PROTECTING WHITE SPRUCE UNDERSTORIES WHEN HARVESTING ASPEN

Progress Report

Brace Forest Services[1]
1992

This is a joint publication of Forestry Canada
and the Alberta Forest Service pursuant to the
Canada-Alberta Partnership Agreement in Forestry

[1]Edmonton, Alberta

Project No. 1480

DISCLAIMER

The study on which this report is based was funded in part under the Canada-Alberta Partnership Agreement in Forestry.

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Catalogue No.: FO42-91/101-1992E
ISBN: 0-662-20110-8

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ABSTRACT

Project 1480 was initiated in 1988 under the Canada-Alberta Forest Resource Development Agreement. It was a cooperative project between the federal and provincial governments, industry, and FERIC. It has both harvesting and silvicultural components.

Harvesting production, costs, and special planning and operating procedures which are effective for protecting spruce understory are reported separately by FERIC.

This report provides details of the silvicultural component. It stresses post-harvest implications, particularly blowdown risk and growth and yield potential of released understory, and regeneration and growth of spruce, aspen, and poplar on mechanically harvested mixedwood sites.

New density and stocking criteria, survey techniques, and growth and yield methodology for species growing together on mixedwood sites are necessary if mixedwood management is anticipated.

The project addresses well-publicized concerns about maintaining the coniferous component of mixedwood forests and finding alternatives to clearcutting. It covers the current status of operational understory protection and some related aspects of integrated resource management.

Silvicultural results to date are tentative but encouraging. Blocks should be remeasured after 5 growing seasons, with consideration for extending operational tending and harvesting trials to a wider range of sites and ages. The spruce understory steering committee recently supported priorities for continued remeasurement and technology transfer of Project 1480 results, and operational R & D on mitigating spruce blowdown, under the new Canada-Alberta Forestry Agreement.

There is a need for renewed research into the physiology and ecology of mixedwoods targetted specifically on increasing the success of both natural and artificial regeneration of spruce, including underplanting of fire-origin aspen and post-harvest in-planting on mixedwood sites. Information from past and new research should be in a format suitable for use in decision support systems (DSS) designed to deal with the complexities of mixedwood ecosystem management.

New approaches to mixedwood ecosystem management raise policy and regulations issues for provincial and industrial managers in the areas of land tenure and resource-sharing, mixedwood stocking and performance standards, annual allowable cut (AAC), and the guidelines under which forest land operations are conducted. Cooperative projects like this one should continue to provide managers with information relevant to evolving mixedwood management strategies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

PROTECTING WHITE SPRUCE UNDERSTORIES WHEN HARVESTING ASPEN
PROGRESS REPORT
CANADA-ALBERTA FRDA PROJECT 1480

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1.0 INTRODUCTION

Project 1480 was initiated in 1988 under the Canada-Alberta Forest Resource Development Agreement. The project is aimed primarily at technology transfer, demonstrating the integration of silvicultural and harvesting techniques for protecting spruce understories in mixedwoods.

The following background information places the project in the context of the resource base, particularly the role and importance of spruce understory in mixedwoods, current operational practices, and some related aspects of integrated resource management planning.

The two-stage tending and harvesting model, which forms the basis for treatments tested in the project is described, along with initial silvicultural results and recommendations for future regional R & D supportive of new provincial and industrial mixedwood management strategies.

2.0 BACKGROUND

2.1 The Boreal Mixedwood Resource

The extent of boreal mixedwoods within four regional Forest Sections (Rowe 1972) is illustrated in Figure 1. They occupy an estimated 150,000 sq km representing about one-third of the productive forest land base in the prairie provinces. This project focuses on the white spruce (Picea glauca [Moench]Voss) component of mixedwoods which occurs as an understory with aspen (Populus tremuloides [Michx.]), balsam poplar (Populus balsamifera L.) and white birch (Betula papyrifera Marsh.). Data on the nature and extent of spruce understory stands available from current inventories are not reliable. Recent surveys in Alberta have shown understory stands to be very significant, occurring in up to 80% of stands currently inventoried H (hardwood) and HS (hardwood-softwood) (Brace and Bella 1988). They tend to occur as a continuum, rather than in clearly recognizable associations, due to stand history, site patterns, and species ecology. They require detailed inventory, preferably within the framework of an ecological site classification system.

2.2 The Importance of Spruce Understory

In the long run, supplies of commercial white spruce depend upon successful establishment of new stands, which has proved to be relatively costly and ineffective to date (Henderson 1988; Peterson 1989), even though it has been the subject of considerable regional research for many decades on mixedwood sites (Jarvis et al. 1966). Within the next 60 to 80 years, spruce that have developed to commercial size through natural succession under the protection of hardwoods will be the main source of spruce timber in boreal mixedwoods. However, the demand for aspen, which accounts for 80% of regional hardwoods, is rising dramatically, particularly in Alberta (Brennan 1988; Ondro 1989) where over 70% of the aspen AAC has been committed for new and proposed developments by 1993 (Table 1). Approximately 80% of stands inventoried as H and HS are currently over 60 years of age (Figure 2) and many are now being scheduled for aspen harvest using conventional harvesting equipment and procedures, jeopardizing the associated spruce understory and the future softwood timber supply.

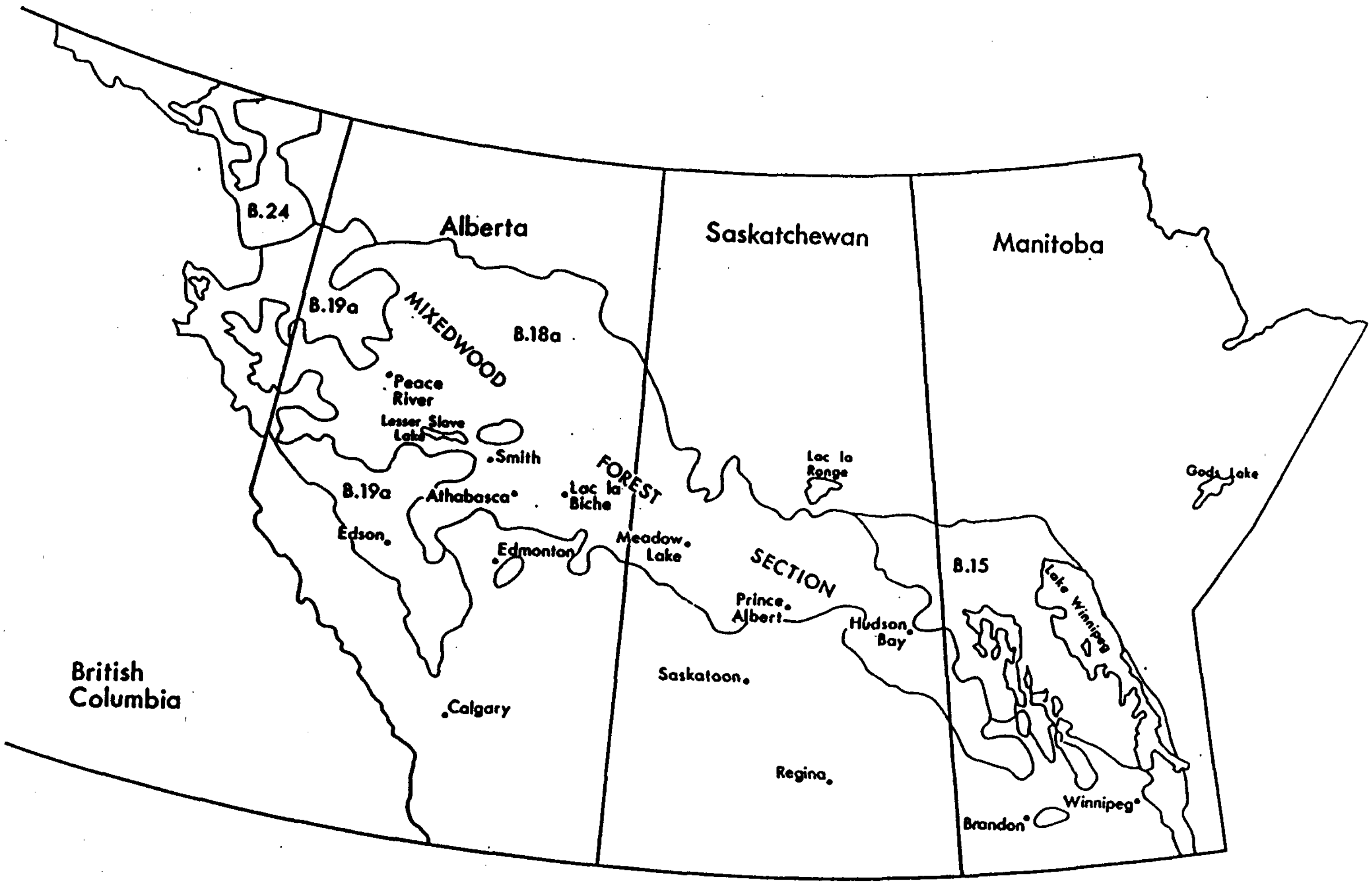
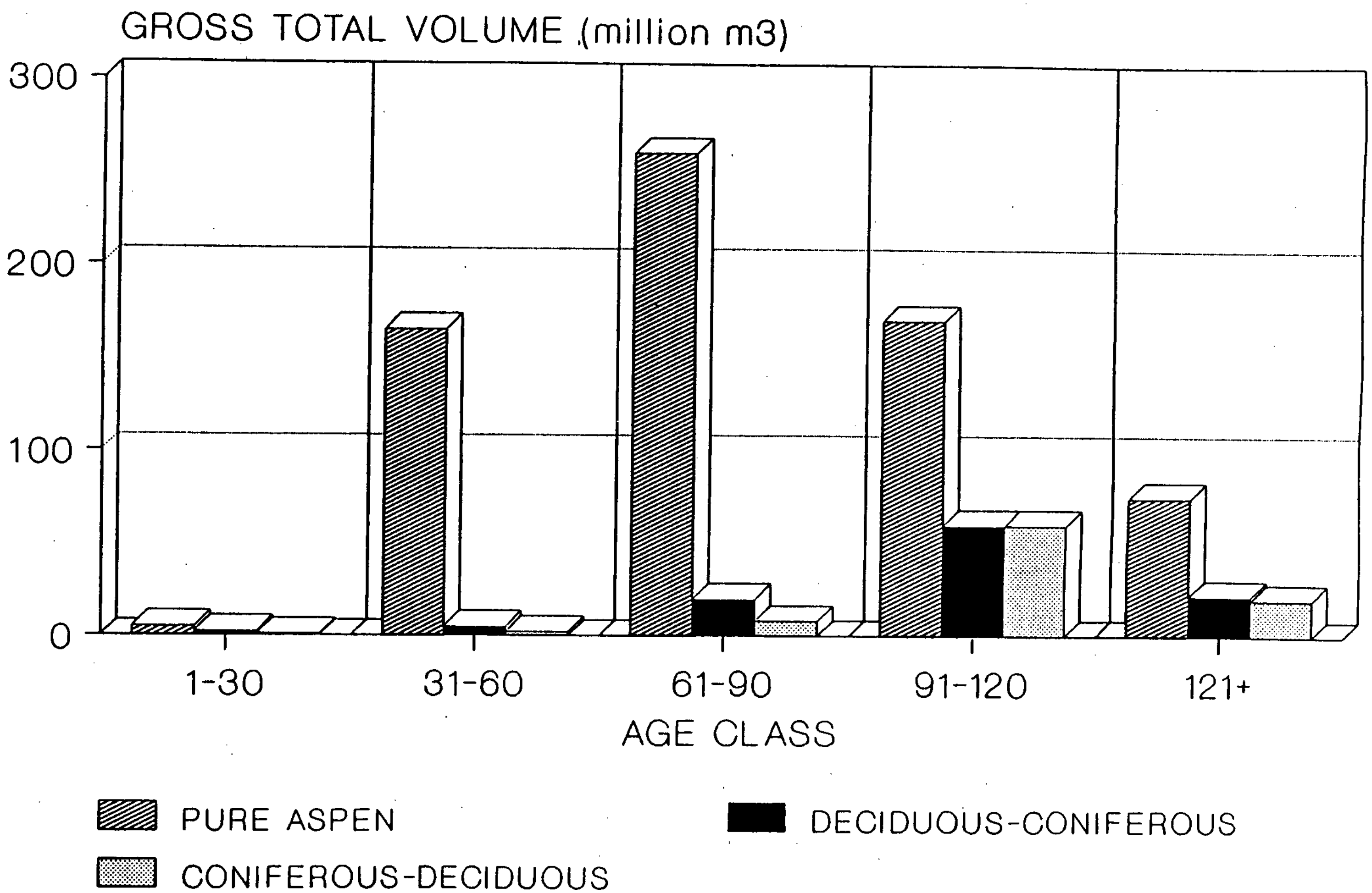


Figure 1 Boreal Mixedwoods - Project 1480.

Figure 2. Gross total volume of aspen and other poplar in hardwood (H) and mixedwood (HS), SH stands in Alberta - 1987 - Project 1480.



From Ondro (1989)

Table 1. Utilization trends and current AAC - aspen - western Canada (million m^3) - Project 1480

	Utilization Trends[1]					
	1978	1983	1988	1993 (est.)	Current AAC[2]	% AAC Committed 1993 (est.)
Manitoba	0.06	0.16	0.14	1.03	1.8	57
Saskatchewan	0.30	0.37	0.84	1.70	2.6	65
Alberta	0.05	0.17	0.89	6.00	8.4	71
B.C. (Northeast)	-	-	0.16	0.16	3.5	5
				8.89	16.3	55

[1]Summarized from information provided by provincial governments.
[2]From Woodbridge, Reed and Associates; 1989.

From a timber management perspective, the value of understory depends on the cost and effectiveness of protection during harvest, post-harvest density, distribution and windfirmness, and relative growth rates after release. If released understory meets establishment and performance standards without additional planting and tending costs its value could exceed $2000/ha--the approximate cost of establishing and tending a spruce plantation on a mixedwood site to about age 30 (Navratil et al. 1989). In most cases, the value of protected understory will be considerably less, declining as density and distribution depart from the ideal, due to rising establishment and tending costs. At some point it will no longer have economic value for timber production alone. Benefits for non-timber purposes like aesthetics and wildlife habitat may enhance understory value, as discussed later.

Understory protection was initiated in stands inventoried H and HS and is now progressing into SH and S stands, due in part to the premium which new free-to-grow (FTG) standards has placed on established coniferous stock. This report is most relevant to H and HS stands with spruce under aspen and poplar.

2.3 Management Considerations

Peterson (1989), in recent interviews with regional mixedwood foresters in industry, government and research, found that they recognized mixedwoods as a well-adapted ecological mix of species, but are puzzled by the complexity of the management problems posed by such ecosystems, one aspect of which is understory protection, which was given a high-priority rating.

The need for more sophisticated management planning systems and tools to deal with such complexity has been well documented by Navratil et al. (1989) and Baskerville (1990).

