JAAKKO PÖYRY
JAAKKO PÖYRY CONSULTING, INC.

Silvicultural Systems

A Background Paper for a Generic Environmental Impact Statement on Timber Harvesting and Forest Management in Minnesota

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Prepared for:

Minnesota Environmental Quality Board
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August 19, 1992

Dr. Michael Kilgore
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Dear Mike:

Pursuant to the State of Minnesota's GEIS contract with Jaakko Pöyry Consulting, Inc. as formally executed on May 15, 1991, the sixth task included preparation of background papers. One of these papers, Silvicultural Systems, is attached for review and approval.

The material contained in the document is presented in accordance with the terms outlined in Attachment A (to the base contract), Section III, subsection F.

We look forward to your approval of this work product in due course.

Respectfully yours,

Doug G. Parsonson
GEIS Project Coordinator

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Attachment

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SUMMARY

The objectives of this paper are to outline and provide background information on:

- the various silvicultural systems available and the factors involved in their selection in forest management;
- costs for the various silvicultural operations used;
- actual silvicultural systems used in Minnesota and extent used;
- extent of silvicultural operations in Minnesota; and
- present example silvicultural guidelines for forest covertypes in Minnesota (appendix 1).

Detailed discussions of the impacts of forest management on other forest values are presented in the paper on Impacts of Timber Harvesting and Forest Management on Forest Wildlife (Jaakko Pöyry Consulting, Inc., 1992a).

The Background Paper is intended to provide information about silvicultural systems to guide the GEIS study groups. The information provides background and a common understanding among the groups to aid in the preparation of the technical papers.

To obtain information on the actual silvicultural practices in Minnesota a questionnaire (appendix 2) was distributed to the major timberland ownerships (i.e., state, county, national forest, forest industry and Indian). Response to the survey was 100 percent, except for county timberlands where it was 95 percent. In addition, review of the literature on silvicultural systems, guidelines and costs applicable to Minnesota was made. Any available manuals, guidelines, data or statistics dealing with forest management in Minnesota were obtained from the various forestry organizations. This information was supplemented with field trips and discussions with field personnel. Based on the survey results, information on total wood consumption and net exports, results from a similar survey made for the *Harvesting Systems Background Paper* (Jaakko Pöyry Consulting, Inc., 1992b), data from the Minnesota DNR Division of Forestry, and the literature, an estimation of silviculture systems used and operations on the other timberland ownerships in Minnesota (i.e., private and other federal) was made.

The total volume harvested from the silviculture survey timberlands was 1.86 million cords or approximately 48 percent of the annual harvest in the period 1990/91. The annual volume removed per acre was 0.24 cords. Of those forest landowners surveyed, the total area with logging operations was estimated to be 90,128 acres. On average, 21.6, 17.2, 8.6, 11.9, and 8.8

cords/acre were removed in clearfellings, seed tree cuts, shelterwood cuts, selective cuts and thinning, respectively.

The total area of Minnesota timberland not accounted for in the survey approximated 6.0 million acres. Of this 97 percent is classed as private, while other federal timberlands account for 3 percent. These ownerships account for 43 percent of the total area of commercial forest land, and 51 percent of the total harvest in the state.

Of the total timber harvested in Minnesota during 1991 it is estimated that 80 percent of the volume came from clearcuts and clearcuts with residuals, which in turn accounted for 71 percent of the area with logging operations. Patch, strip and other modified cutting accounted for 8 percent of the volume and area logged. Seed tree and shelterwood cutting accounted for 2 percent of the volume and 4 percent of the area logged. Selective cutting accounted for 5 percent of the volume and 8 percent of the area logged. The volume removed in thinnings was 4 percent, and they occurred on 10 percent of areas with logging operations. The total area with logging operations was estimated to be 200,000 acres, of which 19,000 acres was thinning. Planting occurred on 32,600 acres, seeding on 6,000 acres, and natural regeneration on 142,000 acres.

The estimated total site preparation area was 28,500 acres or less than 16 percent of all timberland regenerated in 1991. Of this total, 18,000 was mechanical site preparation. Chemical sprays and prescribed burning were also used for site preparation in 1991. The estimated total area with timber stand improvements was 28,000 acres (0.20 percent of timberlands), of which 9,800 acres was chemical release (0.07 percent of timberlands). In 1991, logging operations occurred on 1.44 percent of the state's commercial forest land, of which 1.31 percent were regeneration cuts and 0.13 percent thinnings.

It must be stressed that this paper is not intended as an all-inclusive document on silviculture, and that its purpose is to give background information to the GEIS study groups. However, the data presented on the use of silvicultural systems and extent of silvicultural operations is the best data currently available for the Minnesota GEIS. Also, the *Harvesting Systems Background Paper* (Jaakko Pöyry Consulting, Inc., 1992b) supplies additional information on silvicultural systems, harvesting methods and equipment used, as well as seasons of harvest, wood processing locations and average cutover sizes.

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This background paper has been compiled by Dr. Reino Pulkki for Jaakko Pöyry Consulting, Inc.

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The author acknowledges the considerable input from personnel in all forestry organizations in Minnesota, who have supplied the data and background information, and provided comment.

1 INTRODUCTION

The objectives of this paper are to describe the:

- various silvicultural systems available and the factors involved in their selection in forest management;
- costs for the various silvicultural operations used;
- actual silvicultural systems used in Minnesota and extent used;
- extent of silvicultural operations in Minnesota; and
- present example silvicultural guidelines for forest covertypes in Minnesota (appendix 1).

This paper also served an important role in the GEIS study process by providing silvicultural information to the GEIS study groups to support their impact assessment processes.

Detailed discussions of the impacts of forest management on other forest values are presented in the paper on Impacts of Timber Harvesting and Forest Management on Forest Wildlife (Jaakko Pöyry Consulting, Inc., 1992a).

2 SILVICULTURAL DEFINITIONS AND FACTORS

The following terminology is given to give the readers a common understanding of the silvicultural terms used throughout this paper, and throughout the documents of the Generic Environmental Impact Statement (GEIS) on Timber Harvesting and Management in Minnesota.

2.1 Silviculture and Silvicultural Systems

Squire et al. (1991) defines *silviculture* as using ecological, economic, and social knowledge to manipulate a forest ecosystem to achieve specific sustainable benefits specified for it. Silviculture can also be defined as the art of producing and tending a forest (Smith 1962), or more in particular, as the theory and practice of controlling establishment, composition, constitution and growth of forests (Ford-Robertson 1971). A *silvicultural system* is defined as a process, following accepted silvicultural principles, whereby stands are tended, harvested and replaced, resulting in a forest of distinctive form. Silvicultural systems are most commonly classified according to the reproductive method employed since it has a decisive influence on the form and treatment of the stand (Smith 1986). The reproductive method refers to the method of carrying out the fellings that remove the mature crop with a view to regeneration and according to the type of forest thereby produced

(e.g., clearfelling, seed tree, shelterwood, and individual tree selective systems) (Burns 1983). The two major management methods in high forests are even-aged and uneven-aged management.

2.2 Even-aged Management

Even-aged management is the application of a combination of actions that results in the creation of stands in which trees of essentially the same age grow together; the difference in age between trees forming the main canopy level of a stand usually does not exceed 20 percent of the age of the stand at maturity (Burns 1983). Regeneration in a particular stand is obtained during a short period at or near the time that a stand has reached the desired age or size for regeneration, and is harvested (Burns 1983). Different techniques used for harvesting in even-aged management are clearfelling (i.e., clearcutting, clearcutting with residuals, block cutting, patch cutting, alternate strip cutting and progressive strip cutting), seed tree and shelterwood systems. Thinning is not a silvicultural system but a silvicultural treatment which can be used in any of the above systems.

Clearfelling

To avoid confusion, clearfelling is used instead of clearcutting as the general term depicting the removal of all trees from an area in one cut to produce an even-aged stand. This allows easier differentiation between the various sizes and shapes of harvesting areas. On one scale a clearfelled area could be a small 0.25 acre *patch cut,* while on the opposite scale it could be an extensive *clearcut.*

In clearfelling, the period between harvesting and regeneration of the stand to an acceptable stocking can be reduced to a minimum. Clearfelling usually yields the highest merchantable volume growth per acre, and has the lowest per unit volume harvesting cost. It is also the most feasible silvicultural system for most shade intolerant species (i.e., unable to regenerate and grow under the shade of others). Clearfelled areas can vary in size from 0.25 acres to very large areas. The *Logging Survey* presented in the Harvesting Systems Background Paper (Jaakko Pöyry Consulting, Inc., 1992b) revealed the average logging site area in Minnesota to be 31.5 acres. Another factor which is important when classifying cut area size is the exclusion period for the harvesting of adjacent areas. There are a number of forms of clearfelling. For the purpose of the GEIS they are defined by area and shape as follows:

Clearcutting.—Any clearfelled area which is greater than or equal to 5 acres.

Clearcutting with standing residuals.—Any clearfelled area which is greater than or equal to 5 acres with 6 to 9 live and/or dead residuals left

standing per acre. This method is usually used to mitigate impacts on wildlife. One example is the USDA Forest Service 3/3/2 rule applied in national forests, where three live standing trees, three dead standing trees and two felled trees are left per acre.

Block cutting.—Any clearfelled area less than 5 acres which is regular (usually square) in shape.

Patch cutting.—Any clearfelled area less than 5 acres which is irregular in shape. Patch cuts are generally more aesthetically pleasing than block cuts.

Alternate strip cutting.—A clearfelled area generally the width of the effective seeding distance of standing trees for a species (usually less than 300 feet), a width at least equal to the tree height, and as long as the effective off-road transport distance for the conditions present (generally less than 1,200 feet), with leave strips left between cut strips.

Progressive strip cutting.—A progressive cut of strips equal to the effective seeding distance of standing trees for a species, and generally starting from the leeward side of a stand. Once a cut strip has reached sufficient stocking the next adjacent strip is removed.

Shelterwood

Shelterwood cutting is used to supply seed or an environment conducive to sprouting, and shelter for the regenerating stand. The shelterwood system requires two (i.e., two-stage shelterwood) or more cuts before the final harvest. The initial cuts are used to stimulate reproduction through increasing seed production, stimulating stump and/or root sprouting, and supplying increased light to the new seedlings, sprouts, or advanced regeneration. The remaining stems also provide shelter from excessive fluctuations in temperature (e.g., frost) and moisture (e.g., water stress), and in some cases insect pests. In many cases this system is used in conjunction with thinning. Once the stand is regenerated, the sheltering trees are removed. In the shelterwood system more than 20 dominant trees per acre are left, with the maximum being the point where the regeneration and seedling/sapling growth potential of the species in question are not jeopardized.

Seed Tree

Seed tree cutting is similar to the shelterwood cutting, except fewer trees are left per acre. Seed trees can be left evenly distributed over the cutover or in groups. The number of seed trees left depends on the species and can vary from 10 to 20 dominant, good quality trees per acre. As with shelterwood cutting, thinning can also be used. Once sufficient seedling stocking is reached the seed trees are removed.

Thinning

Thinning is not a silvicultural system, but an intermediate cutting in an even-aged stand used to increase diameter growth on the remaining stems, salvage natural mortality, reduce the rotation age, increase stand quality and hygiene, increase the content of more desirable species within a stand, and in some cases allow the more successful use of shelterwood and seed tree methods (e.g., trees become more *wind-firm*). Thinning may be from below (favor dominant trees) or above (favor most promising trees, not necessarily dominant trees). The thinning methods available are:

Selective thinning.—The removal of individual trees (generally suppressed and poor quality trees) evenly throughout the stand. It is the best thinning method from biological, stand quality and aesthetic views.

Row/strip thinning.—The removal of complete rows (e.g., in plantations) or swaths (e.g., in naturally regenerated stands) of trees at regular intervals throughout the stand, with no regard to the characteristics of the trees removed or left. It is usually the most economical thinning method.

Selective thinning within leave strip.—A combination of selective and row thinning, where rows or swaths are removed at regular intervals and selective thinning is done in the leave strips or rows.

Thinning can be precommercial or commercial. In the past commercial thinning referred to thinning operations which produced a profit. Due to inconsistencies in accounting methods (i.e., was a profit actually made or not, and by whom) commercial thinning is now held as any thinning where the thinned material is removed from the stand for commercial use, irrespective of whether a profit is made or not. Precommercial thinning refers to the practice where the thinned material is left on site. Juvenile spacing is a form of precommercial thinning, but specifically refers to stands which are in the sapling stage.

2.3 Uneven-aged Management

Uneven-aged management is the application of a combination of actions needed to simultaneously maintain continuous high-forest cover, recurring regeneration of desirable species, and the orderly growth and development of trees though a wide range of diameter and age classes; preferably in all age and diameter classes within a rotation (Burns 1983). In practice a stand with tree ages ranging over at least 25 percent of the length of the rotation is classified as an uneven-aged stand (Burns 1983). This is the silvicultural system which requires the most planning, tree-selection and harvesting skill. It is easily misused to become just *high-grading* (i.e., selecting mainly the best trees for removal, thus reducing the quality of the genetic pool in the

stand and the overall quality of the stand). This silvicultural system is most applicable to shade tolerant species (i.e., can grow under the shade of other trees). Two methods of logging can be used in uneven-aged logging:

Individual (single) tree selection logging.—Individual trees are selected for removal uniformly throughout the stand due to overmaturity, poor hygiene, poor form, or some other selection criterion

Group selection logging.—Groups of 3 to 4 overstory trees, as well as any understory trees beneath them, are removed throughout a stand to produce a patchwork pattern. Depending on the size of the opening this system could be also classed as patch cutting

2.4 Factors in Silvicultural System Selection

In forest management, it is not simple to choose one silvicultural system over the others. Many factors must be taken into account. In the northern areas of the state with shade intolerant species adapted to fire, the concentrated regeneration methods are applicable (i.e., even-aged management). The applicability of seed tree or shelterwood methods depends on the species themselves (e.g., wind firmness, seed crops, shade tolerance). In the shade tolerant hardwood forests found in southeastern Minnesota, the uneven-aged management system and selective logging are very applicable. However, much of the oak in the southeastern part of the state is clearfelled and the logging sites are very visible on the hillsides. Due to the concern about clearfelling, much of the following discussion will be focused on the forests where even-aged management systems are most applicable (e.g., forests in the northern part of the state and red oak).

The renewal of northern forests has naturally been through wild-fires. Forest fires can range from several acres to over 500,000 acres. The *clear or open stage* of a shade intolerant stand is a normal part of its development, with certain plant and animal species requiring the conditions present. Clearfelling in many ways mimics wild forest fires, with a major exception that the trees are utilized. Clearcutting (without residuals) does not leave patches of standing timber, snags or individual trees the same way some wild-fires do, due to the many varying intensities of wild-fires. The use of the other clearfelling systems can alleviate most of the above problems outlined for clearcutting without residuals.

In northern forests, the microclimate within stands is quite cool due to shading, so the needles and other forest litter do not decompose quickly. Through fires or clearfelling, light is admitted to the forest floor and the site warms up significantly. This results in faster decomposition of the litter layer into much needed humus. In addition, the release of nutrients and

increased light result in the rapid growth of the young trees. Otherwise, regeneration of shaded, cold soils with deep organic layers is very difficult, and growth is slow. This phase is also important in coniferous forests for the growth of other herbaceous species and humus production, thus preventing the soil from becoming too acidic. The ash produced during a fire can also help buffer the soil.

The water table generally rises due to the lack of transpiration by the trees, thus giving additional water to the shallow rooted seedlings. On lowlands this may be detrimental, as there may be too much water. On the other hand, clearfelling stands growing on coarse, shallow soils may result in the drying of the soil and a more difficult water situation. Water stress can be controlled to a large extent through smaller clearfelled areas (e.g., patch cutting) and through site preparation to produce microsites favorable for seedling growth. If the species can be regenerated through a shelterwood system, good regeneration can be obtained on these difficult sites. In addition, the site is protected from frost damage.

