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ECONOMIC ANALYSIS OF ECOLOGICALLY BASED MIXEDWOOD SILVICULTURE AT THE STAND LEVEL

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Economic Analysis of Ecologically Based Mixedwood Silviculture at the Stand Level** submitted by **Philippa Maria Joan Rodrigues** in partial fulfillment of the requirements for the degree of **Master of Science** in **Forest Economics**.

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ABSTRACT

This investigation provides a narrowly defined, stand level, economic analysis of the ecologically based mixedwood systems described by Lieffers *et al* (1996). Expert opinion was solicited for the information required by the analysis. The results show that for clearcutting operations, silviculture reduces land expectation values substantially. The results also show that understory protection techniques were the least profitable of the options examined. Finally, the results suggest that although ecologically based systems have higher harvesting costs in some cases, such as single tree selection, this is mitigated by the lack of required regeneration treatments, and improved yields. Under the assumption that stumpage rates will continue to increase over time, and given a social discount rate, many of the ecologically based systems become financially feasible. It should be noted that more accurate information about the costs and yields of these systems could have an important effect on the outcome of this analysis.

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CHAPTER I

INTRODUCTION

1.1 Introduction

Historically, the forest industry in Alberta has been focused on coniferous stands in the boreal uplands and the boreal subalpine sections of the province (McDougall, 1988). Forestry operations in the mixedwoods of Northern Alberta were, to a large extent, confined to coniferous dominated, fire origin stands, as spruce and pine were the only commercially viable species. At the time, the technology available, made aspen unsuitable as a source of fibre for pulp or timber. Because of the undesirability of aspen as a commercial species, management practices in the province were biased towards spruce, and most of the silvicultural activities associated with these mixed-wood systems were aimed at establishing relatively pure stands of white spruce (Lieffers, 1996).

This "softwood bias" continues to this day. Mixedwood stands currently allocated for harvest of both hardwoods and conifers are being clear-cut and assigned to either a coniferous or deciduous regeneration schedule, depending upon the volume of conifer in the stand at the time of inventory. This approach has proven to be problematic and expensive. Many of the stands allocated to conifer production are under-stocked because of hardwood and grass competition. There may also be reduced aspen representation in new hardwood stands, especially where balsam polar and white birch are left during the cut (Dancik *et al*, 1990). In addition, there has been little attempt to grow conifers on sites that have been designated as deciduous and visa versa, even though in many circumstances the sites could grow coniferous as well as deciduous species. Finally, many of the benefits of mixed stands, including greater total yield from forests that are measured as mixtures than as single species systems and biodiversity values, can not be realised by the current management systems (Lieffers, 1996).

In the last decade social, as well as economic and technical, factors have precipitated a call for change in the way mixed-woods are managed in the province. Social changes have included increased public awareness of forests as natural ecosystems and the subsequent push for development of silvicultural systems which maintain a wide range of naturally existing stand compositions and structures, while at the same time allowing for significant utilisation of the wood resource. The economic factors that have contributed to the desire for change in mixed-wood management in the province include higher prices commanded for pulp and wood chips. Finally, technological changes, including the advent of new composite wood products such as oriented strand board (OSB) and medium-density fibre board (MDF), and advances in pulping technology, have turned aspen from a "weed" species into what is now commonly referred to as a Alberta's Cinderella species (Brennan, 1988).

In response to these factors Lieffers *et al* (1996) examined the natural development patterns of boreal mixed-wood stand, and developed a range of silvicultural options to produce stands of a wide range of structures and compositions. The development of these alternative systems represent an important step in giving Alberta's forest managers the tools required to manage this resource effectively.

Another important step in this process is to begin the investigation of the economic implications of these systems. Clearcutting is the only option currently used in Alberta on a large scale. Understory protection is becoming more widespread, and other silviculture options are beginning to be used on a trial basis. However, costs for these less common systems are still not generally known. Meaningful economic analysis is dependent to a large extent on the availability of accurate and reliable data. As in many cases, these systems have never been employed operationally, and accurate data on costs and benefits in terms of yield is non-existent. The purpose of this study is thus twofold: first to evaluate the economic implications of the range of silvicultural options identified by Lieffers et al (1996) to the best extent possible given existing data, and second to identify those areas where more information must be collected. As a preliminary investigation, the scope of this study will be limited to purely the financial implications of these systems. Integrating the effect of non-timber values into the analysis is left to future investigations. In addition, it should be noted that two levels of analysis are relevant to this type of an investigation: stand level vs. forest level analysis. This is a stand level analysis.

This study is intended as a first step in the economic analysis of these newly developed silvicultural systems. The emphasis is on collecting all currently available information on these system and identifying areas where information is lacking, as well as on making a preliminary stand level economic analysis of these systems. As these systems become more widely used and information on costs available, and as yield information becomes more refined, more sophisticated methods of analysis, such as dynamic programming could be employed to seek optimum management paths.

This paper is organised as follows. First, a review of the relevant economic and forestry literature is presented. Then the methods used in this analysis are discussed, and results of the economic analysis are presented. Finally, the implications of the results are discussed and areas in need of further investigation are suggested.

CHAPTER II

LITERATURE REVIEW

2.1 Literature Review

Methods for evaluating silvicultural investments have a long and well-established history. A number of studies have been published in which specific silvicultural actions, such as thinning, are evaluated (e.g. Bostrom, 1982). However, studies pertaining to Alberta or even the boreal mixed-woods are scarce. The following review concentrates on boreal forests, when possible in Alberta. The first half of the review will highlight articles that dealt with the economics of silviculture and the second half will cover those that address the biological and technical issues.

2.2 Economics of Silviculture Literature

Very little research has been done relating to the economics of silviculture in Alberta. Most of the work conducted in the province has been done on poplar. Ondro (1989) examined the market potential for Alberta poplar. This study provides a market overview of poplar and wood products, and evaluates the utilisation of poplar in Alberta. The study also describes the size and structure of poplar-using industries and provides directories of the 1987-88 poplar-using industries in Alberta.

In 1991, Ondro evaluated the technological aspects and costs of harvesting poplar in winter. In this study he also determined the optimum recovery in economic terms of poplar products and energy from old and young stands, and evaluated and compared the economics of 15 options for the industrial utilisation of poplar by plant with varying capabilities, including energy generation.

Research relating to other species are limited to Ondro and Constantino's (1990) study of the financial returns from fertilising lodgepole pine near Hinton, and De Franceschi and Bell's (1990) study of the costs of conducting motor-manual release treatments in mixed-wood stands in Manitoba. In De Franceschi and Bell's study labour production rates over a range of stand conditions for both brush saw and chain saw in young stands, and for chain saw in old stands was measured. In addition, the damage, which resulted to crop trees as a result of these different release treatments, was assessed.

This represents the extent of research done on the economics of mixed-wood silviculture in Western Canada. The limited studies that have been conducted have tended to focus on assessing one aspect of a silvicultural system, such as pruning, as opposed evaluating systems in their entirety. In addition, no research has been done on comparing different silvicultural alternatives for similar sites. Likewise, no attempt has been made to place previous studies in an optimum economic rotation (OER) context, leaving the question of whether or not financial results could be improved upon by altering the timing of interventions unanswered. The purpose of this study is to address this lack of knowledge by starting with ecologically appropriate silvicultural alternatives suitable for mesic boreal mixedwood sites, and to assess their economic contributions. The forestry literature on the non-economic aspects of boreal mixed-wood silviculture is better developed.

2.3 Forestry Literature

The pertinent forestry literature can also be roughly divided into two categories: Literature that concerns itself with the development or improvement of silvicultural practices and systems and that which concerns itself with the growth and yield of mixed-wood stands.

2.3.1 Silvicultural Practices

Froning (1980) was one of the original investigators into the development of silvicultural systems suited to the boreal mixed-woods in western Canada. Froning assessed the loss of and damage to the spruce understory at various densities during conventional aspen harvesting. Froning was also among the first to begin the development of an economically feasible logging method for minimising damage to the spruce understory in boreal mixed-woods. Later investigators used Froning's work to develop a wider range of understory protection techniques.

Brace and Bella (1988), and Navratil et al. (1994) continued investigation into developing harvesting options that favoured white spruce and aspen regeneration in boreal mixed-woods. Lieffers (1994, 1996) worked on refining these techniques and making them suitable for use, given a broad range of initial stand conditions. It is these silvicultural options which are used as the basis for the economic analysis in this paper.

2.3.2 Growth and Yield

As mentioned above, growth and yield information suitable for economic analysis is very scarce. Mixedwood yield estimates are confined to the Alberta Phase 3 Forest Inventory Yield Tables for Unmanaged Stands. These tables present volume per unit area and other characteristics of unmanaged (fire origin) stands by age class, species group (yield class) and site class. Provincial yield tables do contain specialised mixed-wood yield tables, however, these represent average yields from stands growing on a wide range of sites and are not specific enough to provide the information required by the economic analysis undertaken in this investigation. Finally, no provincial yield tables exists for uneven-aged stands.

Bella and Gal (1996) examine the growth, development and yield of mixed-wood stands in Alberta following a partial cutting of white spruce (known as diameter limit harvesting) in the 1950s. The purpose of the study was to assess growth rates and productivity of mixed stands containing white spruce and trembling aspen. The study also attempted to determine if diameter limit harvesting would ensure future harvests of white spruce. Finally, the study attempted to explain the mortality dynamics in these partially cuts stands. Because harvesting methods and equipment have changed so drastically since the 1950s the authors warn that, at best, the information presented in their study is only an indication of what could be expected after present day partial cutting with current equipment and techniques.

Although other researchers are currently working on developing yield tables specifically designed for managed mixedwood stands, none were in circulation at the time of this study. This lack of data with regard to both costs and yields present major obstacles to the economic analysis of the systems described in Lieffers (1996). This study attempts to mitigate the effect of lacking yield information by supplementing provincial yield estimates with surveyed estimates given by foresters.

CHAPTER III
METHODS

3.1 Methods

The silvicultural systems developed by Lieffers *et al* (1996) for use on boreal mixedwood sites were used as a basis for this investigation. Their systems are summarised in table 3-1. The starting points of these silvicultural systems were the types of relatively mature stands that are typically found in the forest inventory. In order to simplify the analysis, was assumed that each of the eight initial stand types were fully stocked, C density, and growing on medium sites in the middle of the edotopic grid. The edotopic grid includes moisture on one axis and nutrient regime on the other axis, and is a tool used to help classify different sites. It was also assumed that efficient harvesting equipment was used. These initial starting stand types are located in the first column of table 3-1. The second column of the table describes a set of silvicultural options that can be applied to each of these different stand types. Secondary treatments required for the silvicultural systems are shown in the third column of the table. The last column of table 3-1 states the type of stand produced by each of the different silvicultural options. In addition to the systems developed by Lieffers *et al,* clearcutting, and some other approaches were added as options for all the different stand types. A detailed description of all the options used for each stand is provided in Appendix A.

Table 3-1. Silvicultural options for boreal mixedwood forests (Lieffers *et al*, 1996).

CURRENT STATE	FIRST TREATMENT	SECONDARY TREATMENT	OUTCOME
I. Deciduous (vigorous)	a) Clearcut (suckering)		Deciduous or Deciduous/(coniferous)
	b) Late Understory Plant	Understory Protection	Horizontal mixture of coniferous and deciduous. Patches are of different age.
	c) Early understory Plant Cut with Wind protection	Understory Protection/ Removal Cut	Horizontal mixture of coniferous and deciduous. Patches are of different age.
II. Deciduous (breaking up)	a) Clearcut (suckering)		Deciduous
	b) Understory Site Preparation, Plant	Understory Protection	Horizontal mixture of coniferous and deciduous. Patches are of different age.
	c) Clearcut, Site Preparation, Plant	Vegetation Management	Coniferous or Coniferous-Deciduous
III. Coniferous	a) Clearcut, Site Preparation, Plant	Vegetation Management	Coniferous or Coniferous-Deciduous
	b) Clearcut, Site Preparation, Aerial Seed	Vegetation Management	Coniferous or Coniferous-Deciduous
	c) Clearcut, Site Preparation, Aerial Seed		Coniferous-Deciduous
	d) Clearcut, Site Preparation, Plant		Deciduous/(coniferous)
	e) Clearcut (suckering)		Deciduous or Deciduous/(coniferous)
	f) Shelterwood	Removal Cut	Coniferous or Coniferous-Deciduous
	g) Leave Seed Tree i) Leave for Natural		Deciduous/Coniferous
	g) Leave Seed Tree ii) Site Preparation		Deciduous/Coniferous
	h) Group Selection		Small patches of intermixed species of different ages.
IV. Deciduous *Understory* – short even-aged coniferous	a) Understory Protection		Horizontal mixture of coniferous and deciduous. Patches are of different age.
	b) Clearcut (suckering)		Deciduous
V. Deciduous *Understory* – tall even-aged coniferous	a) Understory Protection with Wind Protection	Removal Cut	Horizontal mixture of coniferous and deciduous. Patches are of different age.
VI. Deciduous *Understory* - Uneven-aged coniferous	a) Conversion to Single Tree Selection	Removal Cut	Horizontal areas of young deciduous between patches of all-aged coniferous, leading to selection system.
	b) Understory Protection, Cut Tall Understory		Horizontal mixture of coniferous and deciduous. Patches are of different age.
VII. Uneven-aged Coniferous	a) Understory Protection with Wind Protection	Removal Cut	Horizontal areas of young deciduous between patches of all-aged coniferous.
	b) Understory Protection, Cut Tall Understory		Horizontal mixture of coniferous and deciduous. Patches are of different age.
	Single Tree Selection		Coniferous (all-aged)
VIII. Coniferous *Understory* - Pockets of coniferous	a) Irregular Shelterwood Removal Cuts	Removal Cut	Coniferous or Coniferous Deciduous (partly uneven-aged)

A questionnaire was prepared and circulated to experts in mixedwood management from industry, and the University of Alberta. Industry participants included representatives from Weyerhaeuser Canada Ltd., Alberta Pacific Forest Industries Inc., Millar Western Inc., and Canadian Forest Products Inc. These companies all have significant experience operating in Alberta's mixedwoods. Provincial government representatives were also solicited for information. However, as they were unfamiliar with, and unable to provide estimates of the costs associated with each system, their estimates were not included in the analysis. A copy of the questionnaire is provided in Appendix B. The questionnaire was mailed to the participants March, 1996, after which appointments were made on an individual basis to complete the questionnaire with the participants in person. The last questionnaire was completed in April, 1997.

The questionnaire was divided into three general parts. First, the participants were asked to identify stumpage values of aspen and spruce from a typical hectare in their land base. Second, the participants were asked to estimate what change in yield would be attributable to each silvicultural system. The questionnaire was constructed in such a way that it was possible to compare the participants responses with what was predicted by the provincial yield tables to provide a counterpoint to their estimates. Finally, the participants were asked to estimate the silviculture and harvesting cost associated with each of the systems.

The data collected from the participants was used to calculate the value of the first, immediate harvest (NPV_{R0}), the net present values resulting from each system excluding NPV_{R0} over one rotation (NPV_{R1}), and finally the net present value over subsequent perpetual rotations (NPV_{R2+}). NPV_{R0} was calculated separately in order to investigate the possibility that the initial cut, where standing timber is being harvested, was subsidising subsequent operations. NPV_{R1} was separated out from NPV_{R2+} in order to investigate alternative silvicultural systems that can be tried after one rotation in perpetuity. The value of all three measures represents the land expectation value (LEV) or the value of the land managed in perpetuity. The variables are depicted in figure defined in the following equations.

The value NPV_{R0} is defined as the value of the initial harvest in year 0.

(1.) $NPV_{0R} = V_0$

Where: V_0 = Return generated by the harvest in year 0[1].

