Ontario

Ontario Tree Marking Guide

Technical Series

Certified Ontario Tree Markers[1]

Objectives

The principal objectives of Certified Ontario Tree Markers are: (1) to develop and promote sound stewardship of Ontario's forest resources where harvesting is carried out using partial-harvest systems; (2) to take an active role in preventing forest degradation resulting from inappropriate harvesting through the use of partial-harvesting systems; (3) to increase awareness and appreciation of the value of tree marking in partial-harvest systems; and (4) to seek the highest standards in all tree marking activities in Ontario's forests.

Code of Ethics

Each Certified Tree Marker, in striving to meet silvicultural objectives related to sustainable forest management, pledges to:

1. endeavour to promote public awareness and knowledge of the values of tree marking in its application to partial-harvest systems;
2. mark all forests, regardless of size or ownership, consistent with appropriate silvicultural systems and maintenance of ecological integrity;
3. ensure that employers are aware of the consequences of deviating from a proposed marking scheme should the marker's professional marking judgement be over-ruled by uncertified authority;
4. undertake only such tree marking work that the marker is deemed competent to perform by virtue of training, experience and certification;
5. subscribe to the highest standards of integrity and conduct, and show pride in their accomplishments;
6. promote competence in tree marking by supporting, and encouraging in others, high standards of education, employment and performance;
7. immediately disclose any conflict of interest, either direct or indirect, which might be construed as prejudicial to their professional judgement in rendering services to their client; and
8. keep all clients' affairs, practices and processes in the strictest confidence unless released from your obligation by the client.

1. Forest Operations and Silviculture Manual. 1995. Under CFSA. OMNR. Pg. 24-25

Ontario Tree Marking Guide

Version 1.1

Single copies of this publication are available for $27.50 from:

Natural Resources Information Centre
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Peterborough, ON
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Current publications of the Ontario Ministry of Natural Resources, and price lists, are also available from this office.

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Cheques or money orders should be made payable to the Minister of Finance and payment must accompany order.

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OMNR. 2004. Ontario Tree Marking Guide, Version 1.1. Ont. Min. Nat. Resour. Queen's Printer for Ontario. Toronto. 252 p.

Cette publication hautement spécialisée Guide de marquage des arbres de l'Ontario n'est disponible qu'en anglais en vertu du Règlement 411/97, qui en exempte l'application de la Loi sur les services en français. Pour obtenir de l'aide en français, veuillez communiquer avec le ministère ministère des Richesses naturelles au 1-800-667-1840 ou informationssis@mnr.gov.on.ca.

This publication is dedicated to the memory of our friend Brenda Chambers, former Forest Ecosystem Classification team leader with the Southcentral Science and Information Section of the Ontario Ministry of Natural Resources.

Brenda was senior author of the *Field Guide to Forest Ecosystems of Central Ontario*, and *Forest Plants of Central Ontario*.

Brenda's personal commitment to ecological sustainability was continually demonstrated in her research, her fieldwork, and in her efforts to transfer her understanding of site and vegetation ecology throughout Ontario. It is our hope that her commitment is reflected in the contents of this guide.

GUIDE DE MARQUAGE DES ARBRES DE L'ONTARIO

Résumé

Le guide de marquage des arbres de l'Ontario (*The Ontario Tree Marking Guide*) s'inscrit dans la série d'information scientifique et technologique du MRN, conjointement aux guides sylvicoles de la région des Grands Lacs et du Saint-Laurent. Le guide vise à appuyer la mise en œuvre du Programme provincial de formation des marteleurs et à orienter les activités des marteleurs qui emploient un régime sylvicole de coupes partielles en Ontario.

Selon les textes de loi actuels, toute activité de gestion doit reproduire les effets des perturbations naturelles. Étant donné qu'au cours de son évolution, une essence d'arbre a développé des moyens de réagir à de telles perturbations – qu'il s'agisse d'un cas isolé de déracinement par le vent ou d'un incendie de forêt étendu – il est logique que ces réflexes inspirent nos régimes sylvicoles. Par conséquent, les marteleurs doivent comprendre l'importance des diverses caractéristiques écologiques telles que la tolérance à l'ombre, le cycle des semences, la réaction au dégagement, etc. tout en comprenant comment profiter de ces adaptations dans le cadre d'un programme de marquage. En combinant telle connaissance à une compréhension des rapports sur le terrain, tels que l'effet de la topographie sur le degré d'humidité du sol ou le rapport entre la texture du sol et sa profondeur et la qualité de la production de bois, le marteleur sera en mesure de prévoir plus précisément la réaction de la forêt au traitement prescrit.

Un marteleur doit tenir compte des options de traitement sur divers plans. On choisit de conserver ou d'éliminer un arbre selon certains indices tels que vitalité, risques et qualité, tandis que ce seront des facteurs tels que la composition des essences, la fermeture du couvert, la structure du peuplement et sa densité et la densité relative qui influenceront les décisions relatives à l'ensemble du peuplement.

Chaque décision prise par un marteleur aura un effet sur la biodiversité à un certain niveau, avec des conséquences sur l'habitat de certaines espèces sauvages. Le marteleur doit donc comprendre les principes généraux de la biodiversité, ainsi que certains aspects clés de l'habitat faunique (p. ex. : couvert hivernal, habitats ripicole et piscicole, petits cours d'eau, écoulement et étangs en forêt-parc, arbres à cavité, arbres à

paisson glandée, conifères parsemés dans des peuplements feuillus et arbres qui dépassent le couvert forestier).

Les directives de marquage des arbres sont tirées de la prescription d’exploitation forestière, qui elle-même découle d’une analyse du peuplement conçue de façon à être compatible avec le niveau de variabilité dans le peuplement et avec l’usage spécifié de l’information. Toutefois, étant donné qu’un examen même approfondi ne saurait tenir compte de toutes les variations présentes à l’intérieur d’un peuplement, un marteleur doit posséder des connaissances et une expérience suffisantes pour procéder à des ajustements dans le cadre de la prescription. Il doit pour cela avoir une certaine familiarité avec les régimes sylvicoles qui exigent le marquage avant sa mise en œuvre – jardinage par arbre ou par groupe, mode de régénération par coupes progressives uniformes, coupe à blanc avec arbres semenciers, ou éclaircie avec améliorations. Selon le cas, le marteleur doit comprendre les critères qui ont guidé le choix de traitement précis pour le peuplement en question, les décisions prises sur le terrain concernant un arbre particulier ou l’ensemble du peuplement et les conséquences sur la réglementation de la récolte.

Le marteleur fondera la plupart de ses considérations sur des principes scientifiques. Toutefois, les activités pratiques relevant d’un programme de marquage des arbres font appel à d’autres connaissances, parmi lesquelles la compréhension des besoins du personnel en matière de formation, l’organisation des équipes de marquage, la supervision, les questions de santé et de sécurité, les styles de marquage, les conventions relatives à la couleur, ainsi que les procédures de suivi et d’évaluation des activités.

Executive Summary

The Ontario Tree Marking Guide is part of the MNR Science and Technology Series, and is produced as a companion document to the two Great Lakes–St. Lawrence Silvicultural Guides. The intent of the guide is to support delivery of the Provincial Tree Marker Training Program, and to provide operational guidance to tree markers who employ the partial cut silvicultural systems in Ontario.

Current legislation specifies that management effort must emulate the effects of natural disturbances. Since tree species have evolved mechanisms to respond to disturbance—whether the isolated incidence of windthrow or a landscape level wildfire—it is logical that those response mechanisms would suggest a silvicultural regime. Tree markers must therefore be aware of significant ecological traits such as shade tolerance, seed periodicity, response to release, etc., and understand how to take advantage of those adaptations during a tree-marking program. Combining this knowledge with an understanding of site relationships, such as the effect of topography on moisture availability, or the relationship between soil texture and depth, and quality wood production, will enable the marker to more accurately project the response of the forest to the prescribed treatment.

Tree markers must consider treatment options at a variety of scales. Individual trees are selected for retention or removal based on indicators of vigour, risk and quality, while factors such as species composition, crown closure, stand structure, stand density, and stocking influence decisions at the stand level.