Clearfelling may be the only effective harvesting and regeneration alternative in a number of situations. This is especially true if the stand is intolerant and past its biological rotation age, and no previous thinning has occurred. If a shelterwood or seed tree cut is made, the remaining trees are often blown over by wind or damaged by snow within a short period. In some cases the stand may be severely damaged or killed by insects or pathogens, and thus the only alternatives to rehabilitate the area are to clearfell or burn it. The site may have been *high-graded* in the past, and/or there may be noncommercial trees on the site. To get an adequate stocking of commercial trees on the site, it is easiest to clearfell and plant it.

Under certain circumstances, clearfelling may allow for an abundance of animal and plant species by creating a mosaic of stands of varying conditions with a large *edge effect*. This spatial diversity can be further enhanced by having a mix of small patch cuts for maximum edge, and larger clearcuts to provide large forest interiors for the future. Other potential benefits of clearfelling relative to selection cutting include more rapid growth of young trees, easier management, and lower harvesting costs. Multiple entries associated with single-tree selection cutting may impose greater risk of damage to the site and residual trees.

In northern forests even-aged management, through clearfelling, seed tree and shelterwood systems, is often the most applicable method in forest renewal due to the nature of the species, climate, site conditions and remoteness. With clearfelling, the forest renewal period (from removal of the mature trees to full regeneration) is a period of radical change in the stand, and quite visible. Through intensive regeneration efforts, this period of high visibility in forest management can be minimized. Also, where

feasible the use of seed tree and shelterwood systems allows for a less dramatic change to the site after harvesting. This is because residual trees are left on site and thus lessen the impacts on wildlife and aesthetics. Due to the large amount of residual tree cover in the shelterwood system there is also the added protection to the site from possible erosion and nutrient runoff.

Indiscriminant use of clearfelling which results in large continuous open areas, has given the practice of clearfelling a very negative connotation. However, the concerns should not be centered on clearfelling per se, but rather on the size of clearfelled areas, the period which should be left before adjacent areas can be cut, whether a certain area (e.g., 160 acres) should be cut using two or more entries into the area, and the seasonal timing of the cuts (e.g., ground disturbance, noise affecting resorts, etc.).

The following list (in no specific order) outlines the many factors which must be considered when specifying a silvicultural system, rotation age, access restrictions, clearfelling area size, exclusion period length for adjacent areas, and whether two, three or more entries into an area are required, or in some cases, whether harvesting should be excluded entirely:

- silvics of the species;
- current stand and forest age class distribution (e.g., all overmature);
- stand/forest hygiene (i.e., presence of insects or disease, fire damage) and the necessity to salvage or contain insects/disease, or utilize wood before it is degraded beyond an economic limit;
- harvesting economics;
- forest industry economics;
- road network requirements;
- wood quantity and quality requirements by industry;
- topography/slope/aspect;
- soil type, quality/nutrients, sensitivity, etc.;
- access constraints to areas due to soil sensitivity, wildlife, recreation, etc., and thus the need for winter logging, other special access (e.g., barge), or exclusion;
- wildlife needs for habitat and the effect of forest fragmentation (i.e, some species need edge, while others need forest interiors, cover, etc.) and effect of forest fragmentation;
- degree and type of recreational use;
- presence of indigenous species (both plant and animal) and their habitat requirements;
- possible presence of rare, threatened or endangered species (both plant and animal) and their habitat requirements;
- maintaining or improving water quality;
- maintaining or improving species (plant and animal) diversity;

- maintaining or enhancing aesthetic forest values in areas of high public exposure and/or recreational use; and
- presence of historically or culturally sensitive areas, or other special forest conditions (e.g., old growth).

A single harvesting and silvicultural policy which would take into account all the above factors is not practical since many of the above conflict, while others are not applicable to all situations. There is even conflict within a single factor: e.g., certain species of wildlife require considerable edge and thus a fragmented forest with small irregular-shaped patches, while other species require a large forest interior and thus larger clearcuts to provide large forest interiors in the future. In other situations (e.g., in a remote primitive access area where only winter access may be allowed) larger clearcuts may be desired, with a minimum number of entries into the area.

A forest-level analysis of the above factors (e.g., species diversity, animal habitat, recreational opportunities, etc.) must be the focus. However, stand-level factors are important to minimize the effects on water quality and soil, to maintain a wide variety of age classes and stand conditions in the forest, and to achieve the forest-level objectives.

3
MINNESOTA TREE SPECIES AND COVERTYPES

Table 3.1 lists most native tree species found in Minnesota; a few minor hardwoods are not listed (i.e., black oak, shagbark hickory, black cherry, butternut, slippery elm, black willow, and some noncommercial species). Table 3.1 also indicates the relative requirements of the species for moisture, nutrients, heat and light. Moisture, nutrients, and heat limit the ability of a species to grow on a site. The light requirement indicates how applicable the uneven-aged and even-aged silvicultural systems are for management of the species. A species with a high light demand (5.0) would require clearfelling or a major disturbance for it to regenerate successfully, while a species with a low light demand (1.0) is very shade tolerant and is amenable to management under uneven-aged silvicultural systems.

To simplify silvicultural prescriptions, species that commonly grow in association which each other are often grouped into covertypes which is named after the dominant species or group of species. This does not mean other species are not found in association with the covertype. For example, all Minnesota tree species can be found in the northern hardwoods covertype. The major covertypes found in Minnesota are listed below:

- Jack pine
- Red pine
- White pine

- Balsam fir
- White spruce
- Black spruce (upland and lowland)
- Northern white cedar
- Tamarack
- Oak-hickory
- Elm-ash-soft maple (lowland hardwood)
- Maple-basswood (northern hardwood)
- Aspen
- Paper birch
- Balsam poplar

Table 3.2 summarizes by covertype the applicability of the silvicultural systems and thinning. The applicability is based on the information presented earlier, the autecology of the major species in the covertype, the sites they are generally found on, and on field observations. The applicability classes are very broad and the actual applicability of a silvicultural system or thinning would have to be based on the factors listed in section 2.4. However, the table does give a very quick reference as to the general applicability of a silvicultural system or thinning to the management of a covertype. For example, uneven-aged management through selective cutting is not applicable to jack pine, red pine, black spruce, tamarack, aspen, paper birch, hybrid poplar and hybrid aspen, irrespective of site. Group selective cutting is applicable to white pine and red oak, however, single tree selective cutting is not. On the other hand selective cutting is applicable under limited conditions for the management of balsam fir and white spruce, while for northern white cedar, black walnut, northern hardwoods and black ash it could be used quite successfully.

Table 3.3 presents data on the extent the various silvicultural systems are used by the Minnesota Department of Natural Resources (MNDNR) for each covertype on state timberlands during fiscal year 1991. Table 3.3 also presents the share of harvest from the various covertypes on state timberlands. Similar data was not available for the other timberland ownerships in Minnesota.

The residuals left in the oak covertype (i.e., clearcutting with residuals) are usually white oak left as masts and snags for wildlife. Also, the residuals are a result of very overmature stands and their poor quality resulting from successive high-gradings.

Table 3.1. Synecological requirements of Minnesota tree species for moisture, nutrients, heat, and light (adapted from Bakuzis and Hansen 1959).

Latin Name	Common Name	Relative requirement values*			
		Moisture	Nutrients	Heat	Light
SOFTWOODS					
Abies balsamea	Balsam fir	3.6	2.0	1.4	2.0
Juniperus virginiana	E. red cedar	1.0	2.6	5.0	3.0
Larix laricina	Tamarack	5.0	1.0	1.0	5.0
Picea glauca	White spruce	2.8	2.2	1.5	2.3
Picea mariana	Black spruce	4.5	1.2	1.0	3.5
Pinus banksiana	Jack pine	1.0	1.1	1.9	5.0
Pinus resinosa	Red pine	1.1	1.6	2.1	4.5
Pinus strobus	White pine	1.7	2.1	2.0	2.8
Thuja occidentalis	N. white cedar	4.2	2.3	1.3	1.2
HARDWOODS					
Acer negundo	Box elder	3.3	5.0	5.0	3.4
A. rubrum	Red maple	1.9	2.3	2.6	3.4
A. saccharum	Sugar maple	3.2	5.0	3.5	1.0
A. saccharinum	Silver maple	3.2	5.0	5.0	4.5
Betula papyrifera	Paper birch	2.9	2.1	1.7	5.0
B. alleghaniensis	Yellow birch	3.7	5.0	2.4	1.7
Carya cordiformis	Bitternut hickory	2.7	5.0	4.8	1.0
Celtis occidentalis	Hackberry	3.3	5.0	5.0	1.6
Fraxinus nigra	Black ash	3.9	3.5	2.6	1.8
F. pennsylvanica	Green ash	3.0	5.0	4.4	3.6
Juglans nigra	Black walnut	1.6	5.0	5.0	2.0
Ostrya virginiana	E. hophornbeam	2.4	5.0	4.3	1.1
Populus balsamifera	Balsam poplar	3.7	2.7	2.1	3.5
P. deltoides	Cottonwood	2.9	5.0	5.0	3.9
P. grandidentata	Bigtooth aspen	1.3	3.0	3.1	3.4
P. tremuloides	Quaking aspen	2.0	2.3	2.1	4.2
Quercus alba	White oak	2.1	5.0	4.6	1.3
Q. ellipsoidalis	N. pin oak	1.0	1.8	3.0	5.0
Q. macrocarpa	Bur oak	1.5	3.2	3.8	3.5
Q. rubra	Red oak	1.5	4.2	3.5	2.8
Tilia americana	Basswood	2.5	5.0	3.8	1.5
Ulmus americana	American elm	3.5	5.0	3.9	2.0
U. thomasi	Rock elm	2.9	5.0	5.0	2.6

* Relative requirement values: 1=least demand ... 5=highest demand.

Table 3.2. Applicability of various silvicultural systems by covertypes, based on autecology of species and site conditions where generally found.

COVERTYPE	Clearcutting	Clearcutting with residuals	Patch cutting	Strip or modified cutting	Seed tree cutting	Shelterwood cutting	Selective cutting	Commercial thinning
Jack pine	+++	+	+++	+++	+	0	0	++
Red pine	+++	++	+++	+++	+	+	0	+++
White pine	+++	+++	+++	+++	+++	+++	+	+++
Balsam fir	+++	++	+++	+++	+	++	++	+++
White spruce	+++	++	+++	+++	+	++	++	+++
Black spruce	+++	++	+++	+++	++	+	0	++
N. White Cedar	++	++	+++	+++	++	+++	+++	+
Tamarack	+++	+	+++	+++	+++	0	0	+
Oak (red)	++	++	+++	+++	+	+++	+	+++
Black walnut	++	++	+++	+++	0	+++	+++	+++
N.hardwoods	++	++	+++	+++	++	+++	+++	+++
Black ash (lowland hw)	++	++	+++	+++	++	+++	+++	+++
Aspen	+++	++	+++	+++	0	0	0	+
Paper birch	+++	++	+++	+++	0	0	0	+
Hybrid poplar	+++	0	+++	+++	0	0	0	0

+++ - high applicability (i.e., applicable in most conditions)
++ - medium applicability (i.e., applicable in some conditions)
+ - low applicability (i.e., applicable only under certain conditions)
0 - not applicable (i.e., not applicable under any conditions)

Note: Jack pine seed tree method requires prescribed burning to open serotinous cones.
Scattered balsam fir and white spruce overstory should be left only if they do not pose a forest health hazard, particularly in regard to spruce budworm.
All black spruce should be felled if dwarf mistletoe present.

As outlined in section 2.4, there are numerous factors which must be considered when developing a silvicultural system or management guidelines for a covertype. In addition to biological factors, the goals of the forest owner and society are also strong determinants in selecting an appropriate management regime. The different ownership groups in Minnesota have varying covertype management guidelines, and these guidelines are evolving as more information becomes available and as goals change. Appendix 1 presents covertype management guidelines which have been drawn (with some additions, deletions, and changes) from the *Forest Development Manual* (draft) prepared by the MNDNR Division of Forestry (MNDNR 1990).

Table 3.3. Silvicultural systems used by the MNDNR on state timberlands by covertypes for FY1991; all values are percent of total area (30,694 acres) with logging operations.

Covertype	Clearcut	Clearcut with residuals	Patch	Strip	Seed tree	Shelter-wood	Selective	Thin-ning*	Other	Percent of area harvested
Jack pine	82	13	3	0	0	0	0	1	0	7
Red pine	33	4	3	0	0	1	15	45	0	2
Spruce/balsam fir	52	44	4	0	0	0	0	0	0	6
Black spruce	75	2	2	8	1	0	0	6	9	14
Cedar	7	49	35	0	0	0	10	0	0	0
Tamarack	46	10	3	36	10	0	0	0	0	1
Oak	24	48	12	0	0	0	8	2	6	1
Bottomland hardwoods	6	57	9	0	0	0	18	11	0	1
Northern hardwoods	7	30	10	0	0	13	20	21	0	2
Aspen	55	48	1	0	0	0	0	0	0	61
Birch	46	42	16	0	0	0	0	0	0	4
Balsam poplar	83	16	1	0	0	0	0	0	0	2
Average for all covertypes	55	36	3	1	0	0	1	2	1	100

*Thinning is not a silvicultural system but a silvicultural treatment.

Because Minnesota's forests are not homogeneous it is important to realize that the guidelines presented in appendix 1 are not necessarily applied uniformly across a harvest area. In fact, a harvest may have a very mixed species composition. These guidelines are largely directed at stand level management. A stand by definition is "a contiguous group of trees sufficiently uniform in species composition, arrangement of age classes, and condition to be a distinguishable unit" (Smith 1986).

In practice, a harvest area may include one to several stands reflecting the range of biotic and abiotic factors described previously. There may also be considerable variability within stands. Under these circumstances, forest managers select silvicultural systems that are the most appropriate for the site while taking into account the management objectives for the stand and overall forest goals. Therefore, where management is sophisticated, such as for wildlife habitat development or where high value products are being grown, the silvicultural systems applied tend to reflect the variability in the forest.

The high variability within covertypes seen in some areas of Minnesota today is indicative of the low levels of management typically practiced in the past. Such minimal management inputs are the result of historically low valued commodity products, and tend to result in simplistic and unformally applied silvicultural systems producing highly variable results. With more management resources, managers may seek to either increase stand size for ecological or economic reasons; or favor development of diverse and smaller stands.

Finally, while the silvicultural guidelines are labelled as to covertype, actual stand mixtures and management resources may provide significant options. For example, a jack pine stand with a high proportion of aspen may be harvested and treated to favor the return of jack pine or treated to favor replacement by aspen.

4
SILVICULTURE SURVEY RESULTS

A survey was made to determine current (1990–91) use of silvicultural operations on the major timberland ownerships in Minnesota (i.e., state, county, national forest, forest industry and Native American). The response to the survey covered 100 percent of state, national forest, forest industry and Native American timberlands, and 95 percent of county timberlands based on timberland areas reported in the Minnesota forest inventory statistics (Kingsey 1991, Leatherberry 1991, Murray 1991, Hahn and Smith 1988).

The survey results are presented in table 4.1. A copy of the questionnaire is included in appendix 2.

A similar survey for other timberland ownerships (i.e., private nonindustrial and other federal forest land [e.g., Bureau of Land Management]) was not possible due to a lack of consolidated information on silviculture and harvest statistics. However, estimates of silvicultural operations on the other ownerships were made based on the silviculture survey, logging survey (Jaakko Pöyry Consulting, Inc., 1992), state and forest industry private forest assistance programs, MNDNR data, and literature on Minnesota private timberlands (e.g., Henly et al. 1988). *Determining harvesting and silvicultural operations on private timberlands should be an area of further research.*

The total volume harvested from the silviculture survey timberlands was 1.86 million cords, with the annual volume removed per acre averaging 0.24 cord/acre/year. For those ownerships surveyed, the total area with logging operations was estimated to be 90,128 acres. On average, 21.6, 17.2, 8.6,

11.9, and 8.8 cord/acre were removed in clearfellings, seed tree cuts, shelterwood cuts, selective cuts and thinning, respectively (table 4.2).