The net present value (NPV_{R1}) is defined as the present value of expected future returns minus the present value of expected future costs, with the costs and returns discounted by a selected discount rate. The net present value for one rotation was calculated using the following equation:

(2.) $NPV_{R1} = [V_{R1}/(1+i)^{R1}] - [C_n/(1+i)^n]$

Where: R1 = number of years to the first rotation

V_{R1} = return generated at first rotation

n = number of years from the present

C_n = costs incurred (in year n)

i = the interest rate

As it is in theory possible to continue harvesting into perpetuity, the next step in the analysis was to calculate the net present value of the land following the first two

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1 In should be noted that in a small minority of these silviculture systems there is no harvest in year 0. In these cases no NPV_{0R} exists.

harvests used to produce perpetual rotations of timber[2]. This was calculated with the following equation:

(3.) $NPV_{R2+} = [V_{R2} - C_n(1+i)^{R2-n}]/[(1+i)^{R2-R1} - 1]/(1+i)^{R1}$

Where: R2 = number of years to the second rotation

V_{R2} = return generated at the second rotation

Finally, the land expectation value (LEV) was calculated.

(4.) $LEV = NPV_{R0} + NPV_{R1} + NPV_{R2+}$

Sensitivity analysis was conducted with respect to two key variables. Interest rates of 2%, 5%, and 10%, were used with stumpage rate combinations of $3.00 (aspen) and $8.00 (spruce), $5.00 (aspen) and $10.00 (spruce), $10.00 (aspen) and $30.00 (spruce). The first stumpage rate combination was suggested by the questionnaire results, and the subsequent values were used to reflect the fact that some stands, due to their location, ease of logging or other factors, will be of higher value to their stakeholders than others.

Part of the analysis was targeted at trying to find the optimum economic rotation, or that rotation age which maximises the Land Expectation Value. However it was not possible to elicit growth and yield estimates for every possible harvest age for all types of treatments. Instead expert opinion was elicited for yields at a rotation age of 100 years for spruce and 70 years for aspen. The experts whose opinion was solicited for this study suggested these ages.

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2 It should also be noted, that some of these silvicultural options can not be repeated into infinity. In such cases assumptions were made as to the most likely composition of the stand arising after the first rotation, and then the simplest repeatable method (in most cases clearcutting and allowing the site to

In order to calculate the Land Expectation Values at different rotation ages, a method had to be devised to derive what the participants' estimates of yields would be at ages other than the rotation, for which data was collected on the questionnaire. The participants estimate of yield at the given rotation age was scaled with a volume factor in order to adjust volume estimates to different ages.

(3.) $X = Vol_E / Vol_{PhaseIII}$

Where: X = the volume factor

Vol_E = the average volume estimated by the experts

$Vol_{PhaseIII}$ = Volume predicted by Provincial Yield Tables

This number was used to scale the provincial yield table estimates for that stand type by multiplying the yields predicted each year by this number.[3]

The volume factors that were used in the analysis are provided on page 16 in table 3-2. The columns of table 3-2 list the volume factors used for both the hardwood and softwood components of each harvest for the first and subsequent rotation. For example, "Volume Factor (1) Aw" refers to the factor calculated for the aspen component of the first cut of the system described in the row that the factor appears in. Whereas, "Volume Factor (2) Aw" refers to the factor calculated for the aspen component of the second cut of the system described in the row that the factor appears in. The last two columns of

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sucker to aspen) was applied in order to calculate the present value of harvests in perpetuity.

3 Where the silvicultural scenario called for a specified percent removal of basal area, the Phase III volumes were multiplied by this percent to come up with the provincial yield estimate for this scenario. For example scenario IIIf calls for 50% removal in year zero, therefore the Phase III estimate was multiplied by 0.5 to get the provincial yield estimate for this scenario.

table 3-2 are factors that were calculated for systems that are not based on rotations, but are based on a cut that occurs on a cutting-cycle.

It should be noted that in some cases the volume factors indicate a huge discrepancy between what the expert's estimate of yield and the provincial yield table estimates. This may be due to several reasons. First, the Phase III mixedwood tables represent average yields from stands growing on a wide range of sites, and are most probably based on stands with mixed overstories, which represent only a very small portion of the stand types examined by this investigation. For example, stand types I and II are predominantly deciduous mixedwood stands, however the provincial tables indicate almost twice as much spruce than aspen for an average mixedwood stand on a medium site. Thus, in these cases the experts estimates of yield will be significantly lower for spruce than the Phase III estimates. Second, the scenario may have called for the preferential removal of one species over the other. For example, aspen over spruce in the understory protection scenarios. In this case the volume factor for aspen will be significantly larger for spruce than it will be for aspen in the first cut. Finally, although it was specified that all eight initial starting stands were found on identical sites, the participants may not have consistently applied this assumption. This may have caused some of the variation seen within the options developed for the same stand type. Finally, the participant may not have been familiar enough with the less common silvicultural techniques and stand types to give accurate estimates for these types of systems. These factors should be taken into consideration when interpreting the results of the analysis. However, note that these volume factors where only used in the analysis of the optimum economic rotation to adjust volumes to different ages. As will become evident in the results, the difference between OER based values and non OER based values is slight.

Despite the fact that volume factors allowed for calculation of LEVs at different rotations, finding the optimal economic rotation (OER) proved difficult. The stand structure and composition produced by each of these silvicultural systems is generally not the same as the as that of the initial stand, thereby creating the potential for differing optimal harvest ages for initial and subsequent stands. Furthermore optimal harvest ages for each cut may not be solved for independently, as postponing the initial harvest affects the optimum harvest age of subsequent stands. Solving this problem would require some sort of optimisation algorithms, which is beyond the scope of this thesis. To simplify the optimisation, it was assumed that the initial cut could not be postponed. Secondly, OERs were only calculated for those systems that could be repeated into perpetuity.

Table 3-2. Volume factors used to scale provincial yield table estimates.

Stand Type	System	Vol. Factor (1) Aspen[a]	Vol. Factor (1) Spruce[a]	Vol. Factor (2) Aspen[b]	Vol. Factor (2) Spruce[b]	Vol. Factor[c] Aw/Cutting-Cycle	Vol. Factor[c] Sw/ Cutting Cycle
I. Deciduous (vigorous)	a) Clearcut (suckering)	2.21	0.14	2.21	0.46		
	b) Late Understory Plant	1.43	0.09	1.13	1.30		
	c) Early understory Plant Cut with Wind protection	2.10	0.48	0.53	1.42		
II. Deciduous (breaking up)	a) Clearcut (suckering)	1.79	0.18	1.85	0.72		
	b) Understory Site Preparation, Plant	1.24	0.13	0.83	1.31		
	c) Clearcut, Site Preparation, Plant	0.87	0.47	0.30	1.97		
III. Coniferous	a) Clearcut, Site Prep., Plant, Veg. Man.	0.64	1.26	0.39	1.78		
	b) Clearcut, Site Prep., Aerial Seed, Veg. Man.	0.51	1.13	0.51	1.13		
	c) Clearcut, Site Prep., Aerial Seed	-	-	-	-	-	-
	d) Clearcut, Site Prep., Plant	-	-	-	-	-	-
	e) Clearcut (suckering)	0.68	1.26	1.85	0.61		
	f) Shelterwood	2.54	1.51	0.61	1.87		
	g) Leave Seed Tree i) Leave for Natural ii) Site Preparation	-	-	-	-	-	-
	h) Group Selection					2.03 (25)	1.16 (25)
IV. Deciduous *Understory* - short even-aged coniferous	a) Understory Protection	2.33	0.02	1.65	0.91		
	b) Clearcut (suckering)	2.36	0.14	2.42	0.78		
V. Deciduous *Understory* - tall even-aged coniferous	a) Understory Protection with Wind Protection	1.85	0.28	0.15	1.02		
	b) Clearcut (suckering)	2.03	0.24	2.03	0.61		
	c) Understory Protection with Wind Protection	1.54	0.34	0.86	0.80		
VI. Deciduous *Understory* - Uneven-aged C	a) Conversion to Single Tree Selection	6.18[e]	0.49	1.94	0.67	0.73 (25)	1.84 (25)
	b) Understory Protection, Cut Tall Understory	1.77	13.99[e]	1.33	0.67		
	c) Clearcut (suckering)	2.06	0.23	2.29	0.47		
VII. Uneven-aged coniferous	a) Clearcut, Site Preparation, Plant	0.33	1.07	0.62	1.36		
	b) Clearcut (suckering)	0.42	1.08	1.14	1.33		
	c) Understory Protection with Wind Protection	-	-	-	-		
	d) Single Tree Selection	1.27	2.01			1.42 (25)	0.79 (25)
VIII. Coniferous *Underst.* - pockets of uneven-aged C	a) Clearcut, Site Preparation, Plant	0.45	1.09	1.06	1.06		
	b) Irregular Shelterwood Removal Cuts	0.61	1.03	1.92	1.03		
	c) Clearcut (suckering)	0.62	0.72	1.46	0.72		

[a] Volume factor calculated for either the aspen, or the spruce component, of the first cut.
[b] Volume factor calculated for either the aspen, or the spruce component, of the second cut.
[c] Volume factors that were calculated for systems that are based on a cut that occurs on a 25-year cycle.
[d] This stand type is missing one option that was included in the published version of the Lieffers *et al* (1996) paper but was not included in the draft version used as a basis for this thesis.
[e] Note: These factors are very high because the inflexibility of the provincial yield tables in accounting for varying stand types caused a very large discrepancy between the experts estimates and the yield table predictions..

Note: The shaded rows are options that were not in the Lieffers *et al* (1996) paper, but were included for purposes of comparison in this analysis. Rows with no information in them are ones where the participants were unable to provide information on the system.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Stumpage Values and Expectations

Table 4-1 shows the estimates gathered from the questionnaire regarding stumpage values and their expected change over time. The following three stumpage rate combinations were used in the analysis: $3.00/m^3 for aspen and $8.00/m^3 for spruce; $5.00/m^3 for aspen and $15.00/m^3 for spruce; and finally, $10.00/m^3 for aspen and $30.00/m^3 for spruce. Overall the participants predicted that the value of aspen would increase almost twice as much over the next one hundred years as that of spruce. Although the expected price increases are not directly captures in the following economic analysis, sensitivity analysis with respect to prices and interest rates captures their expectations indirectly.

Table 4-1. Expected changes in Stumpage Value.

Statistics	Aw - Expected Change (%/year)	Sw – Expected Change (%/year)
Average:	2.75	1.63
No. of Observations	5	5
Stand. Deviation	1.71	1.11

4.2 Costs

Table 4-2 presents the way in which the harvesting costs associated with each of the systems were incorporated into the analysis. The questionnaire asked participants how much each option would cost on a per hectare basis. However, the participants found it easier to estimate the average increase in logging costs per meter cubed associated with the partial cut categories of silviculture systems relative to the clearcut scenarios.

Accordingly, these increased costs were interpreted to be stumpage penalties associated with the non-clearcut systems. The average amount of the stumpage penalties was then deducted from the stumpage collected for non-clearcut systems. Thus, if the option was a variant of a shelterwood system a penalty of -$7.00/m^3 was imposed on the stumpage collected, to account of the increased logging costs associated with this type of system.

Table 4-2. Stumpage Penalties.*

Statistics	Clearcut	Understory Protec. & Shelterwood	Single Tree Selec. & Group Selec.
Average:	$0.00/m^3	-$7.00/m^3	-$9.00/m^3
No. of Obser.:	4	4	4
Stand. Dev.:	N/A	2.18	2.59

* Rounded to the nearest $0.50.

4.3 Yields and Silviculture Costs

The following tables (tables 5 to 11) summarise the information collected regarding the yields and silviculture costs associated with each of the silviculture options for each one of the eight, mixedwood stand types.

In some cases the standard deviations are alarmingly high. There are several possible explanations for the high standard deviations. One reason may be the inherent difference of growing conditions, including availability of seed source and soil conditions, between the respondents' management areas. Furthermore, the fact that these systems are not, for the most part, widely used in Alberta may have meant that the participants were not familiar enough with them to respond to specific questions regarding costs and yields. A second reason might be that interpretation of some of the questions might have varied across participants. For example, the description of the different silviculture options may not have been specific enough with regards to the availability of seed source and other relevant factors. Finally, the respondents may not have been familiar with the less common stand types (i.e. VII, and VIII).

One option considered was to eliminate those silvicultural options with high standard deviations from the analysis. However, all options were included in the analysis because the emphasis was on collecting all currently available information on these systems and identifying areas where information is lacking. Therefore, the financial results that follow should be interpreted within the context of the variability shown in tables 4-3 through 4-9.

The results reported in tables 4-3 through 4-9 are organised as follows. The first two columns of the table show the provincial yield estimates for aspen and spruce from an average mixedwood stand on a medium site. The average volume estimates collected from the experts for aspen and spruce for the first and second cut (Aw Vol. 1 and 2, and Sw Vol. 1 and 2, respectively) are given in the next four columns of the table. The last four columns of the table are devoted to reporting the estimates of silviculture costs collected in the questionnaire. They are listed under the heading "SilvC."

4.3.1 Clearcutting

Tables 4-3 summarises information gathered on clearcutting and allowing the sites to sucker to aspen in the different stand types. In all but three cases, the participants estimate of aspen yield for the first and second cut was higher than what was predicted by the provincial yield tables. Not unexpectedly, the provincial estimates for the coniferous portion of the first and second cuts were consistently higher than those provided by the experts. This is due to the lack of suitability of the provincial yield tables to this type of application. As mentioned previously, the tables are based on averages of coniferous and deciduous yields from a full spectrum of stand types. Given the above scenario (i.e. clearcut the initial stand and then allow the site to sucker to aspen) the provincial tables will overestimate the coniferous portion of the second cut because the silvicultural system is deliberately reducing the naturally occurring coniferous component of the second-generation stand. Another trend apparent in the table is that the estimate of volume given for aspen is also generally higher than what is predicted by the provincial tables. This trend has a different basis than the one previously discussed. It is due to the fact that the majority of the experts solicited were of the opinion that, overall, the provincial yield estimates were too conservative in their predictions of yield. Regeneration delay (the 8 and 9 columns in tables 4-3) refers to the amount of time it will take for preferred crop trees to be established on a site. Given these silvicultural scenarios, this was sometimes difficult to estimate in a consistent fashion. For example, scenario VIIb involves clearcutting a predominantly uneven-aged stand of conifers and then allowing the site to sucker to aspen.

Table 4-3. Clear Cutting (no regeneration treatments) - Averages, and Standard Deviations (Number of observations appear in italics).

Stand Type and System	Aw Vol. Phase III	Sw Vol. Phase III	Aw Vol. (1) (m^3/ha)	Sw Vol. (1) (m^3/ha)	Aw Vol. (2) (m^3/ha)	Sw Vol. (2) (m^3/ha)	Aw Regen Delay	Sw Regen Delay	SilvC (1)[a] ($/ha)	SilvC (2)[b] ($/ha)
Ia. (D) (vigorous)	64.93	144.97	146.00 (31.10) *5*	20.00 (7.07) *5*	146.00 (31.10) *5*	16.00 (11.40) *5*	0.40 (0.89) *2*	11.25 (8.84) *2*	16.25 (2.50) *4*	16.25 (2.50) *4*
IIa. (D) (breaking up)	109.94	199.93	118.00 (79.42) *5*	26.25 (12.94) *5*	121.99 (53.47) *5*	25.00 (16.58) *5*	0.60 (0.89) *2*	15.00 (7.07) *2*	16.25 (2.50) *4*	16.25 (2.50) *4*
IIIe. (C)	64.93	144.97	44.99 (26.91) *5*	182.49 (76.21) *5*	121.99 (43.12) *5*	21.00 (12.45) *5*	0.40 (0.89) *2*	27.50 (10.61) *2*	16.25 (2.50) *4*	16.25 (2.50) *4*
IVb. (D) *Understory*, short even-aged C	64.93	144.97	156.00 (53.08) *5*	20.00 (7.42) *5*	160.00 (51.60) *5*	27.00 (8.37) *5*	0.40 (0.89) *2*	11.00 (8.49) *2*	16.25 (2.50) *4*	16.25 (2.50) *4*
Vb. Deciduous *Understory*, short even-aged C	64.93	144.97	133.99 (48.17) *5*	35.00 (18.71) *5*	133.99 (48.17) *5*	21.00 (10.25) *5*	4.00 (8.94) *2*	10.00 (14.14) *2*	16.25 (2.50) *4*	16.25 (2.50) *4*
VIc. (D) *Understory*,short uneven-aged C	64.93	144.97	136.23 (55.31) *5*	33.33 (26.46) *5*	151.23 (80.69) *5*	16.25 (7.50) *5*	0.50 (1.00) *2*	17.50 (17.68) *2*	16.25 (2.50) *4*	16.25 (2.50) *4*
VIIb. Uneven-age Coniferous	64.93	144.97	28.00 (16.43) *5*	157.49 (26.79) *5*	74.97 (35.19) *5*	46.00 (40.99) *5*	0.40 (0.89) *2*	-20.00 (42.43) *2*	16.25 (2.50) *4*	16.25 (2.50) *4*
VIIIc. (C) *Understory*, pockets of C	64.93	144.97	41.25 (14.36) *5*	104.99 (83.20) *5*	96.23 (22.90) *5*	25.00 (17.32) *5*	1.00 (1.41) *2*	11.00 (1.41) *2*	16.25 (2.50) *4*	16.25 (2.50) *4*

[a] Cost of one survey in year 6.
[b] Cost of one survey in year 13.