Every decision made by tree markers affects biodiversity at some level, and as a result affects habitat for some species of wildlife. The tree marker must understand general biodiversity principles as well as some of the key aspects of wildlife habitat (e.g. winter cover, riparian forest and fish habitat, small streams, seepages and woodland pools, cavity trees, mast trees, scattered conifers in hardwood stands, and supercanopy trees).

Tree marking direction is taken from the Forest Operations Prescription, which is in turn derived from a stand analysis designed to be consistent with the level of stand variability and with the intended end-use of the information. However, since even intensive surveys will not capture all within-stand variation, tree markers must have sufficient knowledge and experience to adapt the prescription within bounds set by the prescription writer. This requires familiarity with the silvicultural systems that require tree marking prior to implementation—single tree selection, group selection, uniform shelterwood, clearcut with seed trees, and thinning and improvement. For each, the marker has to understand the criteria for allocating a stand to that treatment type, the tree and stand level considerations affecting on-site decisions, and subsequent impacts on harvest regulation.

Most considerations of the tree marker are based on sound scientific principles. However, the “business” of administering a tree marking program requires additional knowledge, including an understanding of staff training requirements, marking crew organization, supervision, health and safety considerations, marking style, paint colour conventions, as well as procedures for monitoring and assessment of the operation.

Foreword

This tree marking guide is published as part of the Ontario Ministry of Natural Resources' (OMNR) Science and Technology Series. It is intended to serve as a companion volume to *A Silvicultural Guide for the Tolerant Hardwood Forest in Ontario,* and *A Silvicultural Guide to the Great Lakes–St. Lawrence Conifer Forest in Ontario* (OMNR 1998a and b), and to support much of the information in *A Silvicultural Guide to Managing Southern Ontario Forests* (OMNR 2000).

The guide has been prepared to support delivery of the Provincial Tree Marker Training Program leading to certification of tree markers, and to provide operational guidance to those doing the work of tree marking. The document reflects relevant literature and research; and of equal importance, it incorporates the knowledge and experience of forestry staff in the management of these forests in Ontario. The supporting science for this work is extensive. Since this is an operational document, the reader wishing to access much of the background science is referred to the silvicultural guides noted above, and more particularly to *A Tree Marking Guide for the Tolerant Hardwoods Working Group* (Anderson and Rice 1993).

This guide is intended for use at the tree and stand level, where marking prescriptions are normally determined by both tree and stand characteristics in relation to timber, wildlife, and other ecosystem management objectives. In particular, the guide can be used by all natural resource managers, specialists, and technicians as a source of information that, together with local knowledge and experience, can form the basis of silvicultural tree marking prescriptions within the context of the forest management planning process.

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The Ontario Tree Marking Guide writing team coordinator is indebted to the members of the writing team for their work as co-authors in the preparation of this guide. Each member of the team contributed to the development of several (in some cases all) of the sections making up this guide. However, only those who accepted a lead role for a particular topic are actually noted in the body of the document. The entire team consisted of:

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Lyn Thompson, Communication Transfer Specialist for Southern Science and Information Section, completed the desktop publishing.

Much of the information in this guide was adapted from the work of Harvey Anderson and Jim Rice. Because the Ontario Tree Marking Guide is intended to support a somewhat different group of users, some of the information in Anderson and Rice (1993) was abbreviated and some was not included. Nevertheless, the science summarized in *A Tree Marking Guide for the Tolerant Hardwoods Working Group in Ontario* is critical to a more complete understanding of the rationale for many of the approaches outlined in this effort, and should be referred to for added detail.

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MNR's Strategic Directions and its Statement of Environmental Values

The Ministry of Natural Resources (MNR) is responsible for managing Ontario's natural resources in accordance with the statutes that it administers. As the province's lead conservation agency, MNR is steward of Ontario's provincial parks, natural heritage areas, forests, fisheries, wildlife, mineral aggregates, fuel minerals, Crown lands and waters. Crown lands and waters make up 87 per cent of the province.

In 1991, the Ministry of Natural Resources released a document entitled *MNR: Direction '90s* that outlines the Ministry's goal and objectives. They are based on the concept of sustainable development. This document was updated in 1994 with a new publication, *Direction '90s…Moving Ahead '95.*

In 1994, the MNR finalized its Statement of Environmental Values (SEV) under Ontario's Environmental Bill of Rights (EBR). The purpose of the Environmental Bill of Rights (EBR) is to ensure the integrity of the environment by protecting, conserving, and where reasonable restoring Ontario's environment. The EBR has a public review process for new polices, acts, and regulations. In accordance with the EBR, any new policy, direction, act, instrument, or regulation must be posted on the EBR web site for public review and comment; these comments must be considered prior to final approval.

MNR's Statement of Environmental Values is based on *Direction '90s, Direction 90s…Moving Ahead '95.* The SEV describes how the EBR is to be applied when decisions that might significantly affect the environment are made in the Ministry. It also provides an interpretation of the Ministry's objectives at an operational level to assist in setting priorities for legislative and policy reform, policy and program development, and the application of legal and policy direction through resource management practices.

In 2000, MNR released a document *Beyond 2000* that reaffirms the Ministry's mission of ecological sustainability, and sets out six supporting strategies for the Ministry. Recognizing the importance of maintaining healthy and productive ecosystems across the province, *Beyond 2000* embraces the concept of sustainable development and ecological sustainability as originally expressed by the World Commission of Environment and Development. Policy and program development for Ontario's forest resources are also rooted within the long-term strategic direction provided by the Policy Framework for Sustainable Forests (OMNR 1994). These strategic directions and principles of resource management are considered in Ministry land use and resource management planning.

During the development of *Ontario Tree Marking Guide*, MNR has considered *Direction '90s, Direction '90s…Moving Ahead '95, Beyond 2000* and its Statement of Environmental Values. This guide is intended to reflect the directions set out in these documents and to support the objectives of managing our natural resources on a sustainable basis for future generations.

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1.0 Introduction

by A. Corlett

Tree marking involves the careful selection of trees for harvest or retention based on tree size, vigour, quality, biodiversity concerns, and wildlife habitat value. Tree marking has been practised in the Crown forests of central and southern Ontario since the 1960's. Historically however, many of these forests were subjected to various types of unregulated harvest, from clearcutting where strong pulpwood markets existed, to varying degrees of high-grading for the best quality timber. These harvest approaches strongly influenced the health of Ontario's forests by reducing timber quality, growth, wildlife habitat, and species composition. Present day tree marking and silvicultural practices are focused on creating healthy forests.

Tree marking is required for the successful implementation of partial cutting silvicultural systems such as single-tree or group selection, clear cut with seed trees, and uniform shelterwood. Since fully two thirds of the silvicultural activity in the Great Lakes–St. Lawrence (GLSL) forest is accomplished through one of these systems; the tree marker clearly has a significant influence on the ecology and economics of that forest and its dependent communities. For this reason, qualified tree markers must be knowledgeable in silviculture, tree and wildlife biology, and forest economics in order to choose the right trees to mark for cutting. McLean (1976) has outlined some of the knowledge required for proficiency as a tree marker:

- ability to identify species
- understanding of silvical characteristics of species
- familiarity with site and land features
- recognition of tree defect characteristics and indicators
- appreciation of tree quality and vigour, including use of an acceptable tree classification system
- comprehension of stocking levels and structural types
- appreciation of commercial values of species, products, and grades, and
- appreciation of wildlife habitat, biodiversity, and other ecosystem values

Tree marking involves the integration, interpretation, and application of these disciplines, and thus may be considered as much as art as it is a science.

1.1 Purpose

This guide updates *A Tree Marking Guide for the Tolerant Hardwoods Working Group* (Anderson and Rice 1993) that was produced as a companion to *A Silvicultural Guide for the Tolerant Hardwoods Working Group in Ontario* (OMNR 1990). With the exception of hemlock, the original marking guide was not intended to address conifer species. Several initiatives have made it necessary to revise the original marking guide:

- recently published silvicultural guides for the tolerant hardwood forest (OMNR 1998a), the GLSL conifer forest (OMNR 1998b) and the southern Ontario forest (OMNR 2000)
- the requirement under the Forest Operations and Silviculture Manual that tree markers working on Crown land in the deciduous and GLSL region be certified
- the establishment of the Ontario Tree Marker's Training Program as a prerequisite for tree marker certification

This guide is intended to serve as a field reference for certified tree markers and to provide background knowledge for prescription writers. The guide also supports the Ontario Tree Marker's Training Program and contains much of the information taught in the week-long training course. The revised guide addresses the management requirements of most of the conifer and hardwood species managed under partial cutting systems in Ontario.