While the debate over boreal mixedwood ecosystem management continues, forest industry and provincial land managers in western Canada are being challenged immediately to modify and adapt harvesting systems to remove aspen while protecting white spruce understories. This poses problems with implications for policy and regulations in the areas of land tenure, stocking and performance standards,

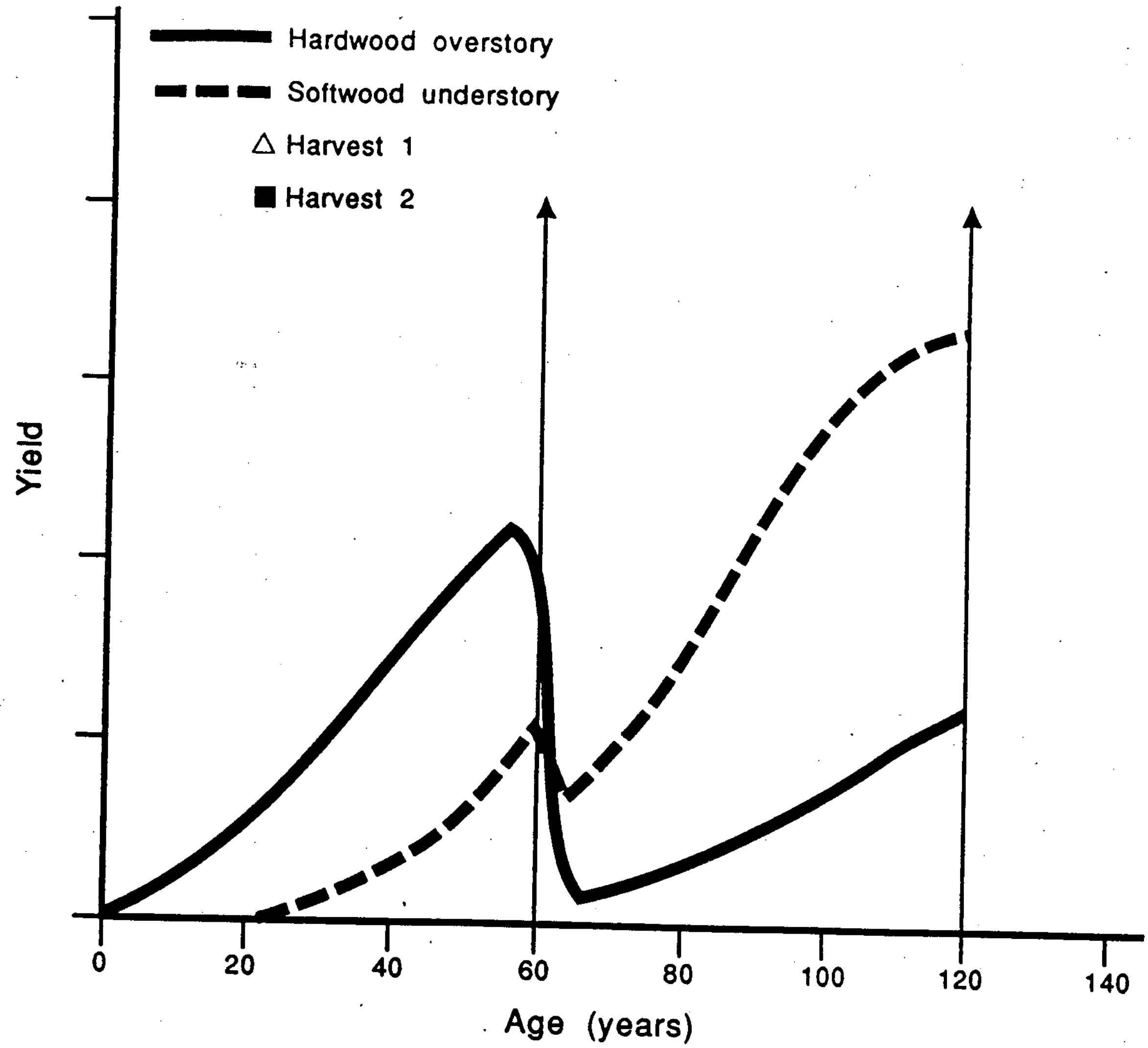


Figure 3. Generalized two-stage tending and harvesting model - Project 1480.

larger protected understory which will begin bearing seed in the future. If planted or natural spruce regeneration becomes established under aspen clumps and sufficient aspen regeneration becomes established and develops within protected spruce clumps following the first harvest, the result will be a land base shift between aspen and coniferous components of the block at the time of the second harvest.

When the second harvest is taken at age 120 years, options for managing the stand as either mixedwood, hardwood or conifer could be exercised.[4] Navratil et al. (1989) describe some of the silvicultural challenges posed by these options.

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[4] In reality, new free-to-grow (FTG) reforestation standards which now apply in Alberta will determine what can be done operationally, and some study stands have already been planted to improve coniferous density and distribution.

and operational ground rules, and raises operational questions in the areas of technical feasibility, costs, regeneration, and growth and yield (Samoil 1988).

The need for protection of spruce as a component of boreal mixedwoods goes beyond concern for the future commercial softwood timber supply. Concerns also include fisheries and wildlife habitat, aesthetics and recreation, a general dissatisfaction with clearcutting in mixedwoods and a strong interest in mixedwood perpetuation, as expressed in 41 public meetings on forestry development in northern Alberta (Concord Scientific Corp. 1989) and in the recent expert panel report on forest management (Expert Panel 1990). Also, at a recent forum on the environment organized by the Canadian Pulp and Paper Association (CPPA), industry leaders strongly expressed forest management concerns much beyond timber supply (Addison et al. 1989). There is clearly a need to develop new approaches to mixedwood harvesting, particularly where spruce understories need protection.

Bonar (1989) illustrates the importance of integrating timber and non-timber objectives at the planning stage of forest management, rather than considering non-timber objectives as "add-ons" at a later stage. The recent work of an integrated resource planning team working on the Weldwood FMA at Hinton[1] is a good example of such planning for wildlife and timber. Other examples are provided in a recent report by Penner[2] and in the Saskatchewan Forest Habitat Project[3].

Increases in hardwood utilization, coupled with public demand to maintain mixedwoods for a variety of non-timber purposes are challenging the traditional softwood bias in mixedwood management, requiring management objectives beyond softwood silviculture and growth and yield and creating the need for an effective multi-disciplinary approach to both management planning and operations.

2.4 Two-Stage Harvesting and Tending Model

A two-stage harvesting and tending stand-level model, described by Brace and Bella (1988) was adopted as the basis for silvicultural prescriptions (Appendix I) which were used as treatments in project 1480. Figure 3 illustrates the model, which has been designed to accommodate two harvests of aspen in a 120-year cycle and to realize the yield potential of associated understory spruce.

To illustrate the process, assume a first harvest of aspen at age 60 years and understory spruce at age 40 years. The aspen and all spruce over 25 cm dbh could be harvested, leaving a released spruce understory. Following harvest, aspen and poplar suckers and seedlings will regenerate in the available spaces, resulting in a stand comprised of separate clumps as well as mixtures of hardwoods and conifers. Conifers could be planted in areas found by survey to be inadequately stocked to acceptable conifers or hardwoods, and both planted and naturally regenerated conifers tended as necessary to maintain growth rates. This would result in perpetuation of a mixedwood for the period necessary for a new hardwood crop and the released spruce to mature, possibly by age 120 years. During this time spruce could seed in under aspen, assuming a seed source is maintained, particularly if the site is scarified by logging activity. Seed could originate from adjacent stands, from seed-trees purposely left during harvest, and from

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[1] Anon., 1990. Integrated Management of Timber and Wildlife Resources on the Weldwood Hinton Forest Management Agreement Area. Unpublished MS.

[2] Penner, D. 1991. Integration of Wildlife Objectives with Silvicultural Systems in the Boreal-Mixedwood Ecoregion. Unpublished contract report prepared for Forestry Canada, NoFC.

[3] Available fron Saskatchewan Natural Resources, Prince Albert, Saskatchewan.

Advantages of the model could include:

a) reduction or avoidance of the costs and risks associated with establishing and growing spruce on mixedwood cutovers,
b) improved utilization of aspen and increased spruce AAC through increased growth and shorter rotations for spruce released from the understory,
c) demonstration of the maintenance of mixedwood landscape aesthetics, wildlife habitat, recreational values and biodiversity thereby addressing major shortcomings of the clearcutting system as now practised on many mixedwood sites,
d) contribution to solving the problems created where hardwood and conifer harvesting rights are held by different companies on the same land base, and where protection of understory spruce is a priority for the softwood user.

Some current limitations of the model include:

a) uncertainty about the feasibility of adapting available harvesting technology to protect understory across a range of stand age, density and site conditions,
b) potential for windthrow of released spruce, particularly on moist sites, as well as the risk of leader-weevilling in released spruce,
c) inadequate density and stocking criteria for mixed stands of protected spruce and aspen regeneration following the first harvest, and lack of knowledge of growth and yield and AAC implications for such mixed stands prior to the second harvest.

The two-staged model is a potential option for mixedwood stands in which aspen are of usable size and quality, understory density and distribution is suitable, and risk of blowdown and other damage is acceptable. There should be a significant number of these stands in Alberta since about 66% of stands inventories H, HS or SH are in the 61 to 120 year range, according to Phase III inventory statistics, and many contain spruce understories. Stands which are either too young or too old and decadent to be viable for timber harvest, or where understories are deemed more valuable than overstories, require other management approaches (see Navratil et al. 1989).

3.0 PROJECT 1480

Project 1480 was a cooperative study under the Canada-Alberta FRDA program, involving Forestry Canada, the Alberta Forest Service, Weyerhaeuser Canada Ltd., Weldwood of Canada Ltd., Blue Ridge Lumber (1981) Ltd., Millar-Western Industries Ltd. and FERIC. It had both harvesting and silvicultural components.

Cooperators participated as members of the Spruce Understory Steering Committee (Appendix II), whose main function was to establish stand selection criteria and agree on silvicultural prescriptions and harvesting methods to be tested.

There are a total of nine study blocks, located in areas designated 1, 2 and 3 (Drayton Valley, Hinton and Whitecourt respectively) in Figure 4. For reporting purposes they were designated DC (control), D1 and D2 in the Drayton Valley area, HC (control), H1 and H2 in the Hinton area, and WC (control), W1 nd W2 in the Whitecourt area. Figures 5 and 6 show examples of pre- and post-harvest stand appearance and harvesting sequence.

Figure 4. Location of study stands - Project 1480.

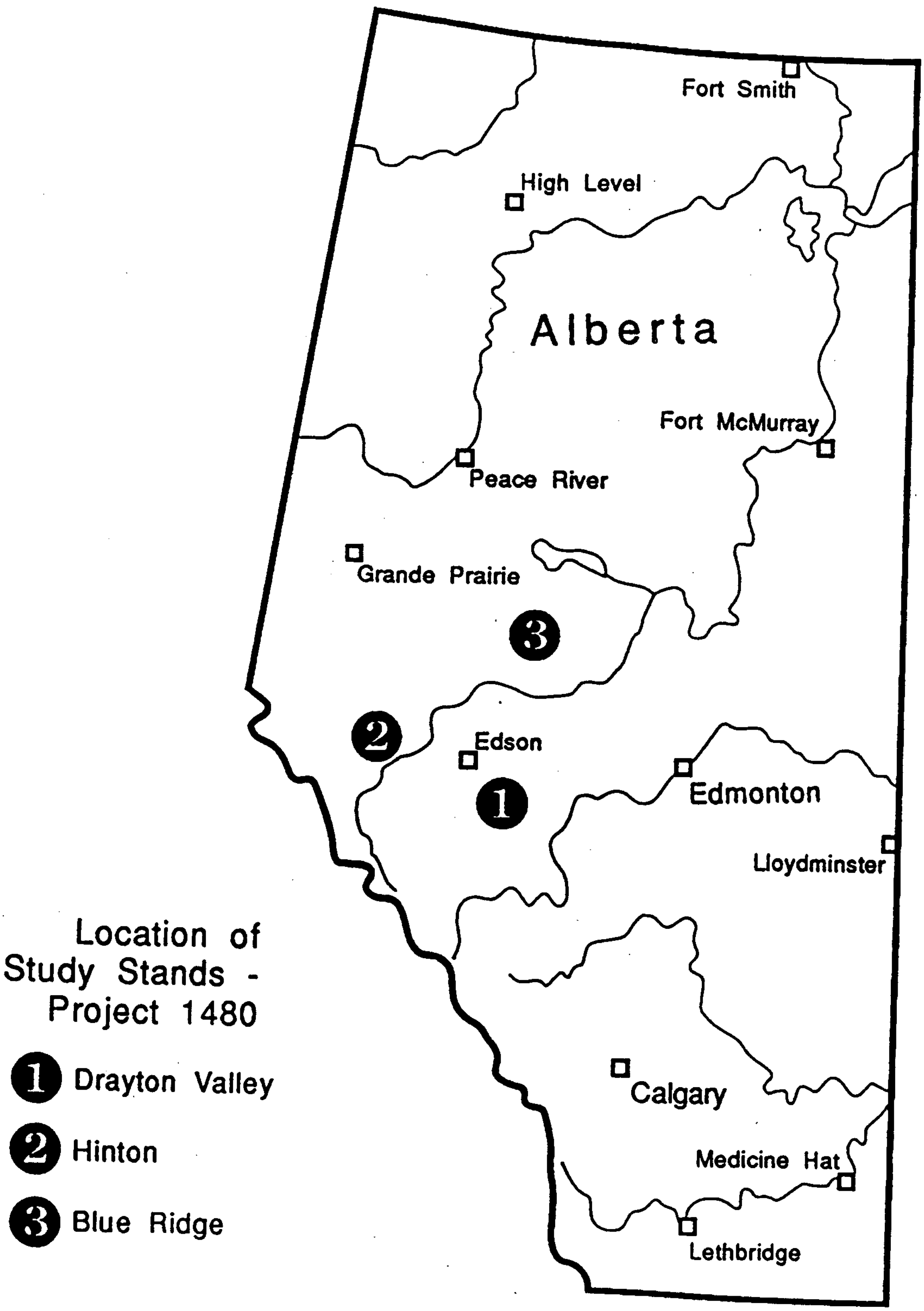


Figure 5. Top photo: Pre-harvest appearance of stands harvested in Project 1480. Bottom photo: aerial view of (1) understory protection using Rottne shortwood system; (2) conventional clearcut using FB/GS; and (3) understory protection using FB/GS.

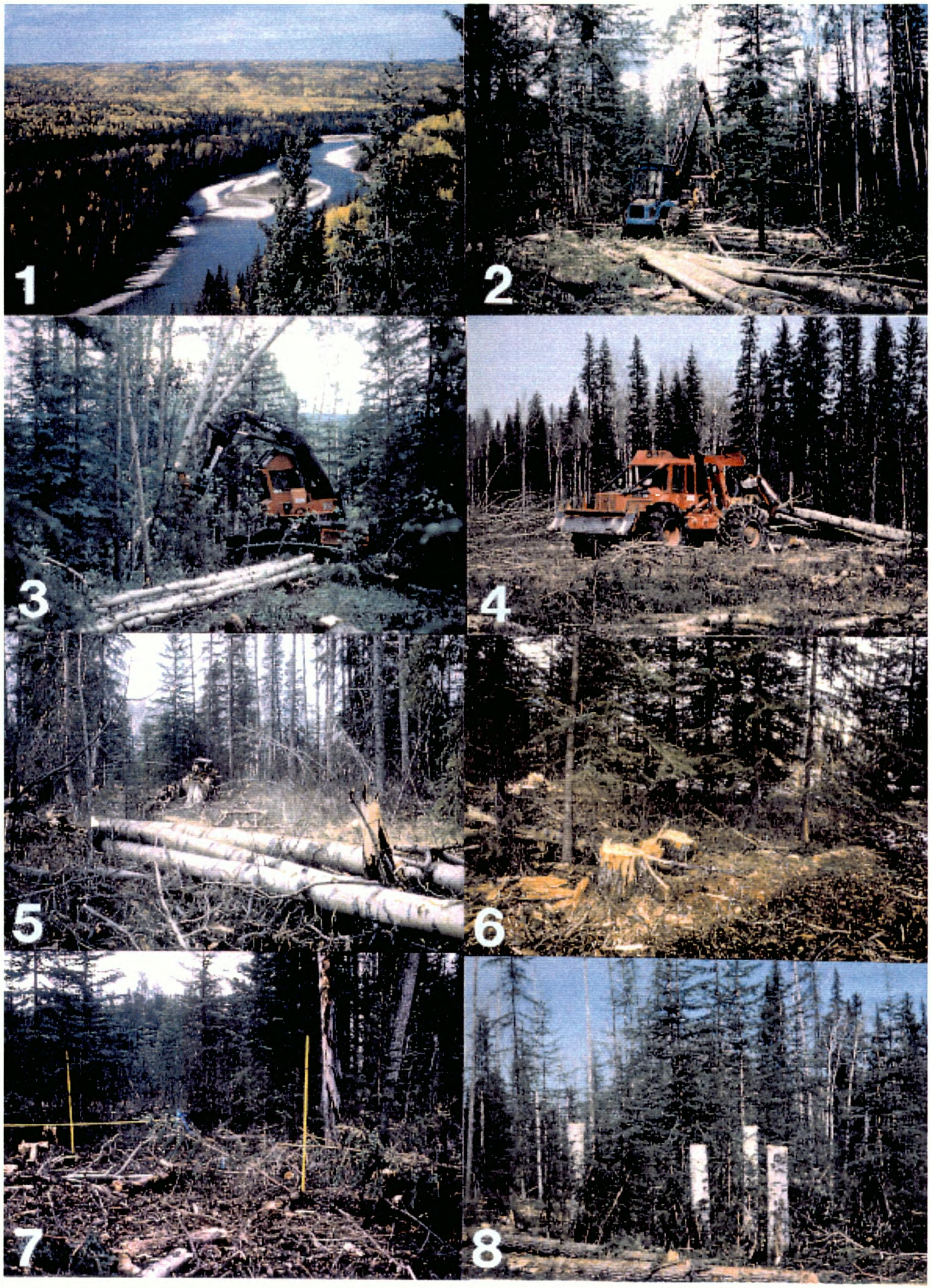


Figure 6. Typical mixedwood landscape; (2) understory protection using Rottne shortwood harvester; (3) understory protection using FB/GS; (4), (5) grapple skidding full tree and tree length aspen; (6) stumps of aspen removed from spruce clump by FB/GS; (7) assessing logging damage on residual spruce; (8) post-harvest scene with rub-stumps and protected spruce clump.