4.3.2 Clearcutting with regeneration treatments

Tables 4-4 summarises the results of the clearcutting, and planting to conifer option. In some cases, site preparation and vegetation treatments were also prescribed. In tables 4-4, the participants' estimates of coniferous yield were somewhat higher than the provincial estimates in every case except for initial harvest of the deciduous stand type. The clearcutting and planting option, as well as clearcutting without any silviculture, produced the highest combined coniferous and deciduous yields of all of the options examined in Tables 5-11 in the initial harvest. However, if all the yields from all the different scenarios are averaged for the first cut and for the second cut, only three of the thirteen clearcutting scenarios produced above average yields for the second cut. The average estimate of the regeneration delay for spruce in scenarios where the site was planted with spruce directly after harvest, and received one aerial application of glyphosate, was 2 years. The estimates of spruce regeneration delay were longer where aerial seeding was utilised or when no herbicide was applied. Aspen regeneration delay was related to the use of herbicide as well as to site characteristics.

Table 4-4. Clear Cutting with Regeneration Treatments - Averages, and Standard Deviations (Number of observations appear in italics).

Stand Type and System	Aw Vol. Phase III	Sw Vol. Phase III	Aw Vol. (1) (m^3/ha)	Sw Vol. (1) (m^3/ha)	Aw Vol. (2) (m^3/ha)	Sw Vol. (2) (m^3/ha)	Aw Regen Delay	Sw Regen Delay	SilvC (1)[b] ($/ha)	SilvC (2)[a] ($/ha)	SilvC (3)[c] ($/ha)	SilvC (4)[a] ($/ha)
IIc. Decid. Breaking up	**109.94**	**199.93**	97.99 (41.34) *5*	95.00 (123.29) *5*	39.00 (48.79) *5*	286.00 (80.50) *5*	1.00 (0.71) *2*	2.00 (1.41) *2*	958.75 (221.98) *4*	16.25 (2.50) *4*	241.25 (27.80) *4*	16.25 (2.50) *4*
IIIa. (C)	**64.93**	**144.97**	42.40 (15.45) *5*	182.49 (55.31) *5*	51.00 (45.61) *5*	259.00 (72.84) *5*	0.00 (0.00) *2*	2.00 (1.41) *2*	920.00 (258.84) *4*	16.25 (2.50) *4*	241.25 (27.80) *4*	16.25 (2.50) *4*
IIIb. (C)	**64.93**	**144.97**	34.00 (13.42) *5*	163.74 (25.36) *5*	66.00 (66.09) *5*	191.99 (39.79) *5*	1.00 (1.41) *2*	8.50 (4.95) *2*	460.00 (121.93) *4*	16.25 (2.50) *4*	241.25 (27.80) *4*	16.25 (2.50) *4*
VIIa. Uneven - Age (C)	**64.93**	**144.97**	21.80 (17.78) *5*	156.23 (50.34) *5*	41.00 (36.12) *5*	197.00 (113.67) *5*	5.00 (7.07) *2*	2.50 (2.12) *2*	861.25 (135.55) *4*	16.25 (2.50) *4*	16.25 (2.50) *4*	16.25 (2.50) *4*
VIIIa. (C) *Understory*, Pockets of C	**64.93**	**144.97**	30.00 (20.00) *5*	158.74 (90.17) *5*	70.00 (60.00) *5*	154.00 (80.81) *5*	1.00 (1.41) *2*	4.00 (0.00) *2*	861.25 (135.55) *4*	16.25 (2.50) *4*	16.25 (2.50) *4*	16.25 (2.50) *4*

[a] Cost of one survey in year 4 (SilvC (1)) and one in year 15 (SilvC (4)).
[b] Cost of site preparation and planting in year 0 (except option IIIb, which is aerial seeded instead of planted).
[c] Cost of one survey and one aerial glyphosate treatment in year 8 (except options VIIa and VIIIa where it only includes the cost of one survey).

4.3.3 Understory protection

Tables 4-5 summarises the results of the understory protection options. Once again yields estimated by the experts and those predicted by the provincial yield tables differ because of the lack of flexibility in the yield tables. The concept of a regeneration delay becomes less meaningful when using understory protection techniques. All of these scenarios assume an existing spruce understory which is preserved. This implies that there are trees on the site throughout the entire cutting cycle, in effect eliminating any regeneration delay. This is reflected in the largely negative numbers which the respondents gave for the spruce regeneration delay (column 9 in tables 4-5). The negative number represents the average age of the trees remaining on the site after the first cut. When compared to the average yield predicted by the experts for the first and second cut, five of the eight understory protection scenarios produced volumes that were higher than average. After the second harvest, three of the eight placed in the above average category. When compared to the average volumes produced by the clearcutting scenarios, the understory protection techniques produced lower combined aspen and spruce volumes in the first cut and substantially higher combined volumes in the second cut, due to increased spruce yield generated by these systems.

Table 4-5. Understory Protection - Averages, and Standard Deviations (Number of observations appear in italics).

Stand Type and System	Aw Vol. Phase III	Sw Vol. Phase III	Aw Vol. (1) (m^3/ha)	Sw Vol. (1) (m^3/ha)	Aw Vol. (2) (m^3/ha)	Sw Vol. (2) (m^3/ha)	Regen Delay Aw	Regen Delay Sw	SilvC (1)[a] ($/ha)	SilvC (2)[b] ($/ha)	SilvC (3)[b] ($/ha)	SilvC (4)[c] ($/ha)
Ib. (D) (vigorous)	64.93	144.97	146.00 (31.10) *5*	16.67 (5.00) *5*	115.00 (36.97) *5*	188.99 (69.32) *5*	0.00 (0.00) *2*	-15.00 (0.00) *2*	781.25 (128.1) *4*	16.25 (2.50) *4*	16.25 (2.50) *4*	- - -
Ic. (D) (vigorous)	64.93	144.97	138.99 (35.79) *5*	16.67 (5.00) *5*	78.75 (43.28) *5*	206.00 (75.37) *5*	1.00 (1.41) *2*	10.00 (12.73) *2*	- - -	16.25 (2.50) *4*	16.25 (2.50) *4*	862.50 (2.45) *4*
IIb. (D) (breaking-up)	109.94	199.93	125.99 (79.18) *5*	25.00 (12.25) *5*	85.00 (50.66) *5*	190.99 (69.86) *5*	0.00 (0.00) *2*	-7.00 (11.31) *2*	793.50 (123.2) *4*	16.25 (123.1) *4*	16.25 (2.50) *4*	- - -
IVa. (D) *Under* – short even-aged C	64.93	144.97	154.00 (54.01) *5*	28.75 (30.12) *5*	130.00 (127.9) *5*	132.00 (62.61) *5*	37.50 (53.03) *2*	-7.50 (24.75) *2*	- - -	16.25 (2.50) *4*	16.25 (2.50) *4*	- - -
Va. (D) *Under.* – tall even-aged C	64.93	144.97	121.99 (49.59) *5*	40.00 (34.64) *5*	22.00 (8.37) *5*	148.00 (74.63) *5*	20.00 (28.28) *2*	-30.00 (42.43) *2*	- - -	16.25 (8.63) *4*	16.25 (2.50) *4*	- - -
Vc. (D) *Under.* – tall even-aged C	64.93	144.97	102.00 (43.82) *5*	48.75 (34.35) *5*	33.00 (28.20) *5*	160.00 (60.42) *5*	30.50 (41.72) *2*	-30.00 (42.43) *2*	- - -	16.25 (8.04) *4*	16.25 (2.50) *4*	- - -
VIb. (D) *Understory* - even-aged C	64.93	144.97	116.97 (56.00) *5*	47.50 (27.93) *5*	51.00 (36.47) *5*	134.99 (50.99) *5*	1.50 (0.71) *2*	-25.00 (35.36) *2*	- - -	16.25 (11.05) *4*	16.25 (2.50) *4*	- - -

a Cost of understory site preparation and underplanting.
b Cost of surveys.
c Cost of understory site preparation and underplanting.

4.3.4 Shelterwood Systems

Shelterwood systems rely on leaving some trees on the site to act as a seed source for the next crop as well as to help reduce competition on the site by intolerant shrubs and grasses. Tables 4-6 contains the results for a shelterwood system applied to the coniferous stand. These systems also produced below average volumes as compared to all other options. The respondents estimated that it would take an average of eight years for spruce seedling to become established on the site, with the primary seed source being the shelter/seed trees left on the site after the seeding cut. It was estimated that aspen would take an average of one year to establish themselves after the initial seeding cut.

Table 4-6. Shelterwood- Averages, and Standard Deviations (Number of observations appear in italics).

Stand Type and System	**Aw Vol. Phase III**	**Sw Vol. Phase III**	Aw Vol. (0) (m^3/ha)	Sw Vol. (0) (m^3/ha)	Aw Vol. (1) (m^3/ha)	Sw Vol. (1) (m^3/ha)	Aw Regen Aw	Sw Regen Sw	SilvC (1)[a] ($/ha)	SilvC (2)[a] ($/ha)	SilvC (3)[a] ($/ha)
IIIf. (C)	**6.49**	**57.10**	48.75 (45.89) *4*	85.00 (24.96) *4*	20.00 (21.60) *4*	136.24 (49.05) *2*	1.00 (1.41) *2*	8.00 (5.66) *2*	16.25 (2.50) *4*	16.25 (2.50) *4*	16.25 (2.50) *4*

[a] Cost of surveys in years 4, 8, and 15.

Tables 4-7 summarises the results of the irregular shelterwood scenario. This scenario, which involves enlarging patches of advanced regeneration using shelterwood cutting techniques, produced the below average volumes as compared to all other options.

Table 4-7. Irregular Shelterwood - Averages, and Standard Deviations (Number of observations appear in italics).

					Every 25 years				
System and Stand Type	**Aw Vol. Phase III**	**Sw Vol. Phase III**	Aw Vol. (0) (m^3/ha)	Sw Vol. (0) (m^3/ha)	Aw Vol. (25) (m^3/ha)	Sw Vol. (25) (m^3/ha)	SilvC (1)[a] ($/ha)	SilvC (2)[a] ($/ha)	SilvC (3)[a] ($/ha)
VIIIb. (C) *Understory -* C (clustered)	**1.10**	**26.09**	10.00 (0.00) *3*	37.33 (8.74) *3*	3.33 (5.77) *3*	37.33 (8.74) *3*	16.25 (2.50) *2*	16.25 (2.50) *2*	16.25 (2.50) *2*

[a] Cost of surveys in years 4, 8, and 15.

4.3.5 Uneven-aged systems

The management framework for even-aged stands is built around the rotation and the stand, which is classified by age or size class. In uneven-aged management, stands are not classified by age or tree size. Instead, they are described by volume, structure, and composition. Because stands are mixed in age, there is no beginning or end of a strand in point of time and the concept of regeneration delay becomes less useful. Uneven aged silvicultural systems concentrate on individual trees or groups of trees (Davis 1966).

Group selection involves the removal of mature timber in small groups at relatively short interval, repeated indefinitely by means of which the continuous establishment of new seedlings is encouraged and an uneven-aged stand is maintained (Smith 1962). Theoretically, group selection should produce the same volume of timber as clearcutting only this volume is removed at 25 year intervals over a one-hundred-year period, instead of all at once at the end of the 100 year rotation. However, according to the results printed in tables 4-8, this system produces above average volumes as compared the average volumes produced by the clearcutting scenarios over a one hundred year period (308 m^3/ha of combined aspen and spruce, as opposed to 212 m^3/ha for the clearcutting scenarios). As this variation of group selection relies on natural regeneration, the only silvicultural costs are the surveying costs.

Table 4-8. Group Selection - Averages, and Standard Deviations (Number of observations appear in italics).

All costs and volumes occur at the end of every 25 year cutting cycle.							
System and Stand Type	**Aw Vol. Phase III**	**Sw Vol. Phase III**	Aw Vol. (25) (m^3/ha)	Sw Vol. (25) (m^3/ha)	SilvC (1)[a] ($/ha)	SilvC (2)[a] ($/ha)	SilvC (3)[a] ($/ha)
IIIh. (C)	**16.23**	**36.24**	33.50 (51.53) *5*	42.19 (14.49) *5*	16.25 (2.50) *4*	16.25 (2.50) *4*	16.25 (2.50) *4*

[a] Cost of surveys in years 4, 8, and 15.

Tables 4-9a and 4-9b presents the results of the single tree selection scenario. This is more complicated silvicultural system in which individual trees are removed from the stand according to their diameter, the object being to keep the number of trees in each diameter class such that a continuous supply of merchantable trees is always available for harvest. On average, this system also produced higher volumes than did clearcutting over a one hundred year period.

Table 4-9a. Single Tree Selection - Averages, and Standard Deviations.[a]

Stand Type and System	**Aw Vol. (0) Phase III**	**Sw Vol. (0) Phase III**	Aw Vol. (0) (m^3/ha)	Sw Vol. (0) (m^3/ha)	**Aw Vol. (25) Phase III**	**Sw Vol. (25) Phase III**	Aw Vol. (25) (m^3/ha)	Sw Vol. (25) (m^3/ha)
VIa. Deciduous *Understory* - C (size range)	**43.83**	**10.87**	102.00 (50.32) *5*	17.81 (14.91) *5*	**14.61**	**3.62**	32.00 (7.58) *5*	24.25 (19.99) *5*
	Costs and Yields per 25 year Cutting Cycle							
	Aw Phase III	**Sw Phase III**	Aw (m^3/ha)	Sw (m^3/ha)	SilvC (1)[a] ($/ha)	SilvC (2)[a] ($/ha)	SilvC(3)[b] ($/ha)	
	14.61	**3.62**	12.00 (13.04) *5*	67.00 (53.83) *5*	26.81 (6.09) *2*	16.67 (2.89) *2*	16.67 (2.89) *2*	

[a] Note: The upper portion of the table relates to the process of converting the stand to unevenaged management, while the lower portion of the table is representative of the of the stand once the conversion process is complete.
[b] Cost of surveys in years 4, 8, and 15.

Table 4-9b. Single Tree Selection - Averages, and Standard Deviations.

					Every 25 years				
Stand Type & System	**Aw Vol. Phase III**	**Sw Vol. Phase III**	Aw Vol. (0) (m^3/ha)	Sw Vol. (0) (m^3/ha)	Aw Vol. (25) (m^3/ha)	Sw Vol. (25) (m^3/ha)	SilvC (1)[a] ($/ha)	SilvC (2)[a] ($/ha)	SilvC (3)[a] ($/ha)
VIId. Coniferous (size range)	**1.62**	**32.62**	21.00 (14.32) *5*	73.13 (44.57) *5*	17.00 (17.18) *5*	71.50 (44.57) *5*	16.25 (2.50) *4*	16.25 (2.50) *4*	16.25 (2.50) *4*

[a] Cost of surveys in years 4, 8, and 15.

4.4 Economic Analysis

The following tables depict the calculated results for the value of the initial harvest (NPV_{R0}), net present value of the first rotation (NPV_{R1}), the value of the stand into perpetuity (NPV_{R2+}), and the sum of these tree values that make up the land expectation value (LEV). The shaded areas in the tables highlight the stumpage and interest rate combinations that produced negative values. In addition, the tables are divided into two vertical parts. The left part describes the results obtained when the rotation age used is the same as the one used in the scenario. The right part of the table describes the results obtained when the optimum economic rotation (OER) is employed. Where no OER analysis was attempted the left half of the table is filled with dashes.