Table 4.3 presents data on percentages of timberland and harvest volumes reported in the silviculture survey, and estimates of total volume and area harvested on private and other federal timberlands (other ownerships). Since county responses covered 95 percent of the county timberland the total volume harvested from county forests was estimated to be 553,071 cords (i.e., 527,622 cords/0.95) (table 4.3).

Based on Jaakko Pöyry files, published data, MNDNR data, and information obtained directly from wood processing facilities, the total industrial wood consumption, including net exports, was estimated to be 3.31 million cords for fiscal year 1990–91. The amount of fuelwood from roundwood was estimated to be 530,000 cords (MNDNR statistics). This yields a total estimated annual harvest of 3.84 million cords for fiscal year 1990—91 including the most recent expansions in wood consumption.

This total differs slightly from that used in the base harvest scenario. The minor differences can be explained by the fact that the scenarios are based on wood demands from industry, whereas the figures in this paper are based on wood harvested from the forests during a particular period. Therefore, factors such as fluctuations in the amount of wood stockpiled at mills and variations in the actual volumes of wood processed can account for these differences.

It must be noted, however, that although 530,000 cords of fuelwood come from roundwood it is unclear as to what extent this comes from timberlands and noncommercial trees.

Subtracting the estimated harvest of 1.88 million cords on survey timberlands from the total consumption, yields an estimated harvest level of 1.96 million cords for the other ownerships (private and other federal timberlands). This corresponds to an average annual removal of 0.33 cords/acre/year. Assuming the same harvest volume removed per acre as with the survey ownerships (table 4.3), the total logging area on other ownerships was estimated to be 109,700 acres.

The total area of timberland area of the other ownerships is 6.0 million acres. Of this 97 percent is classed as private, while other federal timberlands account for 3 percent. The other ownerships accounted for 43 percent of the timberlands, and 51 percent of the total harvest.

Table 4.1. Silviculture operations survey results for state, county, national forest, forest industry and Native American timberlands.

TIMBERLAND OWNERSHIP	State	County	National forest	Forest industry	Native American	Total survey
Area of ownership, ac	2,584,000	2,226,506	1,705,000	834,479	498,046	7,848,031
Total volume harvested, cord	685,900	527,622	344,000	214,635	86,692	1,858,849
Area with logging operations, ac	30,861	26,395	17,296	11,148	4,428	90,128
Natural regeneration area, ac	19,760	20,594	13,113	7,559	3,402	64,428
Artificial regeneration area, ac	9,465	5,128	2,724	2,765	481	20,563
SILVICULTURAL SYSTEMS AND THINNING, % by volume harvested						
- clearcutting (area >5ac)	55	60	0	95	93	52
- clearcutting with standing residuals	38	30	97	1	0	40
- patch cutting (0.25-5ac)	3	5	0	0	0	2
- strip or other modified clearcut	1	2	0	0	2	1
- seed tree cutting	0	0	0	0	0	0
- shelterwood cutting	0	0	0	0	0	0
- selective logging	1	3	0	0	0	1
- thinning	2	1	3	4	5	3
SILVICULTURAL SYSTEMS AND THINNING, % by area harvested						
- clearcutting (area >5ac)	52	56	0	91	83	50
- clearcutting with standing residuals	36	30	91	1	0	39
- patch cutting (0.25-5ac)	3	5	0	0	0	2
- strip or other modified clearcut	2	2	0	0	1	1
- seed tree cutting	0	1	0	0	0	0
- shelterwood cutting	1	0	0	1	1	0
- selective logging	2	5	0	0	0	2
- thinning	5	3	8	7	15	6
REGENERATION AREAS, acres						
- planting	4,750	4,948	1,979	2,442	481	14,600
- seeding	4,715	180	745	323	0	5,963
- natural regeneration	19,760	20,594	13,113	7,559	3,402	64,428
- TOTAL	29,225	25,722	15,837	10,324	3,883	84,991
SITE PREPARATION AREAS, acres						
- chemi-aerial	402	0	0	54	0	456
- chemi-ground	1,402	1,369	0	191	0	2,962
- prescribed burning	825	120	192	100	0	1,237
- mechanical	3,553	1,360	2,431	1,831	444	9,619
- mechanical with band spraying	0	0	0	932	0	932
- TOTAL	6,182	2,849	2,623	3,108	444	15,206
TIMBER STAND IMPROVEMENTS, acres						
- chemical release - aerial	535	2,715	0	2,002	0	5,252
- chemical release - ground	675	1,877	0	1,362	0	3,914
- hack and squirt	20	0	0	0	0	20
- mechanical/manual release	808	455	3,782	53	408	5,506
- noncommercial thinning	427	164	60	203	590	1,444
- residual stem felling	570	271	7,686	474	0	9,001
- pruning	150	28	13	10	0	201
- slash disposal (burn brush piles)	50	41	0	0	0	91
- TOTAL	3,235	5,550	11,541	4,104	998	25,428

Table 4.2. Volumes removed per acre by silvicultural system and in thinning as reported in the silvicultural survey.

Silvicultural system or operation	Cords/acre removed
Clearcutting	21.8
Clearcutting with residuals	21.5
Patch cutting	21.0
Strip or other modified cutting	20.6
Seed tree cutting	17.2
Shelterwood cutting	8.6
Selective cutting	11.9
Thinning	8.8

Table 4.3. Summary of estimates of annual volume harvested and area with logging operations by ownership.

TIMBERLAND OWNERSHIPS SURVEYED	Timberland coverage, percent	Harvest reported, cord	Total harvest estimate, cord
State timberlands	100	685,900	685,900
County timberlands	95	527,622	553,071
National forest timberlands	100	344,000	344,000
Forest industry timberlands	100	214,635	214,635
Indian timberlands	100	86,692	86,692
Total harvest volume estimate from survey ownerships, cords			1,884,298
Total timberland area for survey ownerships, acres			7,965,216
Harvest, cords/acre/year			0.24
Area with logging operations, acres			90,128
Removals from areas with logging operations, cord/acre			20.6
Current industrial wood consumption + net exports + fuelwood, cords[a]			3,843,300
ESTIMATES FOR PRIVATE AND OTHER FEDERAL TIMBERLANDS			
Total harvest estimate for other ownerships[b], cords			1,959,002
Total timberland of other ownerships[c], acres			6,023,800
Industrial removals, cords/acre/year			0.33
Percent of timberland			43
Per cent of harvest			51
Estimate of area with logging operations, acres			109,700

[a] Estimated from Jaakko Pöyry files, published data, information obtained directly from wood processing facilities, and MNDNR data.
[b] Equals the difference between current industrial roundwood consumption, including net exports, and estimated total harvest volume from the silviculture survey ownerships.
[c] From forest statistics for Minnesota.

The estimates of total volume harvested and area with logging operations for the other ownerships were combined with results obtained in the silviculture survey and logging survey (see Harvesting Systems Background paper), to extrapolate silvicultural systems and operations on the private and other federal timberlands (table 4.4 and figure 4.1). In table 4.4, the estimates of percentages of total volume harvested by silvicultural system for other ownerships are the differences between the silviculture survey and logging survey results (i.e., the difference between the two surveys is attributed to operations on the other ownerships). The percentages of area harvested by silvicultural system for the other ownerships are based on the ratios between volume and area percentages obtained in the silviculture survey.

The estimates of regeneration areas for the other timberland ownerships are based on data compiled by the MNDNR from statistics on the non-industrial private forest assistance program and seedling sales from nurseries. The estimates for area of site preparation were assumed to be in proportion to the artificial regeneration areas and site preparation areas obtained for the ownerships reporting in the silvicultural survey. The areas for timber stand improvements are based on data supplied by the MNDNR and distributed to the different categories according to the silvicultural survey results. The estimates presented in table 4.4 may slightly underestimate the forestry/silviculture activities on the other ownership timberlands.

Table 4.5 presents an estimate of total silvicultural operations on Minnesota timberlands (i.e., combines silviculture survey results and estimated on other ownerships). Of the total harvested it was estimated that 80 percent of the volume came from clearcuts and clearcuts with residuals, which in turn accounted for 71 percent of the area with logging operations. Patch, strip and other modified cutting accounted for 8 percent of the volume and area logged. Seed tree and shelterwood cutting accounted for 2 percent of the volume and 4 percent of the area logged. Selective cutting accounted for 5 percent of the volume and 8 percent of the area logged. The volume removed in thinnings was 4 percent, and they occurred on 10 percent of areas with logging operations. The total area with logging operations was estimated to be 200,000 acres, of which 19,000 acres was thinning. Planting occurred on 32,600 acres, seeding on 6,000 acres, and natural regeneration on 142,000 acres (figure 4.2).

Table 4.6 presents the annual area of silvicultural operations as percentages of timberland area for the silviculture survey and total estimate. The percentages should not be added since many of the operations occur on the same areas (e.g., harvesting, site preparation, planting, and stand improvement may all occur on the same site). As can be seen in table 4.5, the percentage of timberland area with silvicultural operations in any one year is quite small, especially in regard to timber stand improvements.

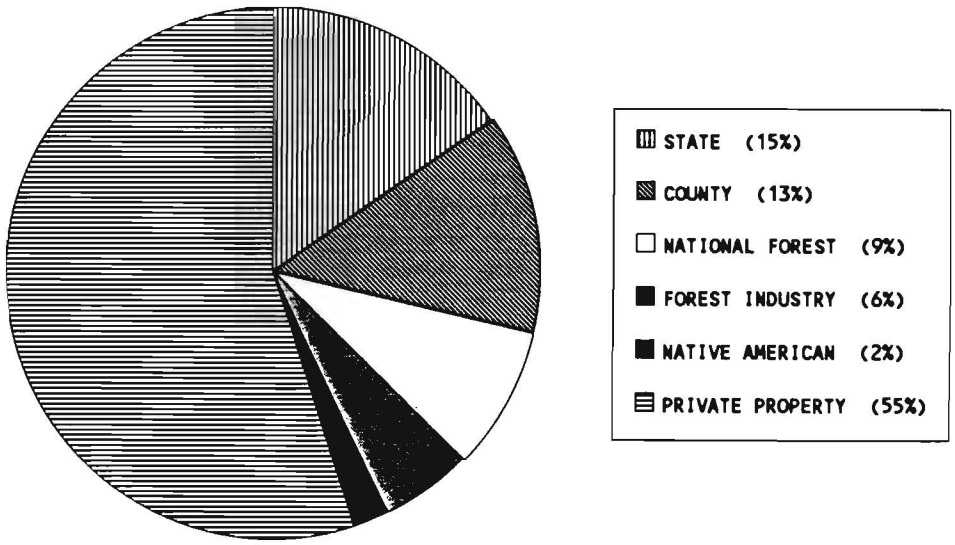

Figure 4.1. Relative estimated annual area of logging operations (by ownership) in Minnesota during the period 1990–91.

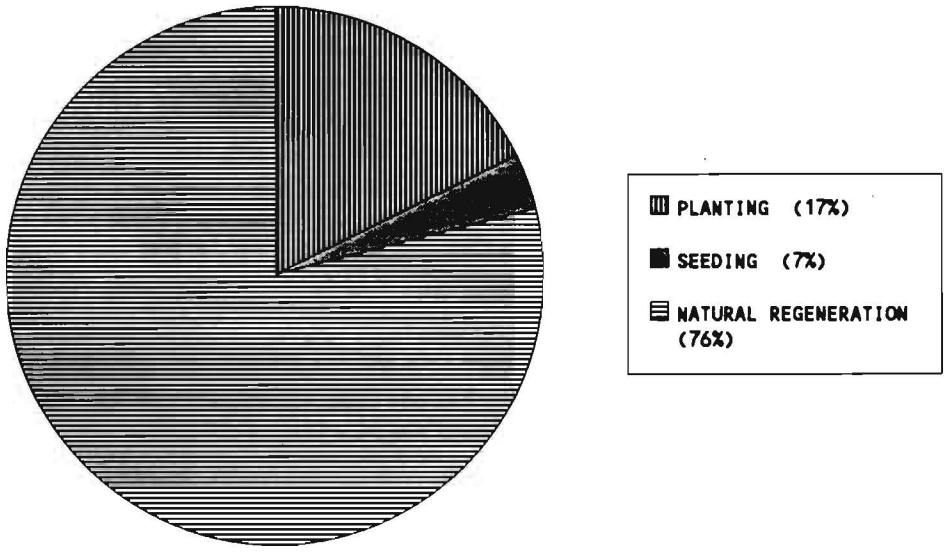

Figure 4.2. Relative use of regeneration techniques in Minnesota during the period 1990–91.

Table 4.4. Estimated silvicultural operations on other ownership (private and other federal) timberlands.

OWNERSHIP	Other ownerships[a]	Silviculture survey[b]	Logging survey[c]
Area of ownership, ac	6,023,800	7,848,031	
Total volume harvested, cord	1,959,002	1,858,849	615,639
Area with logging operations, ac	109,700	90,128	30,782
Natural regeneration area, ac	77,847	64,428	
Artificial regeneration area, ac	18,003	20,563	
SILVICULTURAL SYSTEMS AND THINNING, % by volume harvested			
- clearcutting (area >5ac)	26	52	39
- clearcutting with standing residuals	42	40	41
- patch cutting (0.25-5ac)	7	2	5
- strip or other modified clearcut	6	1	4
- seed tree cutting	1	0	1
- shelterwood cutting	3	0	1
- selective logging	9	1	5
- thinning	6	3	4
SILVICULTURAL SYSTEMS AND THINNING, %by area harvested			
- clearcutting (area >5ac)	21	50	
- clearcutting with standing residuals	35	39	
- patch cutting (0.25-5ac)	6	2	
- strip or other modified clearcut	5	1	
- seed tree cutting	1	0	
- shelterwood cutting	5	0	
- selective logging	13	2	
- thinning	13	6	
REGENERATION AREAS, acres			
- planting	18,003	14,600	
- seeding	0	5,963	
- natural regeneration	77,847	64,428	
- TOTAL	95,850	84,991	
SITE PREPARATION AREAS, acres			
- chemi-aerial	399	456	
- chemi-ground	2593	2,962	
- prescribed burning	1083	1,237	
- mechanical	8,421	9,619	
- mechanical with band spraying	816	932	
- TOTAL	13,313	15,206	
TIMBER STAND IMPROVEMENTS, acres			
- chemical release - aerial	366	5,252	
- chemical release - ground	273	3,914	
- hack and squirt	1	20	
- mechanical/manual release	383	5,506	
- noncommercial thinning	172	1,444	
- residual stem felling	1,071	9,001	
- pruning	24	201	
- slash disposal (burn brush piles)	11	91	
- TOTAL	2,301	25,428	

[a] Includes nonindustrial private and miscellaneous federal forest land.

[b] Includes county, state, USDA Forest Service, industry, and Native American forest lands.

[c] Represents 16 percent of total volume harvested statewide, all ownerships.

Table 4.5. Summary of estimated annual silviculture operations on timberlands by ownership over the period 1990–91.