Harvesting results, including equipment productivity, costs, and the crucial role of planning, equipment selection, supervision, modified operating techniques, crew motivation and training in achieving operationally practical understory protection are reported separately by Sauder (1992). Harvesting prescriptions are summarized in Table 2.[5]

A two-stage harvesting and tending model forms the silvicultural basis for block treatments. The model provides a framework for discussing ways of combining harvesting and tending to achieve a variety of mixedwood management options, which should be relevant to managers as they evolve new mixedwood management policies and regulations.

Stand selection criteria were set by committee. Sampling and measurement resulted in nine stands being chosen for harvest, three as controls, with no understory protection, and six as treatments, with understory protection, using both FB/GS and shortwood (Rottne) systems. Table 3 shows pre-harvest statistics for each stand.

3.1 Objectives for Forestry Canada

The primary objectives of this project for Forestry Canada were:
a) conduct stand inventories and establish permanent sample plots;
b) assess damage to spruce trees released during harvesting of the aspen overstory;
c) monitor subsequent development of the residual spruce (growth, windthrow and weevil risk), and of new spruce, aspen, and poplar regeneration (density, growth); and
d) demonstrate the role of understory protection in addressing landscape aesthetics and wildlife habitat concerns, in an integrated resource management (IRM) context.

3.2 Role of FERIC

Harvesting productivity, costs and details of operational procedures for each stand harvested in this project were assessed by FERIC and have been reported by Sauder and Sinclair (1989) and Sauder (1992), with reference to spruce damage incurred during harvesting. They developed detailed harvesting prescriptions in consultation with the steering committee and individual companies, which are summarized in Table 2 and shown in detail along with silvicultural prescriptions in Appendix I.

The pre-harvest composition, density, distribution and merchantable volume of overstory species was considered representative of regional mixedwoods aged 70 to 110 years on mesic sites. Understory densities covered the specified range of 250 to 1000 stems/ha between 0.5 and 14.0 m tall. Height and distribution patterns--especially clumpiness--were considered characteristic of regional understories. Spruce age ranged widely and was assumed to be 70 years or less, capable of responding to release. The dynamics of understory establishment and development in relation to strategies for natural and artificial regeneration and subsequent release and tending of spruce were discussed.

[5]Throughout this report, the feller-buncher/grapple skidder (FB/GS) harvesting system is associated with full tree and tree length harvesting, and the Rottne shortwood or Swedish harvesting system is associated with cut-to-length harvesting, either logs or bolts.

Table 2. Harvesting methods and procedures applied by location and treatment - Project 1480

Treatment	Function	Location: Drayton Valley (D)	Location: Hinton (H) and Whitecourt (W)
Control	Felling	Feller-buncher on tracked loader with shear head	Feller-buncher on excavator carrier with shear head (H) and sawhead (W)
	Forwarding	Grapple skidders-full tree	Grapple skidders-full tree
	Procedures	Conventional clearcut with some understory protection. All species topped, delimbed and bucked on the landing by hand	Conventional clearcut. Stroke delimber and slasher at landing.
Treatment 1	Felling	Same as control.	Same as control.
	Forwarding	Same as control - full tree.	Same equipment as control, but tree length instead of full tree and rub-stumps used along trails.
	Procedures	Main skid trails located before harvesting and Feller-buncher operator chose other trails, conifer hand-felled after aspen and skidded separately. All species topped, delimbed and bucked on landing by hand. Bunches "shingled" on skid trails.	Main skid trails prelocated and secondary trails flagged before harvesting. Conifer and aspen felled and bunched at same time and limbed and topped before skidding. Oversize spruce hand felled. Stroke delimbed on landing.
Treatment 2	Felling	Same as control. Some topping before forewarding.	Rottne double grip processor (fell, limb and buck) at (H) and double and single-grip at (W).
	Forwarding	Some full tree, some tree length	Rottne forwarder - cut-to-length
	Procedures	Trail designation as in treatment 1. Conifer and aspen machine - felled and "shingled" down on skid trails by feller - buncher. All species topped, delimbed and bucked on landing by hand, except some stems delimbed before skidding, others before reaching landing.	Highly skilled operators selected trails and controlled operation

Table 3. Summary of pre-harvest statistics for stands inventoried in 1988 - Project 1480

Company	Stand	Location	Stand[1] age	Stand size (ha)	No. Plots			Total Volume (m^3)/ha				Merch Volume (m^3/ha)	No. spruce stems/ha by Ht. Class (m)				
					6 m	1.8 m	Stocking[3] (%)	Aspen	Poplar	White spruce	Total[2]	White spruce	0.5-2.4	2.5-14.0	14+	All .5+	1-12 m
Blueridge Lumber	WC	NW4-62-10-5	100+	9.4	43	85	36	335	12	86	433.7	82	253	177	109	538	350
Blueridge Lumber	W1	NW4-62-10-5	100+	28.0	64	129	45	280	31	83	408.1	77	657	428	98	1184	892
Millar-Western	W2	NW9-61-10-5	70+	15.0	38	76	49	160	25	82	271.5	70	535	578	65	1178	872
Weldwood	HC	NW22-52-24-5	70+	18.1	41	85	72	191	36	74	313.6	49	2158	1744	71	3973	3219
Weldwood	H1	NW22-52-24-5	70+	14.1	44	88	44	246	21	16	282.9	5	511	793	9	1313	1093
Weldwood	H2	NW22-52-24-5	70+	17.8	32	70	76	146	37	66	254.9	45	1917	1991	39	3947	3325
Weyerhaeuser	DC	SE26-48-12-W5	110+	20.0	43	86	41	114	70	46	293.0	37	278	569	27	874	775
Weyerhaeuser	D1	SE26-48-12-W5	110+	20.0	43	87	39	170	47	31	252.4	25	288	405	14	707	586
Weyerhaeuser	D2	SE31-48-11-W5	110+	15.0	36	78	22	157	34	12	232.9	8	106	312	42	459	393

[1]Age of Aspen.
[2]Includes all species.
[3]Spruce 0.5 m+ on mil hectare quadrats.

3.3 Harvesting Effects and Implications for Stand Development

Harvesting effects on understory spruce were assessed in terms of the nature and amount of physical damage, growth and yield potential, and blowdown risk, and natural regeneration following harvest.

3.3.1 Harvesting Damage

Damage assessment covered all spruce 0.5 m and taller, but focused on trees 2.5 to 14.0 m; the lower limit being considered the minimum size of tree expected to remain free-to-grow as aspen suckers develop, and the upper limit representing merchantable size and the expected threshold for excessive potential blowdown. Damage statistics are summarized in Table 4. There was no clear relationship between initial understory spruce density and percent damage and mortality, by harvesting system. Absolute amounts of damage and mortality were greater in more dense understories, but viable residuals could still be retained. The shortwood (cut-to-length) system incurred proportionately more damage and less mortality than FB/GS systems. Significant damage control can be achieved when special precautions are incorporated into harvest planning and operations.

It was possible to protect between 2% and 61% of understory between 2.5 and 14.0 m tall, and to achieve acceptable "levels of damage on 3% to 72%, depending on the degree of protection effort." Sauder (1992) provides operational details on damage mitigation. Table 5 shows the range of results achieved for different harvesting systems.

3.3.2 Growth and Yield Potential

The silvicultural prescription for control stands DC, HC and WC called for planting to spruce and tending and managing as a conifer land base. Understory surviving the harvest will usually occur in isolated clumps, or as individuals in areas of uncut, unmerchantable hardwood, and will not be assessed for growth and yield potential in follow-up plot measurements.

The prescription for treated stands D1, D2, H1, H2, W1 and W2 called for the application of the first cut of the two-stage harvesting and tending model described earlier, removing mature overstory aspen and perpetuating a mixedwood stand for an additional period of about 60 years. During this time, the released understory spruce would develop to provide a spruce harvest along with the second aspen harvest originating from suckers and seedlings following the first cut.

Only preliminary growth information for released understory spruce are available and are not presented here, but height and diameter growth are evident on most blocks within 2 years. Follow-up assessments over a five-to ten-year period are needed to determine the growth and yield potential of a variety of composition, density, and distribution configurations in these post-harvest mixedwoods stands and in similar stands on a wider range of sites.

Jarvis et al. (1966), Johnson (1986) and Yang (1989) have reviewed and published reports on past research studies of the growth of spruce released from aspen. Of particular interest are reports by Cayford (1957), Steneker (1963), Lees (1966) and Steneker (1967, 1974).

Brace and Bella (1988) used relevant data from past projects to predict understory spruce growth and yield following first-stage harvest in the two-stage model, for stand conditions comparable to those in the project. They concluded that released spruce averaging 40 years of age could reach maximum yields by

Table 4. Percent damage to understory spruce during aspen harvesting - height 2.5 m to 14 m - Project 1480

Stand and treatment[1]	Equipment[2]	Initial Nt/ha	Undamaged	Felling		Forwarding		Harvested	Total damage, mortaility and harvest	Total
				Damage	Mortality	Damage	Mortality			
DC	FB/GS	569	40	10	1	20	24	5	60	100
HC	FB/GS	1744	16	6	2	23	49	2	84	100
WC	FB/GS	177	2	0	10	7	74	7	98	100
D1	FB/GS	405	42	15	0	16	25	2	58	100
D2	FB/GS	312	60	9	1	16	13	1	40	100
H1	FB/GS	793	52	13	1	16	18	1	48	100
W1	FB/GS	428	60	8	1	6	21	4	40	100
H2[3]	R	1991	30	24	4	(27)	(14)	1	70	100
W2[3]	R	578	21	30	3	(21)	(15)	10	79	100

[1]D = Drayton valley, H = Hinton, W = Whitecourt, C = control, 1 and 2 = Treatments.
[2]FB/GS = Feller Buncher/Grapple Skidder, R = Rottne Swedish Shortwood Harvester and Forwarder.
[3]The Swedish shortwood systems are not directly comparable to other due to the combined functions of felling, delimbing and bucking. Damage and mortality identified as forwarding was primarily caused by the delimbing and bucking functions. Forwarding effects were minor.

Table 5. Residual spruce by treatment and protection effort - height 2.5 m to 14 m - Project 1480

Stand and treatment[1]	Equipment[2]	Pre-cut No. of trees/ha	Post-cut No. of trees/ha		Post-cut %			Protection effort[4]
			Undamaged	Undamaged + Acceptable damage[3]	Undamaged	Undamaged + Acceptable Damage[3]	Diff	
DC	FB/GS	569	226	284	40	50	+10	Low
HC	FB/GS	1744	278	412	16	24	+8	Low
WC	FB/GS	177	4	6	2	3	+1	Low
D1	FB/GS	405	171	209	42	52	+10	Intermediate
D2	FB/GS	312	189	223	60	72	+12	High
H1	FB/GS	793	416	519	52	66	+14	High
W1	FB/GS	428	260	283	61	66	+5	High
H2[3]	R	1991	591	1130	30	57	+27	High
W2[3]	R	578	119	296	21	51	+30	Intermediate

[1]D = Drayton Valley, H = Hinton, W = Whitecourt, C = Control, 1 and 2 = Treatments.
[2]FB/GS = Feller Buncher/Grapple skidder, R = Rottne Swedish Shortwood Harvester and Forwarder.
[3]Acceptable damage is damage which was found to have minor effects after two years' observation , and included codes 11, 12, 13, 15, 16, 21, 22, 24, 31, and 40 (Form 3, Appendix IV).
[4]Manning, Layout, Supervision, Crew Experience, Attitude.

age 100 (the timing of the second cut in the model) for densities between 600 and 1000 stems/ha. The determination of maximum expected yield is a problem. A first approximation might be made by setting the yield of the particular stand at that obtained in the first harvest (60 years in the model). Yields could be expected to decline 10% at 400 stems/ha and 30% at 200 stems/ha.

There is a critical need for a mixedwood growth and yield methodology which reflects the realities of variable density and stocking of the major species in mixedwood stands.

If these tentative yield results, which do not account for clumpiness, were applied to post-logging stand densities shown in Table 5, using the figures which include acceptable damage, it can be seen that only stand H2, with 1130 stems/ha, can be expected to reach maximum yields, followed by stand H1 with 519 stems/ha. Others with densities ranging from 209 to 296 stems/ha would yield up to 30% below maximum. HC appears to have an unusually high residual spruce density but this is concentrated in a few dense clumps and the stand in general is clearcut.

Figures 7, 8 and 9 illustrate harvesting-caused change in spruce understory density levels in each stand. Harvesting reduced density levels, lowering the number of potentially high-yielding plots in density classes 4 and over (over 600 stems/ha), and increasing the number of low-density plots in classes 0 to 1 (0 to 200 stems/ha) which can be expected to be essentially deciduous stands at the time of second harvest. Aspen yield would be expected to increase in proportion to spruce yield decrease. The significance of these changes can only be judged in terms of management objectives. The lower spruce stocking and yield results would be unacceptable for softwood oriented management, but may be acceptable for mixed-species management once mixedwood yield objectives are set. Even without specific objectives for wildlife habitat (e.g. hiding cover, thermal cover and browse for ungulates) or for landscape aesthetics, the treatment results have already been judged by project participants as superior to conventional operations in these respects.

Smythe and Methven (1978), using a numerical index to quantify aesthetic impact in a mixedwood study (Brace and Stewart 1974) which used mechanized harvesting to release understory, as well as strip shelterwood found a reduction in amenity values of about 2% of maximum theoretical reduction for stands with overstory removal only, compared to 10% reduction for strip shelterwood and 60% for block clearcutting. The effects of such non-timber benefits in an integrated approach to mixedwood management could be most effectively assessed if they were incorporated into management planning as specific objectives at early stages.

The wide range of post-harvest composition, density and distribution conditions represented by the plots in this project could provide a valuable source of mixedwood growth and yield data particularly if they were measured and analyzed in a format usable in a DSS approach to mixedwood ecosystem management.

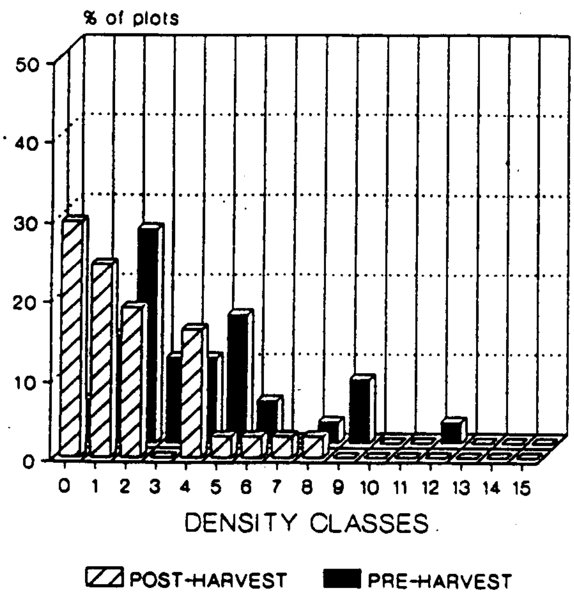
3.3.3 Blowdown Risk

Spruce is known as a species which is prone to blowdown. The blowdown hazard in released understory spruce is a particular concern because of the radical change in exposure and the tendency for the trees to be poorly rooted, particularly on shallow or poorly-drained soils.