4.4.1 Vigorous Deciduous Stands

Tables 4-10 gives the results of the economic analysis of the three silvicultural options proposed by Lieffers *et al* for an even aged (70 year old), vigorous deciduous stand. The first option consisted of clearcutting the stand every 70 years. This method produced positive LEVs for every combination of stumpage and interest rates. This was due to the large positive value of the initial harvest subsidising future costs when higher interest rates where employed in the analysis. This implies that that value of all future harvests is not enough to support the cost of the two required regeneration surveys. In addition, it implies that the losses incurred are being subsidised by currently existing stock. The results obtained when the optimum economic rotation was used were very similar to those obtained by using the conventional rotation age. In most cases, the increase in the LEV was in the range of $0.20 - $5.00 per hectare.

The second option examined for this stand type was under-planting the existing stand, harvesting using understory protection techniques 15 years later, and finally, clear cutting the conifers 100 years later. Because the first cut does not occur until year 15, an NPV_{R0} values does not exist for this silvicultural option. In addition, it was assumed that this system could be perpetuated after the first rotation as option Ia. Thus, the NPV_{R2+} used are identical to the ones resulting from that option. This scenario yielded negative values for almost every measure, stumpage combination and interest rate used in this analysis. From tables 4-10 one can see that in only one case was there a positive LEV value, when the lowest interest rate and the highest stumpage value were employed in the calculations. This result is due to the fact that that the NPV_{R2+} derived from option Ia was large enough to offset the loss incurred after the first rotation. An interesting trend evident in the table is that as interest rates increase, the losses incurred become smaller. This is due to the fact that as the interest rate rises future losses are being discounted by a larger and larger amount.

The final option examined for this stand type was a variant of understory protection. In this case the stand was clear cut initially and then allowed to grow for 15 years before it was under-planted. This option gave more positive values than the method described above (Ib) and, in fact, resulted in a pattern of values similar to those from clearcutting this type of a stand. The land expectation values produced by this option were all positive (except where the lowest stumpage combination and interest rate were used), due again almost entirely to the large positive value of the initial harvest. Once again, when harvesting occurred at the economic optimum the values were very close to those resulting from cutting the stand at the conventional rotation age.

Table 4-10. Financial calculations for stand Type I. Deciduous Stand (Vigorous).

Stumpage ($/m³)	Interest Rate (%)	NPV$_{R0}$ ($/ha)	NPV$_{R1}$ ($/ha)	NPV$_{R2+}$[4] ($/ha)	LEV ($/ha)	*LEV ($/ha)	*Rotation Age
(a.) Clearcut, Sucker							
		Rotation = 70				Rotation = *	
$3.00/m³	2	598.00	114.52	38.18	750.70	800.28	89
&	5	598.00	-2.14	-0.07	595.79	596.08	73
$8.00/m³	10	598.00	-13.16	-0.02	584.82	584.90	64-65
$5.00/m³	2	1030.00	215.54	71.86	1317.39	1406.28	89
&	5	1030.00	11.14	0.38	1041.51	1042.10	73
$15.00/m³	10	1030.00	-12.65	-0.02	1017.33	1017.45	64-66
$10.00/m³	2	2060.00	458.06	152.71	2670.77	2845.14	89
&	5	2060.00	43.02	1.46	2104.48	2105.55	73
$30.00/m³	10	2060.00	-11.42	-0.01	2048.56	2048.82	65
(b.) Late Under Plant, Understory Protection							
		Rotation = 100				Rotation = *	
$3.00/m³	2	N/A	-1237.03	38.18	-1198.85	-	-
&	5	N/A	-1083.88	-0.07	-1083.95	-	-
$8.00/m³	10	N/A	-941.11	-0.02	-941.13	-	-
$5.00/m³	2	N/A	-902.64	71.86	-830.78	-	-
&	5	N/A	-856.56	0.38	-856.18	-	-
$15.00/m³	10	N/A	-812.53	-0.02	-812.55	-	-
$10.00/m³	2	N/A	-106.97	152.71	45.74	-	-
&	5	N/A	-317.64	1.46	-316.18	-	-
$30.00/m³	10	N/A	-510.41	-0.01	-510.42	-	-
(c.) Early Underplant, Understory Protection							
		Rotation = 115				Rotation = *	
$3.00/m³	2	616.39	-806.92	-92.22	-282.75	-205.82	173+
&	5	616.39	-442.98	-1.63	171.79	173.72	173+
$8.00/m³	10	616.39	-210.48	0.00	405.90	405.91	173+
$5.00/m³	2	1060.65	-544.20	-62.19	454.26	467.69	132
&	5	1060.65	-424.16	-1.56	634.94	635.26	106
$15.00/m³	10	1060.65	-209.96	0.00	850.69	850.73	93-94
$10.00/m³	2	2121.30	49.35	5.64	2176.30	2176.46	116
&	5	2121.30	-380.36	-1.40	1739.55	1745.09	97
$30.00/m³	10	2121.30	-208.70	0.00	1912.60	1912.86	88

[4] Note that because the assumption was made that stand Ib continues as Ia for harvest into perpetuity all of the NPV$_{R2+}$ values are the same as those from scenario Ia.

4.4.2 Deciduous Stands (Breaking-up)

Stand type II represents relatively pure, old aspen stands that are losing vigour and suffering mortality. Three options were also examined for this stand type and are summarised in tables 4-11 below. The first option was clearcutting the stand every 70 years and allowing the site to sucker back to aspen. This option produced the same pattern of results as it did when applied to a vigorous deciduous stand type, with initial harvests generally subsidising subsequent cuts. One cause for this similar outcome may be that the experts solicited for this investigation viewed both stand types as being relatively homogenous. It is interesting to note that provincial yield tables predicted that these older stand types would have more volume than the younger ones. However, all of the experts contacted felt the opposite was true, namely that the older stand would have similar (though slightly lower) volumes than the younger aspen stands. As with stand type Ia, harvesting at the optimum economic rotation did not greatly impact the land expectation values.

The second option examined was moving these stands to a coniferous dominated system by underplanting 10 years prior to harvesting the aspen, similar to option Ib described previously. This scenario also yielded negative values for almost every stumpage combination and interest rate used in this analysis. Again, the only positive LEV occurred when the lowest interest rate and the highest stumpage value were employed in the calculations, and was again due to the fact that that the NPV_{R2+} used were derived from option IIa, and in this case was large enough to offset the loss incurred after the first rotation. As this option was not repetitive no attempt was made at determining the optimum economic rotation.

The third option explored was converting these stands into relatively pure spruce stands by clearcutting, heavy site preparation, and planting with large spruce stock, followed by vegetation control in the next decade. The value of the initial harvest was positive in every case. However, at every stumpage and interest rate combination, the results for NPV_{R1}, and NPV_{R2+} were negative. Despite these results, the land expectation values were positive at the mid and highest stumpage rates because of the subsidising effect of the value of the initial harvest. The seeming anomaly of LEV values that decrease at 5% and then increase again at 10% rates of interest, are due to the fact that as the interest rate rises, future losses are being discounted by a larger and larger amount causing the NPV_{R2+} values begin to approach zero. For example at the lowest stumpage combination and a 10% interest rate NPV_{R2+} drops from -$145.62/ha to -$0.08/ha, thereby having the effect of increasing the LEV. Once again, when the optimum economic rotation was used, the results were very similar to those found using the expert estimated rotation age.

Table 4-11. Financial calculations for Stand Type II. Deciduous (Breaking-up).

Stumpage ($/m³)	Interest Rate (%)	NPV_{R0} ($/ha)	NPV_{R1} ($/ha)	NPV_{R2+}[5] ($/ha)	LEV ($/ha)	*LEV ($/ha)	*Rotation Age
(a.) Clearcut, Sucker							
			Rotation = 70			Rotation = *	
$3.00/m³	2	889.98	114.51	38.18	1042.68	1114.90	91
&	5	889.98	-2.14	-0.07	887.77	888.75	75
$8.00/m³	10	889.98	-13.16	-0.02	876.80	876.83	67
$5.00/m³	2	1543.62	219.27	73.10	1835.99	1967.64	91
&	5	1543.62	11.63	0.40	1555.64	1557.53	75
$15.00/m³	10	1543.62	-12.63	-0.02	1530.97	1531.02	67
$10.00/m³	2	3087.24	465.53	155.20	3707.97	3967.60	91
&	5	3087.24	44.00	1.50	3132.74	3136.36	75
$30.00/m³	10	3087.24	-11.39	-0.01	3075.84	3075.93	67
(b.) Late Under Plant, Understory Protection							
			Rotation = 100			Rotation = *	
$3.00/m³	2	N/A	-1302.85	38.18	-1264.67	-	-
&	5	N/A	-1127.55	-0.07	-1127.63	-	-
$8.00/m³	10	N/A	-964.79	-0.02	-964.81	-	-
$5.00/m³	2	N/A	-859.92	73.10	-786.82	-	-
&	5	N/A	-830.29	0.40	-829.89	-	-
$15.00/m³	10	N/A	-801.86	-0.02	-801.87	-	-
$10.00/m³	2	N/A	180.15	155.20	335.35	-	-
&	5	N/A	-133.99	1.50	-132.50	-	-
$30.00/m³	10	N/A	-422.60	-0.01	-422.62	-	-
(c.) Clearcut, Site Prep., Plant to C.							
			Rotation = 100			Rotation = *	
$3.00/m³	2	1053.96	-909.34	-145.62	-1.00	24.13	116
&	5	1053.96	-1168.98	-8.96	-123.98	-123.86	97
$8.00/m³	10	1053.96	-1123.60	-0.08	-69.72	-69.67	87
$5.00/m³	2	1914.93	-622.23	-99.64	1193.05	1202.50	107
&	5	1914.93	-1153.16	-8.84	752.93	756.59	89
$15.00/m³	10	1914.93	-1123.45	-0.08	791.40	791.76	80
$10.00/m³	2	3829.86	-3.16	-0.51	3826.20	3827.44	102
&	5	3829.86	-1119.06	-8.58	2702.23	2718.16	84
$30.00/m³	10	3829.86	-1123.12	-0.08	2706.65	2707.98	76

[5] Note that because the assumption was made that stand IIb continues as IIa for harvest into perpetuity all of the NPV_{R2+} values are the same as those from scenario IIa.

4.4.3 Coniferous Stands

Tables 4-12 summarises the results of the different options examined for predominantly coniferous stand types. The first option examined for this stand type was to continue to manage the stand as a relatively pure conifer stand by planting white spruce immediately following site preparation. This option produces positive land expectation values at every combination of stumpage and interest rates. However, all of the NPV_{R2+} values are negative, except at the highest stumpage values and the lowest interest rates, indicating that the initial harvest is subsidising subsequent cuts. As in all the previous cases, harvesting at the economic optimum does not increase the land expectation value of the site substantially. For example, at the lowest interest and stumpage rate combination, waiting an additional 15 years to harvest the stand only increases the LEV by $20.66/ha.

The second option examined for this stand type was identical to the previous option described, only the site was seeded to white spruce rather than planted The results calculated for this option were very similar to those produced by option "a". However, as the costs of aerial seeding were lower than those for planting, NPV_{R1} and NPV_{R2+} were positive at mid level stumpage values and interest rates of 2% as well as at the highest stumpage values and interest rates of 2%. Once again, LEVs were positive in all cases, due the subsidising effect of the large positive value of the initial harvest. Again, harvesting at the economically optimal age did not produce dramatically different results from harvesting at the conventional rotation age.[6]

Option "e" involved clearcutting the stand and allowing it to sucker back to a

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6 Options "c" and "d" were dropped from the analysis because of a lack of responses from the participants.

relatively pure stand of aspen. This option had even lower silvicultural costs than the two previously described scenarios and this resulted in NPV_{R2+} values that were positive at lower stumpage values and higher interest rates values than options "a" and "b". Once again land expectation values were positive under all circumstances. As in option "b", harvesting at the optimum did not result in dramatically different land expectation values.

The next option examined was a shelterwood scenario. At the lowest stumpage rates, the value of the initial harvest was negative due to the higher logging costs, and accompanying stumpage penalty, associated with this system. However, at mid and higher stumpage values, NPV_{R0} was positive. As it was assumed that this system could not be perpetuated, the NPV_{R2+} values were taken from the scenario IIIe. Despite the fact that some of these values were negative, LEV for this site was positive when mid and high stumpage rates were employed.[7]

The final scenario examined for this stand type was a group selection system. In this case, patches of forest in openings one to two tree heights in diameter are removed on a 25-year cycle. This technique yielded negative results at the lowest stumpage rates, largely due to the stumpage penalty for higher harvest costs. At the mid and highest stumpage rate combination the NPV_{R0} values became positive. This is due to the fact that at these levels the increased stumpage rates begin to compensate for the increased logging costs associated with this type of silviculture system. At the mid and high stumpage rates the NPV_{R1} and NPV_{R2+} values are generally positive as well. LEVs were also all positive at mid and high stumpage rates.

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[7] Option "g" was dropped from the analysis due to a lack of responses from the survey participants.

Table 4-12. Financial calculations for Stand Type III. Coniferous.

Stumpage ($/m³)	Interest Rate (%)	NPV_{R0} ($/ha)	NPV_{R1} ($/ha)	NPV_{R2+}[8] ($/ha)	LEV ($/ha)	*LEV ($/ha)	*Rotation Age
(a.) Clear Cut, Site Prep., Plant to C, Veg. Management							
		Rotation = 70				Rotation = *	
$3.00/m³	2	1587.08	-800.63	-128.21	658.24	678.90	115
&	5	1587.08	-1051.68	-8.06	527.34	527.51	96
$8.00/m³	10	1587.08	-1022.65	-0.07	564.36	564.41	87-88
$5.00/m³	2	2949.28	-715.05	-114.51	1207.29	1220.82	106
&	5	2949.28	-1046.97	-8.02	981.86	982.87	88
$15.00/m³	10	2949.28	-1022.51	-0.07	1014.17	1014.31	80
$10.00/m³	2	5898.55	35.16	5.63	5939.34	5939.99	101
&	5	5898.55	-1005.64	-7.71	4885.21	4900.54	84
$30.00/m³	10	5898.55	-1022.21	-0.07	4876.27	4877.52	76
(b.) Clear Cut, Site Prep., Seed to C, Veg. Management.							
		Rotation = 100				Rotation = *	
$3.00/m³	2	1411.88	-193.35	-30.96	1187.57	1189.41	105
&	5	1411.88	-369.57	-2.83	1039.48	1041.58	87
$8.00/m³	10	1411.88	-323.80	-0.02	1088.06	1088.27	77
$5.00/m³	2	2626.03	10.38	1.66	2638.07	2638.14	101
&	5	2626.03	-358.35	-2.75	2264.93	2271.51	83
$15.00/m³	10	2626.03	-323.69	-0.02	2302.31	2302.87	74
$10.00/m³	2	5252.05	453.45	72.61	5778.12	5778.98	98
&	5	5252.05	-333.94	-2.56	4915.55	4932.82	81
$30.00/m³	10	5252.05	-323.46	-0.02	4928.57	4929.96	73
(e.) Clearcut, Sucker							
		Rotation = 100				Rotation = *	
$3.00/m³	2	1594.90	106.51	35.51	1736.92	1798.62	90
&	5	1594.90	-3.19	-0.11	1591.59	1592.30	75
$8.00/m³	10	1594.90	-13.20	-0.02	1581.68	1581.71	66
$5.00/m³	2	2962.32	204.27	68.10	3234.68	3346.58	91
&	5	2962.32	9.66	0.33	2972.30	2973.68	75
$15.00/m³	10	2962.32	-12.71	-0.02	2949.59	2949.65	67
$10.00/m³	2	5924.64	435.52	145.20	6505.36	6725.50	90
&	5	5924.64	40.05	1.36	5966.05	5968.65	75
$30.00/m³	10	5924.64	-11.54	-0.01	5913.08	5913.20	67
(f.) Shelterwood.							
		Rotation = 100				Rotation = *	
$3.00/m³	2	-110.00	5.18	35.51	-69.31	-	-
&	5	-110.00	2.34	-0.11	-107.76	-	-
$8.00/m³	10	-110.00	-0.89	-0.02	-110.90	-	-
$5.00/m³	2	582.50	820.36	68.10	1470.96	-	-
&	5	582.50	612.39	0.33	1195.22	-	-
$15.00/m³	10	582.50	382.23	-0.02	964.71	-	-
$10.00/m³	2	2101.25	2578.89	145.20	4825.34	-	-
&	5	2101.25	1928.40	1.36	4031.01	-	-
$30.00/m³	10	2101.25	1208.69	-0.01	3309.93	-	-
(h.) Group Selection..							
		Rotation = 100				Rotation = *	
$3.00/m³	2	-243.19	-189.19	-295.32	-727.70	-	-
&	5	-243.19	-104.00	-43.58	-390.77	-	-
$8.00/m³	10	-243.19	-45.02	-4.58	-292.78	-	-
$5.00/m³	2	119.13	31.65	49.41	200.19	-	-
&	5	119.13	2.99	1.25	123.37	-	-
$15.00/m³	10	119.13	-11.58	-1.18	106.37	-	-
$10.00/m³	2	919.44	519.47	810.90	2249.81	-	-
&	5	919.44	239.33	100.29	1259.06	-	-
$30.00/m³	10	919.44	62.29	6.33	988.06	-	-

[8] Note that because the assumption was made that stand IIIf continues as IIIe for harvest into perpetuity all of the NPV_{R2+} values are the same as those from scenario IIIe.

