is still performed in Manitoba by Abitibi-Manitoba Paper Company for stand-converting aspen to white spruce. Aspen is either windrowed or left standing in strips underneath blades and planted to white spruce containers or seeded. Today's equipment will now be covered in a little more detail.

ANCHOR CHAINS

These widely used and successful "drag" type scarifiers are still used extensively for natural jack pine regeneration on the shallow soils of the boreal forest regions in Manitoba. Studies (e.g., Cayford and Bickerstaff 1968) have shown it to be successful and efficient as well as relatively inexpensive for that application.

Currently about 3500 ha, 2700 in the north alone, are treated annually in Manitoba, with productivity being about 3 ha per hour at a cost of approximately $30 per ha. This is for large cutovers. In comparison the much smaller cutovers of the south cost about twice as much (about $609 per ha) for similar treatment.

The most commonly used setups are anchor chains (32-lb. link) with 2-ft., 1-in. steel bars welded as an X through each link, two, three or four in parallel, attached by swivels to tractor pads or directly to the draw bar. Crawler tractors such as the TJ 550, the JD 740, and the TJ 360 skidder are the most common prime movers.

In Manitoba, anchor chains have proven to be an inexpensive, effective way of obtaining mineral soil exposure and evenly distributing logging slash for natural regeneration of jack pine and black spruce on areas of shallow soil. Regeneration survey results from northern Manitoba show an 85-95% stocking achieved as a result of anchor chain treatment.

SHARK-FINNED BARRELS

Although this Canadian-developed site preparation tool provided good results and had a wide variety of applications (Hallett and Murray 1980; Soos and Kolabinski 1974), it is no longer used in Manitoba. Depending on the terrain and type of cutover, these barrels were shown to be highly effective and had good productivity.

A wide variety of movers, from small crawler tractors to large skidder prime movers, were employed with the usual two or three barrels in series behind sections of tractor pads and attached to a draw bar. At all points of attachment, swivels were used to allow the barrels to roll easily.

The main problems associated with shark-finned barrels were their relative awkwardness and difficulty of transportation and the time-consuming maintenance required. As well, due to their long overall length, turning around was more difficult. Because the barrels are essential free-moving, which was their initial intent, the interrow spacing could be too variable depending on the obstructions encountered. All of these problems made barrels more costly and less effective than the TTS and their use has been discontinued.

FLECO 710 AND 812 DRUM CHOPPERS

This equipment has found a variety of silvicultural applications in southern Manitoba. The Manitoba Department of Natural Resources owns both a Fleco 710 (7-foot width) and a Fleco 812 (8-foot width), which when filled with water, weigh 11 250 lb. and 14 000 lb., respectively. The preferred filler is diesel fuel, which would decrease the weight proportionately. Attached to the drum are replaceable grader blades.

These choppers have been coupled with numerous prime movers such as a D4 or an HD 9 crawler for mechanical thinning, with a JD 450 or JD 550 crawler for prescarification site preparation, or with a D7 for stand conversion.

The choppers were tested on a thinning project involving the strip-thinning of extensive areas of young, extremely dense (6000-55 000 trees per acre) fire-origin jack pine stands in the Sandilands Provincial Forest (Bella and De Franceschi 1971). This project is being monitored and analyzed by the Canadian Forestry Service, Northern Forest Research Centre. Early results show good response. Bella and De Franceschi (1971) found that "Significant release in diameter growth was observed on fresh and moist sandy sites.... In some stands, rate of growth of the largest trees doubled after treatment".

As a silviculture tool, drum choppers proved inexpensive and easy to maintain and repair. The major problems with the stand treatment is that it is nonselective thinning, with no choice of desired crop trees possible, and it increases fire hazard substantially. No new areas are currently being treated with this equipment.

A stand conversion project tried to convert immature, semistagnant aspen/willow stands to white spruce. The project showed the machine unsuccessful at reducing competition; in fact, competition increased with vigorous young growth of suckers. The chopper tended to ride over groups of parallel stems flattened by the dozer blade rather than chop them. Many stems rebounded to the semistanding position. The hand-planting of 2-0 white spruce paper pots that followed is unassessable due to the density of sucker growth but is presumed to be a total failure.

The last application, the prepreparation of cutovers before scarification by the TTS disk trencher, is where the equipment is still in use. It has proven highly successful in crushing the heavy jack pine logging slash present in the areas in the Sandilands where site preparation follows the year after cutting (i.e., no backlog). The slash never has a chance to weather, compact, and decompose. The crushed slash means no additional weight (and corresponding stress) need be added to the TTS to get proper penetration. It also means easier hand-planting after trenching.

In conclusion, the Fleco drum choppers have proven successful in both mechanized strip-thinning and prescarification site preparation in southern Manitoba.

THE TTS 35 DISK TRENCHER

With its use increasing and becoming more widespread all across Manitoba, this Scandinavian rotating disk plough has become the chosen method of site preparation for hand-planting in the province. In fact, the purchase of a second machine is currently being considered as demand is too high for the present trencher.

The favored prime mover in Manitoba is the Timberjack 360 grapple skidder, although others have been used, including the C5D tree farmer, the Clark 668, and the JD 740.

The versatility of the TTS 35 is one of its biggest advantages, along with ease of movement and transport, simplicity of maintenance, and good performance on a wide variety of sites. Approximately 1500 hectares are currently treated annually with the TTS on sites ranging from the deep sand of the Sandilands Provincial Forest to the upland clays of the Abitibi Forest Management License Area and the western Manitoba "mountains". The machine is used in summer pine scarification, winter black spruce scarification for natural regeneration, and stand conversion of poplar to white spruce, where trenching is undertaken under standing aspen.

Since initially purchased and tested in 1978, the TTS has proven cheaper and more effective than barrels for site preparation and, while costs have increased yearly, the annual increase has been mainly inflationary (about 9-10%).

The tendered prime mover contract in the southern region last year was $39.75 per operating hour for a Timberjack 360. Contract completion yielded the following results: productivity approximately 1 hectare per hour, 460 hectares trenched at a cost of $48.80 per hectare, with machine availability 98%. Interestingly, the cost of $48.80 per hectare in 1983 is lower than the cost of barrel scarification in 1979 ($49.10 per hectare).

As can be expected, the teeth on the disks need yearly replacing, particularly if used in rocky soils. This is done at the Pineland Nursery by staff personnel. Teeth are cut from steel plate, hardened, and attached to the disks. Next year another set of disks will be purchased so that spares are available should unforeseen problems arise.

Generally then, the TTS 35 has proven to be a valuable and versatile site preparation tool for Manitoba. Ease of maintenance, transportation, and adjustment make it the preferred scarification tool preceding hand-planting on a wide variety of soil types.

BRACKE SCARIFIER (BRACKE BADGER 2-ROW)

This Scandinavian-designed and built patch scarifier has proven to have little potential in Manitoba (at least in areas tested) as a silvicultural tool. The problems encountered in testing included poor penetration to mineral soil during winter scarification, probably due to a lack of weight on the mattock wheels. This could be overcome by addition of more weight, although the design of the arm prevents that. As well, the rubber wheels tended to skid or spin rather than rotate on frozen ground; essentially the mattock wheels did the walking.

During spring-summer scarification, problems encountered included a tendency to pile slash between the patches, which makes hand-planting a rigorous job. In areas of heavy slash the teeth tend to ride over slash and this makes the spacing very variable. As well, the amount of undesirable vegetation in competition with seedlings remaining between patches adds extra stress to the seedlings. The prepared patches tended to cause ponding of water (particularly in clay soils) rather than drainage. The relatively long length of the machine (as compared to TTS) makes turning around more difficult and time-consuming. The machine is also less adjustable for patch depth or penetration than the TTS, which is important on areas of different soil types, i.e., from clay to sand to organic. In short, its application in Manitoba was unsatisfactory and further use is doubtful.

THE CAZES AND HEPPNER PLOW AND PLANTER

Designed in British Columbia, this dry-land plow, mechanical tree planter combination has had encouraging results in the Sandilands Provincial Forest of southeastern Manitoba. The prime mover used most successfully has been a CAT D7F, although on the sealed-tendered bid system of contracting you don't always get what you want.

A bid bond on the tender is now required for our approval of the prime mover. The contract rate was $58/hour in 1983. Completion of the contract yielded 135 hectares completed at a price of $172.82 per hectare or $0.09 per tree. Rates were one-half a hectare an hour and 2000 trees per hectare. That spacing is limited by the amount of slash and overburden present on site. Since the slash shouldn't be pushed onto the freshly planted row beside it, distance between rows is variable.

For comparison, the hand-planting program in 1983 in the same area cost $0.11 per tree or about $350 per hectare, including TTS scarification. And 75% of the hand-planted and 78% of the machine-planted seedlings were planted well. Machine and plough availability has been over 80% for the past three seasons.

The areas chosen for this machine were very selective (Hallet and Murray 1980); deep sand with light or decomposed slash and loose stumps are preferred in Manitoba. This would make the machine ideal for treating backlog areas. If the planting site is prepared by drum-chopping, the C & H can work well in thicker slash, but the digging foot needs strengthening and hardening frequently due to solid stumps. The twin packing wheels work well in the moist sand on the chosen sites and there is little evidence of J-shaped roots. Preferred size of seedlings is the typical 2–0 jack pine or 3–0 red pine on moister sites. Increasing use of this combination is being recommended in southeastern Manitoba, with only length of optional planting season for bare-root (terra-sob dipped) stock the limiting factor.

In conclusion the C & H plow and planter have proven to be a highly successful silviculture tool in the reforestation of pine cutovers in southeastern Manitoba.

CONCLUSION

As you can see, Manitoba uses a variety of silvicultural equipment developed worldwide, with the TTS disk trencher and anchor chains being the most widely used currently. One promising development to come out of western Manitoba is a seeder attachment for the TTS trencher. This is discussed in G. Ardron's paper on the McBorkan Air Seeder.

REFERENCES

Bella, I.E.; De Franceschi, J.P. 1971. Growth of young jack pine after mechanical strip thinning in Manitoba. Dep. Fish. For., Can. For. Serv., Edmonton, Alberta. Inf. Rep. A-X-40.

Cayford, J.H.; Bickerstaff, A. 1968. Man-made forests in Canada. Dep. Fish. For., For. Branch, Ottawa, Ont. Publ. 1240.

Hallett, R.D.; Murray, T.S. 1980. Recent developments and current practices in forestation in Canada. Environ. Can., Can. For. Serv., Marit. For. Res. Cent., Fredericton, N.B. Inf. Rep. M-X-116.

Soos, J.; Kolabinski, V.S. 1974. Site preparation of jack pine cutovers with shark-finned barrels in Saskatchewan. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-89.