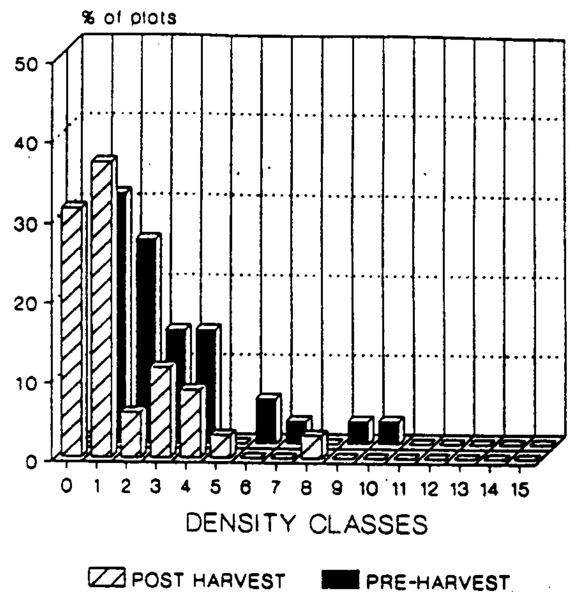
Blowdown data were collected on each sample plot in the treated stands in 1990 and 1991, representing three-year data for stands DC, D1 and D2, and two-year data for the others. Procedures included measurements of tree diameter, height, and crown dimensions, and observations of root-form and

Figure 7. Percent of stocked plots by understoy density class — pre- and post-harvest — Drayton Valley — Project 1480.

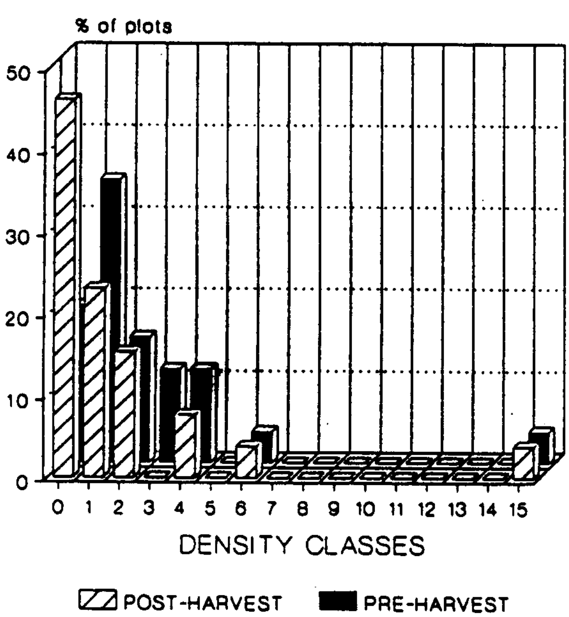
DC 2.5-14.0m



D1 2.5-14.0m



D2 2.5-14.0m

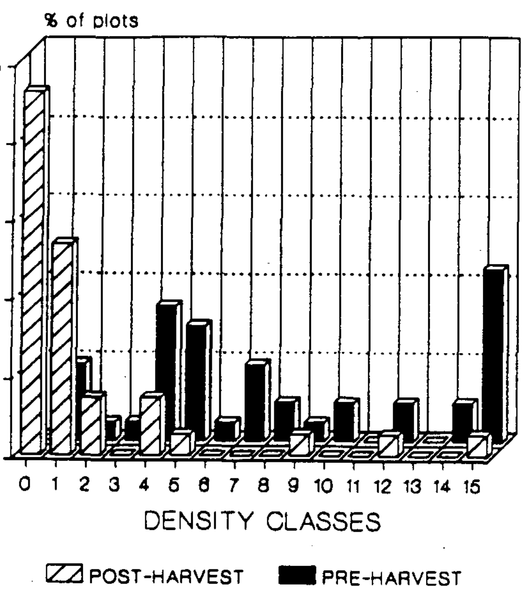


DENSITY CLASSES (TREES/HA)

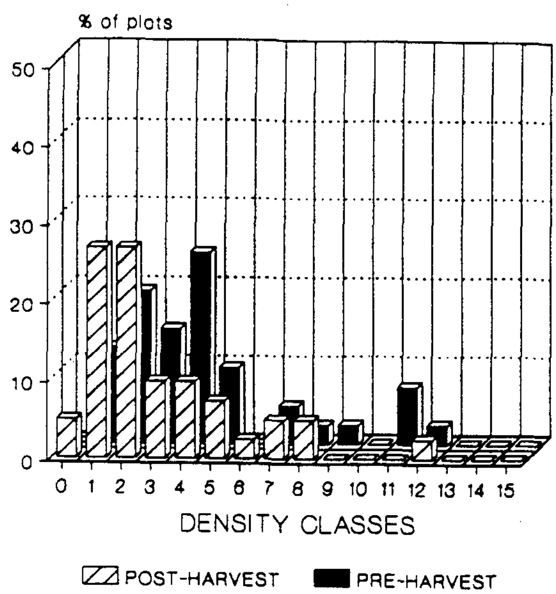
0	0	8	1401-1600
1	1-200	9	1601-1800
2	201-400	10	1801-2000
3	401-600	11	2001-2200
4	601-800	12	2201-2400
5	801-1000	13	2401-2600
6	1001-1200	14	2601-2880
7	1201-1400	15	2800+

Figure 8. Percent of stocked plots by understory density class - pre - and post-harvest - Hinton - Project 1480.

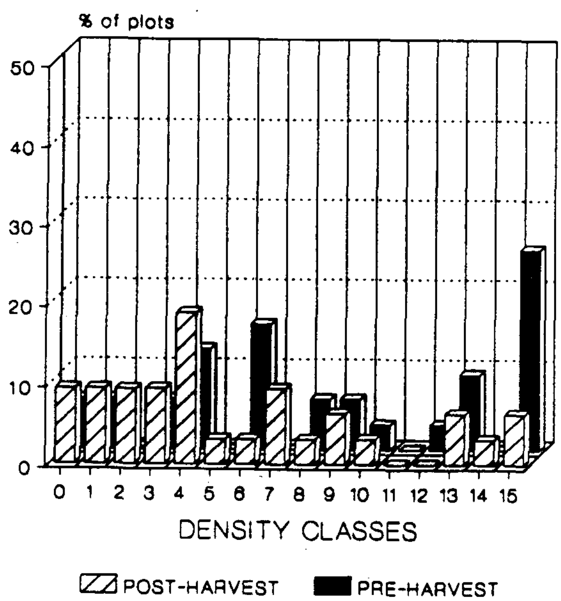
HC 2.5-14.0m



H1 2.5-14.0m



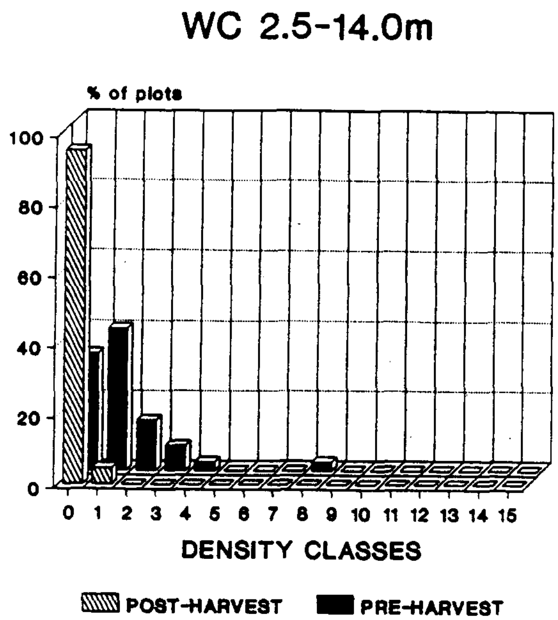
H2-R 2.5-14.0m

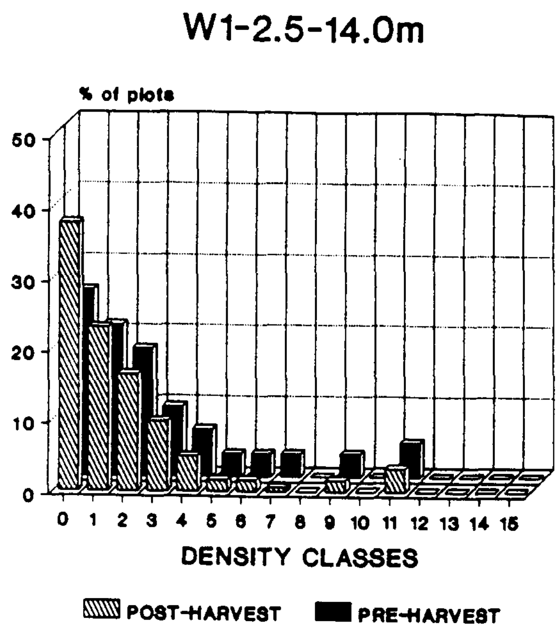


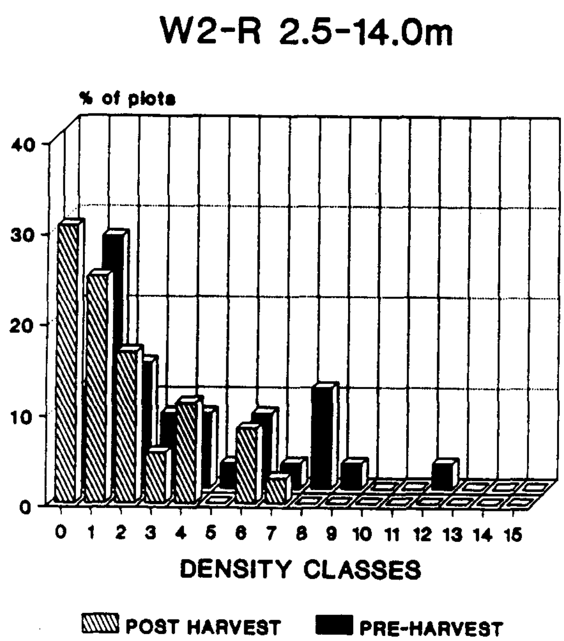
DENSITY CLASSES (TREES/HA)

0	0	8	1401-1600
1	1-200	9	1601-1800
2	201-400	10	1801-2000
3	401-600	11	2001-2200
4	601-800	12	2201-2400
5	801-1000	13	2401-2600
6	1001-1200	14	2601-2880
7	1201-1400	15	2800+

Figure 9. Percent of stocked plots by understory density class - pre- and post-harvest - Whitecourt - Project 1480.







DENSITY CLASSES (TREES/HA)

0	0	8	1401-1600
1	1-200	9	1601-1800
2	201-400	10	1801-2000
3	401-600	11	2001-2200
4	601-800	12	2201-2400
5	801-1000	13	2401-2600
6	1001-1200	14	2601-2880
7	1201-1400	15	2800+

soil moisture condition. Data are tentative and insufficient for conclusive analysis. Figure 10 shows that on average, blowdown affected 5% of residual spruce. It increased with height, affecting over 10% of trees over 10 m tall, and reaching a high of 25% in the 14 to 15 m class. Height is only one factor affecting blowdown risk. There were few observations in some classes and considerable variability in blowdown both within and between stands. Effect on spruce yield can only be determined by remeasurement over a period of at least five years.

There is a critical need for comprehensive blowdown-risk rating information for spruce, which should be obtained by sampling a wide range of site, stand and environmental conditions. There is also a need for information on operating strategies to minimize blowdown risks, and on tending strategies to develop windfirmness in spruce in young stands. Priority for such work has been recognized under the new Canada-Alberta Agreement, and was strongly supported at the May 1992 meeting of the Spruce Understory Steering Committee.

3.3.4 Natural Regeneration of Spruce, Aspen, and Poplar Following Harvest

Project prescriptions include regeneration scenarios which could produce information useful to managers as they assess and evolve future mixedwood management strategies.

Control stands DC, HC and WC were assumed to qualify as coniferous land base after harvest since most contained over 50 cu m/ha merchantable conifer. It was expected that the unmerchantable spruce understory, which ranged from 500 to 3900 stems/ha, would be destroyed during harvest. Stands would be subsequently scarified, planted and managed as coniferous land base. Stand DC was an exception with less than 50 cu m/ha (Table 3).

On treatments, some of the stands, notably H1, D1 and D2, would not have qualified as coniferous land base under provincial reforestation criteria due to low merchantable coniferous volume, but all contained over 300 stems/ha of understory spruce between 2.5 m and 14 m. The prescriptions adopted for all treated stands assumed that if understory spruce were adequately protected during harvest, the stands could be managed as mixedwood land base according to the research model adopted. Prescriptions also assumed possible enrichment of spruce by natural seeding-in or planting following the first-stage harvest, although the primary interest was in the existing understory.

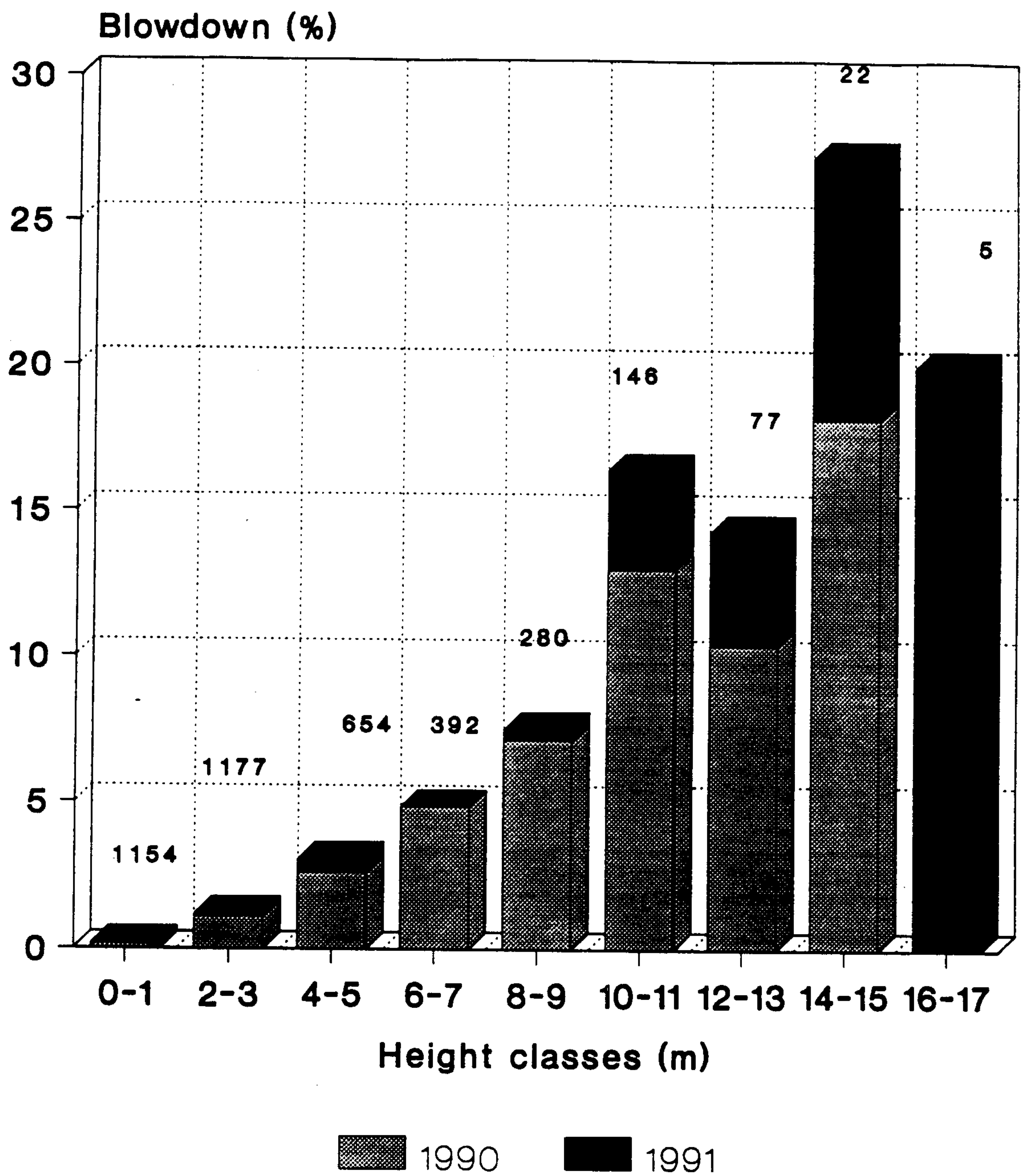
3.3.4.1 Spruce Regeneration

The two-stage model used in this project assumes that natural spruce regeneration may contribute to an increase in spruce stocking of the mixedwood in the approximately 60 years between the first and second harvests. Regeneration will not be a factor in spruce yield at the second harvest.