4.4.4 Deciduous Stands with a Short Coniferous Understory

The next stand type to be examined was a deciduous stand with a short, even-aged coniferous understory. Two options were examined for this stand type and the results of the analysis can be found in Tables 4-13. The first was to harvest the stand using understory protection techniques. The method yielded negative NPV_{R0} values except at the highest stumpage rates. The value of the initial harvest was negative at lower stumpage rates because of the stumpage penalty imposed to capture the increased logging costs associated with understory protection techniques. NPV_{R1} was also negative except at the highest stumpage rate and lowest interest rates. Because it was assumed that the initial cut would produce a stand similar to that in IVb, the NPV_{R2+} values were based on the results of that scenario. These values only became negative at a 10% interest rate for each of the stumpage rate combinations. At the high stumpage values the LEV of the site becomes positive due, in part, to the large positive value of the initial harvest.

The second option was clearcutting the stand and allowing it to sucker to aspen. This produced positive results for all variables, except at an interest rate of 10%. At this interest rate NPV_{R1} and NPV_{R2+} were negative. Nevertheless, the land expectation values remained positive at all interest rates and stumpage values used. Once again, harvesting at the optimum economic rotation, did not produce dramatically different results from those produced at when harvesting at the conventional rotation age.

Table 4-13. Financial calculations for Stand Type IV. Deciduous Understory - short even-aged coniferous.

(a.) Understory Protection							
Rotation = 75						Rotation = *	
Stumpage ($/m^3)	Interest Rate (%)	NPV_{R0} ($/ha)	NPV_{R1} ($/ha)	NPV_{R2+}[9] ($/ha)	LEV ($/ha)	*LEV ($/ha)	*Rotation Age
$3.00/m^3	2	-587.25	-6.96	49.02	-545.19	-	-
&	5	-587.25	-0.50	0.07	-587.68	-	-
$8.00/m^3	10	-587.25	-13.26	-0.02	-600.53	-	-
$5.00/m^3	2	-78.00	269.67	91.44	283.11	-	-
&	5	-78.00	12.99	0.64	-64.37	-	-
$15.00/m^3	10	-78.00	-12.85	-0.02	-90.87	-	-
$10.00/m^3	2	1123.25	566.33	191.89	1881.46	-	-
&	5	1123.25	46.73	1.99	1171.97	-	-
$30.00/m^3	10	1123.25	-11.82	-0.01	1111.42	-	-
(b.) Clearcut, Sucker							
Rotation = 100						Rotation = *	
$3.00/m^3	2	628.00	147.03	49.02	824.04	902.45	90
&	5	628.00	2.13	0.07	630.20	631.05	74
$8.00/m^3	10	628.00	-13.00	-0.02	614.99	615.04	66
$5.00/m^3	2	1080.00	274.29	91.44	1445.74	1588.67	90
&	5	1080.00	18.86	0.64	1099.50	1101.19	75
$15.00/m^3	10	1080.00	-12.35	-0.02	1067.63	1067.71	66-67
$10.00/m^3	2	2160.00	575.58	191.89	2927.46	3209.80	90
&	5	2160.00	58.46	1.99	2220.45	2223.67	75
$30.00/m^3	10	2160.00	-10.83	-0.01	2149.16	2149.32	66

[9] Note that because the assumption was made that stand IVa continues as IVb for harvest into perpetuity all of the NPV_{R2+} values are the same as those from scenario IVb.

4.4.5 Deciduous Stands with a Tall Coniferous Understory

Stand type five represented deciduous stands with a tall coniferous understory. Three options were examined for this stand type. The results of the economic analysis are shown below in Tables 4-14. Option "a" and option "c" are variations of understory protection. It was assumed that after the first rotation these two options would be followed by clearcutting and allowing the site to sucker to aspen into perpetuity. Thus the NPV_{R2+} values are the same for both and are derived from option Vb. As with the other clearcutting alternatives, these technique proved to be unprofitable at the lowest stumpage rates, because of the increased logging costs. However, both the understory protection techniques produced positive land expectation values when the mid and highest stumpage rates were used in the sensitivity analysis. As both Va and Vc were not repeating techniques, no optimum economic rotations were determined. Clearcutting this type of stand and allowing it to sucker produced positive NPV_{R0} values for every stumpage combination and interest rate used in this analysis. The large positive value of the initial harvest subsidised the future costs associated with maintaining the stand, and allowed the LEV of the site to remain positive despite the fact that higher interest rate the NPV_{R1} and NPV_{R2+} values tended to become negative. Once again, harvesting the stand at the economic optimum, did not greatly effect the LEV of the site.

Table 4-14. Financial calculations for Stand Type V. Deciduous *Understory* - tall even-aged coniferous.

Stumpage ($/m³)	Interest Rate (%)	NPV_{R0} ($/ha)	NPV_{R1} ($/ha)	NPV_{R2+}[10] ($/ha)	LEV ($/ha)	*LEV ($/ha)	*Rotation Age
(a.) Understory Protection.							
		Rotation = 40				Rotation = *	
$3.00/m³	2	-447.94	-13.78	38.51	-423.22	-	-
&	5	-447.94	-23.66	-0.07	-471.67	-	-
$8.00/m³	10	-447.94	-21.24	-0.02	-469.20	-	-
$5.00/m³	2	76.03	475.34	73.10	624.47	-	-
&	5	76.03	129.75	0.40	206.17	-	-
$15.00/m³	10	76.03	2.62	-0.02	78.63	-	-
$10.00/m³	2	1285.96	1530.57	155.20	2971.73	-	-
&	5	1285.96	460.71	1.50	1748.17	-	-
$30.00/m³	10	1285.96	54.10	-0.01	1340.04	-	-
(b.) Clearcut, Sucker.							
		Rotation = 70				Rotation = *	
$3.00/m³	2	681.96	115.51	38.51	835.98	898.03	90
&	5	681.96	-2.01	-0.07	679.88	680.51	74
$8.00/m³	10	681.96	-13.16	-0.02	668.78	668.83	66
$5.00/m³	2	1194.93	219.27	73.10	1487.30	1599.72	90
&	5	1194.93	11.63	0.40	1206.95	1208.18	74
$15.00/m³	10	1194.93	-12.63	-0.02	1182.28	1182.35	66
$10.00/m³	2	2389.86	465.53	155.20	3010.59	3231.90	90
&	5	2389.86	44.00	1.50	2435.35	2437.68	74
$30.00/m³	10	2389.86	-11.39	-0.01	2378.46	2378.61	66
(c.) Understory Protection with Wind Protection.							
		Rotation = 60				Rotation = *	
$3.00/m³	2	-359.25	-32.42	38.51	-353.16	-	-
&	5	-359.25	-30.69	-0.07	-390.00	-	-
$8.00/m³	10	-359.25	-22.48	-0.02	-381.74	-	-
$5.00/m³	2	186.00	329.05	73.10	588.15	-	-
&	5	186.00	32.81	0.40	219.20	-	-
$15.00/m³	10	186.00	-18.58	-0.02	167.40	-	-
$10.00/m³	2	1427.25	1110.82	155.20	2693.27	-	-
&	5	1427.25	170.13	1.50	1598.87	-	-
$30.00/m³	10	1427.25	-10.16	-0.01	1417.08	-	-

10 Note that because the assumption was made that stands Va and Vc continue as Vb for harvest into perpetuity all of the NPV_{R2+} values are the same as those from scenario Vb.

4.4.6 Deciduous Stands with a Uneven-aged Coniferous Understory

The next stand type examined was a deciduous stand with an uneven-aged coniferous understory. Tables 4-15 summarises the results of the economic analysis of the three options examined for this stand type. The first option was moving the stand into single tree selection management through a series of partial cuts aimed at removing the overstory. This system was generally unprofitable, generating negative NPV_{R0}, NPV_{R1}, and NPV_{R2+} values at the lowest stumpage rates, because of the high front-end costs associated with removing the deciduous overstory in combination with the lower softwood values. At mid level stumpage values, NPV_{R2+} becomes positive despite the fact that NPV_{R1} remains negative. This seemingly contradictory result stems from the fact that NPV_{R1} captures the value of harvesting the lower values deciduous overstory, whereas NPV_{R2+} captures the result of harvesting high value conifers into perpetuity. The LEV at this level of stumpage remains negative, however, due to the large loss incurred after the initial harvest. Harvesting at the highest stumpage level, produced positive values for every stumpage combination and interest rate used in this analysis.

The second option examined for this stand type was understory protection. Once again it was assumed that this stand would be clearcut and allowed to sucker every 70 years into perpetuity after the first rotation. Therefore the NPV_{R2+} values used were the same as those from option VIc. The pattern of positive and negative results were very similar to those produced by option VIa. Results were negative when the lowest stumpage combination was employed in the analysis, and positive and the mid and high stumpage levels.

The final option examined was clearcutting this stand and allowing it to sucker every 70 years into perpetuity. Clearcutting this type of stand and allowing it to sucker once again produced positive NPV_{R0} values for every measure, stumpage combination and interest rate used in this analysis. Furthermore, NPV_{R1} and NPV_{R2+} values tended to become negative at higher interest rates. Despite this result, the large positive value of the initial harvest was enough to ensure positive LEVs at every combination of stumpage and interest rates used in the analysis. The OER analysis showed almost identical results.

Table 4-15. Financial calculations for Stand Type VI. Deciduous *Understory* - uneven-aged coniferous.

Stumpage ($/m³)	Interest Rate (%)	NPV_{R0} ($/ha)	NPV_{R1} ($/ha)	NPV_{R2+}[11] ($/ha)	LEV ($/ha)	*LEV ($/ha)	*Rotation Age
(a.) Single Tree Selection							
		Rotation = 70				Rotation = *	
$3.00/m³	2	-629.81	-169.62	-191.27	-990.70	-	-
&	5	-629.81	-93.57	-29.65	-753.03	-	-
$8.00/m³	10	-629.81	-40.79	-3.42	-674.03	-	-
$5.00/m³	2	-301.13	-27.14	277.81	-50.45	-	-
&	5	-301.13	-24.54	31.36	-294.31	-	-
$15.00/m³	10	-301.13	-19.22	1.20	-319.14	-	-
$10.00/m³	2	476.06	292.10	1291.15	2059.32	-	-
&	5	476.06	130.12	163.15	769.33	-	-
$30.00/m³	10	476.06	29.12	11.20	516.38	-	-
(b.) Understory Pr. with Wind Protection.							
		Rotation = 100				Rotation = *	
$3.00/m³	2	-420.39	-49.17	39.66	-429.90	-	-
&	5	-420.39	-6.46	-0.05	-426.90	-	-
$8.00/m³	10	-420.39	-0.25	-0.02	-420.65	-	-
$5.00/m³	2	146.06	265.55	74.35	485.96	-	-
&	5	146.06	34.91	0.41	181.37	-	-
$15.00/m³	10	146.06	1.34	-0.02	147.38	-	-
$10.00/m³	2	1443.42	955.65	157.70	2556.76	-	-
&	5	1443.42	125.62	1.53	1570.57	-	-
$30.00/m³	10	1443.42	4.84	-0.01	1448.24	-	-
(c.) Clearcut. Sucker.							
		Rotation = 115				Rotation = *	
$3.00/m³	2	414.93	118.95	39.66	573.531	623.94	88
&	5	414.93	-1.56	-0.05	413.31	413.60	73
$8.00/m³	10	414.93	-13.14	-0.02	401.77	401.85	65
$5.00/m³	2	692.84	223.01	74.35	990.21	1080.60	89
&	5	692.84	12.12	0.41	705.37	705.95	73
$15.00/m³	10	692.84	-12.61	-0.02	680.21	680.34	66
$10.00/m³	2	1385.68	473.02	157.70	2016.40	2193.80	88
&	5	1385.68	44.98	1.53	1432.20	1433.25	73
$30.00/m³	10	1385.68	-11.35	-0.01	1374.32	1374.59	65

[11] Note that because the assumption was made that stand VIb continues as VIc for harvest into perpetuity all of the NPV_{R2+} values are the same as those from scenario VIc.

4.4.7 Uneven-aged Coniferous Stand

Tables 4-16 summarises the results of the different options for stand type VII. This represents a conifer-dominated stand with a size range of understory saplings. Three options were developed for this stand type. The first was clearcutting the stand and replanting with spruce. The results for this option were positive values for the initial harvests at every stumpage and interest rate. However, in the majority of cases, the positive NPV_{R0} values were not enough to subsidise the costs associated with this system into perpetuity. The net result of this was negative land expectation values at every interest rate and stumpage value combination with one exception. Interest rates of 2% and the highest stumpage combination produce positive a positive LEV. Once again harvesting at the optimum economic rotation produced almost identical results to harvesting at the conventional rotation age.

The next option was to clearcut the stand and to allow in to sucker back to aspen. The silviculture costs associated with this option were lower than for the previous one and therefore positive values occurred for all the variables at all three stumpage combinations, not just at the highest level. Cutting at the economic optimum made the largest impact for all three stumpage combinations when the lowest interest rate was applied. For example, postponing the harvest 25 years at an interest rate of 2% and stumpage values of \$3.00/m3 and \$8.00/m3 for spruce increase the land expectation value from \$275.66 to \$403.96. At the next stumpage and interest rate LEV only increases from \$112.46 to \$115.63.[12]

[12] Option "d" was dropped do to a lack of responses by the participants.

The final option examined a single tree selection system. This system produced negative results for all measures at the lowest stumpage values. At higher levels of stumpage the value of the initial harvest became positive enough to subsidise the costs of subsequent harvests so that the land expectation value was always positive, despite the fact that at higher interest rates NPV_{R2+} values were negative.

Table 4-16. Financial calculations for Stand Type VII. Uneven-aged coniferous.