THE McBORKAN AIR SEEDER

G. Ardron
Forester
Manitoba Department of Natural Resources
Swan River, Manitoba

This brief presentation is on a direct seeding system that has been named the McBorkan Air Seeder. This seeder was designed and built in Manitoba by the Western Forestry Branch staff and a local farm implement dealer. The intent was to have a system where in one pass over the site we could prepare a seedbed using the TTS disk trencher and apply seed at regular intervals.

With the help of the implement dealer, an air seeder was designed and built to meet these requirements. The seeder was made small enough to be mounted under the arch of the skidder where it was relatively safe and easily accessible for seed loading. From the seeder hopper the seed could be blown through two 1-inch hoses to the back of the trencher, where it could be dispersed on the freshly prepared seedbed.

The seeder was put into use in the fall of 1980 and over the next few months, over 1000 hectares were seeded with white spruce and black spruce. During this time the seeder ran quite well with very little down time or complications. Early regeneration surveys indicated that this system could be a successful reforestation tool. At Year Two after seeding, stocking percentages ranged from 50 to 75%.

At this stage we felt that there were still too many unanswered questions to continue operational seeding at this scale, and thus a controlled research study was established to evaluate the whole system. The main objectives of the study were as follows:

1. to determine a seeding intensity that would give us a minimum of 75% stocking at Year Five,
2. to determine the most acceptable season for direct seeding, and
3. to monitor seedling emergence, growth, and mortality up to Year Five.

Three distinctly different sites were chosen for the study area. Two were seeded with white spruce and one with black spruce. On each site, three seeding intensities were applied. These ranged from 350 grams per hectare (0.31 pounds per acre) to 1150 grams per hectare (1 pound per acre). The seeding was carried out in the fall of 1982 and the winter of 1983. Due to extremely wet conditions in the spring of 1983, we were not able to complete our spring seeding.

In the fall of 1983 permanent sample plots were established and evaluated for first-year germination. The evaluation indicated relatively high first-year germination with stocking ranging from 53 to 99%. It should be noted here that our criterion for stocking was to have two germinants in a 0.5 $\times$ 2 m plot running along the furrows.

It is too early to draw any firm conclusions from this first-year evaluation, but some trends seem to be apparent. As expected, the higher seeding rates produced both the highest stocking percentages and the highest number of seedlings per plot. It was also noticed that for all three intensities the fall seeding produced much better initial results than the winter seeding.

To conclude, I would like to say again that we will be monitoring the plots for at least the next 5 years. At that time we hope to know the most efficient seeding schedule with which to obtain our 75% stocking requirement.

ERGONOMICS AND SAFETY ON SILVICULTURE AND REFORESTATION OPERATIONS

J.D. Nugent
Manager
Forest Products Accident Prevention Association
North Bay, Ontario

INTRODUCTION

The Forest Products Accident Prevention Association (FPAPA) of Ontario was founded in 1915 with a mandate to supply safety education to the logging, sawmill, and veneer-plywood industries. The efforts of the association have primarily been directed to the harvesting and processing end of the business because these are high-hazard and high injury-producing areas.

With the advent of forest management agreements and the responsibility being placed on companies for silviculture and reforestation, the FPAPA recognized the need for safety and health education in this field. We are now in the process of gathering information from various sources to fill this need.

DEFINITIONS

Silviculture: the art of producing and tending a forest and forest trees.

Reforestation: to renew woodlands, replant with trees.

Safety: the state or condition of freedom from danger or risk, freedom from injury.

Ergonomics: scientific study of the efficiency of workers in their working environment.

It has been my observation that Canadian forestry people devote much more time, effort, and finances to developing machinery and equipment than they do to developing people. To keep things in perspective, it must be emphasized that the whole purpose of the exercise is to produce goods for human use, and to improve the quality of our lives both at work and leisure.

I would like to present a series of slides showing a typical site preparation, planting, and thinning operation in eastern Canada and some European forest scenes. As you view the slides, try to identify potential hazards that could cause injury or health problems.

Some typical injuries that we can observe during planting and thinning operations are listed below.

1. Planter climbing over brush in scarified area slipped and broke her arm.
2. Planter jumped over a small creek, landed on a slippery stone, and broke her ankle.
3. Planter working on a line lifted a rope to clear slash. Rope struck another planter in face, breaking her glasses.
4. Planter stepped in a hole covered by brush and sprained her knee.
5. Thinning saw operator, cleaning a twig from saw guard, cut off thumb.
6. Thinning saw operator struck on head by dead limb 5 in. in diameter by 8 ft. long.
7. Thinning saw operator jammed blade in a tree, another operator attempted to cut tree to free blade. His saw ran up shaft, lacerating first operator's left arm and abdomen.
8. Thinning saw operator tripped and fell on saw, amputated three fingers.
9. Spray machine operator became nauseous when overcome by fumes when wind shifted.
10. Supervisor received bruised arm when pinched between skidder wheel.
11. Sapling sprung back, striking saw operator on left testicle.

The four basic areas to consider when implementing a work program are people, equipment, material, and the environment, and their relationships to each other to produce the desired results.

First let us consider **people**, the most important element. They are the foresters, planners, technicians, supervisors, equipment operators, planters, thinning saw and chain saw operators, and government personnel such as site inspectors.

In the planning stage, a program should be established for the selection, indoctrination, and training of workers. Planters in particular often have had no previous experience in this type of work, which is usually temporary employment. Planters are often drawn from the ranks of the unemployed, students, housewives, and native people. A qualified supervisor can train his own workers on work procedures and advise them on inherent job hazards, emergency procedures, and first aid requirements. Training should be at least one day. A good program will include scheduled crew safety meetings.

The following is a partial list of hazards encountered on planting and thinning operations:

1. Exposure to chemical residues when planting too soon after spraying applications.
2. Worker slips and falls on rough terrain and slash. Sturdy footwear is required and might be difficult for women to obtain in some areas.
3. Downed trees left in corridors and dead standing timber left in cutover areas.
4. Sprains to wrists and ankles when hitting rock with planting tools.
5. Insects: blackflies, mosquitoes, wasps, and snakes in some areas.
6. Dermatitis from gum off bare-root stock.
7. Cuts from brush saws resulting from improper filing or handling.
8. Tripping: trouser cuffs catch on stubs if they are not tucked in.
9. Overhead hazards, such as chicots and broken branches.
10. Eye injuries and hearing loss can be prevented by saw operators wearing a hard hat equipped with face screen and earmuffs.

The second element, **equipment**, has received a lot of attention recently. Mr. Herb Bax (R.P.F.) presented a paper at the CPPA Woodlands Section meeting entitled "Design, use and maintenance of site preparation equipment — do we know what we are doing?" Mr. Bax concluded his paper by saying, "Five years from now, will the results of your efforts be a healthy, vigorously growing stand or an unacceptable forest slum? Our choice in the design, use and maintenance of site preparation equipment must be made so that the results prove to be the former, not the latter." The one element not covered here was the effect machines have on the health of operators in the long term.

Ergonomic studies are beginning to play an important role in North American forestry and we have much to learn from our European counterparts. John Garner of Great Lakes Forest Products in Thunder Bay has covered the development and adaptation of equipment for reforestation in his paper "The silvicultured operations nightmare". On a basic ergonomic survey, he found that a skidder operator exceeded the ISO vibration standard by 300% on a slightly rolling site with sandy soil, and a TJ 380 pulling a Bracke scarifier exceeded the standard in 1 hour on a CPPA terrain Class 11 roughness site. A D7 Cat pulling drags on a similar site exceeded the standard in three-quarters of an hour. These measurements were limited to vertical, up-and-down vibration and did not include pitch and roll.

In 1983, Dr. Bob Webb and Patricia Hope conducted a study, funded by the Canadian Forestry Service, on "Ergonomics and skidder operations in northern Ontario: a preliminary investigation." Their conclusions read like an indictment against equipment manufacturers and neglect or indifference on the part of woodlands management.

Some areas where ergonomic principles apply when selecting equipment are as follows: mounting and dismounting, operator working position, the operator's seat, controls and their location, instruments, visibility, vibration and shaking, lighting, working climate, noise, exhaust emissions, and maintenance.

I would recommend two publications for your use. One is *Ergonomic checklist for transport and materials handling machinery,* published by Skogsarbeten, Sweden, and the second is a *Checklist for ergonomic valuation of forest machines,* by Dr. Dietrick Rehshuh of KWF, Gross Umstadt, Germany.

The third element is **material.** On silviculture operations, the materials handled are herbicide and fertilizer chemicals and either bare-root or containerized seedlings. Regulations governing the use of chemicals vary among provinces and jurisdictions. In Ontario an annual license is required by people involved in handling chemicals and aerial spraying operations. The herbicide 2-4-D is approved for aerial spraying, with a heavy application used prior to planting and a light dosage applied after the seedlings have been established.

While mixing chemicals for air or ground application, manufacturers' instructions should be followed very carefully. Personal protection used should suit the situation, but generally goggles or a full face shield, a double-filter face mask, gloves, and an apron or protective clothing should be worn. Washing facilities should be provided and food and drink should be kept well clear of mixing areas.

With some species of bare-root stock, gum can be a problem to the women planters' hands. Barrier creams are effective, and on Eddy Forest Products operations, the planters wear latex rubber gloves that do not interfere with the work.

The final element is the **environment**. This should cover not only the terrain and weather conditions, but also the important aspects of work environment, such as attitudes and morale. A crew that works as a team to accomplish a recognized objective will be very efficient. Where regular contact is maintained with the supervisor and regular safety meetings are held, workers become involved and have a sense of ownership in the project.

On the Valley Forest Products planting and thinning sites, an air horn is mounted on an oxygen cylinder to call people in from the field in any emergency such as a serious injury or storm warning.

I have not covered the subject of accident costs because it is a complex problem and different criteria are used in the various jurisdictions, but in Ontario in 1983 the average cost per accident for compensation and medical aid was $15 467. So accident prevention is not only enlightened management and workers, it is also good business.

THE ROLE OF MECHANIZED SILVICULTURE AND THE GREAT LAKES FOREST RESEARCH CENTRE

L.F. Riley
Program Manager, Resources
Great Lakes Forest Research Centre
Sault Ste. Marie, Ontario

Involvement in mechanized silviculture at the Great Lakes Forest Research Centre (GLFRC) began in 1969 with a joint proposal by the center and the Ontario Ministry of Natural Resources to develop a new type of planting machine for the boreal forest of Ontario. The planting machines then available, all of which were of foreign manufacture and almost all of which were of the continuous furrowing type, were considered inadequate for the often rocky, usually slash-covered cutovers common to Ontario's northern forests. A device using a new kind of tree insertion principle was required. Of course, that development was undertaken and the product became known as the Ontario Planter, an intermittent furrowing planting machine. Its commercial spin-off was the Timberland Planter.