Spruce regeneration is one of the most pressing problems in boreal mixedwood management (Waldron 1966; Jarvis et al. 1966; Lees 1963, 1970). Successful regeneration requires an adequate supply of good-quality seed and a favorable seed-bed (usually mineral soil) as well as suitable microclimatic conditions for germination, survival and growth.

This project was not designed to examine natural spruce regeneration in detail, but the plot network could serve that purpose. The 0.8 m radius stocking plots were only assessed for spruce 0.5 m and taller. Examination of Figures 7, 8 and 9, showing post-harvesting density and site disturbance (scarification) potential, gives some indication of natural regeneration potential. There was a significant increase in low-

Figure 10. Distribution of blowdown by height class - 1990 and 1991 data - Project 1480.



density areas (between 0 and 200 stems/ha) which indicate a high probability of logging-related scarification to provide mineral seed-beds on FB/GS operations. Rottne shortwood systems created much less ground disturbance and fewer low density spruce areas(Figures 8 and 9).

Figures 11, 12, and 13 show that harvesting impacted understory across the entire height range in proportion to pre-harvest frequency distributions, with the exception of Rottne stand W2-R. Many stems over 14 m were utilized but there are still enough larger trees to become a seed source in the future, and external seed sources may be available.

These stands provide an opportunity to obtain spruce regeneration data for an array of mixedwood conditions, concurrent with aspen and poplar regeneration surveys.

There is a need to consolidate the abundant literature on spruce regeneration and early growth in mixedwoods, and to reassess old Forestry Canada projects a format suitable for input to a DSS program.

3.3.4.2 Aspen and Poplar Regeneration

The treatment specified for control stands DC, HC and WC was scarification and regeneration of the cutover with planted spruce, followed by competition (largely aspen) control, so that regeneration of vigorous aspen is not intended. However, in stands treated according to the two-stage model, it is assumed that after mature aspen are harvested in the first cut, suckers and seedlings of acceptable density and quality will regenerate in openings, supplementing the yield of released spruce at the second harvest in about 60 years, thus maintaining a mixedwood after the first cut. Therefore the vigor and density of aspen regeneration is of particular interest in the project.

Aspen is known to regenerate well after wildfire and casual observation of aspen regeneration on cutovers, even in cases where aspen were not the dominant species, suggests that regeneration success can be expected. Treated stand inventories (Table 3) indicate a predominance of mature aspen, suggesting a good supply of viable roots for suckering, and Figures 7, 8 and 9 indicate a substantial reduction in understory spruce densities creating space for new deciduous regeneration. Harvesting created many open areas on skid trails and landings, particularly in FB/GS operations during the frost-free period, and these are of questionable future aspen productivity as noted later.

In order to initiate assessment of aspen and balsam poplar sucker and seedling regeneration, all 0.8 m radius plots in each block were surveyed. Tentative results representing 3-year data for Drayton Valley and 2-year data for Hinton and Whitecourt are summarized in Figures 14, 15 and 16, by soil disturbance class. In addition, stands were surveyed photographically to determine the amount of area severely disturbed (mineral soil disturbance easily visible on infra-red photography at a scale of 1:4000) on skid trails and landings (Table 6). All stands are on primarily mesic sites, so do not represent the moist- to-wet spectrum of mixedwood sites in the region.

Aspen sucker and seedling regeneration have been recently described in detail by Navratil et al. (1990), and by Alban (1991), Perala (1991) and Navratil (1991) at a recent aspen symposium in Edmonton, Alberta. In general, aspen sucker regeneration is controlled by factors like apical dominance (broken by felling parent trees) and soil temperature (threshold about 15 degrees C), as well as by excessive soil moisture, soil compaction and mechanical root disturbance. Vigor and growth of suckers is particularly affected by light intensity, which can be reduced to critical lower levels due to shading by residual trees, grass and brush. Seedlings establish on moist mineral seed beds in much of the project area.

Figure 11. Pre and Post-cut number of understory spruce by height class - 2.5 to 14.0 m - Drayton Valley - Project 1480.

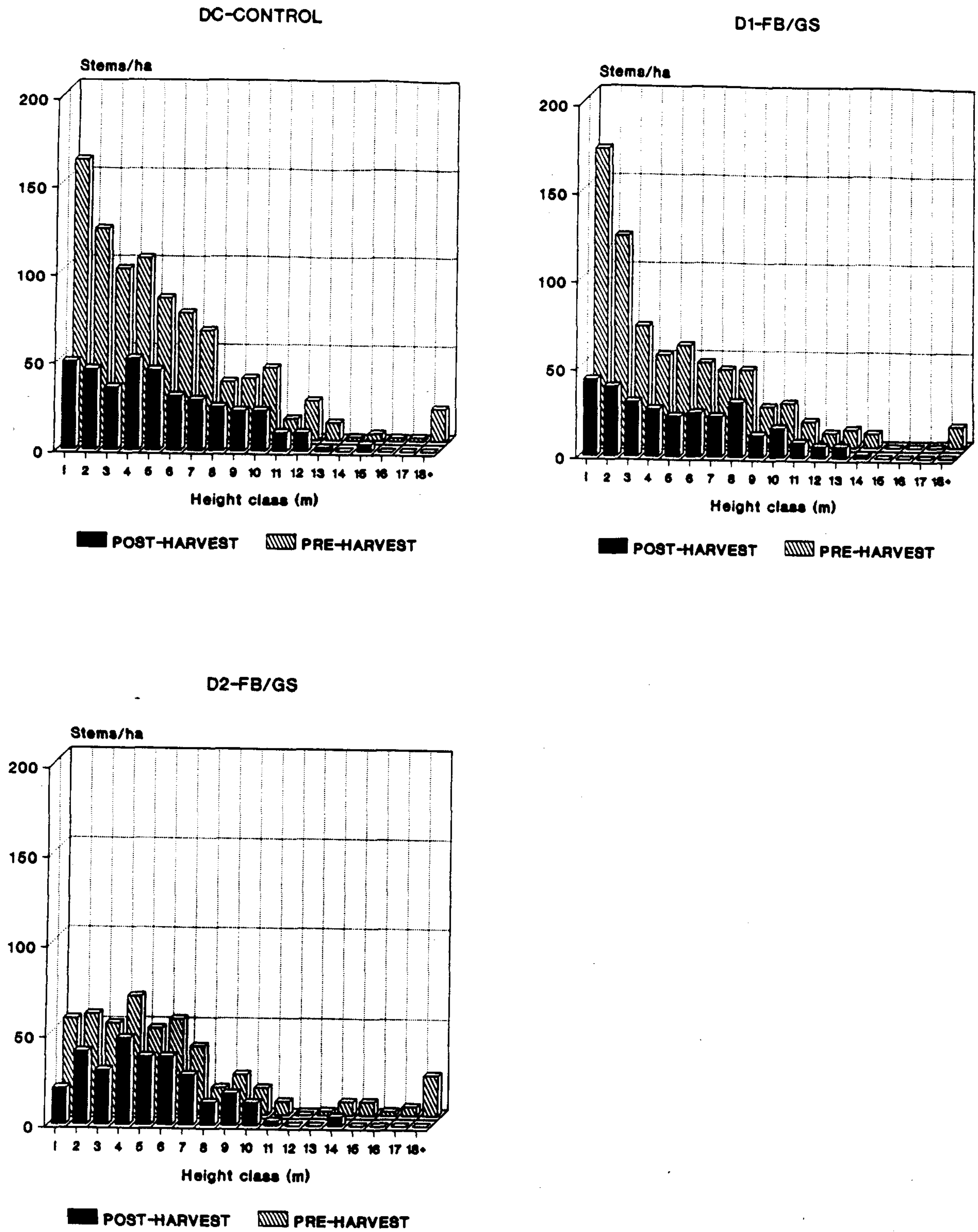


Figure 12. Pre and Post-cut number of understory spruce by height class - 2.5 to 14.0 m - Hinton - Project 1480.

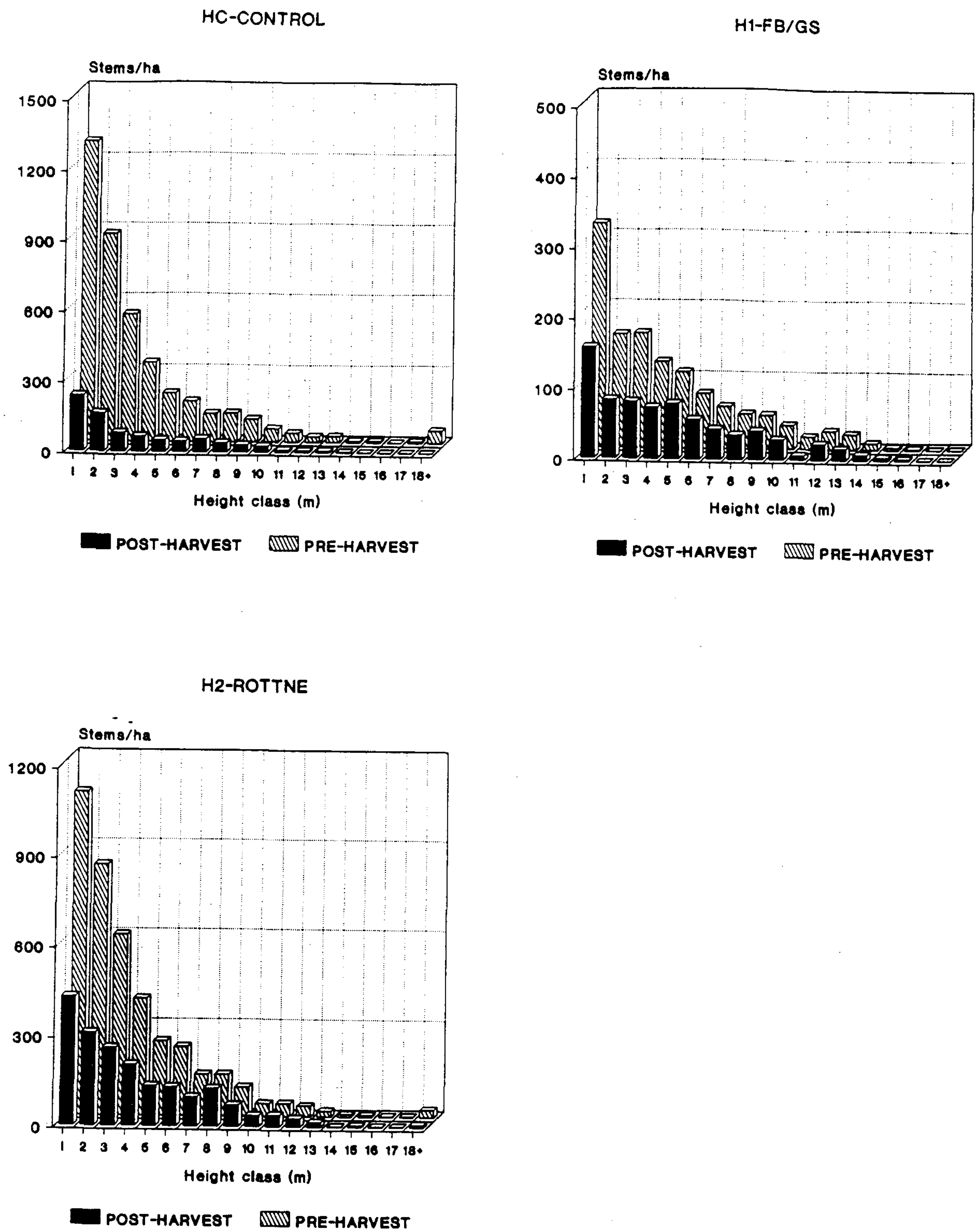


Figure 13. Pre and Post-cut number of understory spruce by height class - 2.5 to 14.0 m Whitecourt - Project 1480.

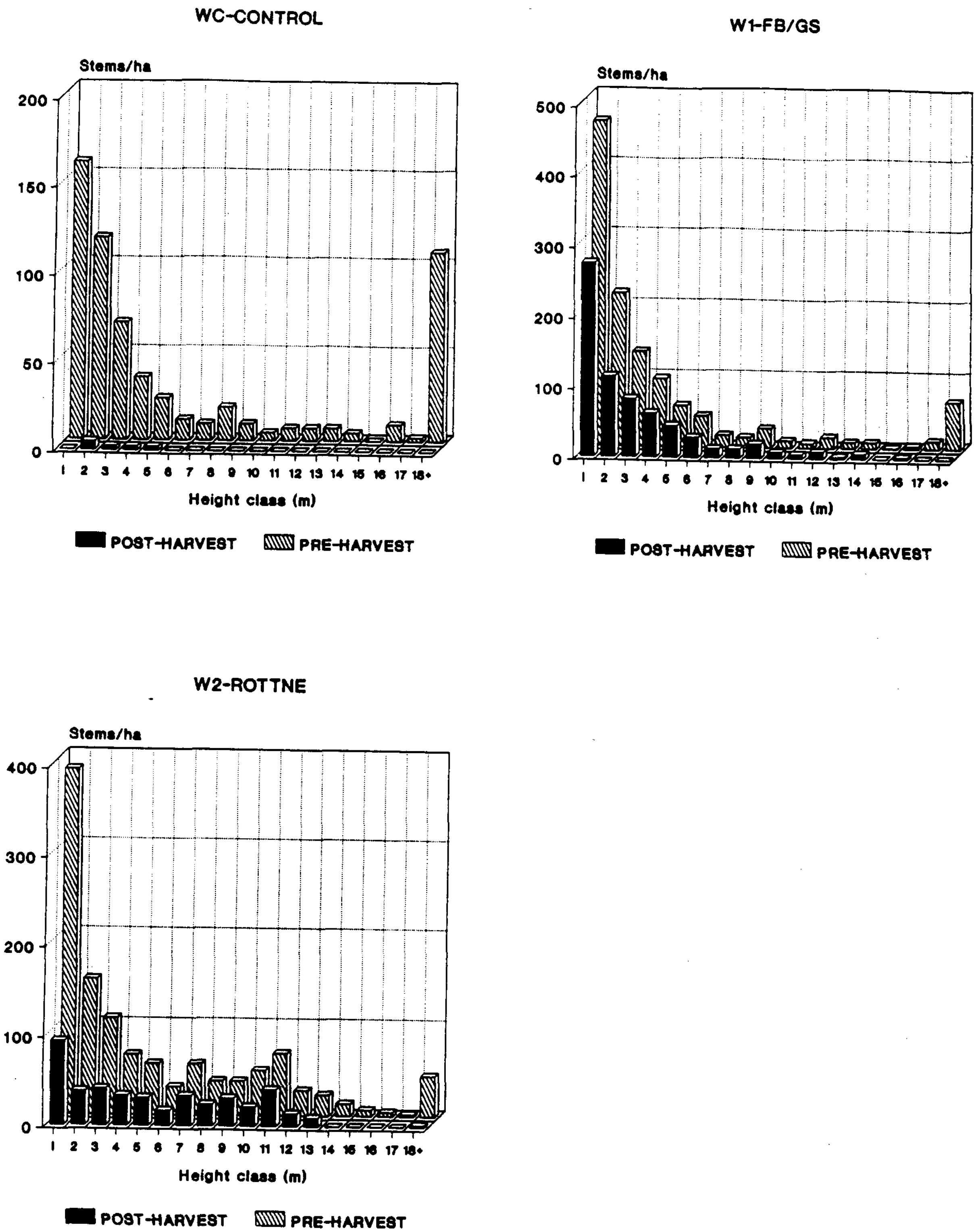
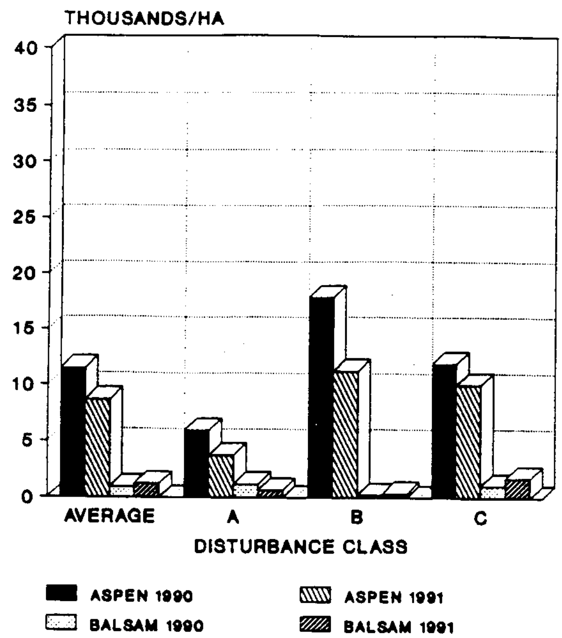
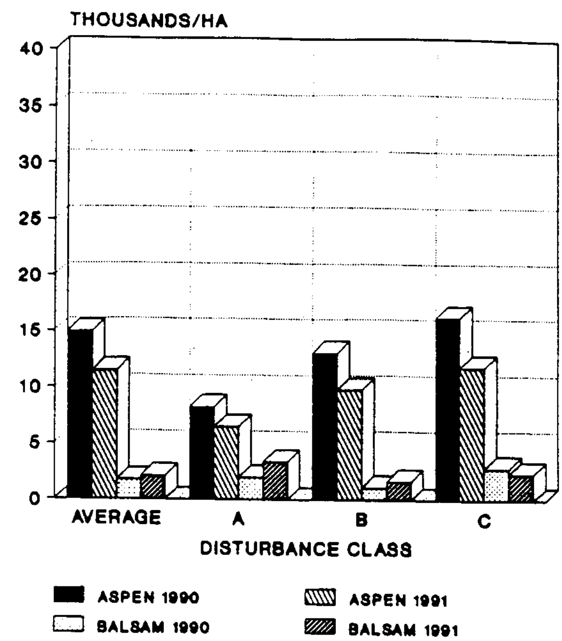