DATA SOURCE	Survey					Estimate	Total estimate
OWNERSHIP	State	County	National Forests	Forest industry	Native American	Private & other	
Area of ownership, ac	2,584,000	2,226,506	1,705,000	834,479	498,046	6,023,800	13,871,831
Total volume harvested, cord	685,900	553,071	344,000	214,635	86,692	1,959,002	3,843,300
Area with logging operations, ac	30,861	26,395	17,296	11,148	4,428	109,700	199,828
Natural regeneration area, ac	19,760	20,594	13,113	7,559	3,402	77,847	142,275
Artificial regeneration area, ac	9,465	5,128	2,724	2,765	481	18,003	38,566
SILVICULTURAL SYSTEMS AND THINNING, % by volume							
- clearcutting (area >5ac)	55	60	0	95	93	26	39
- clearcutting with standing residuals	38	29	97	1	0	42	42
- patch cutting (0.25-5ac)	3	5	0	0	0	7	5
- strip or other modified clearcut	1	2	0	0	2	6	3
- seed tree cutting	0	0	0	0	0	1	1
- shelterwood cutting	0	0	0	0	0	3	1
- selective logging	1	3	0	0	0	9	5
- thinning	2	1	3	4	5	6	4
SILVICULTURAL SYSTEMS AND THINNING, %by area							
- clearcutting (area >5ac)	52	56	0	91	83	21	34
- clearcutting with standing residuals	36	30	91	1	0	35	37
- patch cutting (0.25-5ac)	2	5	0	0	0	6	5
- strip or other modified clearcut	1	2	0	0	1	5	3
- seed tree cutting	0	0	0	0	0	1	1
- shelterwood cutting	1	0	0	1	1	5	3
- selective logging	2	5	0	0	0	13	8
- thinning	5	3	8	7	15	13	10
REGENERATION AREAS, acres							
- planting	4,750	4,948	1,979	2,442	481	18,003	32,603
- seeding	4,715	180	745	323	0	0	5,963
- natural regeneration	19,760	20,594	13,113	7,559	3,402	77,847	142,275
- TOTAL	29,225	25,722	15,837	10,324	3,883	95,850	180,841
SITE PREPARATION AREAS, acres							
- chemi-aerial	402	0	0	54	0	399	855
- chemi-ground	1,402	1,369	0	191	0	2,593	5,555
- prescribed burning	825	120	192	100	0	1,083	2,320
- mechanical	3,553	1,360	2,431	1,831	444	8,421	18,040
- mechanical with band spraying	0	0	0	932	0	816	1,748
- TOTAL	6,182	2,849	2,623	3,108	444	13,313	28,519
TIMBER STAND IMPROVEMENTS, acres							
- chemical release - aerial	535	2,715	0	2,002	0	366	5,618
- chemical release - ground	675	1,877	0	1,362	0	273	4,187
- hack and squirt	20	0	0	0	0	1	21
- mechanical/manual release	808	455	3,782	53	408	383	5,889
- noncommercial thinning	427	164	60	203	590	172	1,616
- residual stem felling	570	271	7,686	474	0	1,071	10,072
- pruning	150	28	13	10	0	24	224
- slash disposal (burn brush piles)	50	41	0	0	0	11	102
- TOTAL	3,235	5,550	11,541	4,104	998	2,301	27,729

Table 4.6. Areas of annual silvicultural operations as percentages of total timberland. Percentages should not be added directly to get an overall total effect since a number of operations could occur on the same site. Includes all timberlands, but results for other ownerships extrapolated from silviculture survey.

	SILVICULTURE SURVEY		TOTAL ESTIMATED	
	Annual forest operations in analysis, acres	Annual forest operations as a percent of timberlands	Annual forest operations in analysis, acres	Annual forest operations as a percent of timberlands
Area of timberland ownership	7,848,031		13,871,831	
Area with logging operations	90,128	1	199,828	1
Natural regeneration area	64,428	1	142,275	1
Artificial regeneration area	20,563	<1	38,566	<1
REGENERATION AREAS				
- planting	14,600	<1	32,603	<1
- seeding	5,963	<<1	5,963	<<1
- natural regeneration	64,428	1	142,275	1
- TOTAL	84,991	1	180,841	1
SITE PREPARATION AREAS				
- chemi-aerial	456	<<1	855	<<1
- chemi-ground	2,962	<<1	5,555	<<1
- prescribed burning	1,237	<<1	2,320	<<1
- mechanical	9,619	<1	18,040	<1
- mechanical with band spraying	932	<<1	1,748	<<1
- TOTAL	15,206		18,519	
TIMBER STAND IMPROVEMENTS				
- chemical release - aerial	5,252	<<1	5,618	<<1
- chemical release - ground	3,914	<<1	4,187	<<1
- hack and squirt	20	0	21	0
- mechanical/manual release	5,506	<<1	5,889	<<1
- noncommercial thinning	1,444	<<1	1,616	<<1
- residual stem felling	9,001	<<1	10,072	<<1
- pruning	201	0	224	0
- slash disposal (burn brush piles)	91	0	102	0
- TOTAL	25,428		27,729	

The estimated total site preparation area was 18,500 acres of which 18,000 was mechanical site preparation. Site preparation occurred on 0.13 percent of the timberland area in the state. The estimated total area with timber stand improvements was 28,000 acres (0.20 percent of timberlands), of which 9,800 acres was chemical release (0.07 percent of timberlands). Logging operations occurred on 1.44 percent of the timberlands, of which 1.31 percent were regeneration cuts and 0.13 percent thinnings.

5
SILVICULTURAL OPTIONS AND COSTS

The planting, site preparation and stand improvement costs presented in tables 5.1, 5.2 and 5.3 have been developed for use in the GEIS study. The costs are based to a large extent on data received from the MNDNR. It should be noted that planting, seeding, site preparation and timber stand improvement costs vary widely from year to year and from site to site.

Table 5.1. Planting and seeding costs, 1991.

	Planting cost, $/ac	Stock cost, $/1000	Root pruning, $/1000	Planting level, stems/ac	Total $/acre
Planting—Bare Root Stock					
Red pine	52.00	85.00	6.00	778	123.00
Jack pine	52.00	85.00	6.00	778	123.00
White pine	53.00	85.00	6.00	778	124.00
White spruce	52.00	85.00	6.00	778	123.00
Black spruce	52.00	85.00	6.00	778	123.00
Balsam fir	52.00	85.00	6.00	778	123.00
Red oak	39.00	150.00	6.00	519	120.00
White oak	39.00	150.00	6.00	519	120.00
Black walnut	51.00	150.00	6.00	519	132.00
Average					123.00
Planting—Container Stock					
Jack pine	56.00	127.50	6.00	778	160.00
White cedar	58.00	127.50	6.00	778	162.00
Tamarack	55.00	127.50	6.00	778	159.00
Average					160.00
Aerial Seeding (mostly for regeneration of black spruce and possibly some jack pine)					
	Seed cost, $/oz	Seed, oz/acre	Seeds/ acre	Helicopter, $/acre	Total $/acre
Black spruce	6.70	2	50,500	4.73	18.00
Jack pine	2.70	6	49,125	4.73	21.00
Tamarack	7.70	2	35,625	4.73	20.00
Balsam fir	1.70	8	29,800	4.73	19.00

Source: MNDNR 1991.

Table 5.2. Site preparation options and costs, 1991.

	Cost, $/acre
Aerial-chemical	70.00
Ground-chemical	88.00
Mechanical and chemical band application	95.00
Prescribed burn	32.00
Mechanical (average)	74.00
Mechanical, shear blading	110.00
Mechanical, brush raking	100.00
Mechanical, disking	60.00
Mechanical, patch scarification	40.00
Mechanical, "V" plow, mowing	50.00

Source: MNDNR 1991.

Table 5.3. Stand improvement options and costs, 1991.

	Cost, $/acre
Aerial-chemical	70.00
Ground-chemical	72.00
Hack and squirt	100.00
Mechanical release	54.00
Noncommercial thinning	73.00
Manual spacing/cleaning	100.00
Residual stem felling	44.00
Pruning	34.00
Burning slash piles	10.00

Source: MNDNR 1991.

6
EXPECTED VOLUME YIELDS ON TIMBERLANDS

The results from the silviculture survey (table 4.2) show that removals from all logged areas averaged 20.6 cords/acre (including thinnings) or 0.23 cords/acre/year. Removals in cords/acre by silvicultural systems and in thinning are presented in table 4.3.

Table 6.1 presents a summary of the mean annual increments (MAI) in the base case scenario by covertypes calculated from the *Initial Harvesting*

Scenarios results (Jaakko Pöyry Consulting, Inc., 1992c). As can be seen the MAIs vary from 0.15 to 0.64 cord/acre/year depending on covertype.

Table 6.1. GEIS base scenario statistics on mean annual increments by covertypes (data from Initial Harvest Scenario results, Jaakko Pöyry Consulting, Inc. (1992c)).

Covertype	Base scenario MAI, Cord/acre/year
Jack pine	0.40
Red pine	0.63
White pine	0.44
Black spruce	0.18
Balsam fir	0.37
N. white cedar	0.29
Tamarack	0.19
White spruce	0.54
Oak/hickory	0.38
Elm/ash/soft maple	0.31
Maple/basswood	0.41
Aspen	0.44
Paper birch	0.43
Balsam poplar	0.37

Figures 6.1, 6.2 and 6.3 present long-term results on yields due to three levels of forest management on higher site class norway spruce stands in Finland. **These figures are presented solely to illustrate the relative increase in merchantable MAI and reduced rotation ages which are possible through more intensive forest management.** If more intensive forest management such as use of genetically improved planting stock, fertilization and thinning, is practiced in Minnesota, there is no reason why similar gains in merchantable yield per acre could not be expected (i.e., doubling of yields presented in table 6.1). On the other hand, there are higher harvesting costs in thinning, and stumpage prices or other forest management funding would have to increase significantly to cover the additional costs of forest management.

Another area to increase yields is through using genetically improved planting stock and seeds in regeneration. The Minnesota Tree Improvement Cooperative indicates the following height growth gains from using genetically superior seeds (although research results are not yet available they also indicate that based on the literature the volume gains may be twice the height gains):

	1st Generation	2nd Generation
• Black spruce	- 6%	- 3-4%
• White spruce	- 10-12%	- 6-10%
• Jack pine	- 4-5%	- 5-6%
• Red pine	- 2%	
• White pine	- emphasis to produce blister rust resistant trees	

Use of hybrid aspen can also increase yields. Generally it is felt that the mean annual increment in hybrid aspen will be about 2 cords/acre/year.

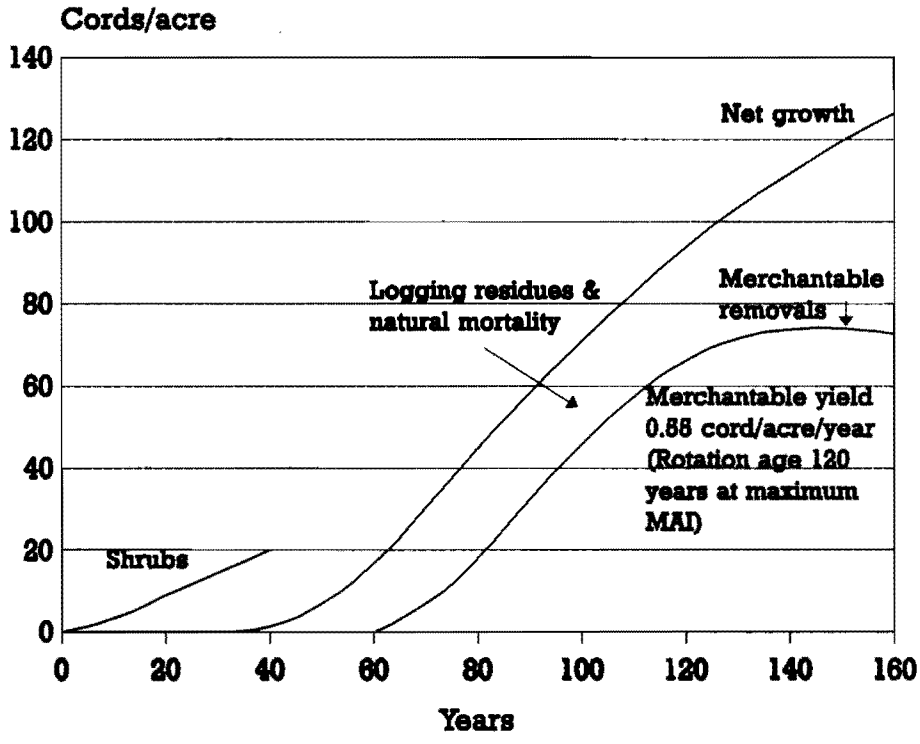

Figure 6.1. Yield and rotation for extensive management of good site class Norway spruce in Finland (Mälkönen 1991).

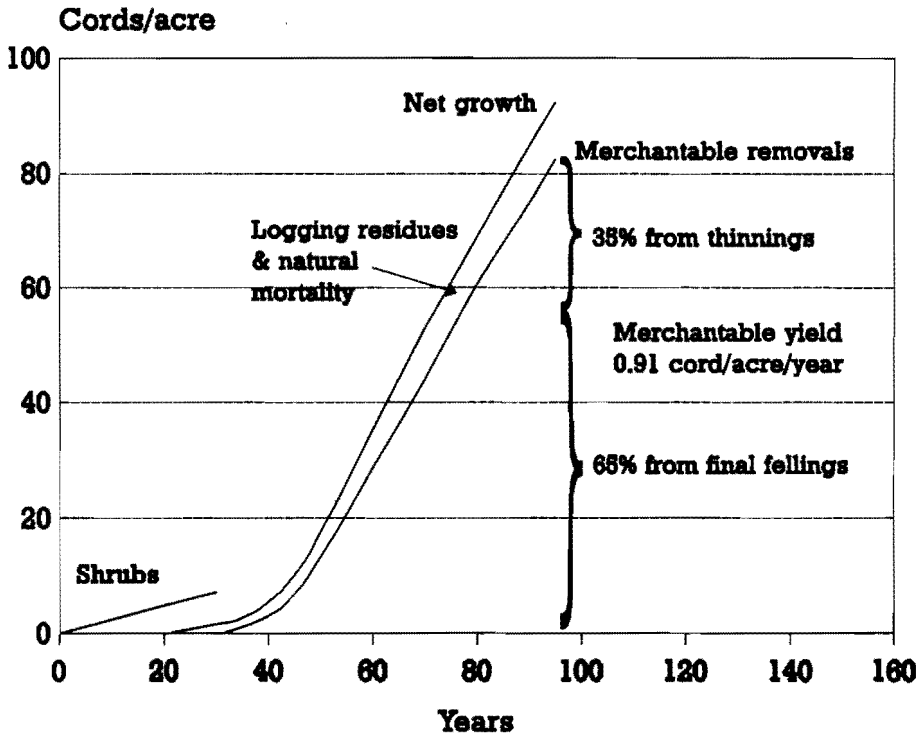

Figure 6.2. Yield and rotation for intermediate management of good site class Norway spruce in Finland (Mälkönen 1991).

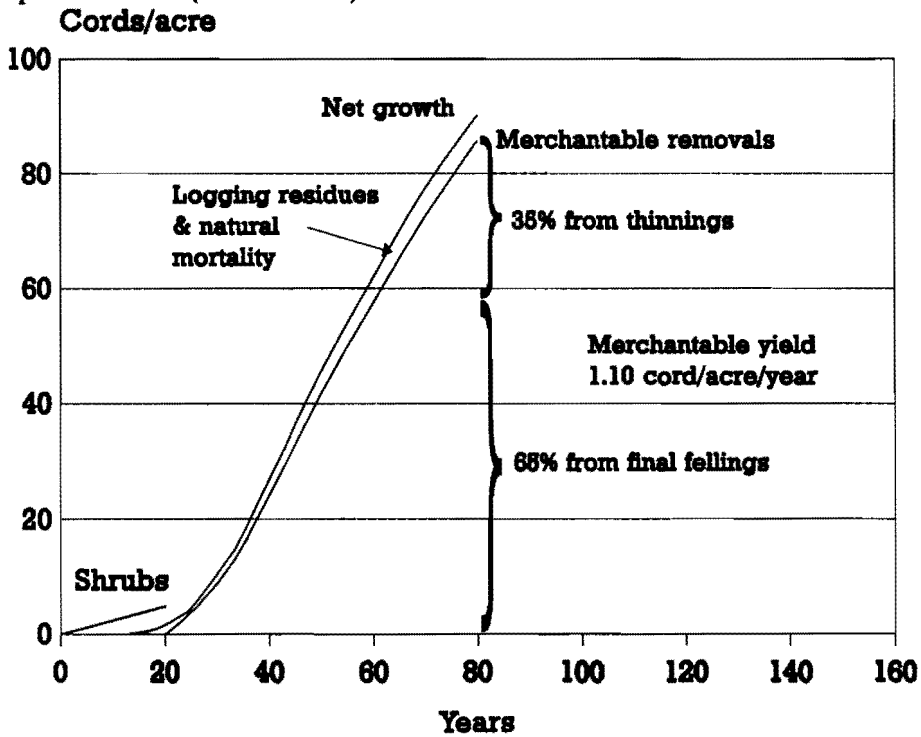

Figure 6.3. Yield and rotation for intensive management of good site class Norway spruce in Finland (Mälkönen 1991).