Because of the urgent need to mechanize the planting process in order to increase our capability to tree more of the area harvested and burned each year, and because the development of the new planter would take a number of years, it was decided that a program of testing of available planting machines would be undertaken to determine if any were suitable, despite their shortcomings, on an interim basis for Ontario's conditions. Between 1970 and 1975 five commercially available planting machines were tested.

If the results of machine testing are to have meaning and to be understood by anyone other than those involved in the actual test, and if the results of the testing of a machine on one site are to be compared with test results of the same machine on another site, there must be some commonality of approach to the test procedure and to the collection of data. The same is true if one wishes to compare the results of the testing of one machine against those of another machine on the same site. Thus GLFRC staff developed our center's Standard Assessment Procedure for the evaluation of silvicultural equipment. The procedure is described in Brad Sutherland's paper.

During this time period we also concerned ourselves with the improvement of frontal slash clearing because of our belief that the one-pass approach, in which debris clearing and tree planting would take place on the same pass, was the only realistic approach to take if costs were to remain in line with those being experienced with hand-planting. Various blades and slash-parting devices were tried but were unsatisfactory, either because they were too wide or because they removed too much soil due to excessive digging, both of which require extra prime mover horsepower. Center staff designed and developed the Canadian Forestry Service (CFS) V-blade, which had the advantage of being narrow and of having greater flotation than any of the other blades available at the time. Authorization to manufacture and sell the blade was given to several firms and perhaps a dozen or more have been put into use.

With the completion of the planting machine testing program in 1975, our interests swung to site preparation, with the exception of the continued development of the Ontario Planter. This change in direction corresponded with a move away from crude scarification tools and an increasing interest in the biological quality of site preparation efforts on the part of the forest manager as new equipment designs from Scandinavia began to hit the Canadian market. There was little understanding of the thinking behind the particular designs, and tools were being purchased for use in applications for which they were never intended. This led to improper applications, inadequate results (compared to what the user wanted), and disenchantment of many with what seemed to be high-priced equipment. A program of testing was initiated to understand better the application of some of these tools. The Standard Assessment Procedure was again the instrument for gathering this information.

By 1980 the development of the Ontario-Timberland planter had reached an end. Ten years of developmental work had reached an unsatisfactory conclusion as the planter did not receive user acceptance and, in truth, was surpassed by new technologies. Nevertheless, this pioneering effort has exposed many practitioners to machine planting techniques and has spurred the interest of other developers. At latest count there are seven planting machines being developed by or available from Canadian interests for forest land use. At the beginning of the 1970s there was none.

In 1980 the Great Lakes Forest Research Centre was designated the center of excellence for the Canadian Forestry Service in mechanization of silviculture. Several staffing changes took place and positions were added from the old Forest Management Institute. At present the mechanization of silviculture unit at the center has a complement of seven staff members.

This new emphasis required, of course, that the unit change its role from a purely regional one (Ontario) to one that was national in scope, a challenging and somewhat daunting demand. Canada is a very large country with great diversity in its forests and approaches to forestry. There is a large number of biogeophysically different forest regions, there is a broad range of site-specific species, and there is a confusing array of site, soil, and climatic conditions with which to contend. Each region has its own peculiar set of requirements for treatment and few machines are capable of treating more than a few of them satisfactorily. Thus it was incumbent upon us, in developing this national program, to become as familiar as possible with the needs, priorities, and concerns of forest managers in the various regions of the country.

Our initial efforts were directed toward developing contacts and liaisons with all provincial forestry departments through head office contacts and visits to district and regional centers. Emphasis was placed on tours of field operations to become more familiar with the problems of the local forest managers. At the same time discussions were undertaken with the regional CFS research centers to enlist their cooperation and to ensure their understanding of our intent. To make this work, unit staff members were assigned specific regions of responsibility. It was felt that this would allow for greater familiarity with the concerns and needs of various parts of the country than would be the case if all staff members were involved in projects across the country. As a result, Brad Sutherland is responsible for the area from Ontario westward and Rod Smith is responsible for the area from Ontario eastward. Ontario is something of a common ground because of the location of the center in Sault Ste. Marie.

After the initial contacts had been made, our liaison efforts were extended to include industry, universities, and the Forest Engineering Research Institute of Canada, which had also at that time initiated some investigations in mechanization of silviculture. There is and will continue to be strong emphasis on these liaison activities.

Beyond these purely fact-gathering efforts, the role of the unit was to be one of emphasizing the conduct of equipment evaluation trials wherever such a need existed. Before this was implemented, however, the CFS established the National Committee on Mechanization of Silviculture (NACMEC) to provide advice to GLFRC on the most pressing needs in mechanization of silviculture in Canada. This advice guides the mechanization of silviculture unit in the development of its program. Although currently being restructured, NACMEC has been comprised of 17 representatives from the provinces, industry, universities, FERIC, and the CFS regional centers. The committee meets annually in the spring and to date has held three meetings. (The 1984 meeting was deferred and will be held in conjunction with the CPPA Woodlands Field Equipment Demonstration in Thunder Bay in September 1984). NACMEC recommended that the role of the unit should be threefold:

1. to develop and provide information on mechanization of silviculture and on silvicultural equipment,

2. to conduct equipment evaluation trials, and

3. to coordinate equipment trials and demonstrations.

In the three years that the unit has been functional, considerable progress has been made in these three areas. The following developments have occurred:

- A Mechanization of Silviculture Equipment Information Bank has been developed. The bank provides forest managers with ready access to information on silvicultural machines and equipment currently on the market. Information has been collected on almost 400 machines and tools from the developed forestry nations and is now stored in the center's computer system. Rapid search and retrieval through a data base management system are essential features of the information bank. Information is provided on request on a short turnabout basis, with the customer receiving a printout of data pertaining to the specific request. A booklet describing the information bank and how to access it is available upon request. Contact John Richenhaller at GLFRC.

- The Mechanization of Silviculture Newsletter is produced by the unit on a semiannual basis. Two newsletters have been produced to date and a third is in preparation for distribution in the late spring of 1984. Regular features include information on coming events relevant to mechanized silviculture (including meetings, symposia, equipment demonstrations, and exhibitions), reports on meetings attended, equipment demonstrations, trials or operations observed by staff of the unit, highlights of other events, updates on GLFRC involvement in equipment trials and related fieldwork, and lists of recent reports relevant to mechanization of silviculture.

- A number of field trials and projects have been conducted, including a cooperative trial with FERIC and E.B. Eddy in Ontario on the effect of slash resulting from tree-length and full-tree harvesting operations on the operation of three different scarification tools; a demonstration and evaluation of seven scarification tools in Saskatchewan in conjunction with the Government of Saskatchewan, the Northern Forest Research Centre, and Prince Albert Pulp and Paper; a trial of the Bracke Mounder in British Columbia in conjunction with the British Columbia Ministry of Forests and the Pacific Forest Research Centre; and assistance to Great Lakes Forest Products in Ontario in the development of a powered-head scarifier, to Alan Moss and Associates in the development of a spot planter, and to the Government of Ontario and FERIC in the development of a wetland planter for Japanese paper pots.

- Although it is funded through the ENergy from the FORest (ENFOR) biomass program, the unit has for several years been directly responsible for the development of a smallwood biomass harvester developed after the principle of the Finnish Pallari Brusharvester. This unit, now known as the Crabe Combine, is scheduled for initial field trials in the summer of 1984. At present, developmental work is being concentrated on the felling/chipping head. Biomass collectors will be the subject of future development. Thus the first application of the unit is likely to be as a brush-clearing device for silviculture operations and rights-of-way.

One important recent addition to the unit's responsibilities is the review of all formally submitted unsolicited proposals in the area of mechanization of silviculture. This ensures some uniformity of approach in the evaluation of such submissions and also ensures that the mechanization of silviculture unit at GLFRC is aware of all submissions to the CFS in this field.

An area of critical importance to the proper functioning of the unit is the interaction with the regional research centers of the CFS. The mechanization unit in no way infringes upon the silvicultural research responsibilities of the various centers. Staff of the centers have the intimate knowledge of local biological conditions and the many contacts upon which the success of the efforts of the unit depend. Thus we work closely with the regional centers and ensure their awareness of what it is we are doing when in their area of responsibility. Involvement with the mechanization of silviculture unit varies according to the interest of the regional centers. In the Western and Northern Region of the CFS, staff of the Northern Forest Research Centre, principally Lorne Brace and Ron Gorman, have developed a keen interest and have been actively working with us in field projects, the development of contacts, and the gathering of data for the information bank. We sincerely appreciate their strong efforts and willing cooperation.

On a final note, but one which I consider to be of crucial interest to Canadian industry, strong effort must be put forward to develop a viable Canadian silvicultural equipment industry. To date most of the silvicultural equipment in use in Canada has been obtained from foreign sources. While much of this equipment is of sturdy manufacture, it was not developed for Canadian conditions and problems. It often does not perform the task in a manner suited either to our terrain and site conditions or to our specific biological requirements. There is no shortage of capability in this country. But Canadian equipment manufacturers will not go it alone. They will not accept the high-risk development costs associated with what they correctly perceive as a low-volume market. Government subsidies must be available just as they are in other countries. On the other hand, manufacturers must be willing to take greater risks than they are now willing to countenance. They must strive to put out a high-quality, high-performance product and to be aggressive in developing off-shore markets for their products. With this kind of approach and attitude, Canadian industry will be able to take its rightful place as one of the leading countries in the manufacture of silvicultural equipment, just as it has done with respect to the manufacture and sale of forest products.

A STANDARD ASSESSMENT PROCEDURE FOR EVALUATING SILVICULTURAL EQUIPMENT

B. Sutherland
Forestry Officer
Great Lakes Forest Research Centre
Sault Ste. Marie, Ontario

WHY ASSESS SILVICULTURAL EQUIPMENT?

As the level of forest management in Canada intensifies, so too does the desire of forest managers to site-prepare and plant logged-over areas in order to maximize tree survival and growth. To help achieve this goal there exists on the market an ever-increasing variety of silvicultural tools, some general in function, others aimed at a particular or unique biological prescription. It is becoming increasingly difficult for the forest manager to choose which tool or tools will provide the desired result at reasonable cost. The ability to make correct, well-reasoned decisions becomes increasingly important as equipment costs soar and as greater land areas are treated. Such decisions can only be made if adequate and sound technical information is available on equipment performance under defined field conditions. Too often equipment is selected on little more than gut feel by the potential user, or based on claims by manufacturers' brochures that may not provide information pertaining to local conditions. The user, once committed, faces an equipment life span of 5-10 years or longer and will treat thousands of hectares of land in this time. If the tool is suited to providing the required site preparation and if used properly, it is a good investment. If not the tool may well be used anyway providing mediocre results or, if deemed wholly unsatisfactory, it will probably end up in the local bone yard. The user needs to know what a tool can do under local conditions or have a common set of equipment performance standards available that can be used when evaluating tools or local conditions.