Figure 14. Aspen and poplar regeneration by disturbance class - Drayton Valley - Project 1480.

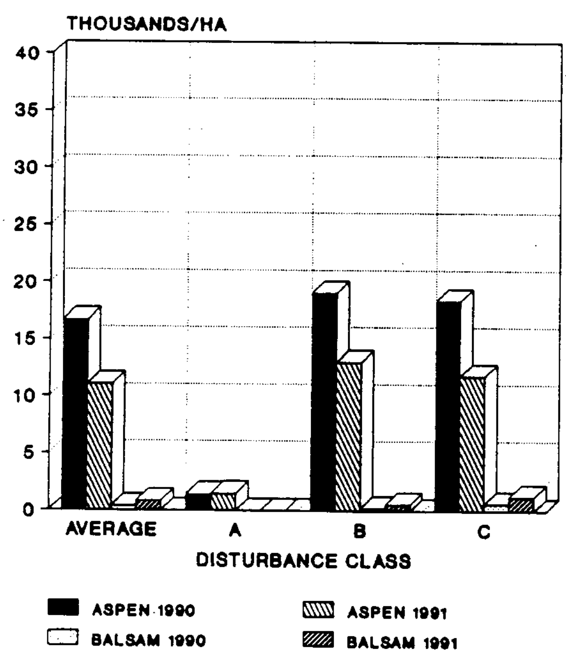
DRAYTON VALLEY DC



DRAYTON VALLEY D1



DRAYTON VALLEY D2



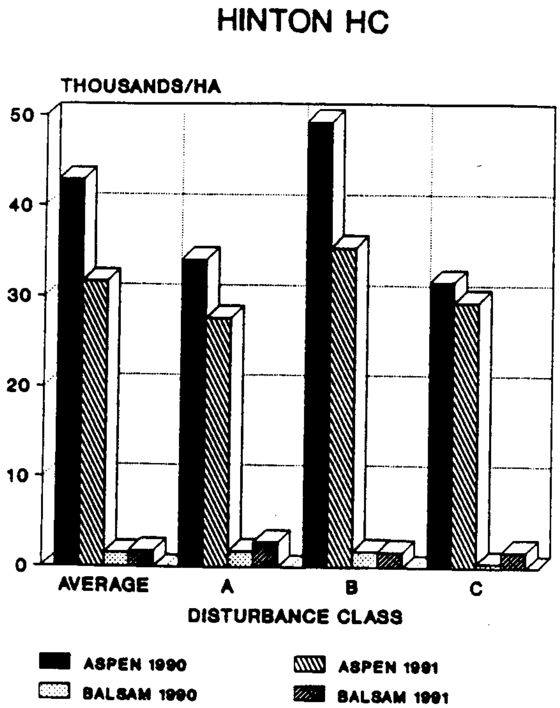
DISTURBANCE CLASSES

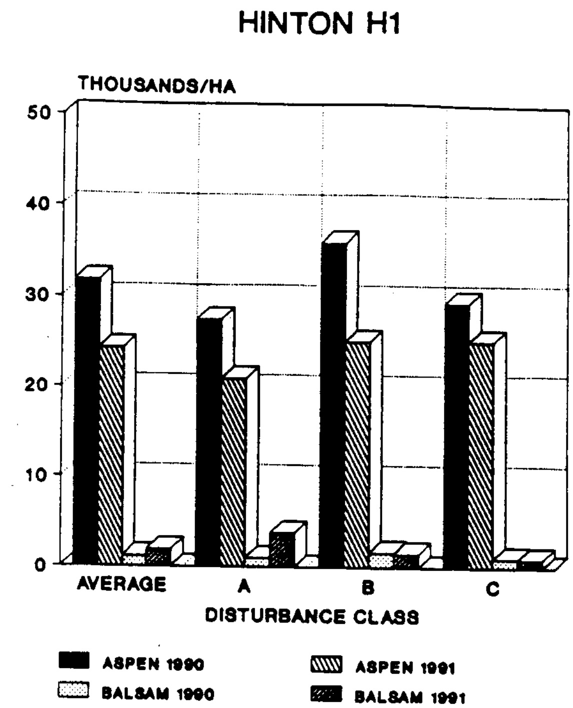
A - MINERAL SOIL

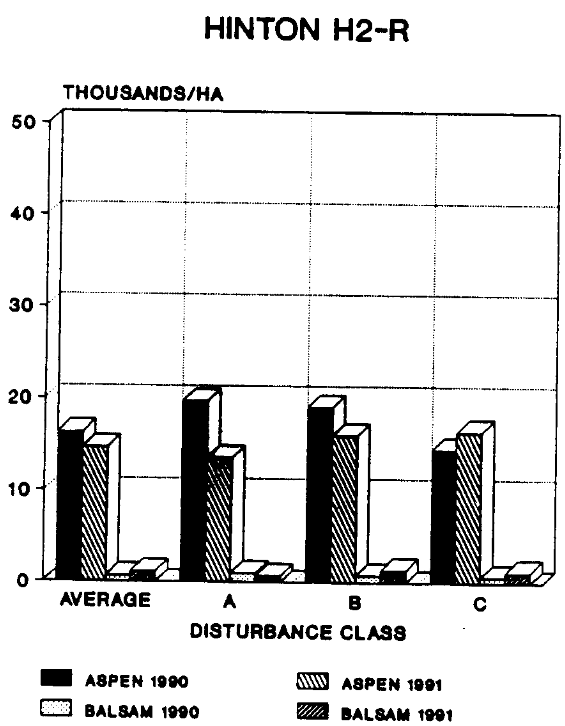
B - DUFF AND TRAFFIC

C - DUFF NO TRAFFIC

Figure 15. Aspen and poplar regeneration by disturbance class - Hinton - Project 1480.







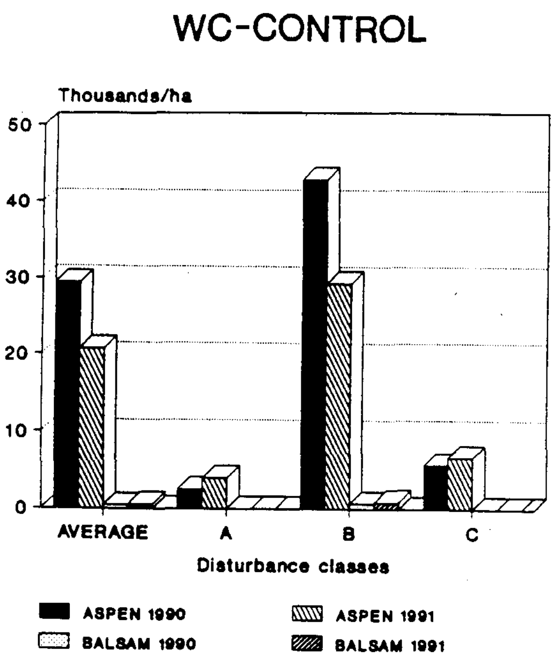
DISTURBANCE CLASSES

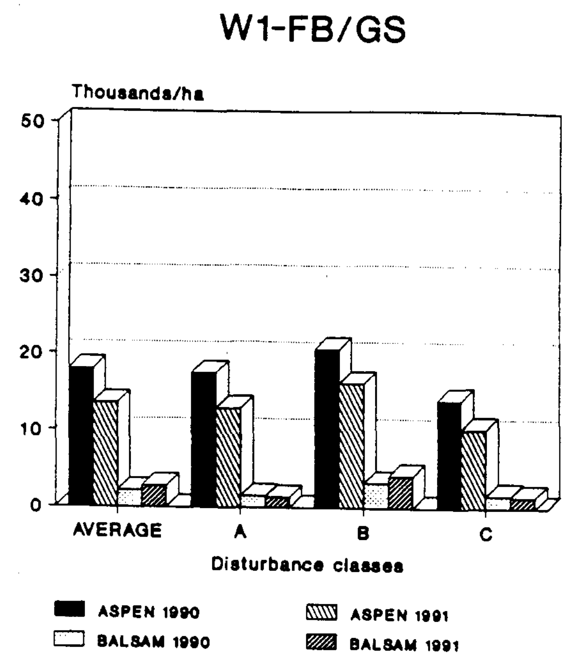
A - MINERAL SOIL

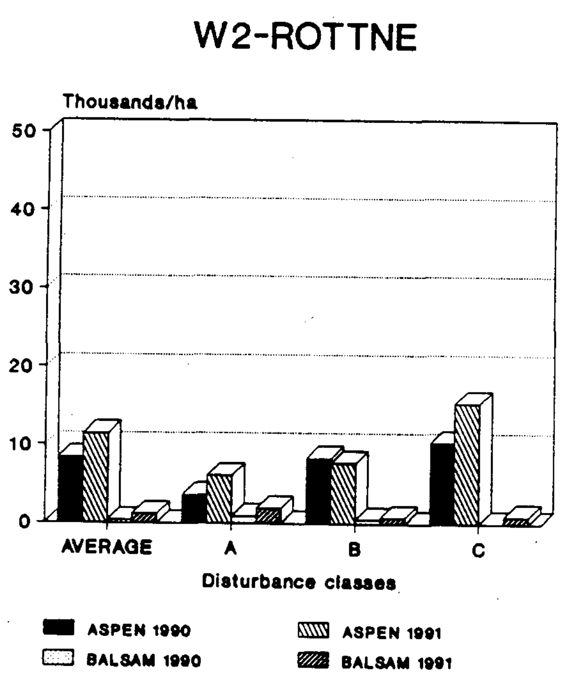
B - DUFF AND TRAFFIC

C - DUFF NO TRAFFIC

Figure 16. Aspen and poplar regeneration by disturbance class - Whitecourt - Project 1480.







DISTURBANCE CLASSES

A - MINERAL SOIL

B - DUFF AND TRAFFIC

C - DUFF NO TRAFFIC

Table 6. Percent site disturbance on skid trails and landings in harvested stands - Project 1480

Stand and Treatment	Equipment[1]	Stand size (ha)	Skid Trails[2] Area (ha)	Skid Trails[2] %	Landings Area (ha)	Landings %	Total[3] Area (ha)	Total[3] %	Notes
DC	FB/GS	20.0	1.65	8.25	1.86	9.30	3.51	17.55	
HC	FB/GS	18.1	0.91	5.03	-	-	-	-	Skidded to main road - no landings
WC	FB/GS	9.4	.94	10.00	.85	9.04	1.79	19.04	
Weighted mean control stands (FB/GS)				7.37[2]		9.21		18.03	
D1	FB/GS	20.0	1.50	7.50	1.96	9.80	3.46	17.30	
D2	FB/GS	15.0	1.20	8.00	1.81	12.07	3.01	20.07	
H1	FB/GS	14.1	1.09	7.73	-	-	-	-	Skidded to main road - no landings
W1	FB/GS	28.0	2.91	10.39	1.33	4.75	4.24	15.14	
Weighted mean treated stands (FB/GS)				8.69		8.10		17.00	
Grand weighted mean all stands (FB/GS)				8.19		8.56		17.33	
H2	R	17.8	1.22	6.85					Forwarded to main road - no landings
W2	R	15.0	1.45	9.67					Forwarded to main road - no landings
Weighted mean treated stands (Rottne)				8.14		0.00		8.14	

[1]FB/GS = Feller Buncher/Grapple Skidder, R = Rottne Swedish Shortwood Harvester and Forwarder.
[2]Only main trails visible on color IR photography (1:4000), assuming mean width 3 m.
[3]Excludes roads within blocks.

There is a need for information on the regeneration and growth of balsam poplar suckers and seedlings which form a significant component of many mixedwood stands, including those in this project.

Initial regeneration results (Figures 14, 15 and 16) indicate wide density variations between areas and disturbance classes, with the highest densities in Hinton and Whitecourt. Average data are the most reliable. Data by disturbance class are not additive, representing various areas and numbers of observations, since up to 3 disturbance classes of varying aerial extent could occur in any given plot.

Average aspen densities for all areas are within acceptable (full-stocking) levels of 10,000/ha at 2 years and 6,000/ha at 3 years (Doucet 1989), not including balsam poplar which are increasing each year in most cases, on all disturbance classes. Aspen densities are declining by the second year in all areas and disturbance classes for FB/GS treatments, as would be expected. However, aspen density is showing an increase on one disturbance class in the Rottne treatment at Hinton (H2-R) and in all disturbance classes in the Rottne treatment at Whitecourt (W2-R). These treatments also tend to have less regeneration than FB/GS treatments on the same area, possibly because of the presence of slash over the areas, which may be keeping soil temperatures down, delaying suckering. There is evidence of less deciduous regeneration on disturbed mineral soil than in other disturbance classes for FB/GS treatments, especially in areas DC, D2 and WC, which may reflect compaction and/or root damage during logging in DC and D2, and in WC log decks were stored throughout the first summer on landings impeding suckering. The Hinton blocks had no in-block roads or landings and show little evidence of deciduous regeneration reduction in the disturbed mineral soil class.

Table 6 shows that site disturbance on main skid trails was approximately the same for all areas and both logging treatments, ranging from 7.37% to 8.69%. Disturbance on landings was about the same as on main skid trails for FB/GS treatments, resulting in a mean total disturbance of 17.33% for the treatment, about twice that of the Rottne treatment which had no landings. These disturbance levels compare favorably to FB/GS operations in other areas.