7
REFERENCES

Anon. 1990. *Water quality in forest management: Best management practices in Minnesota.* Legislative Commission on Minnesota Resources, Minnesota Pollution Control Agency and Minnesota Department of Natural Resources/Division of Forestry.

Bakuzis, E. V., and H. L. Hansen. 1959. *A provisional assessment of species synecological requirements in Minnesota forests.* Forestry Notes no. 84. St. Paul, MN: University of Minnesota.

Benzie, J. W. 1977a. *Manager's handbook for jack pine in the north central states.* Gen. Tech. Rep. NC-32. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Benzie, J. W. 1977b. *Manager's handbook for red pine in the north central states.* Gen. Tech. Rep. NC-33. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Burns, R. M., comp. 1983. *Silvicultural systems for the major forest types of the United States.* Agric. Handbook no. 445. Washington, D.C.: USDA For. Serv.

Ford-Robertson, F. C., ed. 1971. *Terminology of forest science, technology, practice and products: English language version.* The Multilingual Forestry Terminology Series no. 1. Washington, D.C.: Society of American Foresters.

Hahn, J. T., and W. B. Smith. 1988. *Minnesota's forest statistics, 1987: An inventory update.* Gen. Tech. Rep. NC-118. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Henly, R. K., P. V. Ellefson, and M. J. Baughman. 1988. *Minnesota's private forestry assistance program: an economic evaluation.* Misc. Publ. 58. St. Paul, MN: University of Minnesota, Minnesota Agricultural Experiment Station.

Jaakko Pöyry Consulting, Inc. 1992a. *Impacts of timber harvesting and forest management on forest wildlife.* A technical paper for a generic environmental impact statement on timber harvesting and management in Minnesota. Tarrytown, NY: Jaakko Pöyry Consulting, Inc.

Jaakko Pöyry Consulting, Inc. 1992b. *Harvesting systems in Minnesota.* A background paper for a generic environmental impact statement on timber harvesting and management in Minnesota. Tarrytown, NY: Jaakko Pöyry Consulting, Inc.

Jaakko Pöyry Consulting, Inc. 1992c. *Initial harvest scenarios.* A technical paper for a generic environmental impact statement on timber harvesting and management in Minnesota. Tarrytown, NY: Jaakko Pöyry Consulting, Inc.

Johnston, W. F. 1977a. *Manager's handbook for black spruce in the north central states.* Gen. Tech. Rep. NC-34. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Johnston, W. F. 1977b. Manager's handbook for northern white-cedar in the north central states. Gen. Tech. Rep. NC-35. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Johnston, W. F. 1986. *Manager's handbook for balsam fir in the north central states.* Gen. Tech. Rep. NC-111. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Kanscher, H. M. 1984. *Growth and yield of white spruce plantations in the Lake States (a literature review).* Res. Pap. NC-253. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Kingsey, N. P. 1991. *Forest statistics for Minnesota's Aspen-Birch Unit.* Resource Bull. NC-128. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Leatherberry, E. C. 1991. *Forestry statistics for Minnesota's Central Hardwood Unit.* Resource Bull. NC-135. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Minnesota Department of Natural Resources (MNDNR). 1990. *Forest development manual (draft).* St. Paul, MN: Minnesota Department of Natural Resources.

Minnesota Department of Natural Resources (MNDNR). 1985. *Forestry-wildlife guidelines to habitat management: Forest-transition-prairie.* Mimeograph.

Murray, P. 1991. *Forest statistics for Minnesota's Northern Pine Unit.* Resource Bull. NC-131. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Myers, C. C., and R. G. Buchman. 1977. *Manager's handbook for elm-ash-cottonwood in the north central states.* Gen. Tech. Rep. NC-98. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Mälkönen, E. 1991. *Pohjoiset havumetsät luonnonvarana.* Teollisuuden Metsäviesti 2:4-9.

Ohmann, L. F., H. O. Batzer, R. R. Buech, D. C. Lothner, D. A. Perala, A. L. Schipper, and E. S. Verry. 1978. *Some harvest options and their consequences for the aspen, birch and associated conifer forest types of the Lake States.* Gen. Tech. Rep. NC-48. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Perala, D. A. 1977. *Manager's handbook for aspen in the north central states.* Gen. Tech. Rep. NC-36. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Sander, I. L. 1977. *Manager's handbook for oaks in the north central states.* Gen. Tech. Rep. NC-37. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Schlesinger, R. C., and D. T. Funk. 1977. *Manager's handbook for black walnut.* Gen. Tech. Rep. NC-38. St. Paul, MN: USDA For. Serv. North Central Forest Experiment Station.

Smith, D. M. 1962. *The practice of silviculture.* New York: John Wiley and Sons, Inc.

Smith, D. M. 1986. *The practice of silviculture (8 ed.).* New York: John Wiley and Sons, Inc.

Squire, R. O., D. W. Flinn, and R. G. Campbell. 1991. Silvicultural research for sustained wood production and biosphere conservation in the pine plantations and native eucalypt forests of south-eastern Australia. In *Long-term field trials to assess environmental impacts of harvesting,* eds. W. J. Dyck and C. A. Mees, 3-28. Proceedings IEA/BE T6/A6 workshop, Florida, February 1990. IEA/BE T6/A6 Report no. 5. FRI Bulletin no. 161. Rotorua, NZ: Forest Research Institute.

Tubbs, C. H. 1977. *Manager's handbook for northern hardwoods in the north central states.* Gen. Tech. Rep. NC-39. St. Paul, MN: USDA For. Serv., North Central Forest Experiment Station.

Van Arsdel, E. P. 1961. *Growing white pine in the Lake States to avoid blister rust.* Stat. Pap. 92. St. Paul, MN: USDA For. Serv., Lakes States Forest Experiment Station.

APPENDIX 1
Covertype management guidelines

The following covertype management guidelines have been drawn (with some additions, deletions, and changes) from the *Forest Development Manual* (draft) prepared by the MNDNR Division of Forestry (MNDNR 1990). **The guidelines present information on possible management scenarios on state timberlands. This does not mean all other ownerships manage their timberlands in the same manner, or have the same goals.**

Other ownerships, notably the USDA Forest Service, have their own guidelines which are applied to their lands. Their guidelines reflect their particular management objectives. Likewise, the county lands and forest industry lands are managed to reflect their objectives.

Private property lands are often harvested without management input and hence any explicit use of silvicultural guidelines. Where professional advice is sought, such as from state extension personnel, the silviculture practiced is likely to reflect the guidelines presented.

Therefore, the guidelines should not be viewed as a *cookbook* for management on state timberlands. However, the guidelines provide valuable information and direction on the management of various covertypes in Minnesota conditions. Other sources of covertype management guidelines are *Silvicultural Systems for the Major Forest Types of the United States* (Burns 1983) and *Covertype Specific Guidelines for Minnesota* (Benzie 1977a,b; Johnson 1977a,b; Perala 1977; Sander 1977; Schlesinger et al. 1977; Tubbs 1977; Ohman et al. 1978; Kanscher 1984; Myers et al. 1984; Johnson 1986). The MNDNR has also developed *Forestry-Wildlife Guidelines to Habitat Management* (MNDNR 1985) for habitat compartment goals and timber sale design. *Water Quality in Forest Management: Best management practices in Minnesota* (Anon. 1990) provides current practices and mitigation strategies for minimizing the effect of forest management operations on water quality.

1.1
Jack Pine

Management Objectives

The objective is to maintain jack pine on sites where it is the most suitable species. On sites where jack pine is *off-site*, conversion to a more suitable species at the end of the rotation is recommended. Off-site implies the species (in this case jack pine) is growing in atypical conditions (see the section on preferred site conditions). Jack pine is managed for pulpwood on all sites. Sawbolts can be produced on the better sites.

Recommended Silvicultural Systems and Rotation Ages

Clearfell at the end of the rotation:

Site index	Rotation age
70+	50+ years
55-70	45-50 years

Seed tree system.—Leave 10 well-distributed, desirable quality seed trees per acre. The seed trees should have an abundant supply of serotinous cones (i.e., cones open after being exposed to heat). Prescribed burning is recommended to consume the slash, reduce competition, prepare favorable seedbeds, and open the serotinous cones on the seed trees. Any live seed trees should be removed after successful regeneration of the site. This is to prevent the seed trees from developing into wolf trees and from becoming reservoirs for *Diplodia* and *Sirococcus*, which are two fungi which can cause serious damage to seedlings and saplings.

Recommended Regeneration System

Planting bare root or container grown seedlings is a major regeneration method following clearfelling. Successful use of direct seeding has more or less been limited to the northeastern part of the state. It is usually accomplished by helicopter in the spring of the year. The recommended seed application is 3 oz. per acre of coated (bird and rodent repellent) seeds. Scattering and burning slash can also be used to regenerate the site, but results have been erratic. On poorer sites, where the slash is left on site, good regeneration results have been obtained by light scarification and distributing the slash so it is close to the ground (i.e., for sufficient heat to open the serotinus cones).

Cultural Practices

Release and thinning.—Jack pine is a very shade-intolerant species and should be released if serious competition develops. Where natural regeneration is used the stand may become too dense and require juvenile spacing. The consequences of excessive density are a slow growing stand or stagnation of growth. Thinning can be used, but is not practiced to any great extent. If jack pine is thinned, the basal area should be maintained between 70 to 100 ft^2/acre. On the better sites (site index 60+) thinning can be used to increase the production of sawbolts. Thinning should be from below, and intermediate and suppressed classes should be removed; these crown classes help sustain a jack pine budworm population.

Wolf tree removal.—Open-grown stands with basal areas less than 70 ft^2/acre should be scheduled for immediate harvest. Stands with a basal area greater than 70 ft^2/acre, but with scattered open-grown wolf trees, should have the wolf trees removed to help manage the jack pine budworm.

Conversion.—Stands with a site index less than 55 should be converted to a species more suited to the site conditions.

Pest Considerations

Jack pine budworm is a major pest of jack pine. To naturally control outbreaks of this defoliator, vigorous stands on sites with site indices of 55 or greater should be maintained, stands should be harvested before exceeding 50 years of age, stocking should be maintained between 70 to 100 ft^2/acre, and large continuous areas of jack pine should be broken up with other species.

Major Wildlife Considerations

The jack pine covertype is considered to be very important as winter cover in much of northern Minnesota. As winter cover it is considered equivalent to or even better than the cedar and black spruce covertypes (especially for deer due to larger amounts of browse).

Preferred Site Conditions

Jack pine is a low moisture and nutrient demanding species and is typically managed on somewhat poorly to well drained sand, loamy sand, and sandy loam textured soils. Jack pine requires a minimum of an 18 inch rooting zone free of root restricting barriers, such as saturated soils, bedrock, or very dense soil horizons. The pH range should be between 5.5 and 7.0. Jack pine does not thrive well on soils with high $CaCo_3$ concentrations (pH 8.0+) at the surface.

Even though jack pine is a low moisture and nutrient demanding species, it can grow very well on rich, finer textured soils (even silty and clayey textures) if these soils have at least 18 inches of well aerated rooting zone. Jack pine does not compete well with the typically denser vegetation found on these richer sites.

1.2 Red Pine

Management Objectives

The management objectives for red pine are for timber products and recreation. Thinning can be used to concentrate growth on the best trees, maintain uniform growth rates and thus quality, remove injured/wounded trees, salvage trees otherwise lost to natural mortality, and increase overall merchantable yields.

Recommended Silvicultural Systems

Pulpwood, posts, poles, cabin logs, pilings, and small sawtimbers can be obtained from thinnings. High quality sawtimber can be obtained from the final felling. The first commercial thinning can occur at age 25 to 30, with

repeated thinnings occurring at 10 to 20 year intervals (depending on site and management objectives). Thinning generally occurs when the stand basal area reaches 150 to 175 ft^2/acre, and the basal area is reduced to 90 to 110 ft^2/acre. Use of the seed tree system in red pine has only yielded limited success. Burns (1983) recommends the use of the shelterwood system where aesthetics and other multiple-use needs require the mature stand to overlap the establishment period. However, it must be remembered that red pine is highly shade-intolerant (4.5 on a scale of 5.0), thus the applicability of the shelterwood system in red pine management on a larger scale is limited.

Rotation Ages

The mean annual growth culminates earlier in stands periodically thinned to a basal area below the minimum recommended stocking. Growing stands at higher densities and longer rotations will produce a higher total growth and yield. However, growing stands at high density would preclude the use of the shelterwood system. Recommended rotation ages are:

Site index	Rotation age
45-54	100 years
55+	80 years

Regeneration Systems

The degree of site preparation should be suited to the site. The poorer sites only require slash removal by full tree harvesting, or light brush raking or disking if the limbs and tops are left on site. On the better sites heavier site preparation is needed. Red pine seeding has not been successful, therefore, bare root or containerized stock should be planted. Burns (1983) also outlines the use of the shelterwood system for red pine regeneration.

Major Pest Considerations

Diplodia and *Sirococuss* spreading from overstory pines can cause heavy mortality in young red pine stands. These fungi can be controlled by removing all residual pine during the timber sale or site preparation operation.

Bark beetles require freshly cut, killed or stressed trees to build up populations. Full tree skidding and slash piling, with optional burning is the best method of control. If slash is left in the stand during a partial cut operation, harvesting should only be done between September 1 and March 1.

Scleroderris canker can be partially controlled by avoiding low depressions in planting sites.

Armillaria root rot is very difficult to control once it becomes established in a stand. Site conversion areas, particularly conversion of off-site oak stands, create conditions which can result in severe economic losses.

Saratoga spittlebug can be a serious problem in plantations between 3 to 10 feet in height. These plantations should be risk rated based on the amount of woody shrubs in the plantation and incidence of spittlebug (as determined by a scarcount survey). Therefore, scarcount surveys should be conducted in 3 to 10 foot high plantations during the normal plantation survival surveys.

Major Wildlife Considerations
Red pine plantations generally provide poor food and cover for game birds and animals, although large, old growth trees may be used by birds of prey. Landings can serve as wildlife openings and provide needed food plants. Red pine plantations can be planned to provide better habitat values. Natural stands are fair habitat because of species mix and irregular spacing.

Preferred Site Conditions
Red pine is typically managed on moderately well to well drained sand, loamy sand, and sandy loam soils. Red pine requires a minimum 30-inch rooting zone free of root restricting barriers such as saturated soils, bedrock, or very dense soil horizons. The pH range should be between 5.5 to 7.0. Red pine does not thrive well on soils with high $CaCo_3$ concentrations (pH 8.0+) at the surface.

Even though red pine is a low moisture and nutrient demanding species, it can grow very well on rich, fine textured soils if these soils have at least 30 inches of well-aerated rooting zone. Red pine does not compete well with the denser vegetation on the richer sites and does not tend to utilize richer sites as effectively as other species.

1.3 White Pine

Management Objectives
White pine is managed for sawtimber. In large areas of hardwood, white pine can be maintained for aesthetics, species diversity and wildlife habitat. For all management objectives, a commitment must be made to manage white pine blister rust.

Recommended Silvicultural Systems and Rotation Age
In blister rust hazard zones 1 (low) and 2 (Van Arsdel 1961) white pine can be clearcut at rotation age. In blister rust hazard zones 3 and 4 (high) a two-cut shelterwood system allowing a mixed hardwood-pine stand to regenerate should be used. The first cut should remove 40 to 60 percent of the

overstory. Hardwood brush must be treated before the first cut. The following rotation ages are recommended:

Site index	Rotation age
64+	80 years
54-64	100 years

Preferred Site Conditions

White pine occurs on a very wide range of site conditions. Good growth occurs on most texture and drainage classes. White pine is more tolerant of wet conditions than red pine or jack pine, but is less tolerant of droughty conditions. White pine has the highest overall nutrient demand of all conifers. Best growth will occur on sites with the following characteristics:

- medium to fine soil texture;
- medium to high fertility;
- somewhat poor to well drained soil;
- constant moisture supply; and
- rooting zone greater than 18 inches deep.