BENEFITS OF STANDARD ASSESSMENT PROCEDURE

1. *Provides quantitative and qualitative information on equipment operation and performances.*

Outputs of silvicultural equipment vary greatly but generally are considered to be a form of surface or subsurface disturbance in the case of site preparation equipment or, in the case of planting machines, the proper placement of seedlings in a suitable growing medium. A knowledge of the biological requirements for tree establishment and growth will allow the forest manager to describe the range of microsite conditions or planting quality standards that are desirable and can be artificially created. In an assessment of site characteristics the quality of site preparation can be assessed by recording the quantity, by area, of disturbed ground that has been previously described and that represents varying degrees of suitability for seed germination and/or tree growth. The soil disturbance classes measured are then accumulated and represent a pattern of results for the implement being considered. When you combine this with a time and motion study of the equipment, the overall performance of the tool can be established. Similarly, tree planting equipment can be assessed by establishing a series of quality standards for planting, which would include a rating of microsite suitability for each attempt recorded.

2. *Enables comparative evaluation of equipment performance on measured site conditionss.*

There are many factors that can affect the operation and proper functioning of silvicultural equipment. Variability exists in ground surface conditions such as roughness, debris, slope, presence of residuals, to name a few, as well as subsurface conditions such as soil texture and moisture content. As part of an assessment process, most of the characteristics that can affect equipment action must be quantified. Knowledge of the site characteristics that exist will enable the comparison of performance results with the same tool on different sites representing varying degrees of difficulty. Similarly, if it is desirable to compare two or more different pieces of equipment on similar site conditions, the assessment procedure provides a means of determining the degree of similarity between sites. The manager contemplating a comparative assessment under these circumstances is cautioned against the false impression of similarity of site condition that one can obtain by just casual observation of site parameters. For example, to try and determine stump frequency on a debris-covered site on one hand and on a vegetation-covered site on the other by visual inspection may be totally misleading. An actual stump tally is required.

The recording of site factors associated with an equipment trial is useful to readers in other parts of the country as it allows them to relate the test results to their own local conditions.

3. *Allows a cause and effect relationship to be drawn between site parameters and equipment performances.*

The recording of pretreatment site factors that affect equipment operation followed by a postscarification assessment provides an opportunity to determine the relationship between shortcomings in expected results and the impediments that affect machine operation. For example, slash distribution can vary considerably on a site due to the method of logging or through variations in stand density or age. The presence of slash can have a significant effect on equipment performance and should be recorded by depth and loading prior to scarification. The post-scarification appearance of the site will in most cases be drastically altered in terms of slash distribution. Knowledge of the prescarification conditions may help to relate, for example, a tool's inability to penetrate sufficiently due to slash loading. This type of cause and effect relationship can be drawn for other parameters such as stump density, duff depth, and vegetative cover. Posttreatment observations on their own do not provide an adequate explanation for shortcomings in equipment performance.

HOW WAS THE GLFRC[1] STANDARD ASSESSMENT PROCEDURE DEVELOPED?

Standardized equipment assessment procedures have been used for a number of years for both logging and silvicultural equipment. The procedure currently used by the mechanization of silviculture unit at GLFRC is the result of the evolution and refinement of a system developed by GLFRC and used for equipment evaluation in Ontario for a number of years. It has been modified, where appropriate, by methodology found in other proven systems. The overall result is a procedure that is consistent with other previously accepted systems but that is adaptable to the particular circumstances found in most forest regions of Canada. The time study portion of the assessment procedure is based on the CPPA[2] system with modifications as required for the evaluation of silvicultural equipment. Further modifications in cooperation with the Forest Engineering Research Institute of Canada have resulted in a mutually agreeable format (see Fig. 1).

The overall procedure was developed to obtain necessary and essential information with minimum effort while not losing accuracy. In its simplest form, the assessment procedure becomes one of recording, before treatment, those conditions on a site that are likely to impede and/or be changed by the equipment, recording the events of the treatment operation, and recording the results obtained in relation to the objectives of the treatment as set by the forest manager.

ELEMENTS OF PROCEDURE

The assessment procedure is divided into the following four steps:

1. *Office planning and field plot setup*

Once a decision has been made to evaluate a silvicultural tool, or to compare several tools, the assessor must first decide what questions are being asked and whether the answers can be found through a field evaluation. If, for example, mineral soil exposure is the desired result, and heavy slash loading is a common problem, the assessor must choose the sites and establish standards for mineral soil exposure that will make possible a rating of the tool's ability in various slash loadings. Site selection is probably the most important, and can be one of the most difficult decisions to make in the entire planning phase since there are so many site parameters that affect equipment function. For example, it may be difficult to find sites where one site factor, e.g., slash loading, is to be considered without other factors such as stumps of ground roughness confounding your observations. Another example is the Smoothstone Lake evaluation of seven site preparation tools conducted in Saskatchewan in 1983. The task was to locate an area of mixed poplar-spruce cutover wherein the density and distribution of the residual poplar stand was relatively constant and where the other site factors such as slash, stumps, soil texture, slope, and ground roughness were similar across the range of test plots. Careful searching of photos and maps, and verification of the choice by field inspection, finally led to the adoption of the Smoothstone Lake site.

[1] Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario.

[2] Canadian Pulp and Paper Association, Montreal, Canada.

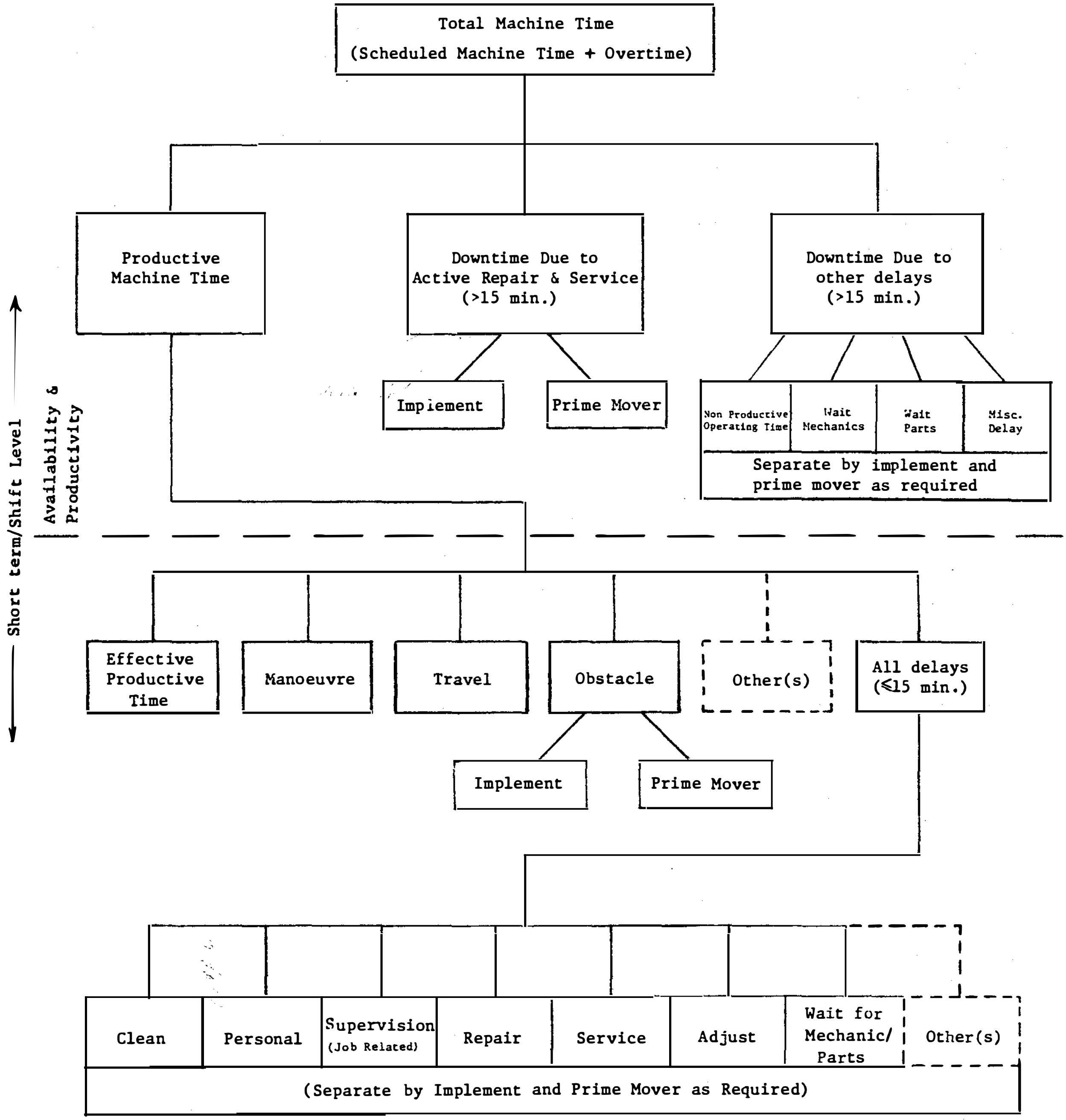

Figure 1. Great Lakes Forest Research Centre standard assessment procedure for evaluating silvicultural equipment.

Presampling of site conditions is the best method of determining what is on the site. But this can be a costly and time-consuming process. The best policy is to inspect candidate test areas as thoroughly as budget and time will allow prior to implementing the assessment procedure.

Once the site has been selected a series of plots are established on which ground conditions are assessed both before and after treatment. The standard basis of measurement is 20 × 20 m subplots that are arranged so as to not affect the normal operation of equipment. The subplots are normally strung together in a series of five to make one plot for ease of assessment.

2. *Pretreatment assessment*

Once plots are established, all features that can affect the operation of equipment are measured along transect lines within the plot boundaries. The following parameters are generally the most important: slash and debris weight or volume and age (also height), stumps, rock, residual stem size and frequency, slope, brush, minor vegetation frequency, height and percent coverage, soil and duff depth, soil type, ground condition and ground roughness. The last two parameters, adopted from the Swedish system of terrain measurement (Anonymous 1969), are composite parameters. Ground condition is based on soil moisture, soil type, and stone content. Ground roughness is based on height and frequency of obstacles.