The tree marking advice contained in this guide is consistent with an ecosystem-based approach to management and supports the following objectives:

- to maintain a healthy forest that satisfies the requirements of timber production, wildlife habitat, the conservation of biological diversity, and aesthetics, consistent with the implementation of regional forest management strategies
- to ensure a continuous and predictable supply of high-quality sawlogs and veneer bolts from the more productive forest sites by maintaining and enhancing timber quality and yield through the application of appropriate silvicultural techniques

- to maintain or improve the forest genetic base by applying sound genetic principles when implementing partial cutting silvicultural systems

The principles of tree marking are relevant in the GLSL forest region, and for tree species included in the silvicultural guides for the GLSL forest where they occur in the boreal forest. However, in either the boreal or deciduous forest, the application of the silvicultural principles expressed in this marking guide will require a sound understanding of local site and species relationships. The *Silvicultural Guide to Managing for Black Spruce, Jack Pine and Aspen on Boreal Forest Ecosites in Ontario (OMNR 1997)* and *Silviculture Guide to Managing Spruce, Fir, Birch and Aspen Mixedwoods in Ontario's Boreal Forest* (OMNR 2003) provide ecological and management interpretations for a range of conditions in the boreal forest. Background science and overall strategies for management of species found in the deciduous forest are provided in *A Silvicultural Guide to Managing Southern Ontario Forests* (OMNR 2000).

1.2 Guide application

This guide must be used in conjunction with the approved silvicultural guides for the Great Lakes–St. Lawrence (GLSL) forest (OMNR 1998a and b) (i.e. site regions 4, 5, and 6) and where appropriate, the silvicultural guide for the deciduous forest (OMNR 2000) (site region 7). Those using the boreal forest silvicultural guides (OMNR 1997 and 2003) may also find some of the concepts in this guide helpful when dealing with partial harvest systems. The silvicultural guides provide background science and overall strategies for management, while this marking guide deals with the implementation and assessment of tree marking procedures employed in the various partial cutting systems of management.

Individuals preparing forest management plans with an implementation date of April 1, 2007 or later must consider this guide during planning and use it when implementing partial harvest prescriptions in the site regions discussed above. Foresters working with existing forest management plans may wish to use some of the concepts in this guide sooner.

2.0 Ecological foundation

by F. Pinto, M. Woods

The Crown Forest Sustainability Act requires that publicly owned forests be managed sustainably, ensuring that biodiversity and productivity are conserved and that human needs can be met today and into the future. To meet this objective, the Ontario Ministry of Natural Resources is committed to using silvicultural practices that most closely emulate the effects of natural disturbances.

Emulation silviculture exploits the adaptations that tree species have evolved to regenerate after natural disturbances and thus ensures efficient and effective regeneration of harvested forests. This approach maintains compositional and structural diversity of forests, which maintains their function as habitat for wildlife and conserves biodiversity.

Timber harvest and natural disturbances such as wind and fire are inherently different. It is recognized that managed forests will never be identical to natural forests in terms of composition and structure. However, this approach strives to ensure that none of the key functions of natural healthy forests are lost.

Thus, tree markers must understand the types of disturbances that commonly affect Ontario's forests, the resulting reproductive and growth responses of various tree species, and how silvicultural practices may produce conditions resembling some aspects of those natural disturbances.

2.1 Natural disturbances

Natural disturbances have played a critical role in shaping plant diversity, wildlife habitat and timber quality. The amount of light reaching the understorey, humidity, rates of decomposition and nutrient cycling, and the structure of the overstorey and understorey all may be affected to varying degrees, depending on disturbance type and intensity.

Table 2.1 and Table 2.2 illustrate the types of natural disturbances affecting stand development using some of the broad forest types that are typically managed under one of the partial cut systems. Associated silvicultural systems that emulate some aspects of these natural disturbances are provided as a guide for the prescription writer and tree marker.

2.2 Tree responses

All tree species have developed mechanisms over time that allow them to respond through reproduction and growth to particular disturbances. Some of these characteristics or traits in turn regulate potential response to the various partial cutting strategies. The important traits for the principal species dealt with in the two GLSL silvicultural guides are briefly outlined in Table 2.3 and 2.4. The four silvicultural guides provide similar information for associated species and competitors not listed here. An understanding of their potential response to partial release is equally important in the successful implementation of a tree marking program.

Table 2.1 Common disturbance types and frequencies in some conifer dominated forest types typically managed under one of the partial cut systems (OMNR (2000), Pinto et al. (1998), Anderson et al. (1998), Burns and Honkala (1990a, 1990b)).

Forest type	Typical disturbance type	Frequency of disturbance (years)	Range in disturbance size	Age structure	Suggested silvicultural regime
white pine/red pine	ground fire	120–180	small to very large	even-aged	uniform shelterwood or clearcut with seed-tree
white pine/red pine/jack pine	ground fire	80–120	small to very large	even-aged	uniform shelterwood or clearcut with seed-tree
white pine/red oak	ground fire	200–300	small to very large	even-aged	uniform shelterwood
white pine/tolerant hardwoods	ground fire/wind	625	small to very large	even-aged	uniform shelterwood or clearcut with seed-tree
intolerant hardwoods/white pine	ground fire/wind/insects	60–90	small to very large	even-aged	clearcut with seed-tree
white spruce/white pine	ground fire/wind/insects	80–120	small to very large	even-aged	uniform shelterwood or clearcut with seed-tree
white spruce	wind/insects	80–120	small to very large	even-aged	uniform shelterwood or clearcut with seed-tree
red spruce	light to moderate wind/snow/ice	1250	small to moderate ($10m^2$–$40m^2$)	multi-aged	group selection
	wind/disease/insects	annual	small to moderate ($10m^2$–$40m^2$)	multi-aged	single tree or group selection
hemlock/tolerant hardwoods	ground fire	150	moderate ($40m^2$)	multi-aged	single tree or group selection
	wind/snow/ice	1000	large	even-aged	uniform shelterwood
	wind/disease/insects	annual	small to moderate ($10m^2$–$40m^2$)	multi-aged	single tree or group selection
eastern white cedar	wind/snow/ice	100	small ($10m^2$)	multi-aged	single tree or group selection
	wind/ground fire	1250	moderate to large (>$40m^2$)	multi-aged	group selection
	wind/disease/ insects	annual	small to moderate ($10m^2$–$40m^2$)	multi-aged	single tree or group selection

Table 2.2 Common disturbance types and frequencies in some tolerant hardwood dominated forest types typically managed under one of the partial cut systems (OMNR (2000), Pinto et al. (1998), Anderson et al. (1998), Burns and Honkala (1990a, 1990b)).

Forest type	Typical disturbance type	Frequency of disturbance	Range in disturbance size	Age structure	Suggested silvicultural regime
beech/tolerant hardwoods	wind/snow/ice	625-1000	small to moderate ($10m^2$–$40m^2$)	multi-aged	single tree or group selection
	wind/ground fire	250	small to very large	even-aged	uniform shelterwood
	wind/insect/disease	annual	small to moderate ($10m^2$–$40m^2$)	multi-aged	single tree or group selection
basswood/tolerant hardwoods	wind/snow/ice	625	small gaps ($40m^2$)	multi-aged	single tree or group selection
	wind/insect/disease	annual	small to moderate ($10m^2$–$40m^2$)	multi-aged	single tree or group selection
red oak/tolerant hardwoods	wind/snow/ice	625	small to moderate ($10m^2$–$40m^2$)	multi-aged	uniform shelterwood
	wind/ground fire	250	small to very large	even-aged	uniform shelterwood or group selection
	wind/insect/disease	annual	small to moderate ($10m^2$–$40m^2$)	multi-aged	single tree or group selection
sugar maple/hemlock/ yellow birch	wind/ground fire	1000	small to very large	even-aged	uniform shelterwood
	wind	625	moderate ($40m^2$)	multi-aged	single tree or group selection
	wind/insect/disease	annual	small to moderate ($10m^2$–$40m^2$)	multi-aged	single tree or group selection

Table 2.3 Key traits of the principal GLSL conifer species that influence the choice of partial cutting management options.