Stumpage ($/m³)	Interest Rate (%)	NPV$_{R0}$ ($/ha)	NPV$_{R1}$ ($/ha)	NPV$_{R2+}$ ($/ha)	LEV ($/ha)	*LEV ($/ha)	*Rotation Age
(a.) Clearcut, Plant							
		Rotation = 100				Rotation = *	
$3.00/m³	2	94.59	-651.40	-104.31	-661.11	-646.14	114
&	5	94.59	-879.62	-6.74	-791.76	-791.62	96
$8.00/m³	10	94.59	-883.69	-0.06	-789.16	-789.12	92
$5.00/m³	2	163.74	-438.87	-70.28	-345.41	-340.84	105
&	5	163.74	-867.91	-6.65	-710.82	-707.74	83
$15.00/m³	10	163.74	-883.58	-0.06	-719.90	-719.62	80
$10.00/m³	2	327.48	24.47	3.92	355.87	355.87	100
&	5	327.48	-842.38	-6.45	-521.36	-508.21	84
$30.00/m³	10	327.48	-883.32	-0.06	-555.92	-554.87	74
(b.) Clearcut, Sucker.							
		Rotation = 70				Rotation = *	
$3.00/m³	2	113.43	121.67	40.56	275.66	403.96	95
&	5	113.43	-0.94	-0.03	112.46	115.63	78
$8.00/m³	10	113.43	-12.92	-0.02	100.50	100.50	70
$5.00/m³	2	195.18	239.67	79.90	514.75	751.89	95
&	5	195.18	14.57	0.50	210.25	216.19	78
$15.00/m³	10	195.18	-12.32	-0.02	182.85	182.85	70
$10.00/m³	2	390.37	505.91	168.66	1064.94	1535.14	95
&	5	390.37	49.57	1.68	441.62	453.26	78
$30.00/m³	10	390.37	-10.97	-0.01	379.38	379.38	70
(d.) Single Tree Selection							
		Cutting Cycle = 25				Rotation = *	
$3.00/m³	2	-199.13	-145.20	-242.35	-586.67	-	-
&	5	-199.13	-83.00	-45.94	-328.07	-	-
$8.00/m³	10	-199.13	-38.77	-10.62	-248.52	-	-
$5.00/m³	2	354.75	5.70	-6.78	353.67	-	-
&	5	354.75	-9.90	-15.31	329.55	-	-
$15.00/m³	10	354.75	-15.92	-8.29	330.53	-	-
$10.00/m³	2	1556.63	339.27	513.92	2409.81	-	-
&	5	1556.63	151.71	52.41	1760.75	-	-
$30.00/m³	10	1556.63	34.58	-3.16	1588.05	-	-

4.4.8 Cluster Pockets of Uneven-aged Conifers

The final stand type examined were stands with scattered patches of advanced regeneration separated in an irregular mosaic of spruce-dominated mixedwoods. Three options were examined for this stand type. The results of which are summarised in tables 4-17.

Option "a" involved clearcutting the stand and replanting the site with spruce seedlings immediately after site preparation. Option "c" also involved clearcutting, but the site was left to sucker to aspen instead of replanting with spruce. These two options both produced positive land expectation values regardless of the interest rates and the stumpage values used. Option "a" always produced negative NPV_{R1} and NPV_{R2+} values, whereas the option "c" values were positive at all stumpage values, and low to moderate interest rates. For both of these option cutting at the optimum economic rotation did not produce significant changes in the land expectation values. Actual OER ages were, predictably, shorter for option "c", as the costs associated with this option were lower.

The irregular shelterwood system produced negative values for all the measures, when the lowest stumpage combination was employed. At the mid and highest stumpage rates were employed in the calculations, the values for all the variables, including NPV_{R2+}, became positive. This surprising result may be due to the fact that the participants may have over estimated the volumes associated with each pass due to a lack of familiarity with this silvicultural system, and relatively uncommon stand type.

Table 4-17. Financial calculations for Stand Type VIII. Coniferous. Understory - pockets of coniferous.

Stumpage ($/m³)	Interest Rate (%)	NPV_{R0} ($/ha)	NPV_{R1} ($/ha)	NPV_{R2+} ($/ha)	LEV ($/ha)	*LEV ($/ha)	*Rotation Age
(a.) Clearcut, Plant							
		Rotation = 100				Rotation = *	
$3.00/m³	2	1359.94	-675.35	-108.15	576.45	590.79	115
&	5	1359.94	-880.94	-6.75	472.25	472.32	97
$8.00/m³	10	1359.94	-883.70	-0.06	476.18	476.20	87
$5.00/m³	2	2531.14	-488.68	-78.26	1964.21	1967.78	105
&	5	2531.14	-870.65	-6.67	1653.81	1656.47	88
$15.00/m³	10	2531.14	-883.60	-0.06	1647.47	1647.71	80
$10.00/m³	2	5062.28	-75.15	-12.03	4975.09	4975.11	99
&	5	5062.28	-847.87	-6.50	4207.91	4220.46	83
$30.00/m³	10	5062.28	-883.39	-0.06	4178.83	4179.81	75
(b.) Irregular Shelterwood							
		Cutting Cycle = 20				Rotation = *	
$3.00/m³	2	-2.67	-97.86	-201.39	-301.91	-	-
&	5	-2.67	-63.34	-38.31	-104.32	-	-
$8.00/m³	10	-2.67	-34.10	-5.95	-42.72	-	-
$5.00/m³	2	278.67	121.62	250.27	650.56	-	-
&	5	278.67	59.58	36.03	374.28	-	-
$15.00/m³	10	278.67	14.38	2.51	295.56	-	-
$10.00/m³	2	888.67	607.17	1249.46	2745.30	-	-
&	5	888.67	331.50	200.51	1420.68	-	-
$30.00/m³	10	888.67	121.63	21.24	1031.53	-	-
(c.) Clearcut, Sucker.							
		Rotation = 70				Rotation = *	
$3.00/m³	2	963.67	95.20	31.74	1090.60	1162.37	92
&	5	963.67	-4.68	-0.16	958.83	960.03	76
$8.00/m³	10	963.67	-13.26	-0.02	950.39	950.41	68
$5.00/m³	2	1781.10	187.07	62.37	2030.54	2161.50	92
&	5	1781.10	7.40	0.25	1788.75	1791.02	76
$15.00/m³	10	1781.10	-12.80	-0.02	1768.29	1768.31	68
$10.00/m³	2	3562.20	401.14	133.73	4097.07	4355.19	92
&	5	3562.20	35.53	1.21	3598.94	3603.30	76
$30.00/m³	10	3562.20	-11.71	-0.01	3550.47	3550.52	68

CHAPTER V

CONCLUSIONS

5.1 Conclusions

A range of silvicultural systems will be needed by today's natural resource managers to meet the increased ecological and economic expectations placed on industrial forestry activities. The ecologically based mixedwood management systems developed by Lieffers *et al* (1996) provide managers with the type of range and flexibility required. However, to date very little is known about the economics of silviculture in boreal mixedwood forests.

This investigation provides a narrowly defined economic analysis of the ecologically based mixedwood systems described by Lieffers *et al* (1996) by including only those benefits arising from the value of the timber, and those costs associated with harvesting and replanting the stands in the analysis.

The lack of both financial and biological information regarding silviculture in boreal mixedwoods made it necessary solicit expert opinion for much of the information required by this analysis. The required information was gathered with a questionnaire that was completed by five experts in mixedwood management in Alberta.

The reliance on expert opinion presented several problems. The most important of which was that many of the ecologically based systems described by Lieffers *et al* are not currently in use in Alberta. Therefore, estimating the costs and yields associated with systems was difficult for the participants. This is evident in table 3-2, were some the volume factors used in the analysis show a huge discrepancy between the participants estimates and the provincial yield estimates. It is also evident in some of the very high standard deviations calculated for estimates shown in tables 4-3 through 4-9. Another potential problem with the reliance on expert opinion is the potential for strategic responses by the industry participants. Namely, it may be in the interests of industry participants to overestimate harvesting costs and the growth and yield potential of stands in that the information could be used in negotiating stumpage fees and AAC levels with government. Despite these inherent difficulties, the results of the analysis still provide important insight into the economics of these ecologically based silviculture systems.

The value of the initial harvest, or NPV_{R0}, was positive for all clearcutting options. All other systems examined produced negative NPV_{R0} values when lower stumpage values were used in the analysis, indicating that these systems are not financially viable alternatives except in high value stands. The losses incurred by the ecologically based systems after only the first harvest is due to the stumpage penalty imposed on them in this analysis. The stumpage penalties were chosen as a method of incorporating into the analysis the increased logging costs associated with the ecologically based systems. It is anticipated that as familiarity with these new systems increases, a gradual improvement in harvesting equipment and techniques could occur, and as a result, the higher harvesting costs for these systems could gradually be brought down over time, resulting in positive NPV_{R0} values.

In the majority of the cases examined, NPV_{R1} and NPV_{R2+} values became negative at mid to high interest rates, irrespective of the whether high, medium, or low stumpage values were assumed. This result underlines the importance of the value of the initial stand in subsidising future costs associated with each of the systems. Put another way, NPV_{R1} and NPV_{R2+} values did not contribute significantly to the overall land expectation value of a site. The LEV value of the site was almost solely determined by the value of the initial harvest, or NPV_{R0}. For these reasons, clearcutting with regeneration treatments and some of the understory protection techniques (especially those that required an underplanting) yielded some of the highest losses in terms of NPV_{R1} and NPV_{R2+} values, of the options examined. Conversely, those systems which included few or no regeneration treatments (i.e. site preparation, vegetation control, or planting) produced positive NPV_{R1} and NPV_{R2+} under a wide range of financial circumstances. In addition to clearcutting and allowing the site to sucker, these profitable options included uneven-aged management systems such as group and single tree selection methods. However, it should be noted that the uneven-aged and group selection system values were benefiting from subsidising effects of existing trees that were not all cut in the initial harvest.

If silvicultural systems are compared within like stands in terms of overall LEV values, we find that clearcutting systems tend to dominate. A notable exception occurs with single tree selection, at higher stumpage rates, for uneven aged coniferous stands (stand type VIIId), when the stumpage penalty is overcome. It should be noted, however, that these results are based on yield information with high standard deviations, and that improved yield information may play a large role in changing these results. Adding regeneration treatments to clearcutting systems, as opposed to relying on natural regeneration, reduces LEVs. With the exception of single tree selection, noted above, clearcut systems with regeneration treatments generally dominated shelterwood, and group selection options. Understory protection treatments generally performed the worst of all treatments examined. However, a notable exception is in vigorous, deciduous stands (stand type Ic) where results were similar to clearcutting with regeneration treatments.

Under the assumption that stumpage for both aspen and spruce will increase at approximately 2% per year, and given a social discount rate, many of the ecologically based silviculture systems may become financially feasible. However, it should also be noted that improved yield information may play a role in changing these results.

Examination of the optimum economic rotation revealed that the rotation lengths suggested by the experts were in all cases already very close to the optimum. In many instances, the change in LEV attributable to harvesting at the economic optimum was in the $0.20/ha - $10.00/ha range. Thus the large volume factors used to scale provincial yield estimates in the OER analysis proved not to be problematic because in all cases the length of the rotations where already very close to the optimum.

One of the major anticipated benefits from using these ecologically based systems was the potential increase in total yield attributed to growing trees as mixtures as opposed to in single species systems (Lieffers *et al* 1996). The results of this investigation tended to confirm this assumption. The investigation also showed that regeneration treatments such as site preparation and vegetation control are cost inefficient but effective methods of improving yields in single species systems. Overall, the silviculture systems that produced the highest overall average yields were, in descending order, single tree selection methods, understory protection techniques, and clearcutting with regeneration treatments.

The current lack of empirical data on the benefits, costs, and growth of various stand compositions, dictated the use of information derived from expert opinion in this investigation. Given the limitations of this method discussed above, an important area for further research is the improvement of existing financial and growth and yield information. Re-estimation of the information using a more sophisticated expert opinion methodology, such as a Delphi processes, may be another method of refining the response data from the participants.

Another area for further research is the development of a user friendly computer package for use in the analysis of silvicultural options in boreal mixedwoods forests. Having such a package available could help simplify the task of choosing site appropriate silvicultural systems for forest land managers.

This study was strictly a stand level analysis of these silviculture systems. At the stand level, rational decision-makers are faced with the problem of weighing the costs of these systems against the benefits of any increased future yields. However, most forest tenure holders are operating at the forest level where they are constrained to maintaining a constant harvest level over the entire rotation. This sustained yield constraint has an effect on the economic returns from silviculture and is known as the allowable cut effect (ACE). More research is required into the forest level implications of ACE and other issues on the economics of these systems.

Finally, this study focused on the benefits and costs strictly related to the harvesting and regeneration of timber on the site at a stand level. There are, however, other non-timber values associated with these the implementation of this type of management. For example, the wider range of stand structures associated with most of these systems is likely to result in a range of benefits such as greater resistance of stands to insects, disease, and fire. Another benefit is that ecologically based mixedwood management should sustain more ecosystem components than the current management system. There may also be aesthetic benefits to these systems, which become especially important in forests that are in public view. Inclusion of these non timber values into the analysis would provide a more truly economic, as opposed to financial, evaluation of these systems. It should be noted that based on the results of this analysis, any non-timber values associated with these systems would, in many cases, have to by very large to alter the negative financial results produced by some of these systems. It will be the task of future investigations to incorporate these non-timber values into the analysis.

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APPENDIX A

Description of Silvicultural Systems from Lieffers *et al* (1996).

Note: Assume existing stands are fully stocking, C density, and growing on medium sites in the middle of the edotopic grid. Also assume efficient harvesting equipment. Volume estimates given, come from Alberta Forest Inventory Yield Tables for Unmanaged Mixedwood Stands (Minimum DOB at 0.03 m, Stump = 15 cm, Minimum top DIB = 10.00 cm, where age refers to the total tree age.) Please answer all questions in current dollars.

(I.) Vigorous deciduous and/or deciduous dominated mixed stands (Species comp 90% Deciduous, Age of Deciduous 70 years)

I a.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

I b.) Late Underplant - Understory site preparation (merri crusher) and underplant existing stand with spruce (4-10s) 15 years prior to harvest (planting layout in accordance with projected harvest layout) - harvest deciduous component using understory protection - harvest coniferous component 85 years after the underplanting.

I c.) Early Underplant - Understory site preparation (merri crusher) and underplant with spruce (40-10s) relatively early in the development of the aspen stand, 15 years after establishment (planting layout in accordance with projected harvest layout) - harvest deciduous component using understory and wind protection in strips (60m cuts, 10m residuals) 55 years - harvest coniferous component 45 years later.

(II.) Decadent deciduous and/or deciduous dominated mixed stands (Species comp: 90% Deciduous, Age of Deciduous Comp.: 90 years):

II a.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

II b.) Understory site prep. (merri crusher/ blading) and then underplant (4-10s) existing stand 15 years prior to harvesting (planting layout in accordance with projected harvest layout) - harvest deciduous component using understory protection - harvest coniferous component in 85 years.

II c.) Clear cut existing stand - heavy site prep. (linear path mounder) - planting with large white spruce stock (4-15s) - vegetation control (one aerial glyphosate treatment) in next decade - clear cut at 100 years of age.

(III.) Coniferous stands and/or coniferous dominated mixed stands (Species comp: 80% Coniferous, Age of Conifers: 100 years):

III a.) Clear cut existing stand - light site prep. (power disk trenching) and plant (4-10s) to white spruce - vegetation management (one aerial glyphosate treatment) - harvest coniferous component at 100 years of age.

III b.) Clear cut existing stand - light site prep. (power disk trenching) and aerial seed to white spruce - vegetation management (one aerial glyphosate treatment) - harvest coniferous component at 100 years of age.

III c.) Clear cut existing stand - light site prep. (blade) and aerial seed to white spruce. Clear cut in 120 years.

III d.) Clear cut existing stand - light site prep. (power disk trenching) and plant (4-10s) to white spruce. Results in an aspen stand with a white spruce understory.

III e.) Clear cut existing stand (winter) - leave (suckering) - clear cut aspen in 70 years

III f.) Shelterwood systems - Initial Seeding Cut, (assume a stand age of 90 years), leaving large windfirm white spruce as shelter/seed trees, removing 50% of basal area - Removal Cut, in 10 years using careful logging techniques.

III g.) Clear cut existing stand, leaving windfirm seed tree clusters (one group of 10 trees/ha) and allowing remaining areas to sucker to aspen.

III h.) Group selection - Remove patches 1 to 2 tree lengths in diameter, using a cutting cycle of 25 years - the mosaic of different ages of patches would regenerate to a mixture of deciduous and coniferous species - openings would be left to regenerate naturally.

(IV.) Deciduous stands and/or deciduous dominated mixed stands with a short coniferous understory (Overstory - Species comp: 90% Deciduous , Age of Deciduous: 70 years. Understory - Species comp: 90% Coniferous, Age of Conifers: 25 years)

IV a.) Understory protection - Harvest the deciduous component using understory protection techniques - clear cut conifers in 75 years.