3. *Operational time study*

The time study establishes how efficiently the equipment is performing relative to the site conditions being treated and the silvicultural goal of the treatment. In essence it is the identification, both in duration and in nature, and in a standard manner, of all equipment activity and inactivity during the designated period of evaluation. The breakdown of these "operating" and "nonoperating" times can be as fine or as broad as is required to evaluate adequately the equipment for the envisaged need. Because most silvicultural equipment is not self-propelled and requires a separate prime mover, it is necessary to isolate operational delays as they occur and assess them either to the prime mover or to the silvicultural equipment. In this way, silvicultural equipment being operated with, for example, a prime mover in poor repair, is not penalized when compared to another tool where the prime mover is in good repair. The elements of time are broken down and coded so that the reason for delay such as clearing debris, turning at the end of a row, or a repair is known. From the time data it is possible to calculate utilization and availability.

4. *Post treatment assessment*

This is the final stage in the field portion of the assessment procedure and involves reinspection of the treated plots. Two basic formats are utilized depending on the site treatment, i.e., scarification or mechanical planting.

Scarification

Scarification can be done with various goals in mind. It may be done to improve access for hand planters, to provide ground control in terms of spaced rows in which a manual planter may work, or to expose the mineral soil for planting a specific size and type of planting material. It may also be done to promote natural regeneration from cones left on the ground, from adjacent standing seed sources, from aerial seeding or other methods of direct seeding, or by inducing suckering. Whatever the trial the result of scarification is some form of surface or subsurface disturbance.

Using the same transect lines and subplots established in the pretreatment assessment, the following information is recorded: the quantity, in percent area, of soil or duff (fermentation and humus layer) disturbed by the implement and/or other sources such as the prime mover or as a result of logging, and the quality of ground disturbance by prescribed soil-duff modification classes, the description of which is categorized into plantable, nonplantable, and marginal microsites. In addition, a detailed description of plantable microsites can be made that will record microrelief, presence of competing vegetation or debris, and penetration problems.

Planting

The assessment procedure for planting involves the same plot/subplot setup as for scarification. Assessment takes place along the planted rows. The survey records the quality of planting, quality of site preparation for planting, and reasons for less than satisfactory planting, either fair or not-planted. The effect of the pass on the previously planted row is also tallied.

Upon completion of the fieldwork portion of the assessment procedure, the data collected can now be compiled and analyzed. The results of the postassessment tally for both scarification and planting can be related back to the preassessment tally and the reasons for nonperformance determined. From the time study data it is possible to calculate equipment utilization and availability. This bank of information will enable the forest manager to rate or compare items of equipment in quantitative terms and help provide a sound technical basis for equipment selection.

REFERENCE

Anonymous. 1969. Terrain classification for Swedish forestry, Skogsarbeten Drottninggatan 97. 113 60 Stockholm, Sweden. Rep. 9.

MECHANIZATION OF SILVICULTURE ON THE ST. REGIS (ALBERTA) LTD. FOREST MANAGEMENT AREA

J.C. Wright
Chief Forester
St. Regis (Alberta) Ltd.
Hinton, Alberta

While the title of my presentation listed on the program is "Development of site preparation equipment and its role on the St. Regis lease", I intend to expand on this theme by outlining the chronological development of our silviculture operations under the following four separate headings and to discuss the present and future roles of mechanization in each case:

1. site preparation for natural regeneration,
2. developments in seeding and planting techniques,
3. site preparation for artificial regeneration, and
4. developments in stand tending and stand improvement.

All four phases interact in our objective of obtaining optimum stocking levels and distribution of our second-generation stands of white spruce and lodgepole pine.

SITE PREPARATION FOR NATURAL REGENERATION

St. Regis began woods operations on its Forest Management Area (FMA) in 1955 and regeneration techniques from the beginning involved the preparation of a proper seedbed by scarification. From a knowledge of history and research of harvesting and regeneration techniques on the east slopes, it was abundantly clear that regeneration of white spruce and lodgepole pine to acceptable stocking levels within the time constraints of 10 years, as referred to in the agreement with the Crown, would depend upon the preparation of a receptive seedbed. It was also our policy that every acre that supported a merchantable stand worth harvesting at maturity in the first rotation was also worth regenerating to produce at least as valuable a crop in succeeding rotations.

A variety of equipment that was available at the time was tested, including the Flecco Rake, brush rakes, V-blades, and the Athens disk. In 1957 it was decided to opt for the new generation of wide-tracked, high-powered crawler tractors and our own design of toothed blade to break down the slash and residue, baring the mineral soil, and thus preparing a more receptive seedbed. Observations during the wet summer of 1957 by Canadian Forestry Service (CFS) and company personnel on site suggested that there were insufficient cones being distributed over this seedbed, and an anchor chain drag-mounted on a spreader bar was designed to be towed by the tractor for this purpose.

Both the scarification blade and the drags underwent several modifications up until about 1965, when the present design was adopted. While this equipment worked well and gave satisfactory results on about 70% of the stands being harvested, there were certain conditions where it was ineffective.

After reviewing the results of several years of operation with the plow-drag combination, it was decided that the drags were only necessary in areas where pine cones were relatively scarce, such as in the very old pine stands and along skid roads and landings. In spruce stands and in pine stands nearer to rotation age where there was no shortage of cones, the well-spaced furrows created more-favorable microsites when the plows only were used and consequently, the drags are no longer used in such stands.

The next such condition was the very moist, deep duff, up to 24 inches in depth, which had built up in the old "climax" spruce-fir stands of high elevations. The furrows made by the scarification plows frequently didn't penetrate the heavy slash and duff to reach mineral soil, and where this was accomplished, the duff layer merely fell back into the furrow behind the tractor. In 1965 we began a program of angle dozing this material off into compressed windrows in the spring of the year as the snow was melting and when the duff layer could be peeled off to the still-frozen mineral soil. While this "blading" method prepared a good seedbed or planting site, the length of time available for this treatment was very short, often only a week or two, making the operation quite costly, particularly if there was a significant snow depth and not much frost.

In 1980 this treatment was replaced by the present Craig-Simpson rear-mounted ripper plow, which could be operated during the early winter months as soon as there was sufficient frost to support the tractor and before the snow accumulation was too deep. This method not only extended the season, but reduced the width of the exposed path and consequently the size of the intervening windrows. Where natural regeneration in lodgepole pine was the objective, anchor chains were mounted on the hitch on either side of the plow and dragged behind to break up the slash and distribute the cones into the furrow. By using a large tractor, we were able to mount two plows on the parallelogram hitch with about 7-ft. spacing between the plows to double the productivity of the machine. Combinations of single and double plows could be used, depending on the amount of slash and steepness of terrain. This equipment is also used to treat upland pine sites that are inaccessible during the frost-free period.

The condition that still had to be addressed was the wet site supporting pine and/or black spruce with little duff or competition, but too wet to support the large tractors during the summer months. While we had experimented with little success during the early 1970s with large grid packers and with barrels and chain drags in our old spruce-fir stands and deep duff areas, in 1982 we again began trials with barrel and chain drags in an attempt to treat the growing backlog of these wet pine/black spruce types. We found that we were able to do an acceptable job of site preparation using lighter tractors on these areas, and in 1983 we built two drags incorporating modified barrels. These have proven to be a good addition to the growing arsenal of equipment at our disposal to tackle the difficult job of treating all of our harvested areas at reasonable cost.

While we are basically satisfied with the equipment we have at this time, all of which can be mounted on or towed behind equipment that is readily available to us, we are always on the lookout for something better that might be developed at other locations and that can be adapted to our conditions.

There is no single piece of equipment that is the answer for all of the varied conditions that are encountered in the forest, and each species, stand condition, soil type, regional climate, and variation in slash and duff condition provides a new challange.

DEVELOPMENTS IN SEEDING AND PLANTING TECHNIQUES

Seeding

Because it was recognized from the outset that it would not be possible to obtain satisfactory natural regeneration on all of the areas being harvested, experiments began in 1960 on the development of seeding and planting techniques that would give satisfactory results on the FMA. Early trials of spot seeding were largely unsuccessful due to losses to rodents and inadequate site preparation, and broadcast seeding using hand-operated Cyclone Seeders on scarified blocks gave varied results generally related to the amount of mineral soil exposure. With the advent of blading in 1965 and the availability of a helicopter, we purchased a Brome Seeder and carried out our first aerial seeding in 1966. While this seeder was not too reliable, it showed definite possibilities and between 1966 and 1978 several thousand acres were treated with this system using a rented aerial seeder, with generally quite good results. Planting techniques, however, had by this time improved to the point where very reliable results were being obtained and, with the problems of obtaining sufficient white spruce seed for aerial application, no seeding has been done since 1978 nor is any contemplated in the foreseeable future.

Planting

Disenchanted with the results of planting efforts in the late 1950s and early 1960s using bare-root stock grown for us at the provincial tree nursery, investigations began in 1962 into growing seedlings in containers, starting with Walter's "Bullet". In 1965 St. Regis built its first greenhouse and produced a crop of a quarter of a million trees grown in three-quarter-inch split plastic tubes (the "Ontario" tube). This system was readily adaptable to mechanization both in the greenhouse and in the field, and between 1965 and 1971 more than 6 million tublings were grown in our nursery and planted on the Forest Management Area. These tublings were planted with a dibble on a variety of sites and seedbed conditions from untreated and deep duff areas to scarified upland sites. It soon became evident that the best growth was obtained when trees were planted in mineral soil (although we have many excellent stands where the seedlings were planted directly into the moss). Frost heaving and drought, however, caused heavy mortality and efforts were redirected to the development of a container that not only would encourage better root development while maintaining the high utilization of greenhouse space, but that could be removed at the time of planting to permit planting of the unrestricted root "plug".

The Spencer-Lemaire Rootrainers were first used in 1972 and a series of renovations and additions had by this time increased the capacity of our greenhouses to approximately 2 million seedlings per year. A new greenhouse was brought on stream at Hinton in 1980 with a capacity of 3 MM/year, based on a three-crop system and designed to take advantage of the mechanization potentials associated with the container system, such as vacuum seeding, tray filling, and vibration packing. The extent of economically feasible mechanization is dependent on the productive capacity of the greenhouse, e.g., palletizing. To date, nearly 20 million seedlings grown in rootrainers have been planted, for the most part with the Pottiputki planting tube. Trials with mechanical tree-planting machines at Hinton have convinced us that given good site preparation, planting production per person using a Pottiputki tube is almost as high as with a planting machine, while the quality of planting and site selection is vastly superior to machine planting. Because there is no shortage of high-quality tree planters when container-grown seedlings are involved (permitting a longer planting season), further work on development of mechanical tree planters by government agencies would appear to be a waste of taxpayers' money.