Site impacts from a timber production perspective (nutrient loss, compaction, rutting, soil displacement and mass wasting) can result from both harvesting and site preparation, and have been documented in the literature since the 1960's[6]. It is now limited by law in B.C. where PHSP's are required and the concept of maximum allowable site degradation (MASD) is recognized. Operating guidelines are being prepared (Lewis et al. 1989; Curran et al. 1990; Krag et al. 1991).

Measurement of plots on this project and other sites should be continued in order to get site-specific data on long-term effects of different types and degrees of site disturbance upon the density and vigor of deciduous regeneration. Objective measurements of disturbance are essential to such work. Available aspen and poplar regeneration literature and knowledge should be formatted for input to DSS in order to pinpoint information gaps, which are known to be significant for poplar. The importance of such work is recognized by the current Alberta Forest Research Advisory Committee (AFRAC)[7] priority on monitoring and documenting environmental impacts of forestry operations and by an AFS/AFPA soil management task force on site sensitivity. In view of the observable negative effects of specific disturbances on aspen

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[6]The AFS sponsored a soils management workshop on April 23, 1991, in Edmonton, to initiate development of new soils management strategies in recognition of the potential significance of site disturbance to productivity.

[7] AFRAC 1991. Environment task force report. Available from Alberta Forestry Lands and Wildlife.

density and vigor, in-block roads and landings should be minimized and winter operations maximized. There is also evidence of reduced conifer growth on severely disturbed sites, and the effectiveness of reclamation on such areas is still questionable.

4.0 PROGRESS IN IMPLEMENTING UNDERSTORY PROTECTION

In January 1992 a questionnaire was distributed to seven industrial foresters known to have an interest in spruce understory protection in Alberta. Responses, and subsequent analysis and discussion, are set in the context of the current practice of attempting to achieve poorly-defined non-timber benefits like improved aesthetics and wildlife habitat as "add-on's" or constraints on timber production objectives. The latter are set by reforestation standards designed for areas zoned high priority for timber production.

When timber is a priority, the choice of post-harvest land base (coniferous or deciduous) currently depends on the pre-harvest proportion of merchantable coniferous and deciduous timber. If spruce understory exists in such stands at a density and distribution which may reduce establishment and tending costs necessary to achieve a specified regeneration standard, it can become a factor in choosing regeneration and management strategy.

The future of understory protection on land zoned high priority for timber production depends on answers to questions like:

1. how do added costs to protect understory relate to coniferous regeneration and tending costs and future coniferous AAC?

2. how do the added costs to protect understory relate to non-timber benefits like improved aesthetics and wildlife habitat, and what are the coniferous AAC effects of managing jointly for non-timber objectives?

3. how can timber and non-timber interests be more effectively integrated?

The rationale for protecting understory on lands zoned high priority for non-timber resources, such as critical wildlife areas or riparian zones, is not considered here.

4.1 Status of Operational Understory Protection - 1989 to 1992

Table 7 summarizes data provided by five of the six industrial respondents. There has been a general increase in total area harvested for understory protection, from 2137 ha in 1989 to a projected 2875 ha in 1992, averaging 2359 ha over the four-year period. Two respondents are operating at a scale of 50 ha per year or less, and three at a much larger scale, one over 1000 ha per year for each year reported or projected. Average block size is stable at around 20 ha, as are harvest volumes at around 150 cu m/ha. Estimated added costs averaged $1.30/cu m, varying from $.80 to $2.00 in the sample, less than the differences reported by Sauder (1992) for Project 1480 research blocks, where a detailed accounting system was employed. The comparability of planning, operations and protection results between Project 1480 and operational protection is unknown. Added cost will be discussed later under costs and benefits.

Table 7. Operational understory spruce protection statistics - 1989 to 1992 - Project 1480

	1989		1990		1991		1992		
	Total	Mean	Total	Mean	Total	Mean	Total	Mean	Grand mean[2]
Area harvested (ha)	2137		2413		2134		2875		2359
Block size (ha)		21		24		17		22	20
Harvest volume (m^3/ha)		149		140		164		149	152
Estimated added cost ($/$m^3$)		1.50		.90		1.57		1.20	1.30

[2]Basis: five industrial respondents in Alberta providing data on questionnaire. Weighted by no. of observations.

4.2 Planning, Stand Selection and Layout Criteria, Crew Training and Supervision, and Harvesting Systems

All six respondents providing written comments do pre-harvest planning for understory protection to varying degrees, with one initiating formal PHSP's in 1992.

Stand selection and layout criteria vary widely. Air photographs were used by three respondents, with a scale of 1:10,000 preferred. Selection criteria tended to recognize white spruce density classes of low (less than 250/ha), medium (250 to 750/ha) and high (more than 750/ha). Degree of layout effort increases with increasing density. Understory height criteria were noted mainly with respect to windthrow hazard. One respondent preferred heights less than 1.5 m, which would severely restrict understory stands being considered for protection. Clumpiness of understory was recognized as a common distribution pattern, and layout and operating strategies to address distribution varied from protecting high value clumps to protecting the entire understory stand, depending on density and distribution. One respondent noted that stands with heavy understory, and merchantable deciduous and conifer volumes of less than 100 cu m/ha, were excluded from harvest.

All respondents indicate some degree of crew training as well as layout and field supervision, which tends to increase as understory density increases. Sauder (1992) describes the importance of these protective planning and operating factors in detail.

Harvesting systems employed included shortwood (mainly mechanical) 6%, tree length 22% and full tree 72%. Among the three respondents most active in understory protection, there was a strong preference for tree length over full tree systems, in order to minimize understory damage caused by feller-bunchers and grapple skidders.

4.3 Operational Problems (Costs) and Benefits

Operating problems (costs) and benefits outlined by six industrial respondents providing written comments are shown in Table 8.

The main regeneration-related operational problems cited by respondents are: susceptibility to windthrow, inadequate density and clumpy distribution, and questionable growth and yield potential (AAC) of released undrerstory. Other major operational concerns include added costs of planning, supervision, and operations and inadequate working room for both harvesting and scarification equipment.

Table 8. Operational problems and benefits of understory protection - Project 1480[1]

Problem	Times noted	Rank
Susceptibility to windthrow	4	1
Added cost (planning, supervision, operations)	4	1
Inadequate spruce density and clumpy distribution	3	2
Inadequate working room - logging and site preparation	3	2
Questionable growth and yield potential - AAC	2	3
Seasonal logging limitations - soils moisture	2	3
Conflict with government over equipment/procedures	2	3
Insects and disease potential in residual spruce	1	4

Benefit	Times noted	Rank
Improved wildlife habitat - birds and mammals	5	1
Improved landscape aesthetics - public relations	5	1
Possible increased conifer AAC	4	2
Possible regeneration cost savings	2	3
Added volume for harvest	1	4
Appease regulatory agency	1	4
Possible opportunity for progressive clearcut	1	4

[1]Basis: six industrial respondents in Alberta providing written comments to questionnaire. Weighted by number of observations.

This does not reflect the perspective of the regulatory agency which has particular concerns about the effects of in-block road and landing size and location on understory protection success and future block productivity.

The main operational benefits cited by respondents are: improved wildlife habitat, improved landscape aesthetics (PR) and possible increased conifer AAC and reduced regeneration costs. The need for stand valuation and selection criteria to maximize timber production benefits of understory was also mentioned.

As noted earlier, comments by industrial respondents regarding operational problems and benefits of understory protection relate almost entirely to the new regeneration standards, specific to coniferous establishment and performance on lands zoned for timber-production priority. These standards are being phased in over a five-year period and are subject to reassessment during that time.

There is no reference to establishment and performance of hardwood regeneration either as a component of the new mixedwood (D/C) standard - a subset of the coniferous land base - or on the deciduous land base. Comments therefore reflect the overriding concern with maintaining coniferous AAC, based on past experience, and do not deal with the significant issue of deciduous regeneration.

Problems (costs) and benefits shown in Table 8 can be reviewed in relation to the three previously posed questions:

First, how do added costs to protect understory relate to regeneration and tending costs and future coniferous AAC? "Added cost" (averaging $1.30/cu m in Table 8) will only be the "total cost" of achieving current coniferous establishment and performance standards in exceptional cases of ideal post-harvest understory composition, density, distribution and growth potential. The further the post-harvest understory departs from these conditions, the greater the expenditure required to meet standards and achieve increased AAC benefits, and the further the total cost departs from the initial added cost of protection. Standards could be modified to increase the proportion of hardwood acceptable in the regenerating stand, at the expense of coniferous AAC, with a probable reduction in regeneration and tending costs. A complete assessment of the cost-benefit relationship between understory protection, regeneration and tending costs, and coniferous AAC, requires a knowledge of the costs of protection, reforestation, tending and expected AAC changes, for specified post-harvest conditions.

The greatest need for new information appears to be in the areas of blowdown risk prediction and amelioration, and growth of mixed species stands and its linkage to yield and coniferous AAC on different sites. The role of natural coniferous and deciduous regeneration in these scenarios should also be further examined to determine potential regeneration cost savings.

The two-stage tending and harvesting model discussed earlier in this report provides an opportunity to examine windthrow and the regeneration and growth components of a variety of stand development scenarios, for pure coniferous and deciduous and mixed species stands.

Secondly, how do added costs of understory protection relate to non-timber benefits like improved aesthetics and wildlife habitat, and what are the coniferous AAC effects of managing jointly for non-timber benefits? Since neither specific objectives nor assessment criteria for aesthetics or wildlife habitat were determined prior to operations, their perception as benefits in Table 8 can only reflect the opinion or intuitive judgment of respondents, relative to the added cost of achieving them. The improved aesthetics or PR value of a block with protected understory over a conventional clearcut is noted by most respondents. This may change if additional costs were required to retain the perceived benefit. Under the circumstances, opinion and intuition are the primary basis for analyzing costs and benefits of the non-timber factors. This extends to the determination of coniferous AAC effects of managing for non-timber objectives.

Finally, how can timber and non-timber interests be more effectively integrated? Both short- and long-term strategies are available. Both must recognize that improved IRM requires better prediction of future effects of management actions and the costs and benefits associated with each option, and that monitoring and feedback, including public input, are essential.

Short-term actions to incrementally improve integration include:

1. conduct retrospective audits of existing cutblocks to determine how past actions can be expected to affect specific management objectives as a means of sharpening predictive skills; and

2. incorporate retrospective knowledge and experience into current practices, using more specific up-front objectives, supported by refined operational guidelines and monitoring systems. This

evolutionary process is currently underway in Alberta, with public input to regional and sub-regional plans and later at the stage of management plan review.

Longer-term actions include predictive modelling which is now evolving in IRM projects like IRMSC in Alberta and the Forest Habitat Project in Saskatchewan. This approach is moving toward a sustainable development philosophy, viewing both timber and non-timber resources as by-products of management constrained by concerns for ecosystem biodiversity and health (Hopwood 1991). In general, this approach requires joint consideration of timber and non-timber resources at the inception of planning, using predictive models in development of options. There should be public input to the choice of options for inclusion in plans, and an adequate monitoring and feedback system to support field testing.

A major difference between this process and current practice can be exemplified by the approach to wildlife management. Existing practices tend to manage for feature wildlife species like elk or caribou, whereas the modelling approach is moving toward habitat management to maintain a variety of species in viable populations. This is a clear departure from traditional zoning, priority-setting and planning procedures.

In the meantime, it is essential that short-term IRM improvements be continued, along with necessary research, since operations are proceeding.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Project 1480 is a source of information and direction for future mixedwood R&D and for technology transfer. Continued work is contingent on agreement funding. An analysis of mixedwood options in a field-based R&D environment outside the constraints of current policies and regulations can provide valuable feedback relevant to FTG and AAC to managers currently evolving mixedwood strategies.

Three major conclusions and related recommendations are as follows:

1. The harvesting component of Project 1480 has demonstrated operationally practical ways to protect understory spruce during overstory harvest of aspen stands aged 70 to 110, on mesic sites. This has increased the mixedwood manager's options when considering understory protection as a means of obtaining both timber and non-timber benefits. Blowdown risk for released spruce and potential negative impacts of harvesting operations on site productivity are two major concerns.

   Recommendations:

   a) operational harvesting trials could be combined with silvicultural systems like modified shelterwood to test and develop strategies for reducing spruce blowdown risk following harvesting operations. This work should cover the range of sites and ages considered operable for timber production (see 2(d) following).
   b) the cooperative approach in 1(a) could be extended to pre-commercial stands aged 30 to 60 where harvesting could be combined with tending in some cases to develop windfirmness in understory prior to later overstory harvest (see 2(d) following).
   c) operational harvesting trials could be combined with silvicultural trials to obtain site-specific data on the effects--positive and/or negative--of objectively measured site disturbances upon the establishment, vigor and growth of spruce, aspen, and poplar on mixedwood sites (see 2(g) following).

d) there is a real opportunity to use harvesting equipment to create manageable density and stocking patterns for mixed species.

2. The silvicultural component of Project 1480 has measured the nature and extent of harvesting-related damage and determined that a significant post-harvest residual can be retained with adequate harvesting precautions. The two-stage harvesting and tending model used for treatments provides the opportunity to measure and analyze regeneration, growth and yield in an array to post-harvest composition, density and distribution patterns for all major mixedwood species. Also, a large number of operationally protected understory blocks are now available to provide R&D and operational information.

   Preliminary plot measurements--up to three years only--indicate that released spruce understory is showing a positive height and diameter growth response on most areas, and that deciduous regeneration has reached densities suitable for full stocking on all blocks. Assessments also indicate some possible aspen density reduction associated with harvesting-related site disturbance, and indicates that blowdown risk is of concern even on some mesic sites.

   Recommendations:

   a) a blowdown risk rating should be developed immediately based on literature review and experience, as well as reassessment of plots on Project 1480 and in additional areas covering a range of sites and ages.
   b) develop density and stocking criteria and survey techniques for protected understory spruce of different ages and for associated deciduous regeneration following the first harvest.
   c) develop and test a growth and yield methodology which reflects the realities of variable density and stocking of the major species growing on mixedwood sites.
   d) cooperation should be encouraged with operational harvesting and tending trials to field-test blowdown risk criteria (see 1(a) and 1(b) above). Consider extending objectives of these field trials to include mixedwood regeneration, growth and yield implications of systems like shelterwood, if warranted, following review in (e) below.[8]
   e) available data and knowledge on spruce regeneration and early growth should be consolidated. Include reassessment of old Forestry Canada harvesting and management projects, and make available in DSS format.
   f) additional more basic R & D into the physiology and ecology of inter-specific competition in mixedwoods should be done, which, in combination with 2(e) above, could contribute to the success of natural and artificial regeneration and tending systems for spruce in mixedwoods. These may include underplanting in fire-origin aspen and in-planting on post-harvest mixedwood sites, both of which may be necessary to maintain desired coniferous content in mixedwoods.
   g) silvicultural and operational harvesting trials should be combined to obtain site-specific data on the effects of logging-related soil disturbance on site productivity (see 1(c) above).
   h) the project 1480 plot network should be remeasured to obtain fifth year and possibly tenth year data to determine:
      i) growth and yield potential of a variety of post-harvest composition, density and distribution configurations which include mixtures of released understory spruce and new deciduous regeneration on treated blocks, and deciduous regeneration on control blocks. Data should

[8]Extension of operations into mixedwood (SH) and coniferous (S) blocks with coniferous understories requires a careful assessment of the growth and yield and stability characteristics of such understories, which may be significantly different from understories in H and HS stands described in this project.

be shared with projects doing related work on juvenile stand development on a wider range of sites; and

ii) blowdown incidence, data from which should be shared with the blowdown studies in 2(a) and 2(d) above.

i) available data and knowledge on aspen and poplar regeneration and early growth should be consolidated, in a DSS format, identifying information gaps, which appear to be particularly significant for poplar. Undertake new poplar regeneration and growth R&D.

j) in all operational field R&D trials, there should be clear agreement on project objectives and necessary modifications of current harvesting and regeneration regulations to maximize the potential for R&D benefits. Regulations intended to expedite understory management can sometimes function as obstacles to progress during the evolution of new mixedwood strategies.