IV b.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

(V.) Deciduous stands and/or deciduous dominated mixed stands with a tall coniferous understory (Overstory - Species comp: 90% Deciduous, Age of Deciduous: 70 years. Understory - Species comp: 90% Conifers, Age of Conifers: 60 years):

V a.) Understory protection - Harvest the deciduous component using understory protection techniques - clear cut conifers in 40 years.

V b.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

V c.) Harvest deciduous component using understory and wind protection techniques (60m cuts, 10m residuals) - harvest coniferous component in 60 years using careful logging techniques.

(VI.) Deciduous stands and/or deciduous dominated mixed stands with a mixed (tall and short) coniferous understory (Overstory - Species comp: 90% Deciduous, Age of Deciduous: 70 years. Understory - Species comp: 90% Conifers, Age of Conifers: 10 to 70 years):

VI a.) Harvest deciduous component using understory and wind protection techniques (60m cuts, 10m residuals) - harvest remaining uneven aged spruce using single tree selection techniques (assume the target basal area for each pass is 16m2.)

VI b.) Harvest deciduous component and the taller coniferous understory at the same time (use understory protection techniques) - harvest remaining coniferous component in 70 years using careful logging techniques.

VI c.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

(VII.) Coniferous dominated mixed stands and/or coniferous stands with a size range of conifers (Species comp: 90% Conifers, Age of Conifers: 10 - 100 years):

VII a.) Clear cut existing stand - light site prep. (power disk trenching) and plant) with conifers (4-10s) - Clear cut conifers in 100 years.

VII b.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

VII c.) Harvest deciduous component using understory and wind protection techniques (60m cuts, 10m residuals) - harvest remaining coniferous component at 70 years of age.

VII d.) Harvest coniferous overstory in a series of partial cuts using a cutting cycle of 25 years - giving rise to an unevenaged coniferous stand - single tree selection.

(VIII.) Coniferous dominated mixed stands and/or coniferous stands with a clusters of different sizes of understory conifers (Species comp: 90% Conifers, Age of Conifers: 100 years. Age and Distribution of Clusters: 25 years, distributed over 10% of area):

VIII a.) Clear cut existing stand (winter) - site prep. (power disk trenching) - plant with conifers (4-10s) - harvest conifers in 100 years

VIII b.) Irregular shelterwood system - Regeneration Cut enlarging existing patches of advanced regeneration. Assume 3 cutting entries are needed, 20 years apart. This results in an irregular mosaic of spruce-dominated mixedwoods (regenerated stand has a wider range of ages than uniform shelterwood).

VIII c.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

APPENDIX B

Questionnaire

Note: Assume existing stands are fully stocking, C density, and growing on medium sites in the middle of the edotopic grid. Also assume efficient harvesting equipment. Volume estimates given, come from Alberta Forest Inventory Yield Tables for Unmanaged Mixedwood Stands (Minimum DOB at 0.03 m, Stump = 15 cm, Minimum top DIB = 10.00 cm, where age refers to the total tree age.) Please answer all questions in current dollars.

BENEFITS (under the different silvicultural alternatives)

1. What is your estimate of the stumpage value to your company of 1 m^3 of spruce from a typical ha in your landbase.

   _______ $\$/m^3$ (spruce)

2. What is your estimate of the stumpage value to your company in real terms of 1m^3 of aspen from a typical ha in your landbase.

   _______ $\$/m^3$ (aspen)

3. Over the next 100 years, do you expect these values to change?

Spruce	Aspen
☐ No	☐ No
☐ Yes, by approx.	☐ Yes, by approx.
__________%/year in real terms	_________%/year in real terms

4. Do you feel the value of a m^3 of aspen and/or spruce would change s a result of the different silvicultural alternatives?

Spruce	Aspen
☐ No	☐ No
☐ Yes	☐ Yes

- If the answer is **YES**, record estimate in the space provided at the end of this questionnaire.

COSTS (under different the different silvicultural alternatives)

(I.) Vigorous deciduous and/or deciduous dominated mixed stands (Species comp 90% Deciduous, Age of Deciduous 70 years)

I a.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

5. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 70 YEARS
Aspen (at 70 years of age)	Aspen (at 70 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental spruce volumes that would be recovered using this system? ______________m^3/ha Sw (INITIAL), ________________m^3/ha Sw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ______________________.

5 b. What is your estimate of the regeneration delay using this system.

Aw _________ (years), Sw _______ (years)

6. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

CLEAR CUT (YEAR 0) ________ $/ha

CLEAR CUT (YEAR 70) ____________ $/ha

7. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

8. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so what percent higher or lower? ___________

I b.) Late Underplant - Understory site preparation (merri crusher) and underplant existing stand with spruce (4-10s) 15 years prior to harvest (planting layout in accordance with projected harvest layout) - harvest deciduous component using understory protection - harvest coniferous component 85 years after the underplanting.

9. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation, and 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST (Und. Pr.)	FINAL HARVEST
Aw (at 70 years of age)	Sw (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system?___________m^3/ha Sw (INITIAL) and _____________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on.

☐ Expert Opinion

☐ Model

☐ Other, ______________________

9 b. What is your estimate of the regeneration delay using this system.

Aw _________ (years), Sw _______ (years)

10. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

UND. PR. (YEAR 15) _______ $/ha

CLEAR CUT (YEAR 100) ___________ $/ha

11. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys	Site Prep.	Plant
Cost:___ $/ha, Year completed:__	______ $/ha	______ $/ha
Cost:___ $/ha, Year completed:__		
Cost:___ $/ha, Year completed:__		
Cost:___ $/ha, Year completed:__		

12. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so what percent higher or lower? ___________

I c.) *Early Underplant - Understory site preparation (merri crusher) and underplant with spruce (40-10s) relatively early in the development of the aspen stand, 15 years after establishment (planting layout in accordance with projected harvest layout) - harvest deciduous component using understory and wind protection in strips (60m cuts, 10m residuals) 55 years - harvest coniferous component 45 years later.*

13. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation, and 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST (Und. Pr.)	FINAL HARVEST
Aw (at 70 years of age)	Sw (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system?____________m^3/ha Sw (INITIAL) and ______________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on.

☐ Expert Opinion

☐ Model

☐ Other,_____________________________.

13 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

14. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

CLEAR CUT (YEAR 0)	UND. PR. & WIND PR. (YEAR 70)	CLEAR CUT (YEAR 115)
_______ $/ha	______ $/ha	____________ $/ha

15. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys	Und. Site Prep.	Underplant
Cost:___ $/ha, Year completed:__	______ $/ha	______ $/ha
Cost:___ $/ha, Year completed:__		
Cost:___ $/ha, Year completed:__		
Cost:___ $/ha, Year completed:__		

16. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so what percent higher or lower? ___________

(II.) Decadent deciduous and/or deciduous dominated mixed stands (Species comp: 90% Deciduous, Age of Deciduous Comp.: 90 years):

II a.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

17. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 70 YEARS
Aspen (at 70 years of age)	Aspen (at 70 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental spruce volumes that would be recovered using this system? _________m^3/ha Sw (INITIAL), ___________m^3/ha Sw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ________________________.

17 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw _______ (years)

18. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 70)
_______ $/ha	___________ $/ha

19. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ \$/ha, Year completed:__

Cost:___ \$/ha, Year completed:__

Cost:___ \$/ha, Year completed:__

Cost:___ \$/ha, Year completed:__

20. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so what percent higher or lower? __________

II b.) Understory site prep. (merri crusher/ blading) and then underplant (4-10s) existing stand 15 years prior to harvesting (planting layout in accordance with projected harvest layout) - harvest deciduous component using understory protection - harvest coniferous component in 85 years.

21. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation, and 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST (Und. Pr.)	FINAL HARVEST
Aw (at 70 years of age)	Sw (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? __________ m^3/ha Aw (INITIAL), ________________ m^3/ha Sw (FINAL).

Please indicate what the above estimates are based on:

- ☐ Expert Opinion
- ☐ Model
- ☐ Other, ______________________.

21 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

22. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

UND. PR. (YEAR 15)	CLEAR CUT (YEAR 100)
________ $/ha	______ $/ha

23. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys	Und. Site Prep.	Underplant
Cost:___ $/ha, Year completed:__	______ $/ha	______ $/ha
Cost:___ $/ha, Year completed:__		
Cost:___ $/ha, Year completed:__		
Cost:___ $/ha, Year completed:__		

24. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so what percent higher or lower? ___________

II c.) Clear cut existing stand - heavy site prep. (linear path mounder) - planting with large white spruce stock (4-15s) - vegetation control (one aerial glyphosate treatment) in next decade - clear cut at 100 years of age.

25. Provincial yield tables predict 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 100 YEARS
Aspen (at 90 years of age)	Spruce (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental aspen volumes that would be recovered using this system? _________m^3/ha Sw (INITIAL), ___________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ________________________.

25 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

26. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 100)
_______ \$/ha	____________ \$/ha

27. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys	Site Prep.	Plant	Veg. Control
Cost:___ $/ha, Year completed:__	______ $/ha	______ $/ha	______ $/ha
Cost:___ $/ha, Year completed:__			
Cost:___ $/ha, Year completed:__			
Cost:___ $/ha, Year completed:__			

28. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so what percent higher or lower? ___________

(III.) Coniferous stands and/or coniferous dominated mixed stands (Species comp: 80% Coniferous, Age of Conifers: 100 years):

III a.) Clear cut existing stand - light site prep. (power disk trenching) and plant (4-10s) to white spruce - vegetation management (one aerial glyphosate treatment) - harvest coniferous component at 100 years of age.

29. Provincial yield tables predict 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 100 YEARS
Spruce (at 100 years of age)	Spruce (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental aspen volumes that would be recovered using this system? _________m^3/ha Aw (INITIAL), ___________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ________________________.

29 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

30. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

CLEAR CUT (YEAR 0) CLEAR CUT (YEAR 100)

_______ $/ha ___________ $/ha

31. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys	Site Prep.	Plant	Veg. Control
Cost:___ $/ha, Year completed:__	______ $/ha	______ $/ha	______$/ha
Cost:___ $/ha, Year completed:__			
Cost:___ $/ha, Year completed:__			
Cost:___ $/ha, Year completed:__			

32. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so what percent higher or lower? __________

III b.) Clear cut existing stand - light site prep. (power disk trenching) and aerial seed to white spruce - vegetation management (one aerial glyphosate treatment) - harvest coniferous component at 100 years of age.

33. Provincial yield tables predict 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 100 YEARS
Spruce (at 100 years of age)	Spruce (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental aspen volumes that would be recovered using this system? ________m^3/ha Aw (INITIAL), ___________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

- ☐ Expert Opinion
- ☐ Model
- ☐ Other, ______________________.

33 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw _______ (years)

34. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 100)
_______ $/ha	___________ $/ha

35. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys	Site Prep.	Aerial Seed	Veg. Control
Cost:___ $/ha, Year completed:__	______ $/ha	______ $/ha	______$/ha
Cost:___ $/ha, Year completed:__			
Cost:___ $/ha, Year completed:__			
Cost:___ $/ha, Year completed:__			

36. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so what percent higher or lower? ___________

III c.) Clear cut existing stand - light site prep. (blade) and aerial seed to white spruce.

Clear cut in 120 years.

37. Provincial yield tables predict 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 100 YEARS
Spruce (at 100 years of age)	Spruce
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental aspen volumes that would be recovered using this system? ________m^3/ha Aw (INITIAL), ___________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ______________________.

37 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

38. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

<u>Total Harvesting Costs</u> (including road building and maintenance)

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 100)
_______ \$/ha	____________ \$/ha

39. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys	Site Prep.	Aerial Seeding
Cost:___ \$/ha, Year completed:__	______ \$/ha	______ \$/ha
Cost:___ \$/ha, Year completed:__		
Cost:___ \$/ha, Year completed:__		
Cost:___ \$/ha, Year completed:__		

40. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so what percent higher or lower? ___________

III d.) Clear cut existing stand - light site prep. (power disk trenching) and plant (4-10s) to white spruce. Results in an aspen stand with a white spruce understory.

41. Provincial yield tables predict 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 100 YEARS
Spruce (at 100 years of age)	Spruce
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental aspen volumes that would be recovered using this system? ________m^3/ha Aw (INITIAL), ___________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, _________________

41 b. What is your estimate of the regeneration delay using this system.

Aw _________ (years), Sw _______ (years)

42. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

_______ $/ha

43. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys	Site Prep.	Plant
Cost:___ $/ha, Year completed:__	_____ $/ha	_____ $/ha
Cost:___ $/ha, Year completed:__		
Cost:___ $/ha, Year completed:__		
Cost:___ $/ha, Year completed:__		

44. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower?

_______ $/ha

III e.) Clear cut existing stand (winter) - leave (suckering) - clear cut aspen in 70 years

45. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 70 YEARS
<u>Aspen (at 70 years of age)</u>	<u>Aspen (at 70 years of age)</u>
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental spruce volumes that would be recovered using this system? __________m^3/ha Sw (INITIAL), ____________m^3/ha Sw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ________________________.

45 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

46. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

<u>Total Harvesting Costs</u> (including road building and maintenance)

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 70)
_______ $/ha	____________ $/ha

47. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ \$/ha, Year completed:__

Cost:___ \$/ha, Year completed:__

Cost:___ \$/ha, Year completed:__

Cost:___ \$/ha, Year completed:__

48. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so what percent higher or lower? ___________

III f.) Shelterwood systems - Initial Seeding Cut, (assume a stand age of 90 years), leaving large windfirm white spruce as shelter/seed trees, removing 50% of basal area - Removal Cut, in 10 years using careful logging techniques.

49. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation, and 144.97 m^3/ha spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL SEEDING CUT	REMOVAL CUT
Aspen (at 70 years of age)	Spruce (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? _____m^3/ha Sw (SEEDING), __________m^3/ha Aw (REMOVAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ______________________.

49 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

50. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

SEEDING CUT (YEAR 0)	REMOVAL CUT (YEAR 10)
________ $/ha	____________ $/ha

51. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

52. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so, what percent higher or lower? ___________

III g.) Clear cut existing stand, leaving windfirm seed tree clusters (one group of 10 trees/ha) and allowing remaining areas to sucker to aspen.

53. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation, and 144.97 m^3/ha spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 100 YEARS
<u>Spruce</u>	<u>Spruce</u>
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental aspen volumes that would be recovered using this system? _________m^3/ha Aw (INITIAL), ___________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ______________________.

53 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw _______ (years)

54. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

<u>Total Harvesting Costs</u> (including road building and maintenance)

CLEAR CUT (YEAR 0)

_______ $/ha

55. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

56. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower?

_______ $/ha

III h.) Group selection - Remove patches 1 to 2 tree lengths in diameter, using a cutting cycle of 25 years - the mosaic of different ages of patches would regenerate to a mixture of deciduous and coniferous species - openings would be left to regenerate naturally.

57. Provincial yield tables predict 36.25 m^3/ha of spruce using a 25 year cutting cycle (144.97/4). Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

GROUP CUT (Volume cut every 25 years)	GROUP CUT (Volume cut every 25 years)
Spruce (at 100 years of age)	Aspen (at 70 years of age)
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

Please indicate what this estimate is based on:

☐ Expert Opinion

☐ Model

☐ Other,___________________________

58. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

GROUP CUT (COST EVERY 25 YEARS)

_______ $/ha

59. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

60. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower? __%

(IV.) Deciduous stands and/or deciduous dominated mixed stands with a short coniferous understory (Overstory - Species comp: 90% Deciduous , Age of Deciduous: 70 years. Understory - Species comp: 90% Coniferous, Age of Conifers: 25 years)

IV a.) Understory protection - Harvest the deciduous component using understory protection techniques - clear cut conifers in 75 years.

61. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation, and 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST (Und. Pr.)	FINAL HARVEST
Aw (at 70 years of age)	Sw (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? __________m^3/ha Sw (INITIAL), __________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ______________________.

61 b. What is your estimate of the regeneration delay using this system.