Recommended Regeneration Systems

Natural regeneration from shelterwood cutting.—Mineral soil must be exposed and the first cut should be timed to correspond to a heavy seed crop.

Planting.—In blister rust hazard zone 1 there are no restrictions. In hazard zones 2, 3 and 4, sites with microclimatic conditions favoring disease development should be avoided. Also, for hazard zone 2 a light overstory and gradual basal pruning are recommended, while for hazard zones 3 and 4 understory planting and basal pruning are mandatory. In hazard zone 4 up to a 25 percent loss due to blister rust can be expected, even after following the prescribed management practices. Where there are white pine weevil problems white pine should only be underplanted (i.e., planted under an overstory).

Cultural Practices

Basal pruning.—In hazard zones 2, 3 and 4, pruning should start at ages 5 to 7, and continue until the bottom live branches are at least 9 feet above the ground.

Canker pruning.—Branches with active cankers and inner canker margin 3 to 18 inches from the bole should be pruned. Branches with cankers beyond 18 inches can be left on the trees or pruned during the normal basal pruning cycle.

Rouging.—Where appropriate any trees with cankers on their boles or with active branch canker margins within 3 inches of the bole should be cut down.

Release.—A hardwood overstory should be maintained, particularly in hazard zones 3 and 4, so the pines grow at least 2 feet per year after the trees are 3-feet tall. The final release should be done once the trees reach a height of at least 35 feet.

Disease and Pest Considerations

White pine blister rust is a major limiting factor for successful management of white pine. The regional insect and disease specialist should be consulted when managing and regenerating white pine. *White pine weevil* is the major insect problem of white pine, particularly north of State Highway 210. An overstory should be maintained to control the weevil. In plantations north of Highway 210, overstory maintenance is encouraged. *Bark beetles* (*Ips* spp.), *pine sawflies*, and *pine bark adelgid* are other insects commonly associated with white pine. White pine is intolerant to drought, salt spray and ozone. *Deer and hare browsing* can also be major obstacles to plantation establishment.

Wildlife Considerations

White pine has a fair to good overall rating for wildlife. Both birds and mammals use this species as escape cover and severe weather cover, particularly when the trees are young. As white pine ages its cover value lessens. Seed and browse value is fair. White pine is good for cavity nesters. Mature trees within a quarter mile of water are the most frequently used eagle and osprey nest sites.

1.4 Balsam Fir

Management Objectives

Balsam fir is managed primarily for pulpwood. Low site index stands should be converted to other species as soil types, drainage and textural classes dictate. In spruce budworm outbreak areas (primarily in northeastern Minnesota) the primary objective is to break up large areas of even-aged balsam fir and increase the diversity of species. Spruce budworm causes the most damage to mature and overmature pure or nearly pure balsam fir stands. These balsam fir sites should be converted to other species and manipulated through harvesting to decrease the proportion of balsam fir.

Recommended Rotation Age

The rotation age on all sites should not exceed 50 years. Due to extensive spruce budworm damage, it is recommended the rotation age not exceed 40 to 45 years in the northeastern part of the state.

Recommended Silvicultural Systems
Stands should be harvested using clearfelling in strips or patches. Scattered overstory spruce or fir should not be left standing. This is because the spruce budworm will survive and build up on these residuals and damage the young trees if the site is regenerated to spruce-fir.

Large areas of even-aged balsam fir should be broken up through planned selection of cutting areas and design of the timber sale. Pure stands, or stands with a high proportion of mature and overmature balsam fir, should be scheduled for harvest first. These stands are the ones which will experience the greatest loss from the spruce budworm. Mixed stands, especially when mixed with hardwoods and pines, will experience less damage and can be held longer before harvesting.

Winter harvesting in stands mixed with aspen will encourage the regeneration of aspen to create an aspen stand, or a mixed stand of balsam fir and aspen. Summer harvesting results in more scarification and is recommended when the site is to be converted to other softwood species.

In some cases protection of the understory balsam fir when removing the overstory (e.g., aspen) could result in clumps of balsam fir to improve wildlife habitat.

Type Conversion
Sites with a minimum basal area of 20 ft^2/acre of evenly distributed aspen can be converted to aspen through winter harvesting. Conversion to spruce or pine by artificial regeneration should be considered where aspen and paper birch site indices are less than 60. Planting black spruce on balsam fir sites is an option for northeastern Minnesota. However, on upland sites, root and butt rot can be a problem for black spruce after age 60.

Cultural Practices
Release of young balsam fir from competing vegetation is not recommended. The goal in most balsam fir management is to increase the proportion of other species in the stand. Thinning of mixed balsam fir–white spruce stands is not recommended, but can be used to reduce the proportion of balsam fir in the stand.

Insect and Disease Considerations
Spruce budworm is the major insect problem on balsam fir and has caused widespread mortality and loss of growth. Mature and overmature stands of pure balsam fir, as well as stands with a high proportion of balsam fir, are very susceptible to spruce budworm outbreaks. The spruce budworm also feeds on white spruce and black spruce, but causes minor mortality to these species. Management of the balsam fir type to reduce spruce budworm damage includes:

- a rotation of 40 to 45 years;
- breaking up large blocks of balsam fir by patch and strip clearcuts, to prevent large areas from becoming mature and overmature at the same time;
- site conversion to other species; and
- cultural practices which will decrease the proportion of balsam fir in the stand.

Trunk, root and butt rots are important disease problems on balsam fir. The severity and incidence of rots can be reduced by avoiding wounding. Logging, windthrows, wind breakage, ice, snow, etc., are the major sources of wounds leading to decay. Problems are more likely to occur with the following soil conditions:

- coarse textured, acidic soils; and
- soils with shallow root zones due to high water tables and hardpan.

Wildlife Considerations
Balsam fir provides excellent winter and summer cover for deer and moose. Stand rims and patches of balsam fir can be managed primarily for wildlife cover and travelways. Balsam fir provides good to very good nesting and perching sites for birds, as well as escape cover and insect and seed foods.

Preferred Site Conditions
Balsam fir is very adaptable and grows on a variety of sites. It has a moderate moisture and nutrient demand. Balsam fir grows well on somewhat poorly to well drained sandy loams to clay loams with at least 18 inches of free rooting zone. Best growth occurs on moist loamy soils. Balsam fir frequently occurs on sandy sites as an understory to pine and aspen. With the possible exception of somewhat poorly drained sands, these sites typically do not produce well and may be better managed for other species.

1.5 White Spruce

Management Objectives
White spruce stands with a stand index greater than 45 are managed on an even-aged basis for pulpwood or sawlog production. Stands with a lower site index should be considered for conversion to a species better suited for the site. However, white spruce is generally found as a component of other covertypes or heavily mixed with balsam fir, aspen, birch and even cedar.

Recommended Rotation Ages

Site index	Pulp	Sawtimber
45-55	60	---
55-65	60	70-80
65+	70	80-90

To minimize volume losses to butt and root rot, rotation ages should be shorter on coarse acidic soils or shallow soils.

Recommended Silvicultural Systems

Naturally regenerated white spruce commonly occurs as a component of balsam fir, aspen and northern hardwood stands, and less commonly in pure stands. Harvest methods are dictated by the dominant species of the stand and the management objectives. The stand should be clearfelled if it is going to be regenerated to white spruce. Residual overstory balsam fir and white spruce may act as sources of budworm infestation to the regeneration. When white spruce is a component in northern hardwood stands, uneven-aged management may be possible due to the shade tolerance of white spruce.

Recommended Regeneration Systems

Artificial regeneration is required to establish white spruce stands. Planting stock or seed used is from improved seed. Planting is the most common method used, with both containerized and bare root stock used. Direct seeding attempts have not shown consistent success, with spot seeding showing more promise than broadcast seeding. However, the seeding methods still need to be perfected. Generally, regeneration by seeding is successful in the northeast, but too dense.

Bare root stock should be planted in the spring. Container stock can be planted in the spring or fall. Frost heaving is a problem with fall planted stock on wet or clayey soils. Frost heaving can be greatly reduced by maintaining the litter layer and by planting as early as possible in the fall.

Plantations should be separated from large spruce-fir types with deciduous or red pine cover types. White pine weevil damage may occur in white spruce if established adjacent to jack pine or white pine stands. Open field plantations are susceptible to yellow headed spruce sawfly damage.

Late spring frost damage can be reduced by avoiding areas that tend to collect cold air. In frost prone areas, a canopy of deciduous trees or brush can also be used. Another alternative is to plant black spruce.

Stand Maintenance and Timber Stand Improvement

Plantation white spruce have slow height growth for the first 1 to 10 years as the roots become established. White spruce can survive up to 100 percent

shade during this establishment period. A canopy cover of 50 to 75 percent reduces damage to seedlings from frost and sawflies.

Shading should be reduced after the establishment period. Maximum growth occurs with 25 to 30 percent shading. The ratio of terminal leader growth to leader growth in the first whorl can be used as an indicator of vigor and thus the need for release. Root competition may limit growth more than above ground competition on soils or in climates where soil moisture or aeration is limiting.

In areas with a history of yellow headed spruce sawfly damage, the spruce should not be completely released until they have reached a height of 10 to 12 feet. Trees of this size will generally have sufficient foliage to withstand a heavy attack by sawflies. Open growing plantations with trees less than 10 to 12 feet high should be inspected for sawfly larvae in early June. Direct control should be taken if populations are high and defoliation occurred the preceding year, or if tree mortality and topkill is likely. The regional insect and disease specialist should be contacted. Periodic thinning can be used to maintain vigor and diameter growth for sawlog production.

Preferred Site Conditions
White spruce has a high moisture and nutrient demand. Best growth will occur with the following site characteristics:

- adequate soil moisture available throughout the growing season;
- medium to high fertility;
- medium to fine soil textures;
- good soil aeration;
- a rooting zone greater than 18 inches deep;
- somewhat poorly to well drained soil; and
- gently rolling topography (slopes less than 10 to 15 percent).

Major Wildlife Considerations
Shrubs and forbs in young plantations provide browse for deer and moose. A partial canopy of shrubs or hardwoods reduces insect, disease, and frost damage to seedlings. The value of a plantation for food decreases as the tree canopy closes (i.e., shrubs and forbs are shaded out). Older plantations may provide winter thermal cover for deer when spruce-balsam, white cedar, or other mixed conifer stands are absent.

1.6 Black Spruce

Management Objectives
Even-aged management is used, because of the moderately high light requirement of black spruce, to produce a high sustained yield of pulpwood.

Upland black spruce may be managed with a mixture of other conifers and hardwoods.

Recommended Rotation Ages

Site index	Rotation age
25-45	90 years
45+	60 years

Stands with site indices greater than 45 are usually growing on mineral soils or on upland sites. Black spruce stands on mineral soils should be harvested before 60 years of age because root and butt rots can begin to seriously limit fiber production. If a stand is infected with dwarf mistletoe, it should be harvested as soon as it becomes merchantable, regardless of age. This is to reduce the spread of the disease.

Recommended Silvicultural Systems

All live black spruce 5 feet and taller should be felled when the stand is harvested to eliminate dwarf mistletoe. If harvesting in strips or small patches to encourage natural regeneration, the harvested area should be no wider than 260 to 400 feet. Natural seeding of black spruce is reliable up to 260 feet from the leeward side of a mature stand and up to 130 feet from the windward side on suitable seedbeds.

Site preparation is required if felling all black spruce over 5 feet in height is not feasible (i.e., too expensive). Prescribed burning, herbicide treatment, or winter shearing must be done to kill any dwarf mistletoe infected trees prior to regenerating the site.

If dwarf mistletoe is present in the stand, the timber sale boundaries must be adjusted to include any infected areas (pockets), including a 2 chain (122 feet) wide strip of uninfected trees around the pockets. Removal of the strip is required to remove latent infections which cannot be seen at the time of harvest. The landings should be located in mistletoe infected pockets to help break off and kill small, infected black spruce. Prescribed burning is the best method for controlling dwarf mistletoe. If burning is prescribed the timber sale must be laid out to allow for desired ignition patterns and control.

Use of seed tree and shelterwood systems is limited where dwarf mistletoe is present. Also, black spruce is a shallow rooting species and thus susceptible to windthrow if a stand is opened up. Windthrow can also be a problem along the edges of cut areas. However, if small, windfirm stands are present on upland sites, and there is a strong reason for no clearfelling, the shelterwood system is a feasible option. This is especially true if dealing with a mixedwood stand with a black spruce understory (i.e., progressive removal of the overstory to release and increase the black spruce component).

Winter logging on lowland sites is usually necessary for access and to avoid site deterioration. Logging during non-frozen periods should be carried out with skidders or forwarders equipped with high flotation tires.

Recommended Regeneration Systems

With proper design of the timber sale, natural seeding can provide adequate regeneration if the harvested and surrounding stands are healthy and vigorous, and an adequate seedbed is present. When the stand harvested and the surrounding stands are in decline due to old age, dwarf mistletoe, etc., and an adequate seedbed is present, artificial seeding is required.

A seedbed survey should be done prior to harvesting. A site has adequate seedbed for natural or artificial seeding if it has a minimum 60 percent coverage with sphagnum moss. If the site has less than 60 percent coverage with sphagnum moss, the site should be planted with black spruce seedlings or site prepared. If site preparation is required, two possibilities are to winter shear using a wide pad crawler tractor or burn the slash to promote the growth of sphagnum moss. Prescribed burning can also be used to remove slash, temporarily remove brush, kill dwarf mistletoe residual trees, and to prepare a seedbed when feather mosses predominate (i.e., eliminate feather moss since it is a poor seedbed because it dries out in the summer). When natural or artificial seeding is used to regenerate a site, it is difficult to determine the success until 5 years after the seeding.

Planting is required on sites without an adequate seedbed. This condition is most common on the most productive sites where feather mosses predominate. Container planting stock is the only stock recommended for lowlands. Also, fall planting is preferred over spring and summer planting.

Stand Maintenance and Timber Stand Improvements

Brush competition will seldom cause mortality of black spruce, but if dense, it will reduce growth. If brush competition height exceeds 6 to 8 feet and is dense at age 5 to 6, release of the seedlings may be necessary.

Small pockets of dwarf mistletoe in immature stands must be eradicated, since they are a source of mistletoe spores for new pockets of infection. Mistletoe infected sites which have been harvested should be checked in 10 years to ensure the disease is under control. Tamarack container stock has also been planted in mistletoe pockets to reduce future build-ups of the disease.

Insect and Disease Considerations

Dwarf mistletoe is the major problem in black spruce. Use of the 5-foot felling rule will reduce the impact of dwarf mistletoe and will eradicate the disease from some harvested sites. However, the only way to be certain mistletoe has been completely eradicated from a site is to kill **all** black spruce

on the site, regardless of tree size. One to two years after harvest or treatment to control dwarf mistletoe, all sites should be surveyed to check for the presence of living black spruce trees (1 foot or taller). After the survey the forester should decide if follow-up treatment is necessary or feasible (e.g., hand felling). To ensure eradication of dwarf mistletoe, all remaining black spruce, 1 foot and taller, must be killed. On some sites eradication may not be feasible with current technology or economics. Regeneration with black spruce should proceed only when eradication of mistletoe infected trees is complete. As mentioned earlier, tamarack container stock has been planted in mistletoe pockets to control the build-up of the disease.

Root and butt rots can also cause economic losses, particularly in stands growing on mineral soils or on upland sites. Do not carry stands on these sites beyond 60 years.

Spruce budworm can be an significant pest, especially on upland sites where the spruce are growing with balsam fir.