Species adaptations	White pine	Red pine	White spruce	Red spruce	Eastern hemlock	Northern white cedar
longevity (years)	300+	200+	250–300	up to 400	400–500	300–400 (700+ documented)
age structure	multi/even	even	multi/even	multi	multi/even	multi/even
seed periodicity	3–5	5–15	2–5	3–8	frequent	2–5
vegetative reproduction	nil	nil	nil	nil	nil	layering
time of seed dispersal	August to November	October to November	September to January	September to January	October to January	September to March
dispersal mode	wind, mammals	wind	wind, mammals	wind	wind	wind, mammals
preferred seedbed	moist mineral soil and humus mixture	fine moist mineral soil, lightly burned litter and humus	mineral soil, feathermoss, rotting logs	exposed mineral soil, rotting wood	moist mineral soil, rotten logs, stumps	rotting logs, stumps mosses
growing season microclimate	partial shade with moderate soil surface temperatures	partial shade with moderate soil surface temperatures	partial shade with moderate soil surface temperatures	partial shade with moderate soil surface temperatures	partial shade	partial shade
shade tolerance	seedlings—mid-tolerant Mature—intolerant	seedlings—mid-tolerant Mature—intolerant	mid-tolerant	tolerant	tolerant	tolerant
reaction to competition	germination—good growth—satisfactory	germination—good growth—poor	germination—good growth—satisfactory	germination—good growth—good	germination—good growth—good	germination—good growth—satisfactory
self pruning	moderate	good	poor	good	poor	poor
response to release	moderate	good—regular thinnings	good	good, decreases with age	good	moderate/good depending on site
susceptibility to rot/stain	moderate	low	moderate (susceptible to root rot)	low	low	low
bole/form defect	forks (white pine weevil)	----	branching	---	shake	sweep
decline hazard rating	moderate	low	moderate	low	moderate/high	low
windfirmness	good	good	moderate/poor (can be shallow rooted depending on site)	moderate	moderate/poor	low/moderate

Table 2.4 Key traits of the principal tolerant hardwood species that influence the choice of partial cutting management options.

Traits	**Black cherry**	**White ash**	**Red oak**	**Basswood**	**Beech**	**Yellow birch**	**Sugar maple**
longevity (years)	100–250	250–300	125–250	100–150	100–200	300+	300–400
age structure	even	even/multi-aged	even/multi-aged	even/multi-aged	multi-aged	even/multi-aged	multi-aged
seed periodicity	1–4	3–5	2–5	frequent	2–3	3	3–7
vegetative reproduction	sprouts—common	sprouts—common	sprouts—very common	sprouts—common	root suckers	not common	sprouts—common
time of seed dispersal	September to November	September to December	September to November	November to March	September to November	November to February	September to October
dispersal mode	Gravity, birds, mammals	wind	gravity, mammals, birds	wind, mammals	mammals, birds	wind	wind
preferred seedbed	leaf litter, humus, mineral soil	mineral soil, humus, leaf litter	moist mineral soil	mineral soil—others acceptable	mineral soil, leaf litter	moist mineral soil mixed with humus, rotten logs, stumps	undisturbed litter
light conditions for germination and early seedling growth	partial shade	partial shade	requires light (30% of maximum intensity)	partial shade	partial shade	partial shade (45–50% during first five years	partial shade
shade tolerance	intolerant	mid-tolerant	mid-tolerant	seedling—mid-tolerant mature—tolerant	tolerant	mid-tolerant	tolerant
reaction to competition	germination—satisfactory	germination—good	germination—good	germination—good	germination—good	germination—good	germination—good
	growth—poor	growth—satisfactory	growth—satisfactory	growth—satisfactory	growth—good	growth—satisfactory	growth—good
self pruning	good	good	moderate	good	moderate	good	good
response to release	poor	good	good	good	moderate	moderate	good
susceptibility to rot/stain	moderate	low	moderate/low	low up to 120 years	high	high	high
bole/form defect	sweep	fork	epicormics	epicormics	epicormics	fork	fork
decline hazard rating	moderate/high	moderate/high	moderate/high	moderate	moderate	moderate/high	moderate
windfirmness	moderate	good	good	good	good	poor (shallow)	good

The significance of the traits influencing the choice of management system may be interpreted as follows (from Anderson and Rice [1993]):

- **Shade tolerance** is defined as the capacity of a plant to develop and grow in the shade of and in competition with other trees. Differences in the degree of shade tolerance allow plant species to exploit the varying environmental conditions created by different types of disturbances.

  The seeds of most native tree species germinate well under some shade. Shade maintains moist soil conditions necessary for germination. Once seedlings have become established, the degree of shade plays an important role in long term growth and survival. Trees are classified under three levels of shade tolerance: intolerant, mid-tolerant, and tolerant. Tolerant plants tend to require less sunlight than do intolerant plants in order to reach their maximum growth rate; this gives them a competitive growth advantage in shade.

  Shade tolerance determines the occurrence of advance reproduction beneath an established crown canopy. It is a required attribute for species forming uneven-aged stands, and will greatly influence the choice of silvicultural system.

- **Longevity** refers to the probable length of time trees can potentially survive and grow following establishment in the absence of disturbance. Some species, such as white pine, are long lived and can persist in a stand for over 300 years.

- **Age structure** refers to the distribution of age classes within a stand. Age structure is usually shaped by stand history (e.g., disturbance) and reflects species traits such as the ability to reproduce and grow in its own shade (i.e., advance reproduction). Sugar maple, beech, and hemlock may form both even- and multi-aged stands, while yellow birch and white ash may occur in even-aged groups that develop as a mosaic within a multi-aged stand.

- **Seed periodicity** regulates the availability of natural seedfall. While managers are often unable to dictate the timing of the harvest according to this factor, it should be used in scheduling follow-up treatments such as site preparation for natural regeneration. Seed collection efforts, in anticipation of direct seeding procedures, will also be controlled by seed years.

- **Preferred seedbed** condition will suggest the need for the application of treatments such as scarification or prescribed fire to create suitable conditions for the promotion of seed germination and establishment for individual species. Some species (e.g., sugar maple, beech) easily germinate and grow on undisturbed forest floor conditions, while others (e.g., yellow birch, red pine) require some forest floor disturbance.

- **Vegetative reproduction** reflects the ability of a species to produce stump sprouts or coppice growth (e.g., red oak, basswood) or root suckers (e.g., beech). Coppice or root suckers can augment natural regeneration from seed but may also present severe competition to other desirable species.

- **Reaction to competition** will vary with species and stage of development. In some species (e.g., red oak), competition control is critical to survival; in others (e.g., sugar maple), quality control by means of cull-tree removal or crop-tree selection is more important.

- **Self-pruning** is the natural ability of a tree species to lose lower branches and is directly related to shade tolerance and spacing. It is an essential process in promoting high-quality hardwoods or conifers.

- **Response to release** regulates growth rate and affects wound healing, volume production, and stand structural changes. Some species (e.g., black cherry) show little response to thinning in the polewood stage and therefore may require earlier tending.

- **Rot and stain** are less common in well-managed stands. They remain important in partial-cutting systems because of potential logging damage to residual stems and roots.

- **Bole and form defects** can be controlled to some extent by proper spacing and careful logging practice. Over exposure to sunlight in juvenile stages may limit development of straight, knot-free, clear logs by allowing lower branches and forks to persist.

- **Decline and dieback** may be induced by such interacting ecological factors as drought and insect infestation. While decline and dieback may not be directly controllable, they must be considered at all times in choosing trees to be left to grow as residuals. Susceptible species (e.g., red oak, yellow birch) should be examined carefully for symptoms, and harvesting strategies should consider possible recurrence of such stress events and their effects in relation to site and stand conditions. In some cases logging operations may have to be postponed. Tree markers should look for obvious signs of poor health and usually mark to remove severely declining trees.