3. Increases in the effective operational implementation of understory protection depend on experience and professional judgement as well as on the development of predictive tools for determining future effects of management practice, and better monitoring and feedback procedures. These are essential for determining the costs and benefits of multiple use or integrated resource management (IRM) decisions (including understory protection) which managers must now make even on land dedicated primarily to timber production.

Project 1480 has already contributed to improved IRM through practical experience. It could also be used in a retrospective way, for example, to audit the effects of the understory configurations produced, upon specific timber-production or wildlife habitat objectives. The resulting information and experience could then be applied by incorporating more specific up-front timber and non-timber objectives as well as monitoring and feedback criteria to improve understory protection decisions in the short term.

In the long term, new modelling approaches to IRM should further reduce uncertainties about the costs and benefits of integrating timber and non-timber objectives which are central to operational concerns about the practice of understory protection.

Recommendations:

a) Priority should be given to developing preliminary stand selection criteria to determine suitability for understory protection. Priority should go to criteria for assessing blowdown risk, but should evolve toward criteria for determining the costs and benefits to be expected from a variety of integrated resource management options. This is currently being addressed in some IRM modelling projects.

b) Project 1480 should be used as a source of audit information and experience to make short term improvements in understory protection decisions, rather than waiting for long term modelling and R & D results.

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APPENDIX I

Silviculture and Harvesting Prescriptions - Project 1480

Two generalized pre-harvest silvicultural prescriptions (PHSP's) were developed, one for control stands and one for treated stands. A detailed sample PHSP was developed for stands WC and W1 (attached below) which was operated by Blueridge Lumber (1981) Ltd. and later set up as a demonstration. These stands were harvested prior to the new 1991 FTG reforestation standards so control stands, some of which would qualify as mixedwood (DC) land base under the new system, were assumed to qualify as coniferous land base for future management, even though stand DC, at 37 cu m/ha merchantable conifer, would probably have gone as deciduous land base in both the old and new standards.

Harvesting prescriptions are attached in Table 1.

Control Stands

All control stands were to be clearcut using feller-bunchers and grapple skidders. All conifer stems greater than 25 cm at the stump and all aspen trees were to be felled. Although no special protection measures were designated, the white spruce understory was not to be deliberately run over or knocked down.

Most control stands had at least 50 cu m/ha of merchantable coniferous timber, and it was expected that the understory component would be destroyed during harvest. They were assumed to qualify for management as coniferous land base after harvest. Therefore they would be treated using appropriate scarification, and planted with suitable white spruce seedlings to meet provincial stocking standards. Competition from aspen and grass would be controlled using mechanical treatments as required. The stand would continue to be managed as part of the coniferous landbase.

Treated Stands

Treatment was designed to protect understory spruce during the harvest of hardwood and coniferous overstory in mixedwood stands. Even though some of these stands, notably H1, D1 and D2, would not qualify under 1991 reforestation standards as coniferous land base, because they had less than 50 cu m/ha merchantable spruce, they had significant amounts of understory which was expected to survive harvest. It was assumed that all stands would subsequently be managed as mixedwoods, without reference to current policies and regulations, and that information provided would serve as input to evolving management stratgies.

Treatment represented the first harvest stage of the two-stage mixedwood harvesting and tending model described by Brace and Bella (1988) which provides for:

a) perpetuation of the mixedwood condition for a period as long as 60 years;
b) utilization of merchantable timber, mainly mature aspen;
c) accepting surviving spruce understory within a broad range of density and distribution - often clumped - as the basis for the next spruce harvest in about 60 years. The spruce component of the stand will be enhanced over time by increased growth and yield of the released understory, and by natural seeding of spruce under aspen, which would probably occur soon after logging, when logging-caused scarification is available. Seeding-in would occur from adjacent stands and from windfirm spruce seed-trees left during operations where possible. Also, the larger protected understory spruce would be expected to begin producing seed in the near future.

Table 1. Harvesting Prescriptions Summary[1]

Item	All case Studies Control	Drayton Valley Treatment 1	Drayton Valley Treatment 2	Hinton Treatment 1	Hinton Treatment 2	Whitecourt Treatment 1	Whitecourt Treatment 2
Pre-harvest planning	Only as required for harvest approval	Pre-located main skid trails and landings	Pre-located main skid trails and landings.	Pre-located main skid trails and landings.	Harvester operator selected trailways	Pre-located main skid trails and landings.	Harvester operators selected trailways.
Understory protection	No understory protection	Understory protected.	Understory protected.	Understory protected.	Understory protected.	Understory protected.	Understory protected.
Harvest operations supervision	Minimal.	Minimal.	Minimal	Continuous daily supervision.	Contractor self-supervised	Continuous daily supervision.	Operators self-supervised
Roading required.	As for Treatment 1 in the respective study area.	Followed existing seismic lines.	Followed existing seismic lines.	Only access to one landing required a spur road.	None required.	Loop road with spurs required to access landings.	None required.
Payment method.	As for Treatment 1 in the respective study area.	Piece rate ($/m³) for all crew.	Piece rate ($/m³) for all crew	Hourly rate for all crew.	Piece rate ($/m³) for all crew.	Hourly rate for all crew.	Piece rate ($/m³) for all crew.
Equipment: Falling	As for Treatment 1 in the respective study area.	Aspen felled with shear-equipped front-end loader feller-buncher. Hand fell conifer.	Aspen and conifer felled with shear-equipped front-end loader feller-buncher.	Aspen and conifer felled with excavator-type feller-buncher.	Double-grip harvester felled all trees.	Aspen and conifer felled with excavator-type feller-buncher.	Single- and double-grip harvesters felled all trees.
Skidder	As for Treatment 1 in the respective study area.	Grapple skidders.	Grapple skidders.	Grapple skidders.	10 t-forwarder.	Grapple skidders.	Two 14-t forwarders.
Limbing	Drayton Valley: As for Drayton Valley Treatment 1. Hinton and Blue Ridge: Aspen and conifer delimbed at roadside landing with stoke delimber.	Aspen manually delimbed at landing. Conifer delimbed at landing using skidder blade.	Aspen and conifer stems rough delimbed and topped either at the site, or prior to the bunches entering the landing area.	Aspen and conifer manually rough delimbed and topped at felling site and stoke delimbed at roadside.	At felling site during felling.	Aspen and conifer manually rough delimbed and topped at felling site and stroke delimbed at landing.	At felling site during felling.
Processing	As for Treatment 1 in the respective study area.	Aspen hand-slashed at landing into 2.6-m lengths. Conifer cut to tree-length at landing.	Aspen hand-slashed at landing into 2.6-m lengths. Conifer cut to tree-length at landing.	Aspen slashed into 2.6-m lengths at roadside. Conifer tree-length at roadside.	Aspen cut to 2.6-m length at felling site. Conifer cut to log-lengths at felling site.	Aspen and conifer cut to log-length at landing.	Aspen cut to 2.6-m lengths at felling site. Conifer cut to log-lengths at felling site.

[1]From Sauder (1992).

This strategy reduces the high costs and risks of spruce plantation establishment and management required if conversion to coniferous management were initiated, as in being done in controls; in essence the strategy is to work with natural succession. It also includes the possibility of reduced coniferous AAC.

d) accepting aspen and poplar seedling and sucker regeneration in areas not stocked with spruce.
e) only in-planting and tending those areas defined by survey to be understocked to either desirable hardwoods or conifers, such as landings, and doing minimum required thinning and release tending of both planted and natural spruce. This procedure is considered to be assisted natural regeneration.
f) a demonstration of timber production, wildlife habitat, recreational, landscape aesthetics and biodiversity aspects of mixedwood management while retaining the option to convert to hardwood or coniferous management in the future. The mixedwood option creates technical challenges to silviculturists and loggers alike. However, it addresses many of the major public concerns about clearcutting systems as now practised on mixedwood sites.
g) stands can be assessed for specific aesthetics, wildlife habitat or other objectives to improvise current multiple use practices, until more sophisticated intergrated resource management techniques are developed.

Stands D1, D2, H1 and W1 were logged using feller-bunchers and grapple skidders. On dry sites, all merchantable hardwood stems greater than 25 cm stump diameter were felled. On moist sites, all merchantable hardwood stems greater than 15 cm stump diameter were felled, as larger stems would probably not be windfirm.

Merchantable stems located within dense clumps of white spruce understory were left standing if their removal resulted in excessive white spruce damage. All felling occurred off the skid trails, and feller-bunchers deposited bunches on or beside the skid trails. Feller-buncher travel, and all skidder travel, was restricted to designated trails. In stands H1 and W1, rub stumps were left beside the skid trails and all trees were limbed and topped before they were skidded to landings.

In stand W1 several three-tree clumps of overmature spruce trees were left standing to provide a seed source following harvesting.

Stands H1 and W2 were harvested using Scandinavian equipment. All merchantable hardwood stems greater than 25 cm stump diameter were felled. Merchantable stems located within dense clumps of white spruce understory were left standing if their removal would cause excessive white spruce damage.

Harvesters delimbed the stems so that limbs and tops were left on the harvester-forwarder trails. This provided a mat for the forwarder to travel over and reduced the chance for site disturbance. Forwarders travelled only along the same trails made by the harvesters.

Sample Pre-harvest Silviculture Prescription - Stands WC and W1

Stands WC and W1 are situated just off Branch Road 122 in Twp 62 Rge 10 W 5. Figure 1 shows stand detail[9]. Stand WC will be logged using a sawhead feller-buncher, a grapple skidder and a stroke delimber processor at roadside. This area will act as the "control area" and the harvesting will proceed in what is considered to be a normal manner. No precautions or extra effort will be made to minimize

[9]Note a new seismic line has been run through the stand since it was first selected, providing a north-south baseline for survey control and possibly for harvesting access.

or avoid damaging the understory. Stand W1 will be operated with the same equipment but the following techniques will be used to protect the understory:

1. All skid trails are to be ribboned.
2. Felling will be done starting from the edge of the block and working back toward the landings and all bunching will be done on the designated skid trails only.
3. All trees will be topped by hand before skidding.
4. Skid and return empty travel will be confined strictly to the skid trails.
5. Rub stumps will be used to reduce damage along skid trails[10].
6. Dense clumps of understory will be ribboned and avoided.
7. Large-crowned aspen and spruce within dense clumps which would cause excessive understory damage if felled will be left standing.
8. White-spruce seed trees designated by a blue band, along with selected surrounding trees, should be left undisturbed.
9. For best aspen suckering results in areas designated for aspen production, all hardwoods including poplar and birch should be felled, even if not utilized (see prescription for W1-4).

Prescription for Stand W1

1. General

Stand W1 has been divided into 4 rough cover types (sub-units) which are described in Table 2 for prescription purposes. Table 3 gives prescriptions and expected future cover types. Cover types do not necessarily conform to specific site types based on slope position and moisture condition.

Stand W1 falls within ecosystem association LBC5C (white spruce, Viburnum, Aralia, aspen facies (Corns and Annas 1986). In general, the aspen component of this stand was too old and decadent to provide the best combination of current aspen yield and future yield from released understory spruce, but it represented a cross-section of mixedwood stand conditions typical of many areas in the mixedwoods in Alberta, and should serve well to demonstrate the practicality of the modified 2-stage harvesting and tending model in cases where understory spruce is prominent.

One source of white spruce seed to enhance natural regeneration in the future will be a few selected seed trees clearly marked with blue painted bands. Leaving many large spruce seed trees or clumps of seed trees on this area would be impractical because of windthrow hazard. An additional seed source will be the larger understory white spruce released during harvest. For example, in area W1-2 (Figure 1) there are an average of 92 spruce per hectare in the height class 7.5 to 14 m, and these should be left during harvest to provide a seed source in the next 40 to 50 years as the spruce matures. This would require ignoring the 15/10 rule as many of the trees 14 m and less in height exceed the 15 cm stump diameter and merchantable length criteria. The harvest volume loss from leaving all spruce under 14 m would be minor (< 5%) and even if there were some windthrow loss the seed source insurance provided should be significant. W1-1 is a small merchantable softwood stand which should be combined with W1-2 for operations. On the other hand, leaving all spruce 14 m and less on moist areas (W1-3 and W1-4) could result in substantial windthrow, and so all merchantable softwood should be taken. This could be as much as 15-20% of the spruce in the 7.5 to 14 m class and would result in an increased aspen component in the future stand unless a spruce planting and tending program was

[10]During operations, the contractor and supervisor agreed to cut some aspen high - up to 2 m above ground - to avoid damaging the understory with the felling head.

adopted. Aspen suckering could be reduced in some patches where the water table rises after harvesting, but this should be only on small patches.

Table 2. Statistics for Cover Types Used for Prescriptions

Stand sub-unit	Area (ha)	% Balsam poplar	Merch. Vol. (M^3/ha)		Cover type	Spruce Component No./ha by Ht.				
						Understory			All	
			H	S		0.5-2.5[5]	2.5-7.5	7.5-14	2.5+	14 m+
W1-1[1]	1.5	-	minor	200+	S	-	minor	-	-	100+
W1-2[2]	11.5	8	314	55	H/S	199	385	92	853	376
W1-3[3]	11.5	10	322	189	HS/S	652	177	77	453	199
W1-4[4]	3.5	32	170	121	HS/S	495	141	35	264	88

[1]Clumps of softwood (wS, lP) identifiable on photo. No plots.

[2]Primarily aspen over white spruce. Understory number of trees 2.5 to 14 m = 477 if up to 14 m uncut.

[3]Considerable softwood codominant with aspen. Assume significant amount 7.5 to 14 m is cut due to windthrow risk.

[4]Considerable dominant and co-dominant softwood, and considerable balsam poplar (32%) which will inhibit aspen suckering if not cut. Understory number of trees 2.5 to 7.5 = 141. Assume significant amount 7.5 to 14 m cut due to windthrow risk.

[5]Understory under 2.5 m is not considered even though numbers are significant especially in W1-3 and W1-4 because they will be overgrown by aspen. They are, however, a source of spruce in the next rotation.

Table 3. Silvicultural Prescriptions

Area	Size	Current cover	Age	Understory density 2.5 to 14 m	Topography	Moisture	Treatment	Future cover
W1-1[2]	1.5	S (wS,lP)	100±	minor	upper slope	dry to fresh (2-3)	Clearcut patches and plant in rough to large spruce or pine stock. Some followup release may be needed, but competition potential is relatively low.	S
W1-2	11.5	H-S (A, bP, wS/uwS)	A = 100 ± Ws = 120 ± uwS = 50 ±	Generally good with range 200 to 1500/ha (mean 477)	mid to lower slope	fresh to moist (3-5)	Clearcut aspen patches and remove aspen and large spruce to release spruce understory. Leave designated large spruce seed trees and all spruce under 14 m. No followup anticipated for 40 to 50 years period during which aspen regrows and understory spruce matures.	S-H in generally separate patches. Some S-H/uwS.
W1-3	11.5	H-S (wS, A, bP/uwS)	as in (2)	moderate, range 50 to 800 (mean 254)	lower slope	fresh to moist (3-5) with some wet areas (6)	As in (W1-2) above but cut merchantable spruce under 14 m, resulting in a less prominent spruce residual because there is less understory. There are sufficient aspen (50 +/ha) to generate a good sucker stand even if balsam poplar are not knocked down (10% of hardwood).	H-S with less S than in W1-2 above.
W1-4[3]	3.5	H-S (wS, A, bP/uwS)	A = 100 ± wS = 120 ±	minor range 0 to 200 (mean 176)	lower slope	as in W1-3	Clearcut, including balsam poplar, (32% of hardwood) leaving insignificant amount of residual. If there are ±50 aspen per ha there should be good sucker development and a new aspen stand will develop. Otherwise consider leaving balsam poplar, patch[1] scarifying, planting, large spruce stock, and following with an intensive release program.	H or S depending on alternative chosen.

[1]Consider manual/mechanical scarifier, see attached.

[2]Combine W1-1 with W1-2 and designate as W1-1 for operational purposes.

[3]Combine W1-3 with W1-4 and designate as W1-2 for operational purposes.

APPENDIX II

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