Preferred Site Conditions

Black spruce is typically managed on organic and wet mineral soils. Key factors in site productivity include origin and decomposition of organic material, depth of organic material, and characteristics of the water system that feeds the rooting zone. Best growth on organic soils occurs on moderately to well decomposed material (dark brown to blackish) that contain many fragments of partially decomposed wood fibers **and** has mineral soil in the rooting zone **or** a water system that is carrying nutrients from a mineral soil to the rooting zone (minerotrophic water). The surface 6 inches of the soil need not contain wood fragments.

The poorest growth in black spruce occurs on poorly decomposed (yellowish brown) deep peats of sphagnum origin that depend on precipitation for incoming nutrients.

On mineral soils black spruce is suited to a wide range of sites from sandy to clayey, and will typically out-produce stands occurring on organic soil, although root and butt rots may limit production on these drier soils. Productivity is best on moist, fine textured soils, and it is poorest on dry, sandy soils.

Site productivity for black spruce would be increased by drainage and/or fertilization. However, drainage of wetlands is now against the law (i.e., no net loss of wetlands).

1.7
Northern White Cedar

Management Objectives
White cedar is managed for wildlife habitat value and wood products.

Recommended Rotation Ages

Site index	Pulp and Wildlife	Product
30 and below	120+	Posts
31-40	130+	Posts
41-50	110+	Posts
51-60	90+	Poles/Logs
61+	80+	Poles/Logs

Recommended Silvicultural System
Strip or patch cuts 4 chains (260 feet) or less in width from a prevailing wind seed source are recommended. Other softwood (spruce, balsam, tamarack) seed sources should be eliminated if a mixed stand is not desired.

Recommended Regeneration System
Natural seeding from adjoining stands is possible if the seedbed is prepared through burning (i.e., most lowland cedar sites are very acidic and cedar requires a neutral or slightly basic seedbed for germination and survival). Good seedbeds are hummocks, mosses, and disturbed organic and mineral soil with adequate moisture. Direct seeding should be used only if sufficient and proper seedbeds are present. A major problem in cedar regeneration is browsing by deer; especially when using small strip or patch cuts.

Container grown nursery stock, used in underplanting, is showing promise in artificial regeneration programs. However, deer browsing can be a limiting factor.

Disease and Pest Considerations
White cedar is relatively free of disease and pest problems. Butt and heart rots are prevalent in some mature and overmature stands. The main source of damage to seedlings is mice, hare and deer browsing. Bole form (nondisease or pest related) is the main cause for loss of suitable useable wood for posts, poles, or sawlog material.

Wildlife Considerations
White cedar upland stands, and rims of lowland stands provide excellent winter cover for white tail deer and provides needed browse during severe snow winters. The rotation age should be extended in stands in and near known winter deer yards as needed.

Stands located adjacent to trout streams provide cover and a cooling effect, and should be withheld from harvest.

Preferred Site Conditions
White cedar occurs on a wide variety of site conditions, ranging from very poorly drained organic soils to well drained mineral soils. The best growth occurs with the following site characteristics:

- lowland
  - well-decomposed peat derived from wood plants and sedges
  - pH of 6.5 to 7.8
  - good water movement
  - ground water high in minerals
- upland
  - constant moisture supply
  - somewhat poor to well-drained soils
  - good aeration
  - medium to fine textures high in calcium

1.8 Tamarack

Management Objectives
Tamarack is managed to produce the best quality product from each specific site. The lower site stands will produce pulpwood, fuelwood and post quality materials. The higher site stands will produce higher quality products, such as poles and small sawlogs, on a shorter rotation.

Recommended Silvicultural Systems
Tamarack can be managed by clearfelling or seed tree systems. For successful use of the seed tree system, about 10 windfirm, vigorous, open-grown trees per acre are required.

Rotation Ages
Tamarack growth slows after 40 to 50 years. The lower site stands will require a rotation age of at least 90 years (site class 57+ to 90 years, on lower sites 100+ years). The high site stands, typically of the more upland soils, will produce quality products and high yields on a rotation as low as 40 years, however, 70 years is about the average for upland sites.

Regeneration Systems
The most economical method of regenerating tamarack is by natural seeding. For successful natural regeneration the following are necessary:

- recognition of seedbed requirements;
- proper orientation and size of rim cuts;

- timing of block cuts to occur during heavy seed years; and
- selection of superior quality seed trees.

Artificial regeneration of tamarack is in the experimental stage due to the cost and difficulty of obtaining seed. Seedbed requirements for aerial, cyclone, or shelter cone seeding are as stringent as for natural seedings. The planting of containerized seedlings, grown from superior seed sources, could be considered on site conversion projects or on sites where seeding has failed. Brush and grass competition must be controlled until the fast juvenile growth of the seedlings allows them to dominate the site. Use of mechanical site preparation and/or prescribed burning must be tailored to address site specific competition and water table impacts on the new seedlings.

Major Pest Considerations

Fungi (wood rotters) can cause significant economic losses in off-site situations, overmature stands, and where injury has occurred. The three main fungi are *Phellinus pini*, *Phaeolus schweinitzii*, and *Armillaria mellea*. The most important injuries are due to abnormal water levels from both flooding and drought.

Bark beetles can damage stands that have been stressed from drought, high water, defoliations, and overmaturity. The eastern larch beetle, *Dendroctonus simplex*, is the prime insect. A major contributing factor to bark beetle damage is storing cut products on sale areas. All freshly cut wood products from tamarack areas (also pine areas) must be removed before the start of the growing season.

Major Wildlife Considerations

Tamarack sites offer marginal deer habitat and poor moose habitat due to limited amounts of associated ground vegetation in closed canopy stands. In more open stands the type of undergrowth vegetation will determine the value of the site for wildlife browsing. Mature stands provide excellent great gray owl habitat, especially when in proximity to black spruce. Small cuts, retention of snags, and dispersal of cutover areas are beneficial to numerous nongame species inhabiting the tamarack community.

Preferred Site Conditions

Tamarack is typically managed on wet mineral or shallow organic soils. The key factors in site productivity are origin and decomposition of organic material, depth of organic material, and characteristics of the water system feeding the rooting zone.

The best tamarack growth is on organic soils of moderately to well decomposed material (dark brown to blackish) that contains many fragments of partially decomposed wood fibers, **and** has mineral soil in the rooting zone **or** a water system that is carrying nutrients from a mineral soil to the

rooting zone (minerotrophic water). The surface 6 inches of the soil need not contain wood fragments.

The poorest growth in tamarack occurs on poorly decomposed (yellowish brown) deep peats of sphagnum origin that depend on precipitation for incoming nutrients.

Tamarack grows very well on mineral soils and is best suited for management of wet mineral soils or very shallow, well decomposed peats. Tamarack grows well on poorly to moderately well drained sandy loam to clay soils. Productivity is best on moist, fine textured soils. Very wet or very dry sites should be avoided.

1.9 Red Oak

Management Objectives

It is desirable to try to maintain or increase the oak component. This is because many species of wildlife benefit from and use the oak type, and quality oak always has a ready market. In most likelihood this will also be true in the future. The acreage of oak in Minnesota and nationwide is decreasing because it is being succeeded by more tolerant species.

Oak on good and excellent sites is not regenerating itself. On poorer sites oak maintains itself through stump sprouts and natural seeding. About a half of the oak in Minnesota grows on good to excellent sites. The other half grows on poor sites (sandy loam) and has relatively little commercial value (sawtimber), however, the wildlife value is high.

Recommended Rotation Ages

Site index	Rotation age	Diameter
75+	60-75 years	24-28 inches
55-74	75-90 years	20-24 inches
40-54	90-125 years	16-18 inches

The less productive sites are relatively easy to manage since there is little competing vegetation and the oak may maintain itself in a pure state. As site productivity increases, so does the difficulty in maintaining the oak component in a stand. This is because the competition from more shade tolerant species increases.

Recommended Silvicultural Systems

Oak is managed on an even-aged basis because it is relatively shade intolerant. The final harvest must be a clearfelling (e.g., removal of the overstory if using the shelterwood system).

Recommended Regeneration System
A four step regeneration system is recommended:

1. control understory vegetation;
2. create a medium density shelterwood with 60 percent residual crown cover;
3. if there is insufficient oak stump sprouting, underplant with large diameter nursery stock with clipped tops; and
4. remove the shelterwood through clearfelling three growing seasons later.

The planting may be supplemented by fast-growing oak stump sprouts after the clearfelling or by acorns.

Disease and Pest Considerations
The most serious oak disease is *oak wilt*. Pockets with oak wilt should be harvested, and the roots severed between infected and uninfected trees. Do not prune, trim, cut down, or in any way wound oak trees between April 15 and July 1 in parts of the state where oak wilt is a problem.

Another problem in oak is the *two-lined chestnut borer*, which can infest and kill oaks that are under stress. *Armillaria root rot* can infect and sometimes kill oaks and other hardwoods. Armillaria can live for many years on stumps and dead roots in the soil. Like oak wilt, Armillaria can spread through root grafts.

Wildlife Considerations
Whenever possible, manage oak inclusions in aspen and other types as an entity rather than clearfell with the other species. This helps to maintain age and type diversity. Oak mast is an important source of fat for deer and other wildlife in preparation for winter. Old stands may be desirable in some areas. Also, scattered den and wildlife trees should be left throughout the harvested areas.

Preferred Site Conditions
Best growth of oak will occur with the following site conditions:

- medium to fine soil textures;
- well-drained soils;
- constant moisture supply;
- good soil aeration; and
- rooting zone greater than 3 feet.

Oak is a complex type to manage. More detailed information should be obtained from the literature.

1.10
Black Walnut

Management Objectives
Black walnut is managed to produce sawlogs for veneer production and high quality lumber. Black walnut generally forms a minor component in hardwood stands. Pure stands of black walnut are very rare.

Recommended Rotation Ages
Black walnut should be harvested between 60 to 80 years of age. In determining rotation ages for plantations and individual trees found in other covertypes, the tree size and quality must be considered, as well as available markets, and 5- to 10-year growth projections.

Recommended Silvicultural Systems
Individual tree selection of commercially valuable trees is the recommended harvest method.

Recommended Regeneration Systems
The planting of seedlings is the preferred regeneration method. Nut planting can also be used, but results often are erratic. The initial spacing of black walnut should be 10x10 feet or 10x12 feet. White pine or alder can be interplanted to *train* the walnut and to provide competitive weed control. Planting 2 to 3 rows of pine, and one row of walnut has also worked well.

When establishing black walnut, the potential sites should be carefully screened. Only the best sites should be chosen. Also, do not manage walnut if the current or projected site index is less than 40.

Cultural Practices
Site preparation and weed control.—Intensive competition reduction is required to produce high quality, fast growing walnut trees. Weed control should be practiced for at least three years after establishment.

Pruning.—Lateral pruning should be done. Corrective pruning is no longer strongly advocated since black walnut generally forms a straight stem by dbh 4+ inches. On stunted and malformed trees, coppicing should be used. The lateral branch pruning should begin as soon as the trees are 10-feet tall. Pruning should only be of branches 2 inches or less in diameter. Prune 25 to 100 crop trees per acre, and limit pruning to trees less than 10 inches in diameter. The ultimate goal is to produce trees with 17 feet of clear bole. Due to the risk of canker diseases, pruning should not occur between April 1 and November 1.

Thinning/release.—Keeping the trees free of grass and overtopping wood competition is critical for maintaining good growth. Thinning is used to reduce crop tree competition and to recover more merchantable material.

Insect and Disease Considerations

There are a number of important insect and fungal defoliators in black walnut. Some of these defoliators are the walnut caterpillar (*Databa ubtegerruna*), fall webworm (*Hyphantria cunea*), walnut anthracnose (*Gnomia leptostyla*), Mycosphaerella leaf spot (*Mycosphaerella juglnadis*), and Cristulariella leaf spot (*Cristulariella phyramidalis*).

Stem deformities can be a problem due to shoot and/or terminal bud damage. Damaging agents include late season frost, walnut shoot moth (*Acrobasis domotella*), and shoot dieback associated with *Phyllosticata* spp.

Fusarium sporotrichioides causes a perennial stem canker which can lead to top kill. Thus, pruning should occur only between December 1 and March 31.

Wildlife Considerations

Walnut is normally associated with other hardwood species, and in this combination good plant species diversity provides wildlife benefits. Since walnut also produces food for nut-eating mammals, it is generally rated *good* overall for wildlife.

Preferred Site Conditions

Black walnuts develop best on deep, well-drained, fertile, nearly neutral soils that have at least a 40 inch root zone free of rock or hard pan (e.g., deep loams, loess soils, and fertile, well-drained alluvial deposits), and on north and east slopes. Black walnut is also common on limestone soils.

1.11 Northern Hardwoods

Management Objectives

On good sites manage northern hardwoods for high quality sawlogs. If oak is a major component, manage the stand to encourage the oak or maintain its presence.

Recommended Rotation Ages

The rotation age depends upon the silvicultural system used, the desired products or other considerations. An uneven-aged system does not really have a rotation age, but would require an 8- to 20-year cutting cycle between individual tree or group selection cuts. With even-aged management a rotation age as short as 50 years could be used for fiber and/or early successional wildlife habitat objectives, or 120 years or more if the

management objectives are for aesthetics, large sawlogs, and/or late successional wildlife habitat objectives. Quality hardwood should be grown on fertile, well-drained soils with no heavy clay layer or bedrock within 2 feet of the surface.

Recommended Silvicultural System

Clearfelling should be used in even-aged systems for fiber production or to encourage intolerant species in the stand. The use of the shelterwood system will encourage intolerant species such as red oak and will produce even-aged stands. If aesthetic considerations are important then the uneven-aged system should be used.

Uneven-aged systems require more intensive management, considerable skill in tree selection to prevent high-grading, skill and motivation in harvesting to minimize damage to the remaining trees, and harvesting done on a relatively short cycle. In this situation tolerant species will dominate. In sawlog and veneer stands, cutting would occur when the basal area of trees 10 inches or greater reaches 96 ft^2/acre. The stand would be cut back to a basal area of approximately 65 ft^2/acre.

Recommended Regeneration Considerations

The silvicultural system used will determine the type of regeneration system. Clearfelling will probably be regenerated by stump and root sprouts, and advanced seedling regeneration. A shelterwood cut would be regenerated by advanced regeneration, sprouts, and/or planted seedlings. Uneven-aged management would encourage seedling reproduction of tolerant species.

Disease and Pest Considerations

Nectria canker can be common on hardwoods, especially in even-aged stands. *Sapstreak* will attack trees whose roots have been damaged. *Maple decline* is identified by branch dieback, stunted foliage, and epicormic branching. Maple decline can be reduced by maintaining a well stocked stand with a diversity of species. Large wounds caused by logging or other activities are a major problem, and can introduce serious decay.

Wildlife Considerations

Heavily stocked, northern hardwood stands make poor habitat for most game species because of lack of browse and mast. However, some species such as cavity nesting wildlife and songbirds will benefit from northern hardwoods (especially older stands). Extensive northern hardwood areas can be enhanced for wildlife through age-class diversity, and creation of openings. However, interior forest songbirds may be adversely affected by the creation of openings.

Preferred Site Conditions
Northern hardwoods occur on a relatively narrow range of conditions. Northern hardwoods generally have high moisture and nutrient demands. The best growth can be expected with the following site conditions:

- medium to fine soil textures;
- moderately well to well drained soil;
- constant moisture supply;
- good soil aeration; and
- rooting zone greater than 2 feet.

Northern hardwoods is a very complex type and additional literature should be referred to.

1.12 Black Ash (lowland hardwoods)

Management Objectives
Black ash is managed for high quality sawlogs and veneer on good sites (SI 55+), and for small sawlogs and firewood on poorer sites (SI <55). Brushy, poorly productive northern hardwoods or aspen stands on poorly stocked lowlands should be converted (when suitable) to black ash.

Recommended Rotation Ages
There is insufficient information to make recommendations on rotation ages.

Recommended Silvicultural Systems
To limit site damage and improve equipment access on wet sites, logging should only occur when the ground is frozen. Snow cover will provide additional protection to the site and to advanced regeneration (i.e., seedlings). Clearcutting, strip cutting or shelterwood cutting can be done on drier sites, but considerations must be made for regeneration prior to harvesting. Uneven-aged management with selective logging is the only safe method on wet sites. Clearcutting on wet sites causes a loss of transpiration at the site and can lead to higher water tables. Higher water tables can inhibit seedling establishment and favor grass and brush competition.