- **Windfirmness** describes a tree's relative stability or ability to withstand exposure to strong winds. Residual trees should be windfirm, especially in high-risk areas such as ridges. Leaning stems and trees on exposed sites, or shallow or wet soils must be evaluated during tree marking to minimize post-logging windthrow.

A more comprehensive overview of tree species characteristics can be found in OMNR (2000), Pinto *et al*. (1998), Anderson and Rice (1993) and in Burns and Honkala (1990a, 1990b).

2.2.1 Applying knowledge of natural disturbance factors

The effects of past disturbances are reflected in the species composition and age-class distribution of the stand to be managed. It is a valuable exercise for the forest manager and the tree marker to evaluate the current stand condition, to determine the natural processes that contributed to the stand's development, and to use that information to select the most appropriate silvicultural practice. Such an investigation can validate a given prescription, and can aid in determining the likelihood of attaining the stated objectives for the forest.

The following three disturbance scenarios (medium intensity ground fire, exploitative logging, and logging following certified tree marking) contrast post-disturbance forest condition in a simplified portrayal of a mixedwood forest dominated by white pine. Such forests are common in Ontario. Table 2.5 describes the condition of the stand before disturbance.

Medium intensity ground fire is the most common naturally occurring disturbance type responsible for regenerating white pine in Ontario. Scenario 1 describes the probable impact of such a disturbance on a common mixture of tree species in white pine dominated mixedwood forests.

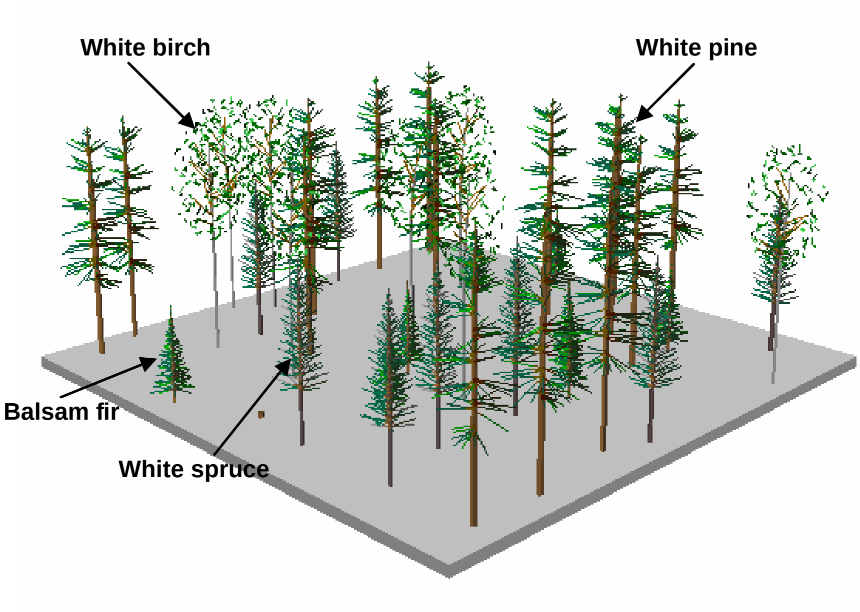
Exploitative or high-grade logging results in the removal of most marketable trees from the stand, and the retention of those of lesser value. This practice was very common in the past. Scenario 2 describes the probable results of such an approach.

Tree marking and subsequent logging according to a prescription that emphasizes the emulation of natural processes in this situation would tend to maintain the species and structure that would follow a medium intensity ground fire. Of course, there are practical limitations as to how closely a natural disturbance may be imitated; for example the distribution of residual pine trees will be more even following a managed harvest than after fire. Scenario 3 describes a probable result of tree marking and subsequent logging.

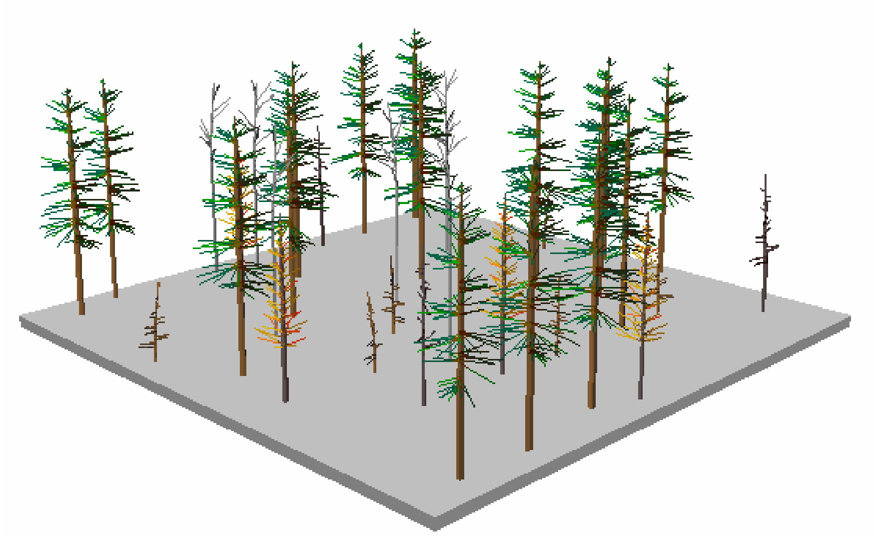
Table 2.5 Description of initial stand species, diameter and height status prior to disturbance.

	White pine		White spruce	Balsam fir	White birch
Size class [1]	Large saw log	Medium saw log	Medium saw log	Pole size	Pole size
dbh[2] (cm)	50	36	32	16	18
Height (m)	25	18	18	10	10
Height to live crown (m)	13	7	5	1	5

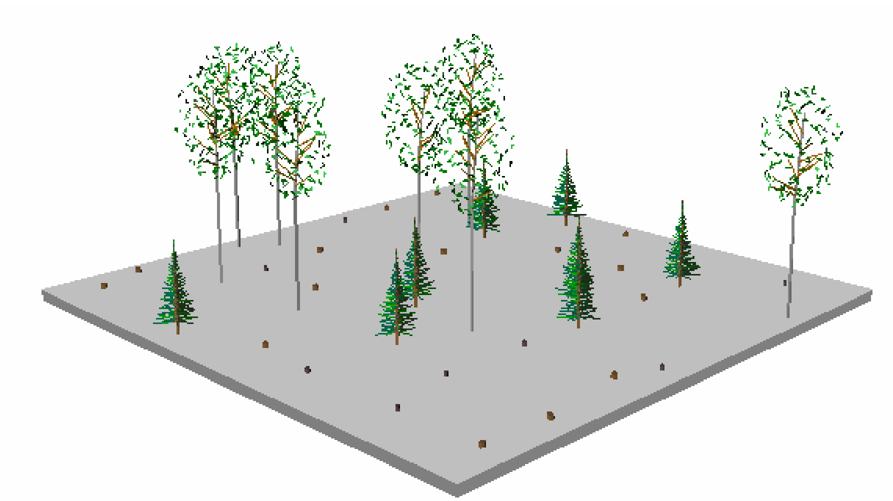
[1] Refer to Table 3.16 for size class
[2] Diameter at breast height