Mechanical Site Preparation for Artificial Reforestation

While the container-grown seedlings generally performed well on scarified and bladed areas, there were areas that were extremely dry and exposed, where seedling survival was simply unacceptable on the scarified sites and where the tough sod made hand-scalping with mattocks unsatisfactory. In 1975 the Bracke cultivator was demonstrated at Sault Ste. Marie, Ontario, and it was evident that this machine could provide the answer for these difficult planting sites. The first Bracke was acquired in 1976 and not only did the unit pay for itself in the first year by reduced planting costs due to higher production, but survival of the planted seedlings was over 90%. During 1976-78 a variety of towing units was tried, including the Clark 668 skidder, Timberjack 240D, F.M.C. tracked forwarder, and a Caterpillar D5 low-pressure tractor. In 1979 we purchased our second Bracke and two Timberjack 240D skidders. Approximately 85% of our planting sites are now pretreated with these units.

Areas of heavy competition from hardwoods remained a problem in terms of adequate pretreatment, so in 1979 we purchased a Cazes & Heppner plow, which we are now using to prepare approximately 10% of our planting sites. This unit is currently mounted on a souped-up Komatsu D65P tractor. These areas of heavy hardwood competition should be followed up 3-5 years after planting with an aerial application of herbicide to permit the planted seedlings to maintain their growth potential. It is in this area that we should be directing our efforts in the immediate future.

A few areas are site-prepared in the winter with the C & S ripper tooth plow, some plantations are established on previously scarified blocks where the treated sites are still deemed acceptable, and some wet mossy areas are probably best planted with no site preparation at all.

Developments in Stand Tending and Stand Improvement

No discussion on mechanization of silviculture would be complete without mentioning what treatments are necessary when overzealous mechanical site preparation results in too many seedlings per acre, or alternately how to reduce to acceptable levels the extremely high stocking levels of lodgepole pine stands originating from wildfire.

Earlier efforts in 1962 and 1963 were concentrated on manual thinning in dense lodgepole pine resulting from a 1956 burn where hand-pulling and sickles, machetes, and brush saws were used. Later (1968–69) trials were carried out with hand application of herbicides both by the company and the CFS, followed in 1969 with aerial applications of Tordon by the CFS in an effort to effect some degree of thinning and release.

Comparison of the results of these earlier efforts were made in 1971 and it was concluded that manual or mechanical thinning would provide much better results than chemical treatments, particularly in terms of growth response. We therefore began experimenting with the various types of equipment available from simple brush axes to lightweight chain saws to the new models of brush saws.

Thinning crews were again employed during the summer months starting in 1974 in the 1956 burn, but by 1976 costs had reached more than $400/acre. Use of rubber-tired or tracked equipment necessary for mechanical treatments was impossible due to the accumulation of standing and fallen brulé. The decision was then made to concentrate our efforts on the treatment of overstocked regeneration resulting from harvesting and site preparation where stocking varied from 1000 to 10 000 stems per acre (compared to 10 000–50 000+ in the fire origin stands). Here too the clearing saw could be used efficiently and we were able to experiment with equipment such as the Kershaw Klearway in row thinning trials.

These tests showed that while the mechanical thinners have some potential for saving in manpower, they do not reduce costs or do as good a job of tree selection, thereby reducing the potential for genetic gain.

It is obvious that if we are going to be able to get involved in the next round of silviculture treatments, i.e., commercial thinning, we must first control initial stocking levels. Otherwise, commercial thinning becomes another unacceptable form of high grading. We should be researching now into the potential for mechanization of this area of commercial thinning, even though its application is possibly 15-20 years in the future.

CONCLUSIONS

I feel that we already have available a wide variety of equipment to enable us to perform our present silvicultural tasks relatively efficiently, although there is an ever-increasing need for research and experimentation to find better and cheaper methods.

A basic requirement for a successful silviculture program is a complete and available data base on all cutover areas, including previous stand history, site and slash conditions (including seed availability) following harvest, recommendations for postharvest treatments, and a record of all treatments and survey results. Only then can one build up a knowledge of best-fit treatments designed to suit the varying needs of a particular set of forest conditions. It is also important that silviculture treatment decisions be made by knowledgeable and experienced staff, because no set of rules or guidelines can be developed to handle the variety of situations encountered in the field.

Mechanization should be attempted only where it can effect improvement in treatment quality and at a price competitive with manual treatments: not mechanization for the sake of mechanization. Two areas where mechanization should be approached with caution are juvenile spacing projects and tree planting. There is nothing wrong with hiring people, and they are usually a lot more reliable and rewarding to work with than a piece of machinery.

What are the results? Currently, 65-75% of our cutover areas regenerate satisfactorily following scarification. Aerial seeding was successful on about 80% of the areas so treated and manual planting following proper site preparation has a success rate of over 95%, with damage from mice and rabbits the main cause of failure. Obviously we are making good progress in our reforestation efforts, but there is always room for improvement.

MECHANIZED SILVICULTURE AT PRINCE ALBERT PULPWOOD

R.J. Orynik
Silviculture Forester
Woodlands Enterprises Ltd.
Prince Albert, Saskatchewan

Before I begin my presentation today on silviculture mechanization at Prince Albert Pulpwood, I would like to set the stage by discussing our silvicultural objectives and by reviewing the forest conditions of our license area.

Our broad objective, as is everyone's, is to maintain or increase the productivity of the forest after harvesting. This objective can be narrowed somewhat in our view, particularly with respect to reforestation, to the execution of biologically sound and financially efficient reforestation of denuded areas in both the short and long terms. We believe both these factors, biological and financial, must be reviewed when reforesting a given area. For example, regeneration through site preparation and planting may be biologically sound for a given area, or any area, but will not be financially efficient if natural regeneration through scarification can be relied upon. In fact, planting may not be biologically sound in the long term if problems such as root deformation occur.

The broad objective of maintaining the productivity of currently harvested sites and the incomplete reforestation program during the early days of our company's existence have resulted in the recent treatment of nonsatisfactorily restocked (NSR) lands. In fact the company's current objective is to treat 110% of last year's softwood cutover. In this way, we will slowly but surely reduce the amount of NSR lands on our license area.

Now that our objectives have been laid out in broad terms, I would like to review with you the forest conditions of our license area. Our area cannot be construed as being average for Saskatchewan; I believe our operations occur on anything but average conditions for the province. There may therefore exist vast differences in the silviculture operations objectives, techniques, results, and costs when compared with the Saskatchewan government's program.

Our operating area for the Prince Albert pulp mill is approximately 3.2 million hectares in size, stretching from Prince Albert to La Ronge and from 104° longtitude to Smoothstone Lake on the west.

In very general terms, our license area can be subdivided into four broad vegetation zones:

1. The most northerly zone is composed mainly of jack pine and black spruce on the precambrian shield.

2. The area immediately south is one of outwash plains supporting stands of jack pine.

3. The third area, stretching across the middle of the license area, is predominantly coniferous forest on glacial till (black spruce, jack pine, and black spruce-jack pine mix).

4. The most southerly belt has some of the richest and hardest-to-manage land in the license area. It can be considered as being mixedwood forest with a large proportion of poplar.

These are very broad zones and of course discrepancies exist within each of these zones.

As an indication of our harvesting levels and type of stands harvested, I have extracted some data from our 1982–83 cutover analysis of 3300 hectares. The data reveal that 34% of the area cut was relatively pure black spruce, 53% was jack pine, and 2% was white spruce, with the remaining 11% being harvested from mixedwood stands.

Of the 587 000 m^3 harvested in that year, 60% was pine and 40% was spruce. This differs substantially from areas to the east and to the west, where mixedwood spruce and aspen predominate and where commercial forest industries are sawmill- and plywood-oriented.

Correspondingly, our silviculture operations in 1983 included: scarification for natural regeneration (3372 ha), site preparation for planting (719 ha), hand planting (908 ha), and mechanical planting (269 ha). The total treated area was 4549 ha, not including the site preparation activities.

Since the early days of our reforestation program, a wide variety of equipment has been tested and used by Prince Albert Pulpwood in an attempt to meet our silviculture objectives. I shall discuss, in a purely historically framework, the variety of equipment we have tested and are currently using. This shall be accomplished by looking at the equipment as well as the two broad reforestation techniques we now use, which are scarification for natural regeneration, and site preparation and planting.

First, scarification for natural regeneration. Activities began in 1967–68 with various trials of anchor chains, barrels, tract pads, etc., in cooperation with the Saskatchewan government and the Canadian Forestry Service (CFS). Ship anchor chains drawn by Clark 668s were the mainstay of our program until 1974, when a Bracke cultivator was purchased, initially pulled by an FMC, primarily to reforest black spruce sites. In 1978 a switch from the FMC to a D6 was made and then a further change in prime mover to a Clark 667 in 1980. This corresponded with an increase in equipment with the acquisition of two Leno patch scarifiers. In that year chains, one Bracke, and two Lenos were used to scarify 4071 ha. Some of this work was winter scarification and required anchor chains. In 1981 a Bracke badger was tested with a TJ 550 as the prime mover; it proved to be efficient and resulted in its purchase, thus utilizing the high horsepower of the TJ 550. Winter 1982 saw the building of a ripper tooth plow for D7 and D8 Cats for winter scarification work. Spring 1983 saw another two-row Bracke enter the license area, pulled once again by a 667. At present, Prince Albert Pulpwood owns and utilizes for scarification:

- Two two-row Brackes
- One three-row Bracke
- Two Lenos
- Three sets of ship anchor chains
- Two ripper tooth plows

Site preparation and mechanized planting have taken longer to develop, as is the case in most regions of Canada. In 1976 a C & H mechanical planter and V-blade were acquired. Then in 1978 the fleet was expanded to two. At this time we realized the great importance that site preparation plays in survival and growth of planted seedlings. Thus these activities increased from relatively zero prior to 1978 to the present position where the company does not plant on unprepared ground. In 1978 a CFS V-blade was constructed and tested along with the C & H V-blade. The CFS V-blade was parked after the test while the C & H V-blade has been in continual use since this test. In 1981 a Marden duplex drum chopper began preparing backlog for planting as well as being utilized in dwarf mistletoe reduction. Straight-blading in the winter of 1983 was a tremendous success, and in the very near future we see the acquisition of a Bracke mounder. Of course, some of the scarification equipment has also been used as site preparation tools.

Other equipment has been viewed or tested and evaluated to meet our objectives. These include disk trenchers (powered and nonpowered), Fesco V-blades, the Bennington shredder, disks, and Timberland tree planters to mention a few. But these have either failed to meet the objectives or have not surpassed the objectives biologically or financially, compared with current equipment.

Of course, problems do exist and to better discuss these, I have grouped them into three categories: biological, financial, and mechanical.