Aw _________ (years), Sw _______ (years)

62. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

UND. PR. (YEAR 0) CLEAR CUT (YEAR 75)

_______ $/ha ___________ $/ha

63. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

64. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower? _______ %

IV b.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

65. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 70 YEARS
Aspen (at 70 years of age)	Aspen (at 70 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental spruce volumes that would be recovered using this system? _________m^3/ha Sw (INITIAL), ___________m^3/ha Sw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ________________________.

65 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

66. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Harvesting Costs (including road building and maintenance)

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 70)
________ \$/ha	____________ \$/ha

67. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

68. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower?________ %

(V.) Deciduous stands and/or deciduous dominated mixed stands with a tall coniferous understory (Overstory - Species comp: 90% Deciduous, Age of Deciduous: 70 years. Understory - Species comp: 90% Conifers, Age of Conifers: 60 years):

V a.) Understory protection - Harvest the deciduous component using understory protection techniques - clear cut conifers in 40 years.

69. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation, and 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST (Und. Pr.)	FINAL HARVEST
Aw (at 70 years of age)	Sw (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? ________________m^3/ha Sw (INITIAL), ___________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ______________________.

69 b. What is your estimate of the regeneration delay using this system.

Aw _________ (years), Sw _______ (years)

70. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

UND. PR. (YEAR 0)	CLEAR CUT (YEAR 40)
_______ $/ha	___________ $/ha

71. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

72. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower? _______ $/ha

V b.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

73. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 70 YEARS
Aspen (at 70 years of age)	Aspen (at 70 years of age)
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental spruce volumes that would be recovered using this system? _________m^3/ha Sw (INITIAL), ____________m^3/ha Sw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ________________________.

73 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

74. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 70)
________ $/ha	____________ $/ha

75. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

76. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower? ________ %

V c.) Harvest deciduous component using understory and wind protection techniques (60m cuts, 10m residuals) - harvest coniferous component in 60 years using careful logging techniques.

77. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 60 year rotation, and 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST (Und. Pr.)	FINAL HARVEST
Aw (at 70 years of age)	Sw (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? ___________m^3/ha Sw (INITIAL), ____________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, _______________________.

77 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

78. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

UND. PR & WIND PR. (YEAR 0)	CLEAR CUT (YEAR 60)
________ \$/ha	____________ \$/ha

79. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

<u>Surveys</u>

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

80. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower? _______ %

(VI.) Deciduous stands and/or deciduous dominated mixed stands with a mixed (tall and short) coniferous understory (Overstory - Species comp: 90% Deciduous, Age of Deciduous: 70 years. Understory - Species comp: 90% Conifers, Age of Conifers: 10 to 70 years):

VI a.) Harvest deciduous component using understory and wind protection techniques (60m cuts, 10m residuals) - harvest remaining uneven aged spruce using single tree selection techniques (assume the target basal area for each pass is 16m^2.)

81. Provincial yield tables predict 48.70 m^3/ha of aspen for the first cut, 16.23 m^3/ha of aspen for the second cut, and 36.24 m^3/ha every 25 years using single tree selection methods. Do you feel confident in these predictions? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

Initial Aspen Removal	Single Tree Selection
Aspen (at 70 years of age)	Spruce (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to ____ m^3/ha (1st pass)	☐ No, closer to _______ m^3/ha
__________m^3/ha (2nd pass)	

What is your estimate of the incidental volumes that would be recovered using this system? _____m^3/ha Sw (1st pass), ____m^3/ha Sw (2nd pass), ____m^3/ha Aw (Single Tree).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ________________________.

82. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

UND. & WIND PR. (YEAR 0)	Aw REMOVAL (YEAR 25)	SINGLE TREE SELECTION (EVERY 25 YEARS)
________ $/ha	______ $/ha	______ $/ha

83. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

84. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower? _______ %

VI b.) Harvest deciduous component and the taller coniferous understory at the same time (use understory protection techniques) - harvest remaining coniferous component in 70 years using careful logging techniques.

85. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation, and 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST (Und. Pr.)	FINAL HARVEST
Aw (at 70 years of age)	Sw (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? ____________m^3/ha Sw (INITIAL), ___________________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ________________________.

85 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

86. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

UND. PR & WIND PR. (YEAR 0)	CLEAR CUT (YEAR 70)
________ \$/ha	_____________ \$/ha

87. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

88. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower? _______ %

VI c.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

89. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 70 YEARS
Aspen (at 70 years of age)	Aspen (at 70 years of age)
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? __________m^3/ha Sw (INITIAL),__________m^3/ha Sw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ______________________.

89 b. What is your estimate of the regeneration delay using this system.

Aw _________ (years), Sw _______ (years)

90. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 70)
_______ \$/ha	___________ \$/ha

91. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

92. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower? _______ %

(VII.)Coniferous dominated mixed stands and/or coniferous stands with a size range of conifers (Species comp: 90% Conifers, Age of Conifers: 10 - 100 years):

VII a.) Clear cut existing stand - light site prep. (power disk trenching) and plant) with conifers (4-10s) - Clear cut conifers in 100 years.

93. Provincial yield tables predict 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 100 YEARS
Spruce (at 100 years of age)	Spruce (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? ___________m^3/ha Aw (INITIAL), _________________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, _______________________.

93 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

94. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 100)
_______ $/ha	____________ $/ha

95. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys	Site Prep.	Plant
Cost:___ $/ha, Year completed:__	______ $/ha	______ $/ha
Cost:___ $/ha, Year completed:__		
Cost:___ $/ha, Year completed:__		
Cost:___ $/ha, Year completed:__		

96. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower?________%

VII b.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

97. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 70 YEARS
Spruce (at 70 years of age)	Aspen (at 70 years of age)
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? ________________m^3/ha Aw (INITIAL), ___________m^3/ha Sw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ______________________.

97 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

98. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 70)
_______ $/ha	____________ $/ha

99. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

100. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower?________ %

VII c.) Harvest deciduous component using understory and wind protection techniques (60m cuts, 10m residuals) - harvest remaining coniferous component at 70 years of age.

101. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation, and 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST (Und. Pr.)	FINAL HARVEST
Aw (at 70 years of age)	Sw (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? __________m^3/ha Sw (INITIAL), ________________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model ☐ Other, ____________________

101 b. What is your estimate of the regeneration delay using this system.

Aw _________ (years), Sw _______ (years)

102. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

UND. & WIND PR. (YEAR 0)	CLEAR CUT (YEAR 85)
_______ $/ha	___________ $/ha

103. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

104. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower?________ %

VII d.) Harvest coniferous overstory in a series of partial cuts using a cutting cycle of 25 years - giving rise to an unevenaged coniferous stand - single tree selection.

105. Provincial yield tables predict 36.24 m^3/ha of spruce every 25 years using single tree selection methods. Do you feel confident in these predictions? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

Overstory Removal (Volume removed every 25 years)	Single Tree Selection (Volume removed every 25 years)
Spruce (at 100 years of age)	Spruce (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? ___________m^3/ha Aw (Overstory Removal). __________m^3/ha Aw (Single Tree).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ______________________.

106. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

PARTIAL CUT (YEAR 0)	PARTIAL CUT (YEAR 25)	PARTIAL CUT (YEAR 75)	SINGLE TREE SELECTION (COST PER 25 YEAR ENTRY)
________ \$/ha	______ \$/ha	______ \$/ha	______ \$/ha

107. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

108. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower?________ %

(VIII.) Coniferous dominated mixed stands and/or coniferous stands with a clusters of different sizes of understory conifers (Species comp: 90% Conifers, Age of Conifers: 100 years. Age and Distribution of Clusters: 25 years, distributed over 10% of area):

VIII a.) Clear cut existing stand (winter) - site prep. (power disk trenching) - plant with conifers (4-10s) - harvest conifers in 100 years

109. Provincial yield tables predict 144.97 m^3/ha of spruce at the end of a 100 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 100 YEARS
Spruce (at 100 years of age)	Spruce (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to ______ m^3/ha	☐ No, closer to ______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? ___________m^3/ha Aw (INITIAL), _________________m^3/ha Aw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ______________________.

109 b. What is your estimate of the regeneration delay using this system.

Aw __________ (years), Sw ________ (years)

110. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 100)
________ $/ha	____________ $/ha

111. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

112. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower?________ %

VIII b.) *Irregular shelterwood system - Regeneration Cut enlarging existing patches of advanced regeneration. Assume 3 cutting entries are needed, 20 years apart. This results in an irregular mosaic of spruce-dominated mixedwoods (regenerated stand has a wider range of ages than uniform shelterwood).*

113. Provincial yield tables predict 29.00 m^3/ha of spruce every 20 years using the irregular shelterwood method. Do you feel confident in these predictions? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

Regen Cut (Volume every 20 years, 3 entries)	Irregular Shelterwood (Volume removed every 20 years)
Spruce (at 100 years of age)	Spruce (at 100 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental volumes that would be recovered using this system? ____________m^3/ha Aw (per Regen Cut), _______m^3/ha Aw (per Irregular Shelterwood Cut).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ________________________.

114. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

Total Harvesting Costs (including road building and maintenance)

REGEN CUT (YEAR 0)	REGEN CUT (YEAR 20)	REGEN CUT (YEAR 40)	HARVEST Sw (COST PER 20 YEAR ENTRY)
______ $/ha	______ $/ha	______ $/ha	______ $/ha

115. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

Surveys

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

116. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower?________ %

VIII c.) Clear cut existing stand (winter) - leave (suckering) - clear cut at 70 years of age.

117. Provincial yield tables predict 64.93 m^3/ha of aspen at the end of a 70 year rotation. Do you feel confident in this prediction? (PLEASE CHECK ONE ANSWER) Note: estimate should include expected blowdown.

INITIAL HARVEST	HARVEST IN 70 YEARS
Aspen (at 70 years of age)	Aspen (at 70 years of age)
☐ Yes	☐ Yes
☐ No, closer to _______ m^3/ha	☐ No, closer to _______ m^3/ha

What is your estimate of the incidental aspen volumes that would be recovered using this system? _________m^3/ha Sw (INITIAL), ____________m^3/ha Sw (FINAL).

Please indicate what the above estimates are based on:

☐ Expert Opinion

☐ Model

☐ Other, ______________________.

117 b. What is your estimate of the regeneration delay using this system.

Aw _________ (years), Sw _______ (years)

118. What is your estimate of the total harvesting costs of such an operation for a typical ha within your landbase?

<u>Total Harvesting Costs</u> (including road building and maintenance)

CLEAR CUT (YEAR 0)	CLEAR CUT (YEAR 70)
_______ $/ha	___________ $/ha

119. What is your estimate of the total silviculture costs of such an operation for a typical ha within your landbase?

<u>Surveys</u>

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

Cost:___ $/ha, Year completed:__

120. Do you think that this silvicultural system would result in higher or lower than average protection costs? If so how much higher or lower?________ %

BENEFITS con'd (under the different silvicultural alternatives)

- If your answer was **YES to question 4**, record your estimates in the space provided here. (%)

Ia Aw _____ Sw _____

Ib Aw _____ Sw _____

Ic Aw _____ Sw _____

IIa Aw _____ Sw _____

IIb Aw _____ Sw _____

IIc Aw _____ Sw _____

IIIa Aw _____ Sw _____

IIIb Aw _____ Sw _____

IIIc Aw _____ Sw _____

IIId Aw _____ Sw _____

IIIe Aw _____ Sw _____

IIIf Aw _____ Sw _____

IIIg Aw _____ Sw _____

IIIh Aw _____ Sw _____

IVa Aw _____ Sw _____

IVb Aw _____ Sw _____

Va Aw _____ Sw _____

Vb Aw _____ Sw _____

Vc Aw _____ Sw _____

VIa Aw _____ Sw _____

VIb Aw _____ Sw _____

VIc Aw _____ Sw _____

VIIa Aw _____ Sw _____

VIIb Aw _____ Sw _____

VIIc Aw _____ Sw _____

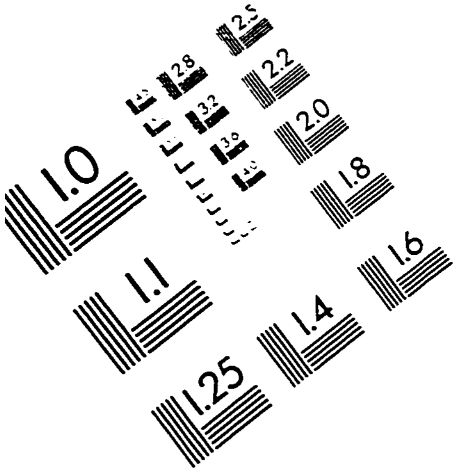
VIId Aw _____ Sw _____

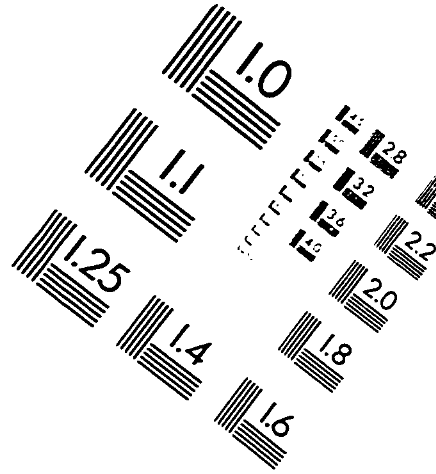
VIIIa Aw _____ Sw _____

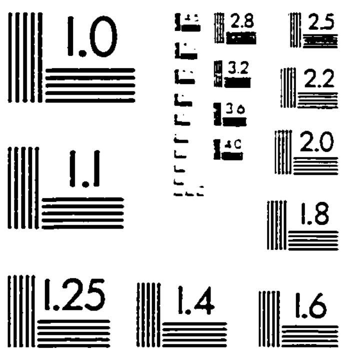
VIIIb Aw _____ Sw _____

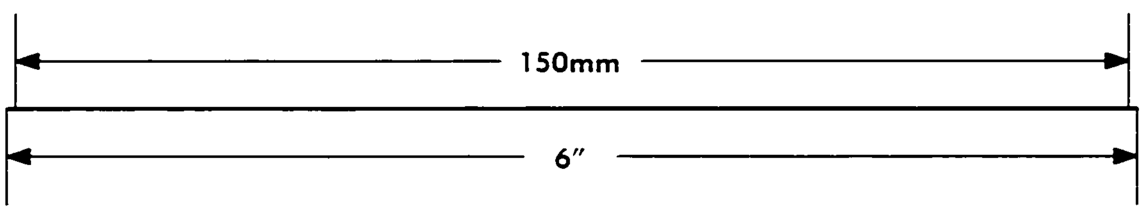
VIIIc Aw _____ Sw _____

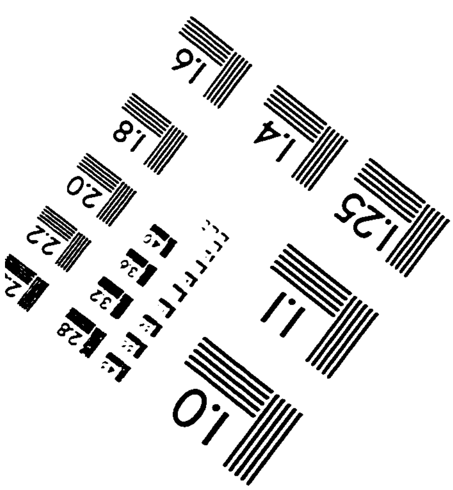
IMAGE EVALUATION
TEST TARGET (QA-3)

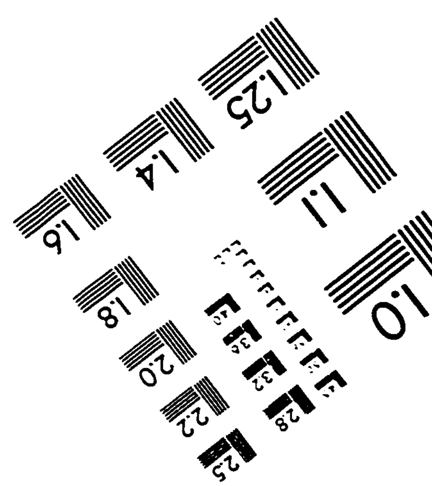












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