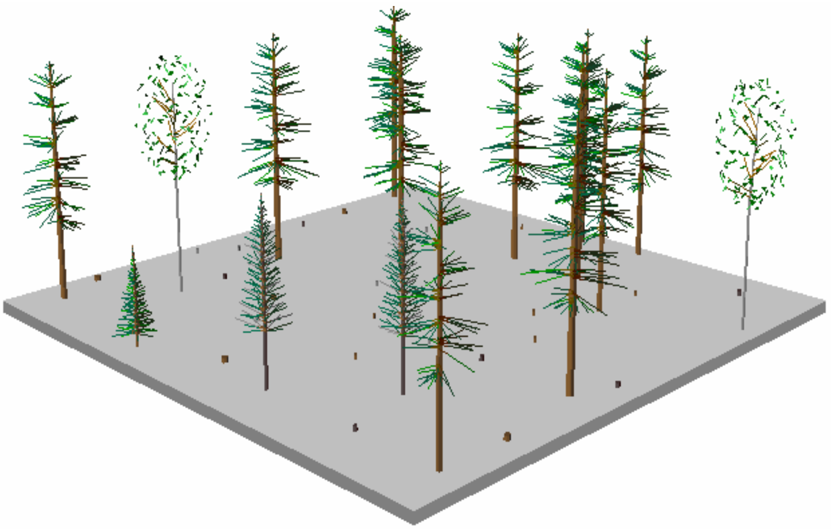
	Scenario 1: Medium intensity ground fire			
Species	**Size**	**Chance of mortality from fire**	**Replacement in future stand**	**Discussion**
White pine	Large sawlog	Low	**High**	The large pine trees with their thick bark and live foliage high above the ground are more likely to survive the fire. White pine seed from large surviving trees can fall onto the burned site where it will germinate and regenerate the site with white pine.
	Medium sawlog	Medium	Low	Medium sized pines have thinner bark and live foliage closer to the ground. These traits increase the odds that fire will girdle their trunks or scorch their crowns resulting in their death.
White spruce	Medium sawlog	**High**	Low	White spruce has thin bark and live foliage quite close to the ground. These factors increase the odds that fire will girdle their trunks or scorch their crowns resulting in their death.
Balsam fir	Pole Size	**High**	Low	Balsam fir has thin bark and flammable living foliage close to the ground. Balsam fir reproduces by seed, which does not retain its viability well in the soil. Seed must blow in from other stands to regenerate this species.
White Birch	Pole Size	**High**	Medium	White birch reproduces by seed that do not retain their viability in the soil. The roots of the birch will probably survive the fire resulting in a high likelihood of root sprouts. White birch seeds may travel from neighbouring stands.



	Scenario 2: Exploitative logging			
Species	**Size**	**Chance of being cut**	**Replacement in future stand**	**Discussion**
White pine	Large sawlog	**High**	Low	White pine is highly likely to be harvested. White pine seed does not remain viable in the soil, nor does white pine reproduce vegetatively. For white pine to regenerate, live trees must be found close to or within the stand as seed fall occurs near the parent trees. Seedlings from these large trees would be rare in the new stand.
	Medium sawlog	**High**	Low	Medium white pine trees are highly likely to be harvested with low probability of contributing to regeneration in the new stand. Seedlings from these medium sized trees would be rare in the new stand.
White spruce	Medium sawlog	**High**	Low	High probability of being harvested. White spruce requires a live seed source to regenerate. Since seed fall usually occurs near the parent tree, it is unlikely that white spruce will replace itself.
Balsam fir	Pole size	Low	**High**	Balsam fir has a low probability of being harvested and a high probability of replacement in the new stand. Balsam fir produces seed regularly. The seed is capable of germinating on duff in the understorey of a stand. The small seed of balsam fir may also suffer less rodent predation than pine seed. These factors make it very likely for balsam fir increasing in abundance in the stand.
White birch	Pole size	Low	**High**	White birch has a low probability of being harvested and a high probability of contributing to regeneration in the new stand. White birch produces seed frequently. This seed can germinate on sites that may be scuffed up by logging. It is likely that the abundance of white birch will increase.



	Scenario 3: Logging following certified tree marking			
Species	**Size**	**Chance of being cut**	**Replacement in future stand**	**Discussion**
White pine	Large sawlog	Low	**High**	Large white pine trees have a low probability of being harvested and a high probability of contributing to regeneration in the new stand. The large trees will serve as a source of seed that may germinate and grow if other plants do not fill in the available sites.
	Medium sawlog	Medium	Medium	Medium sized white pine trees have a medium probability of being harvested with medium probability of contributing regeneration in the new stand.
White spruce	Medium sawlog	Medium	Medium	Medium sized white spruce trees have a medium probability of being harvested and a medium probability of contributing to regeneration in the new stand.
Balsam fir	Pole size	**High**	Medium	Balsam fir has a high probability of being harvested and a medium probability of contributing to regeneration in the new stand. Some balsam fir will not be killed and will serve as a seed source. Some balsam fir advanced growth may be killed through logging and renewal activities. They will have a medium probability of surviving and increasing in their abundance in the new stand.
White birch	Pole size	Medium	**High**	White birch has a medium probability of being harvested and a high probability of contributing to regeneration in the new stand. White birch produces seed frequently. This seed can germinate on sites that may be scuffed up by logging. Without further treatment it is likely that the abundance of white birch will increase.



2.3 Site relationships

The growth potential of a tree species is controlled not only by its silvical characteristics, but also by the quality and suitability of the site. The suitability of a site for a particular species is related to surficial geology, physiography, climate, and soil texture and moisture regime, with much of the variation in forest cover and productivity related to the availability of water in the soil.

Tree markers should be aware of the more obvious indicators of water availability as they progress through a site, i.e.:

- soil depth
- topographic position (top, middle or bottom slope), and
- slope (degree of steepness)

Soil texture is a key indicator as well, but is one that may not be readily apparent to the tree marker without more detailed pre-treatment analysis.

The GLSL forest can be generally characterized by steeply broken bedrock slopes with a shallow covering of dumped till, and occasional ridges covered by deep, moulded till soils. The Sherborne Landtype is in many ways typical, and is used to illustrate the relationships between soil depth, topographic position, moisture regime and some common forest associations (Figure 2.1). The relevant forest ecosystem classification (FEC) (Chambers *et al*. 1997, Lee *et al*. 1998, Racey *et al*. 1996, Sims *et al*. 1997, and Taylor *et al*. 2000) can serve as a tool to identify site characteristics that affect tree species occurrence and growth.

2.3.1 Effects of topography on soil moisture availability

Upper slopes covered with shallow dumped till retain little soil moisture and as a result:

- Conifer species tolerant of dry conditions, especially pines, grow well.
- Red oak regenerates with less competition than on fresher sites lower on the slope.
- The growth of sugar maple and beech is less robust.

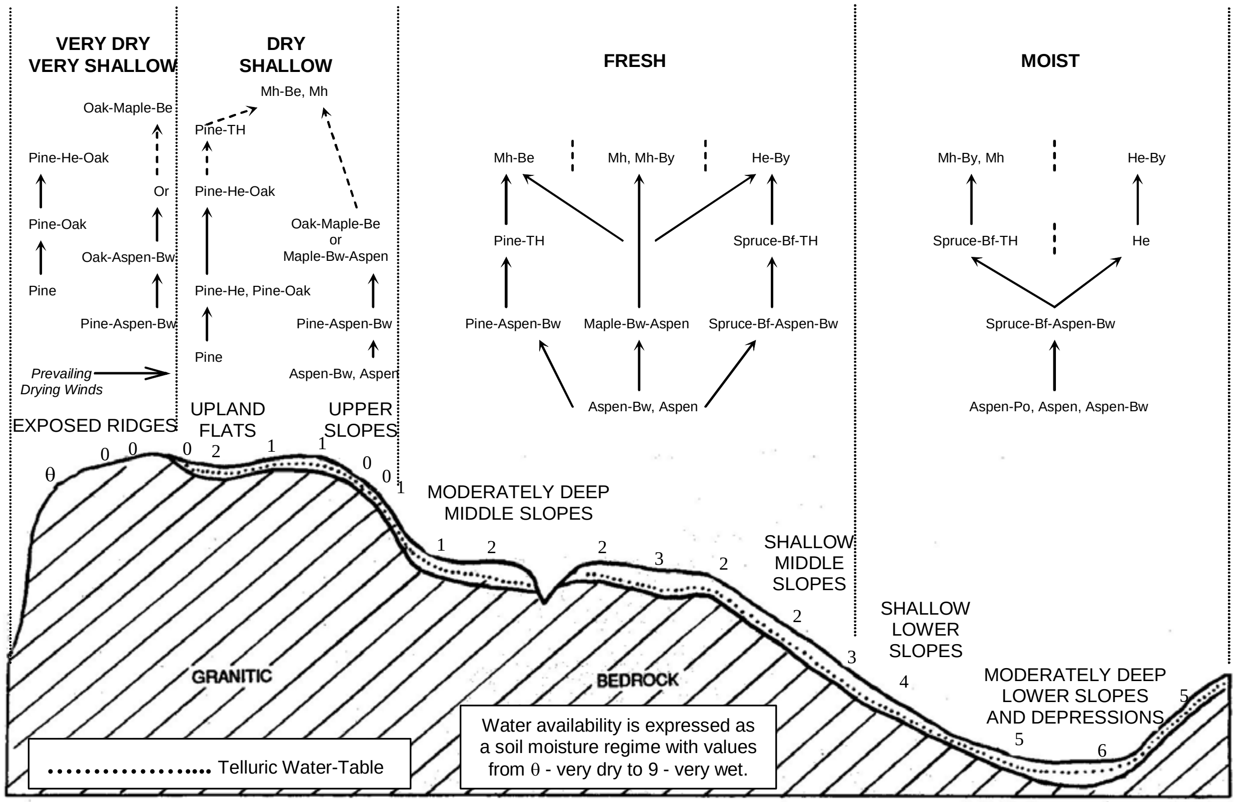


Figure 2.1 Landscape profile of forest associations on Sherborne landtype, site region 5E (from Hills 1959). Arrows indicate successional changes in species composition.