A number of the problems bridge the gaps between categories and this will be evident as I discuss them.

In the **biological** framework our biggest problem has been one of overstocking, the result of anchor chain scarification. This, along with the more desirable stocking levels achievable with patch scarification, has greatly reduced the number of hectares treated with chains. The importance and benefits of site preparation are known to us all; however, excessive site preparation can be detrimental to seedling growth. It is to our benefit to recognize that the microsite is of prime importance. The nutrient-rich top inches of soil must remain in close proximity to the seedlings, not in a brush pile 10 feet away. This is one of the reasons why our straight-blading work is done in the winter rather than the summer. Biologically the C & H mechanical tree planters have not proven effective on heavy soils, and are thus limited to lighter sandy soils.

Secondly, **financial** problems. Low production rates and the high maintenance cost of track vehicles have resulted in our move toward rubber. This can be seen by the change in prime movers from the FMC to the D6 and the 667. The cost of winter work far exceeds that of summer activities; therefore if at all possible, summer treatment is preferable unless limited by biological concerns and access. As mentioned earlier, we must look not just in the short term but in the long term also. Silviculture operations, though financially efficient today, may not be so in the long term when follow-up treatments and costs are considered. If patch scarification can provide adequate stocking levels, why scarify continuously with chains that result in overstocking and the need for thinning in the future? That's not to say the patch-scarified area will not need thinning, but it will be done at a much-reduced cost. Another example is underplanting dense poplar. How do you tend and maintain that crop? Certainly not by chemical spraying from the air.

Mechanical problems are often very closely related to financial problems. Through an efficient mechanical support group such as Prince Albert Pulpwood maintains, these problems can be reduced and availability increased. Prompt action is required, for we cannot afford to be down for long periods of time without drastically affecting our program. For example, if a mechanical planter blows a cylinder, we must have that planter going again the very next day — at the latest. Planting seasons usually cannot be extended without increased mortality.

Now to some specific problems encountered with prime movers. Early overheating problems in the Clark 667s and 668s have resulted in dramatic changes in the cooling system and the installation of low-gear transmissions. Wheel chains were also introduced to reduce tire failure to a more than acceptable level. Utilization of horsepower is also of concern and resulted in the purchase of the three-row Bracke badger. A skidder with the horsepower of the TJ 550 was required to pull chains. In the past the Leno patch scarifier has proven itself to be somewhate unreliable in our operation, but recent modifications have helped considerably. Problems with the axles and the hydraulics have hopefully been overcome. Unlike today's models of the Bracke badger, ours is difficult to contract and extend the spacing to fit a standard low-bed. But we are coping with this problem. All attachments have been modified in some way by our mechanical department. And of course, there is the normal wear and tear on any piece of equipment requiring constant rebuilding, replacement, and maintenance. Upon close examination of these problem areas, I began to realize that if even a small problem exists or is annoying to us, a change is made. For instance, the fuel capacity of a 667 is not enough to last an 8-hour shift scarifying, so their tanks have been increased in capacity.

I will now digress for a moment to discuss an area that significantly affects mechanized silviculture: utilization standards and what I shall call cutover cleanliness. The higher the standards and the cleaner the cutovers, the easier it is to perform any mechanized silviculture operation and the fewer biological, financial, and mechanical problems. I believe we have some of the cleanest cutovers in Canada, making our job far easier than that of other regions.

Stagnation is a problem. The only way to improve is to continuously question current activities. For instance, we are currently reviewing our V-blading program. Why push a V-blade preparing the site for one row of trees when you could push a straight blade for three rows at the same cost? Or, one step further, why continuously site prepare when trees are planted every 6 feet apart?

I believe I can summarize our approach to and goals for mechanized silviculture as the following:

1. to develop site-specific silviculture objectives and maintain an appreciation of the complexity of the sites to be dealt with,
2. to maintain an up-to-date knowledge of all available silviculture equipment,
3. to view, test, and evaluate any piece of equipment that will result in meeting our objectives,
4. to develop a silviculture program along with the equipment to best meet our objectives,
5. to monitor and evaluate present equipment and results on an ongoing basis, and
6. to exchange information at meetings such as this.

The question may be asked: Where do we go from here? I believe some of the directions are as follows:

1. better mechanical planters adaptable to various sites,
2. mechanized stock handling (containers),
3. mechanized thinning and cleaning,
4. spray equipment, particularly if aerial application of herbicides is prohibited,
5. mechanization of new techniques such as shelter cones and peat pillows,
6. improved aerial seeding equipment, and
7. better site preparation techniques, particularly for mechanical planting.

Before I conclude today, let me emphasize that all equipment was designed and built to perform a specific function, usually on a specific site. Changing the site and expecting the same results is unrealistic. In some cases we have learned the hard way, pushing equipment beyond its limits. We must develop site-specific equipment and fine-tune that equipment to fit the site and meet our objectives.

I know when I was asked to give this talk today I was asked to comment on how Prince Albert Pulpwood is dealing with the mechanization of silviculture. I hope I have done that, but I felt I must also talk about our philosophies of silviculture and I hope I have also done that and in so doing have given you some food for thought.

INTERPRETATION OF SITE FACTORS FOR MECHANIZED SITE PREPARATION

I.G.W. Corns
Research Scientist
Northern Forest Research Centre
Edmonton, Alberta

ABSTRACT

Environmental or "site" information, in addition to vegetational information such as species composition and abundance, can be integrated to form an ecological classification. Such a classification can be used to ecologically differentiate areas of forest land and can serve as a basis for making a variety of forest management interpretations, one of which is intensity of site preparation required to expose mineral soil.

INTERPRETATION OF SITE FACTORS FOR MECHANIZED SITE PREPARATION

I am going to talk about using environmental clues that indicate appropriate site preparation options after logging. Those of you involved in silviculture already do this to varying degrees. I will attempt to show you how you might make more accurate interpretations of environmental or "site" information. Making such interpretations is one of the principal objectives of a field guide that the Canadian Forestry Service and the Alberta Forest Service are working on as a cooperative venture. A large number of foresters in government and industry, including a number of people at this meeting, have had input to the project.

I am going to take a fairly liberal interpretation of "site factors" and include the vegetation in addition to the standard soil and site factors. Time does not permit a discussion of the full gamut of site properties, so I will concentrate on a few of those that have important implications in terms of selecting appropriate site preparation and regeneration prescriptions. Such site factors may be put into three main classes: internal site factors (soil, physical, and chemical properties), external site factors (relating to physiography and climate), and stand factors (e.g., stem density, canopy cover, deadfall abundance, species composition, and abundance of the understory). The environmental factors I will discuss are readily observable by the field forester or technician before the area in question is logged, so mechanical site preparation options (where appropriate) for a site might be anticipated prior to timber harvest. A brief discussion of these factors follows.

Internal Site Factors

A few internal site factors will be briefly discussed, including the thickness and type of the organic layer, color of the mineral soil (including mottling), texture, and internal drainage, of which the latter is related to the aforementioned properties.

Organic layer thickness will determine the intensity of site preparation required to expose a mineral soil for planting or seed. Thick organic layers (i.e., >720 cm) will obviously require more-severe scarification, probably using plowing techniques rather than, for example, drag scarifiers, compared with sites with shallow organic layers. The character of the organic layer will give clues to the moisture regime and to some extent, the nutrient regime of the site. An organic layer that is fibric (poorly decomposed) and composed mainly of feather mosses indicates soil that is usually well to imperfectly drained and suggests that lodgepole pine or white spruce may be preferred species for regeneration. A fibric organic layer composed mainly of the brown mosses (e.g., *Tomenthypnum nitens*) or the peat mosses (*Sphagnum* spp.) suggests imperfectly to poorly drained conditions, where the site may be suitable only for black spruce or may not be suitable for planting trees at all if the water table has risen considerably after logging. A humic (well decomposed) black organic layer indicates poorly drained soils that may pose reforestation problems due to excessive moisture and plant competition.

Soil color also provides a good clue to the internal drainage of the soil. Reddish colors in the B horizon of boreal forest soils in our region indicate oxidation of iron and aluminum compounds under well to rapidly drained conditions where drought may pose a problem to young conifer seedlings. Yellowish to brownish colors in the B horizon generally indicate moderately well to well-drained soils where conifer regeneration success should be optimal. Gray to bluish colors in the B horizon or abundant red mottling in the soil matrix indicate imperfectly to poorly drained soils where excess moisture and plant competition may pose significant threats to successful conifer establishment, and where winter site preparation may be necessary when soils are frozen.

Soil texture is an important determinant of site moisture regime, which, as we have seen, is very important from a silvicultural viewpoint. Texture, which is dependent on the type of soil parent material, must be evaluated in conjunction with other site factors such as topographic position, aspect, and climate. For example, a gravelly soil in a lower slope position on a north aspect will have a much more favorable moisture regime than a similar soil on a south aspect in an upper slope position. Fine-textured soils retain more soil moisture than coarse-textured soils and consequently drain more slowly. Generally, coarse-textured soils are thus drier, develop shallower organic layers, require less-severe site preparation, and have less-severe vegetation competition with young conifer stock, but are generally more droughty than fine-textured soils. Fine-textured soils (especially those developed on clay and heavy clay lacustrine parent materials) may be characterized by restricted drainage, thicker organic layers, and severe vegetation competition with conifer stock, and may require more-severe site preparation than the gravelly soil, especially in depressional areas. Reconnaissance soil survey maps (available for most of the west-central Alberta study area) can be useful tools in delineating areas of problem sites.

External Site Factors

External site factors are those that are reflections of the environment outside the soil system but that still influence site productivity. Included are slope gradient, aspect, elevation, and topographic position. All of these are important in determining site characteristics such as moisture regime and thus organic layer type and thickness, which of course will influence site preparation and regeneration prescriptions.

Slope gradient is an obvious factor controlling mechanized site preparation options in the foothills environment, where steep slopes can either deter mechanized equipment or require special management to minimize erosion damage to the site. Slope aspect has an important influence on moisture regime and organic layer thickness, especially on steep slopes. Steep southerly aspects tend to be droughty with shallow organic layers. Although site preparation on such slopes may be minimal, seedling survival may be low. North aspects tend to be more favorable for conifer establishment but may require more severe site preparation than southerly aspects due to deeper organic layers.

Elevation has important implications on seedling survival but less influence on site preparation options. Elevation is a determinant of climate. Growing seasons tend to shorten, temperatures decrease, precipitation increases, and plant competition problems decrease with increases in elevation.