Recommended Regeneration Systems
On the better sites (SI 55+) the shelterwood system should be used. If advanced regeneration is not present, the stand should be thinned from below to 75 percent crown cover. Summer cutting is generally not possible due to the wet conditions of most black ash stands in Minnesota. Regeneration will be most successful if this cut is timed to take advantage of a good seed crop. The final cut to remove the sheltering trees should be done after seedling reproduction has reached 2 to 3 feet in height, and when the ground is frozen and preferably snow covered. The literature indicates that a minimum of

5,000 well-spaced seedlings and low stump sprouts per acre should remain. Stumps should be lower than 12 inches to ensure healthy stump sprouts.

On excessively wet sites, the selection system is the only regeneration system recommended. Regeneration on these sites is highly dependent on stump sprouts. Therefore, the stumps must be cut as low as possible to ensure healthy reproduction.

Bareroot planting stock is currently being produced and can be used to convert sites to black ash, or to supplement regeneration in existing black ash stands. Conversion to black ash will require intensive site preparation to reduce competition. The following types of sites may be suitable for planting black ash:

- lowland brush;
- upland brush with moist soils;
- lowland grass with proper soil conditions;
- upland grass with wet soils;
- aspen or northern hardwood stands with low productivity due to a high water table;
- former elm stands; and
- low value, poor quality, or understocked lowland hardwood stands.

Disease, Pest, and Damage Considerations

Black ash is relatively free of serious disease and pest problems. Unsightly black galls cause by the ash flower gall mite (*Eriophyes fraxinoflora*) are commonly present on the branches of black ash, but there is no indication that these seriously affect growth. Deer browsing on seedlings and sprouts can be a problem. Trees on wet sites are shallow rooted and subject to windthrow.

Major Wildlife Considerations

The ash covertype has fair to good rating for wildlife. The ash community understory is vitally important for providing late fall and winter deer browse (ash, mountain maple and red-osier dogwood less than 6-feet tall). Also, upland edges are important fall feeding sites (gray dogwood and highbush cranberry) for ruffed grouse. Black ash is an important snag and den tree, especially in riparian zones. The ash overstory is sometimes used as nesting sites for blue herons. Mature ash stands are also prime candidates to perpetuate as old growth sites.

Winter shelterwood cuts which take into consideration deer concentration areas, reserve snag and den trees, and any other special wildlife needs (e.g., heron colonies) will provide the greatest utilization for wildlife.

Preferred Site Conditions

Black ash occurs on diverse site conditions, ranging from wet, deep peat to moderately well drained mineral soils. The best growth occurs on soils with the following characteristics:

- organic soils
  - shallow, moderately to well decomposed peat derived from woody plants or sedges
  - pH greater than 5.0
  - water table deeper than 12 inches below surface
  - good water movement through soil
  - groundwater high in minerals
- mineral soils
  - medium texture
  - poorly to somewhat poorly drained
  - good water movement through soil
  - free calcium in rooting zone

1.13 Aspen (Trembling aspen, Bigtooth aspen)

Management Objectives

The management objectives for aspen are to manage it on an even-aged basis for pulpwood, sawbolt, sawlog, or veneer products, and to attain a balanced age structure and maintain or improve site productivity and wildlife habitat.

Recommended Rotation Ages

Site index	Pulp and Wildlife	Sawtimber
50-60	30-35 years	-
60-70	35-50 years	-
70+	45-60 years	50-70 years

Rotation ages should be adjusted if disease or insect conditions exist. If more than 15 percent of the aspen stems have *Phellinus temulae* conks a rotation age of 35 to 40 years should be used. If more than 25 percent of the aspen stems have *Hypoxylon* cankers the stand should be harvested as soon as possible and converted to another species.

Recommended Silvicultural Systems

All stems with a diameter at breast height (dbh) greater than 2 inches should be cut, however, up to 15 ft^2/acre basal area of live residual trees or hard snags may be left for wildlife purposes. Any hardwood clumps (especially oak) and scattered oaks should be reserved. When delineating sale boundaries natural features, such as timber type, topography and soil type should be used.

Serious disturbances from harvesting operations, such as soil compaction and rutting can seriously impair resprout potential. Thus, if any of the following conditions exist a soil specialist should be consulted:

- somewhat poorly drained soil conditions;
- soil properties that cause extended wet conditions following rains; or
- concave or toeslope landscape position.

If any of the following conditions exist the site should be harvested in the winter during frozen ground conditions:

- parent stand has low stocking (less than 50 ft^2 basal area);
- parent stand has 15 to 25 percent incidence of *Hypoxylon* canker; or
- soils are wet during the growing season.

The timber sale should be designed to minimize the amount of vehicular traffic and thus soil disturbance, rutting and compaction, by keeping the following points in mind:

- cut from the back of the sale forward;
- avoid summer operations on sites incapable of supporting heavy equipment;
- concentrate the skidding pattern; and
- avoid reentry into the stand.

If practicing clone selection, delineate desirable clones as follows:

- for grouse, favor male clones;
- for improvement, favor clones with superior growth and form; and
- for disease resistance, favor bigtooth or trembling aspen clones resistant to Hypoxylon canker.

Recommended Regeneration Systems

To ensure adequate regeneration of root sucker sprouts, the parent stand should contain a minimum of 20 ft^2 basal area (or 50 evenly distributed aspen trees per acre). For adequate sprouting success there should be more than 3,000 stems per acre, two years after cutting. Dense sucker stands provide the best protection from insects and disease. If the stand is understocked, the manager must determine the cause and remedy it if possible, or convert the site to another species.

Stand Maintenance and Timber Stand Improvement

The objective is to maintain at least a minimum stocking, with a maximum annual mortality rate of 7.5 percent. If *Saperda* infested trees are found, these brood trees should be removed and destroyed before more trees are infested. If *Hypoxylon* cankers are present on more than 25 percent of the

main boles in a stand, the stand should be harvested as soon as possible, and converted to another species. If more than 15 percent of the aspen stems in a stand have *Phellinus temulae* conks, the stand should be harvested as soon as possible. Aspen stands which are growing on poorly drained soils and are repeatedly defoliated by forest tent caterpillars have a high risk of becoming infected by disease. Conversion of the stand to another species should be considered in these cases.

Major Wildlife Considerations

Aspen communities have a good to excellent overall rating for wildlife. At various stages of development they are an important source of food and cover for a wide variety of game and nongame species. Thus, snags should be reserved in clearcut areas for nongame wildlife. Also, a balanced age class structure evenly distributed and interspersed with openings is most desirable.

Preferred Site Conditions

Trembling aspen is managed on a wide range of soil textures (sandy loam through clay) and drainage classes (somewhat poor through well drained). Best growth occurs on medium textured soils (loam through silt-loam) which are somewhat poorly to moderately well-drained (i.e., soils with a high water holding capacity and good aeration). Aspen is sensitive to water saturated and droughty conditions. A rooting zone of 18 to 24 inches or deeper is required. Growth is good on sites with moderate fertility but is best on sites with high fertility. Soils high in calcium and magnesium have longer biological rotation age, superior growth, and lower incidence of heart rot. Bigtooth aspen can tolerate coarser, drier, and slightly less fertile sites than trembling aspen.

Conversion to Another Species

Conversion of aspen to another species should occur if the stand has greater than 25 percent *Hypoxylon* canker infection. Conversion of aspen stands should be avoided near known deer yards, or if residual stands contain high quality hardwoods. Inadequate regeneration, as well as management objectives to diversify wildlife habitat, may also be reasons for converting aspen.

1.14 Paper Birch

Management Objectives

Paper birch is managed to produce high quality sawlogs. The small sized and poor quality trees can be used for pulpwood and fuelwood.

Recommended Rotation Ages

Site index	Rotation age
40 or less	60
40-80	70
80+	80

Recommended Silvicultural Systems

White birch should be clearfelled in areas no larger than 40 acres in size, or cut using alternate strips or patch cutting. Smaller patch cuts or the progressive strip cut methods provide better seed sources and protection of the site.

The shelterwood system has been tried but study results are limited. With the shelterwood system, the first cut should remove 60 percent of the total basal area, leaving four to five birch seed trees per acre in the overstory after the first cut. The second cut should be made in two years.

Recommended Regeneration Systems

The harvesting should allow natural regeneration of the site. Soil scarification by mixing the organic layer into the surface mineral soil is ideal. Logging should be done when the ground is **not** frozen. Younger stands sprout well from stumps. As stands get older their ability to send up vigorous stump sprouts diminishes, so that by age 80, seeding or planting are the only real alternatives.

When the annual precipitation is less than 25 inches, small patch cuts or progressive strip cuts should be used to prevent the site from drying out. If using strip cuts, the adjacent uncut strips should be harvested within 2 years of the first harvest.

Paper birch is shade intolerant, and tolerant hardwood species will outgrow the birch. Where birch is growing in mixed tolerant hardwood stands, the tolerant hardwoods would have to be controlled to adequately regenerate the birch.

Major Pest Considerations

The bronze birch borer (*Agrilus anxius*) is the major pest of paper birch. This flat-headed borer attacks stressed and declining trees. The yellow-bellied sapsucker attacks the main boles and can cause discoloration and ring shake. Various heart rot fungi, notably *Innotus obliquus*, lower stem quality through decay and discoloration.

Wildlife Considerations

As an intolerant type like aspen, birch shares most of aspen's excellent wildlife habitat values. Birch clearfelled areas provide important browse for

deer and moose, especially in the northeastern part of the state, where there is a shortage of intolerant types.

Preferred Site Conditions
Birch grows best on nutrient rich, moist sites. Paper birch grows the poorest on:

- extremely wet, poorly drained soils;
- extremely dry, with shallow to bedrock soils; and
- coarse sands and gravels on outwash deposits.

1.15 Hybrid Poplar

Management Objectives
Manage hybrid poplar stands for high yields of wood fiber. Yields should be in the range of 3.5 to 6 cords/acre/year. Pulpwood or fuelwood are the most likely products. Intensive silviculture is necessary. Therefore, committed landowners and suitable sites are required. The effects on habitat and habitat improvement should be considered. On state lands it is expected hybrid poplar will not be propagated in any but very insignificant amounts.

Recommended Silvicultural Systems and Rotation Ages
Harvest by clearcutting all stems at rotation age. The rotation ages are not certain at this time, however, they will be between 10 and 25 years for pulpwood. For fuelwood the rotation age could be as low as 3 to 4 years. The harvest may be delayed as long as trees show net growth. If any clones have serious insect or disease damage, they should be harvested or destroyed as soon as possible.

Pest Considerations
Hybrid poplars are quite susceptible to pests. As each hybrid poplar clone is genetically identical, it is very important to actively reduce pest problems since a single outbreak could eliminate the clone. The most important factor is selecting approved clones. The list shown below is suited for the entire state of Minnesota. Planting a variety of clones as described above will also reduce the potential for pest problems. It is also important to monitor growing stands for insects and disease.

Suitable clones:

DN 17	(Robusta)
DN 182	(Raverdeau)
DN 1	
DN 34	(Eugenei, Norway, Imperial)
I 4551	

NC 5260 (Tristis)
NC 5331 (Crandon - rooted only)
NE 298
NE 20
NE 19
NE 287

Preferred Site Conditions

Site selection and weed control are critical for success. Since most of the suitable sites are in traditional farming areas, good soil surveys are available. The following guidelines should be followed to eliminate soils which are not suitable (this implies that most farm soils are suitable for hybrid poplar):

- obtain a Soil Conservation Service (SCS) *Soil Interpretations Record* (portion below) for each soil in the proposed planting site.

A. Narrative	Avoid coarse soils, compacted clays or silt, and excessively well-drained and very poorly drained soils. Beware of soils not commonly used for cropland. Avoid soils which have a described calcareous layer or have free carbonates within 30 inches.
B. Moist bulk density	The moist bulk density should not exceed 1.65 within the first 30 inches. A high number would indicate possible hardpan and restricted rooting.
C. Soil Reaction (pH)	The surface soil should have a pH between 5.5 to 7.5. A pH exceeding 7.2 would indicate possible free carbonates and should be investigated further.
D. Organic Matter	The organic matter content should exceed 3 percent. A higher organic matter content would indicate higher fertility.
E. Flooding	No flooding is always best. Where flooding may occur, its duration should be brief and only in early spring.
F. High Water Table	A water table depth of 3 to 6 feet is ideal. If it is less than 1 foot, the site is unacceptable. *Apparent* means it covers a large area. *Perched* means it could be localized. When the water table depth

exceeds 6 feet, the *Available Water Capacity* must exceed 6 inches in 60 inches.

Recommended Regeneration Systems

Planting.—The site should be chosen carefully and prepared to near agricultural standards. Only approved closes are to be planting. Plant 5-acre blocks of each clone, using as many different clones as possible. Intensive site preparation and weed control are a must to ensure establishment and early growth.

Planting stock.—Unrooted cuttings are acceptable in most cases. The cuttings should be soaked at 50 to 70°F for 2 to 5 days prior to planting. The cuttings are planted at the same time as corn planting. The cuttings are planted with the buds up and leaves less than 1 inch exposed. Rooted cuttings are used on drier sites and also where weed competition is high.

Stump Sprout Management for Regeneration

Hybrid poplars will stump sprout in most instances. When stump sprouts are the method of regeneration, thin the sprouts to the best 1 to 3 stems before the second growing season begins; select vigorous sprouts, originating low on the stump.

Cultural Practices

Herbicides can be used to control weeds. Cultivation must be done and must be less than 2 inches deep to avoid root damage. When the above recommended practices are followed to establish the trees, there should be little need for weed control after the third year. Fertilizer management should be based on soil tests and should concentrate on nitrogen and micronutrients.

Wildlife Considerations

Hybrid poplar plantations are used by a limited number of wildlife species, such as blackbirds, grackles, and morning doves. Great horned owls also use the trees to hunt adjacent farm and prairie lands. Where possible, plantations should be modified to improve winter habitat by including several rows of spruce and fruiting shrubs on the leeward side.

When located in agricultural areas, poplar plantations become *habitat islands* for a variety of species, including white tailed deer and grouse.

APPENDIX 2
Silviculture Survey Questionnaire

GEIS - _____ OWNERSHIP FORESTRY DATA
ANNUAL FOREST MANAGEMENT OPERATIONS (1990 or planned)

Area of timberland	= _____ acre	
Total volume harvested (incl. fuelwood)	= _____ cords	
Area of natural regeneration	= _____ acre	
Area of artificial regeneration	= _____ acre	
SILVICULTURAL SYSTEMS USED		
	Percent by volume	Percent by area
- clearcutting (area >5 acre)	= _____ %	= _____ %
- clearcutting with residuals	= _____ %	= _____ %
- patch cutting (0.25 - 5 acre)	= _____ %	= _____ %
- strip or other modified clearcut	= _____ %	= _____ %
- seed tree	= _____ %	= _____ %
- shelterwood	= _____ %	= _____ %
- thinning	= _____ %	= _____ %
- selective logging	= _____ %	= _____ %
REGENERATION AREAS		
- planting	= _____ acre	
- seeding	= _____ acre	
- natural regeneration	= _____ acre	
- total	= _____ acre	
SITE PREPARATION AREAS		
- chemi-aerial	= _____ acre	
- chemi-ground	= _____ acre	
- prescribed burning	= _____ acre	
- mechanical	= _____ acre	
- total	= _____ acre	
TIMBER STAND IMPROVEMENTS		
- chemical release - aerial	= _____ acre	
- chemical release - ground	= _____ acre	
- hack and squirt	= _____ acre	
- mechanical release	= _____ acre	
- noncommercial thinning	= _____ acre	
- residual stem felling	= _____ acre	
- pruning	= _____ acre	
- slash disposal (burning brush piles)	= _____ acre	
- total	= _____ acre	