Upper slopes covered with deep, moulded till indicate a drumlinoid landform where the weight of glacial ice has reduced the pore space between soil particles. As a result:

- The compacted soils slow the rate of percolation through the soil, keeping the water within reach of tree roots for a longer period during the growing season.
- The upper slope or hilltop position does not necessarily indicate a shallow, dry site.
- An extended period of available moisture creates a fresh moisture regime despite the hilltop location.

Indicators of drumlinoid sites:

- broad areas of continuous hardwoods
- occurrence of large hardwoods, and
- occurrence of yellow birch

Mid slopes have the following site characteristics:

- Moisture is available for a longer period during the growing season than on upper slopes.
- Water percolates into the soil column on the upper slopes and becomes oxygenated and nutrient enriched as it moves down slope. This is referred to as *telluric water* (telluric sites usually have better humus incorporation resulting in a more fertile, moisture retentive soil).
- A fresh moisture regime condition that favours the development of sugar maple and beech.
- Growth of yellow birch, maple, and beech is good on these sites.

Lower slopes have greater water availability than higher elevations and as a result have:

- Increased proportions of yellow birch and coniferous species (e.g., cedar, hemlock, and spruces).
- Reduced proportions of sugar maple and to a greater extent beech.
- Coniferous species such as white spruce, black spruce, and hemlock (or black ash in areas with good air drainage) replacing yellow birch as soil moisture regime becomes wetter.

2.3.2 Relationships between tree species and site condition

As tree markers progress through a stand they will encounter a variety of site conditions, each suited to growing a particular group of species. The relationship between species and site condition for the principal species of the GLSL forest is discussed below. This site specific information, along with an understanding of geographic occurrence (from sources such as range maps), should assist markers to prioritize the species associations to receive focused regeneration effort. Site-species relationships will not be consistent across the GLSL and deciduous forest. For example, on the north shore of Lake Huron, beech, black cherry, red oak and white ash are much less common, and yellow birch tends to perform well further up-slope. West of Lake Superior, species such as basswood, red oak, sugar maple, and white pine are at the northern part of their range, and are less abundant and occur less regularly than in other portions of the GLSL.

White pine

- White pine can colonize and reach maturity on a wide range of soil textures and site conditions. White pine roots on shallow sites may penetrate vertical cracks in the bedrock to tap moisture supplies. White pine can thus exploit shallow sites as well as sites consisting of compacted layers (Merchant *et al*. 1989).
- White pine growing with spruces tend to have low understorey plant diversity while white pine and eastern white cedar stands have high understorey plant diversity (Carlton and Gordon 1992).
- White pine may dominate the species composition on some shallow sites (Carlton and Gordon 1992), but stem quality is poorer than on deeper sites.
- The general productivity of shallow sites (< 30 centimetres [cm] soil) for most tree species is poor (Carlton and Gordon 1992). However, white pine on some shallow sites can display growth rates better than expected due to telluric water carrying moisture and nutrients (Merchant *et al*. 1989).
- Productivity rates for both white and red pine are reduced on soils containing a high component of coarse fragments (>50 percent [%]), but the reduction is most significant for white pine.

- White pine growth is best on finer textured soils (e.g., silty fine sands), on deep sands with loamy material in the upper horizons, and on shallow to moderately deep silty sand tills (Merchant *et al*. 1989).
- Sites that are composed of pure sands or gravelly, cobbley soils yield slightly less growth than finer textured soils.
- Poorest productivity is found on soils with compacted layers in the rooting zone, or on soils with very fine textures such as silty clay loam or heavy clay soils, on very shallow soils, on poorly-drained bottom lands, or on upland depressions (OMNR 1998b).

Red pine

- Although red pine and white pine exhibit similar growth rates on the same sites, red pine may develop root systems that spread throughout the soil.
- Growth of red pine is reduced in soils having a high percent of coarse fragments (>50%).
- Red pine occurs most commonly on sandy soils but reaches highest productivity on well-drained sandy-loam to loam soils.
- Extensive red pine stands grow on sites that are dry, level to slightly rolling, sandy, and of low fertility. Usually these sites are predominantly glaciofluvial, aeolian, or lacustrine in origin (OMNR 1998b).
- Red pine growth may be inhibited on calcareous soils (OMNR 1986).

White spruce

- White spruce grows on a variety of soils of glacial, lacustrine, marine or alluvial origin.
- Growth and development is good on loams and clays as well as both acidic and alkaline soils.
- Best growth is achieved on well-aerated, moist to fresh sites.
- Productivity increases with increasing depth to gley (Burns and Honkala 1990a).

Red spruce

- Occurs over a wide range of sites including moderately well-drained to poorly-drained flats and thin-soiled upper slopes.
- Grows primarily on acidic till soils and moist alluvial soils on lower valley slopes with yellow birch in the central portion of Ontario.

- The species rarely occurs on dry outwash.
- Common on acid, sandy loams with considerable moisture, on shallow rocky soils if hardwood competition is minimal, and on shallow organic soils overlying rock at higher elevations (OMNR 1998b).

Eastern white cedar

- Highest productivity on limestone-derived soils that are neutral or slightly alkaline and moist but well-drained.
- Poorest productivity rates in moist to wet swamp conditions. In swampy areas, cedar is most productive when located near drainage ways or where the organic soil is deep and decomposed or is adjacent to actively moving soil water (Eyre 1980).

Eastern hemlock

- Grows on a variety of site conditions and soil textures. It will grow on shallow rocky acidic soils of the Canadian Shield and on loamy sands, sandy loams, silt loams, limestone soils, and on clay loams of southern Ontario.
- Hemlock stands in Algonquin Park tend to be found more frequently on cooler and drier, moderate to steep north and west facing slopes. They are less frequently found on warmer eastern aspects and knoll sites (Kavanagh and Kellman 1986).

Sugar maple

- Stands tend to develop on relatively fertile, fresh, well-drained upland sites in moisture regimes (MR) 1 to 3. In central Ontario, sugar maple also occurs on dry to moist sites.
- Best growth on sandy loams, loamy sands and silt loams (often melanized), with pH levels greater than 5.5 in the upper soil horizons. However, the species will grow in more acidic conditions and textures from sandy to fine loamy/clayey (OMNR 1998a).
- Sugar maple productivity (SI) ranges are narrow across soil moisture and soil texture groupings (Burns and Honkala 1990b).
- Stem quality development improves with MR 2 to 3 (Burns and Honkala 1990b).
- Sugar maple stands do not tend to establish on infertile sites.
- On fresh sites, sugar maple is found mixed with beech.
- Sugar maple mixed with yellow birch occurs on moist sites.

Basswood

- Occurs commonly (but irregularly) on deep/moderately-deep, fresh (MR 2 to 3) sandy loams and telluric moist (MR 4 to 6) cool sites in site region 5E; also found on fresh loamy soils in site regions 6E and 7E and fresh clay soils in site region 6E (OMNR 1998a).
- In central Ontario, basswood is restricted to fresh-to-wet, moderately rich to rich ecosites. It reaches its highest percent cover on fresh, rich sites (OMNR 1998a).
- Found on soils which are classed as fertile because of their high nutrient content (nitrogen).