Stand Factors

Stand factors refer to the forest and vegetational properties of a site that are functions of the site environment. Included are the various measures of the forest stand, including mortality, tree ingress, etc., plus vegetational properties of the understory. Mainly the vegetational factors are discussed here. The abundance and species composition of vegetation on a forest site are functions of a myriad of environmental factors, some of which have been previously mentioned. The vegetation can thus tell us a great deal about the site before any detailed evaluations of the soils or climate are done. The plant species composition on a site generally allows us to infer information on the site moisture regime, soil drainage class, organic layer type and thickness, type of climate, relative soil acidity or alkalinity, and relative productivity.

CONCLUSION

It is apparent that evaluation of internal and external site factors plus stand factors on an individual basis could be tedious and time-consuming. A rapid and efficient assessment of the forest site can be made using a forest ecosystem classification. Such a classification for the west-central Alberta study area has been evolving for the past 12 years. The field guide now in preparation allows the user to identify quickly the ecological (bioclimatic) zone and ecosystem association with which he is dealing. Significant environmental and vegetational attributes are described. In addition, a number of forest management interpretations are made for each ecosystem association, including season and methods for harvest and site preparation; soil compactivity, puddling, and erosion hazards; species options, method, and limitations for reforestation; frost heave hazard; and vegetation competition, windthrow, and fire hazards.

ACKNOWLEDGMENTS

Thanks and appreciation go to the speakers, who took the time to prepare and present their papers, and to the gentlemen who volunteered their time as moderators during paper presentations and discussions. The contributions of Cazes and Heppner Forest Services Ltd., Canadian Forestry Equipment Ltd., K.B.M. Forest Consultants, Northern Mountain Helicopters Inc., and Okanagan Helicopters, who displayed and discussed their products during the banquet and social function, are also gratefully acknowledged.

The willingness of the abovementioned and the attending delegates to discuss current problems aided in making this workshop a complete success.

ATTENDEES AT THE MECHANIZED SILVICULTURE WORKSHOP

Dave Baird
Manitoba Forest Resources Ltd.
P.O. Box 1950
The Pas, Manitoba
R9A 1L9

Jim Ball
Canadian Forestry Service
104, 180 Main Street
Winnipeg, Manitoba
R3C 1A6

Neil Barker
6409 - 37B Ave.
Edmonton, Alberta
T6L 1R3

Brock Bartlett
Woods Manager
Abitibi-Price Ltd.
Box 10
Pine Falls, Manitoba
R0E 1M0

Elder Berger
Silviculture Supervisor
Woodlands Enterprises Ltd.
P.O. Box 1720
Prince Albert, Saskatchewan
S6V 5T3

Garry Boos
Forester
Zeidler Forest Industries Ltd.
Box 910
Barrhead, Alberta
T0G 0E0

Keith Branter
Forester I/C
Alberta Forest Service
10811 - 84 Avenue
Grande Prairie, Alberta
T8V 3J2

D.W. Brewis
Ministry of Forests
Silviculture Branch
1450 Government Street
Victoria, B.C.
V8W 3E7

Gordon Brown
Alberta Forest Service
Box 450
Lac La Biche, Alberta
T0A 2C0

Kent Cantrell
Syncrude Canada Ltd.
Bag 4009
Fort McMurry, Alberta
T9H 3L1

Christopher R. Carlish
Dep. Indian Affairs and Northern Development
Box 7
Fort, Smith, N.W.T.
X0E 0P0

Brian Carnell
Canadian Forest Producs Ltd.
Box 749
High Level, Alberta
T0H 1Z0

Harvey Clark
Northern Mountain Helicopter Inc.
P.O. Box 368
Prince George, B.C.
V2L 4S2

David Cook
Alberta Forest Service
9525 - 77 Ave.
Grande Prairie, Alberta

Richard Corser
Eddy Tie
P.O. Box 1600
Edson, Alberta
T0E 0P0

Carmen Densmore
Scarification Supervisor
St. Regis (Alberta) Ltd.
Hinton, Alberta
T0E 1B0

Brad Engel
Forestry Safety Supervisor
Revelstoke Companies Ltd.
P.O. Box 2501
Calgary, Alberta
T2P 2N2

Jim Farrell
Development Officer
Canadian Forestry Service
101 - 15 Street East
Prince Albert, Saskatchewan
S6V 1G1

Brian Firby
Saskatchewan Forest Products Corp.
550 - 1st Avenue East
Prince Albert, Saskatchewan
S6V 2A5

Frank Flavelle
Manager, Forest Operations
Sask. Dep. Parks and Renewable Resources
P.O. Box 3003
Prince Albert, Saskatchewan
S6V 6G1

Jack Gilmour
Regional Staff Forester
Dep. Indian and Northern Affairs
Fort Smith, N.W.T.
X0E 0P0

William Gladstone
Forester
Alberta Forest Service
Box 3310
Postal Station B
Calgary, Alberta
T2M 4L8

Carl Halland, Resource Officer
Forestry Division
Sask. Dep. Parks and Renewable Resources
P.O. Box 3003
Prince Albert, Saskatchewan
S6V 6G1

Dave Hanline, Resource Officer
Forestry Division
Sask. Dep. Parks and Renewable Resources
P.O. Box 3003
Prince Albert, Saskatchewan
S6V 6G1

Ingrid Hedin
Forest Engineering Research Institute of Canada
201, 2112 West Broadway
Vancouver, B.C.
V6K 2C8

Doug Hunt
Management Forester
Manitoba Forest Resources Ltd.
Woodlands Division
Box 1590
The Pas, Manitoba
R9A 1L4

Dean Isles
Forest Officer
Alberta Forest Service
Slave Lake, Alberta
T0G 2A0

Ed Johnson
Fire Control Forester
Alberta Forest Service
Whitecourt, Alberta
T0E 2L0

W.E. Jonas
General Manager, Lumber
Manitoba Forestry Resources Ltd.
P.O. Box 1950
The Pas Manitoba
R9A 1L9

K.S. Kowalyk
Forester
Alberta Forest Service
Box 1720
Rocky Mountain House, Alberta
T0M 1T0

Dennis Lamb
Regional Specialist
Box 2550
The Pas, Manitoba
R9A 1M4

Gordon Lehn
Alberta Forest Service
Postal Bag 30
Whitecourt, Alberta
T0E 2L0

Gary Leithead
Chief Forester
Revelstoke Companies Ltd.
Box 2501
Calgary, Alberta
T2P 2N2

Murray Little
Manager, Silviculture
Forestry Division
Sask. Dep. Parks and Renewable Resources
P.O. Box 3003
Prince Albert, Saskatchewan
S6V 6G1

Weldon Louttit
Dep. Natural Resources
Box 1800
Gimli, Manitoba
R0C 1B0

Steve Luchkow
Silviculture Forester
Alberta Forest Service
Whitecourt, Alberta
T0E 2L0

Keith Mang
Contract Forester
Timber Management
Alberta Forest Service
11322 - 122 Street
Edmonton, Alberta
T5N 0B8

Max Matthews
Woodlands Manager
Zeidler Forest Industries Ltd.
P.O. Box 4370
Edmonton, Alberta
T6E 5K1

U.J. Mattis
Senior Silvicultural Forester
St. Regis (Alberta) Ltd.
Hinton, Alberta
T0E 1B0

Wayne Mayan
Forest Protection Superintendent
St. Regis (Alberta) Ltd.
Hinton, Alberta
T0E 1B0

Scott Mayston
Zeidler Forest Industries Ltd.
Slave Lake, Alberta
T0G 2A0

Gord H. McColm
Regional Specialist
Box 10
Dauphin, Manitoba
R7N 3E5

R.G. McMinn
Pacific Forest Research Centre
506 West Burnside Road
Victoria, B.C.
V8Z 1M5

Ray Mitchell
Senior Resource Technician
Blue Ridge Lumber (1981) Ltd.
P.O. Box 1079
Whitecourt, Alberta
T0E 2L0

Ted Mueller
Forest Officer
Forest Research Branch
Alberta Forest Service
Postal Bag 6343
Spruce Grove, Alberta
T0E 2C0

Peter J. Murphy
Associate Dean, Forestry
817 General Services Bldg.
University of Alberta
Edmonton, Alberta
T6G 2H1

Don Myles
Scientific Advisor
Canadian Forestry Service
Place Vincent Massey
Ottawa, Ontario
K1A 1G5

Hans Nagel
Chief Silviculturist
Procter and Gamble Cellulose Ltd.
P.O. Bag 1020
Grande Prairie, Alberta
T8V 3A9

Stan Navratil
Research Manager
Alberta Forest Service
Postal Bag 6343
Spruce Grove, Alberta
T0E 2C0

Terry Oberik
16608 - 78th Ave.
Edmonton, Alberta
T5R 3E6

Roman Orynik
Silviculture Forester
Prince Albert Pulpwood
P.O. Box 1720
Prince Albert, Saskatchewan
S6V 5T3

Walter Palubiski
Marketing Manager
Okanagan Helicopter Ltd.
4391 Agar Drive
Richmond, B.C.
V7B 1A5

Lowell Paul
Professional Engineer
Box 557
Armstrong, B.C.
V0E 1B0

Lester Perrott
2104 Galbraith House
Michener Park
Edmonton, Alberta
T6H 5B5

Steve Price
Northern Forest Research Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Don Pluth
Department of Soil Science
University of Alberta
Edmonton, Alberta
T6G 2E3

Earl Purdy
Mechanical Superintendent
Manitoba Forest Resources Ltd.
Woodlands Division
Box 1590
The Pas, Manitoba
R9A 1L4

Dave Reid
K.B.M. Forest Consultants Ltd.
360 Mooney Street
Thunder Bay, Ontario
P74 5R4

Arden Rytz
Manager
Alberta Forest Products Association
204, 11710 Kingsway Avenue
Edmonton, Alberta
T5G 0X5

Wade Shipka
10411 - 69th Street
Edmonton, Alberta
T6A 2S7

Steve Smith
Manager
Prince Albert Pulpwood
P.O. Box 1720
Prince Albert, Saskatchewan
S6V 5T3

Nick Smud
Forest Technician
Simpson Timber Co.
Box 760
Hudson Bay, Saskatchewan
S0E 0Y0

William J. Stephen
Director, Renewable Resources
Indian and Northern Affairs Canada
P.O. Box 1500
Yellowknife, N.W.T.
X1A 2R3

Gerry Stuart
Resource Officer
Forestry Division
Dep. Parks and Renewable Resources
Box 3003
Prince Albert, Saskatchewan
S6V 6G1

Al Todd
278 Anderson Street
Prince George, B.C.
V2M 5W2

John Walker
Manager
Simpson Timber (Sask.) Ltd.
P.O. Box 760
Hudson Bay, Saskatchewan
S0E 0Y0

Brian Zak
B.C.F.P.
Bag 3000
Grande Cache, Alberta
T0E 0Y0