Beech

- Beech grows best on fertile, well-drained fresh soils, especially loamy soils with high humus incorporation. Also found on sandy to fine loamy and clayey soils (OMNR 1998b, Burns and Honkala 1990b).
- Beech will develop poor stem quality and have less vigour on shallow dry sites (MR 1 to 2).

Yellow birch

- Yellow birch is most productive on moist lower slopes (MR 3 to 5) with deep loamy soils and a moving (*telluric*) water table (OMNR 1998a).
- Stands can also be found on sandy to fine loamy and occasionally organic soils.
- Growth of yellow birch is affected by soil texture, drainage, rooting depth, stone content in the rooting zone, elevation, aspect, and fertility.

Red oak

- Grows in soils ranging from clay to loamy sands and from deep, stone-free to shallow rocky soils.
- Best growth is on deep, well-drained loam to silty, clay loam in coves, and on mid/lower slopes (Burns and Honkala 1990b).
- Commonly found on fresh-to-dry, rich to moderately fertile ecosites in central Ontario. These sites are best characterized by fresh, loamy soils (MR 2 to 4).
- Stands can form on shallow rocky ridges at the northern portion of its range.

- Decreasing soil depth and moisture negatively affects height growth and stem quality development.

White ash
- Site region 5E forms the northern limit of its range where it is restricted to ecosites that are fresh to dry, but fertile (OMNR 1998a).
- Grows best and develops the best stem form on fresh-to-moist well-drained sites (MR 2 to 4) with sufficient nitrogen and calcium (Burns and Honkala 1990).
- Grows well in soils underlain by compacted till supporting a telluric water table (OMNR 1998a).

Black cherry
- Best growth is on moist (MR 3 to 4), rich, well-drained loamy soils; lower slopes and coves are often suitable.
- Poor growth and development on dry soils found on ridge tops.
- Is generally a minor component of the GLSL forest.
- Requires cool, moist sites but seldom occurs north of the 5°celsius mean annual isotherm (OMNR 1998a).

2.3.3 Ecosites, their indicator species and productivity ratings

Tree markers can determine which tree species grow best on a particular site by recognizing shrubs and herbs that indicate soil texture, fertility, and moisture availability. Table 2.6 provides a summary of indicator species for the various ecosites (Chambers *et al*. 1997) and lists potential productivity ratings for the main tree species in central Ontario. Similar ecosites are grouped together. Potential productivity ratings are divided into five classes (very poor to very good) for the main tree species in each ecosite grouping.

Productivity ratings for jack pine, black spruce and trembling aspen in northwestern Ontario are described by Carmean (1996). For further information related to productivity on an ecosite basis, refer to the silvicultural guide for the boreal forest (OMNR 1997) and the field guides to the forest ecosystem classifications for northwestern (Racey et. al. 1996 & Sims et. al. 1997) and northeastern (Taylor et. al. 2000) Ontario.

Productivity ratings for southern Ontario species-soil relationships are provided by Taylor and Jones (1986) in OMNR (2000).

The tree marker is expected to incorporate this site and productivity information, with a consideration of many other factors such as indicators of tree vigour, tree quality, and a whole range of features at the stand level (see Sections 3.0 and 4.0).

2.3.4 Site productivity and wood production

Figure 2.2 and Figure 2.3 provide a generalised reference on the potential for producing high quality sawlogs for a variety of selected species and on a range of landtypes in central Ontario (Hills and Brown 1955). Landtypes include a fractured site complex (Sherborne), water-laid sands (Petawawa) and poorly-drained organic soils (Oakley) at a variety of moisture regimes. Note that these figures do not consider competition, impacts of insects and diseases or other environmental events that can affect tree growth.

The ecodistrict descriptions found in Appendix A of OMNR (2000) provide general site descriptions for southern Ontario (site regions 6E and 7E). Appendix D (adapted from Taylor and Jones, 1986) of the southern Ontario silvicultural guide provides information on tree species suitability for site regions 6E and 7E. In future, growth and yield data will provide relative site productivity estimates for wood production in these regions.

Site productivity facts for tolerant hardwoods in eastern North America

- Tolerant hardwoods usually attain their highest productivity on deep, medium-textured, well-drained soils (Carmean 1978).
- Tolerant hardwoods are least productive on dry, coarse-textured soils or wet, poorly-drained fine-textured soils.
- Site productivity changes considerably with variations in elevation, aspect, and slope position on strongly broken terrain.
- On more level topography, productivity is affected more by soil texture, drainage, and depth-to-mottling.
- Diameter growth of tolerant hardwoods decreases steeply with increasing tree diameter on coarse-textured sites but remains nearly constant on fine tills (Leak 1989).
- Higher rates of growth and prolonged growth periods on good sites result in higher volume production and better timber quality.

Table 2.6 Productivity rating of central Ontario tree species by FEC ecosite groupings.

Ecosite communities	Key indicator species	Site parameters	Productivity rating*
ES11–ES14 white pine—red pine; red pine; jack pine—white pine—red pine; white pine—largetooth aspen—red oak	blueberries, bush honeysuckle, wintergreen, beaked hazel, bracken fern	very shallow	Pw^{2} Pr^{1} Or^{1}
		dry—moderately fresh	Pw^{3} Pr^{3} Or^{2}
ES15–ES16 jack pine; black spruce–pine	blueberries, creeping snowberry, twinflower, feathermosses	very shallow	Pw^{2} Pr^{1}
ES17–ES22 poplar—white birch; poplar—white birch—white spruce—balsam fir; poplar—jack pine—white spruce—black spruce; white pine—red pine—white spruce—white birch—trembling aspen; white cedar—white pine—white birch—white spruce; white cedar—other conifer	beaked hazel, mountain maple, fly honeysuckle, bush honeysuckle, blueberries	very shallow	Pw^{2} Ce^{2}
		dry—moderately fresh	Pr^{4} Sw^{3} Pw^{2} Ce^{2}
		fresh—moist	Pr^{5} Pw^{4} Sw^{3} Ce^{3}
		very moist	Pw^{5}
ES23 & ES25 red oak—hardwood; sugar maple—beech—red oak	striped maple, fly honeysuckle, partridgeberry, spinulose wood fern	very shallow	Mh^{4} Or^{3}
		dry—moderately fresh	Mh^{4} Or^{4} Pw^{3}
		fresh—moist	Mh^{4} Or^{3}
ES24 & ES26 sugar maple—red oak—basswood; sugar maple—basswood	leatherwood, large-flowered bellwort, blue cohosh	very shallow	Or^{3}
		dry—moderately fresh	Mh^{4} Or^{4}
		fresh—moist	Or^{5} Mh^{4}

Table 2.6 Productivity rating of central Ontario tree species by FEC ecosite groupings—continued.

Ecosite communities	Key indicator species	Site parameters	Productivity rating*
ES27–ES30 sugar maple—white birch—poplar—white pine; sugar maple—hemlock—yellow birch; sugar maple—yellow birch; hemlock—yellow birch	spinulose wood fern, fly honeysuckle, striped maple, hobblebush, mountain maple, rose twisted-stalk	very shallow	Ce^4 He^3 Mh^2
		dry—moderately fresh	Pw^4 Ce^4 By^3 He^3 Mh^2
		fresh—moist	Pw^4 He^4 By^3 Ce^3 Mh^2
		very moist	He^4 Ce^4 Mh^3
ES31–ES33 black spruce—tamarack; white cedar—black spruce—tamarack; white cedar—other conifer	sphagnum spp., labrador tea, creeping snowberry, northern wild raisin, blueberries	very moist—mineral	Ce^3
		wet organic	Ce^2
		fresh—moist	Ce^4 By^3
ES34–ES35 white cedar—lowland hardwoods	dwarf raspberry, mountain maple, fly honeysuckle, lady fern	very moist—mineral	By^3
		wet organic	Ce^4

*Productivity rating:
5 = very good
4 = good
3 = moderate
2 = poor
1 = very poor

Note: Sugar maple productivity rating assumes sampled stands were even-aged. In some cases, insufficient plot age data were available to determine if the plots were even-aged or uneven-aged.

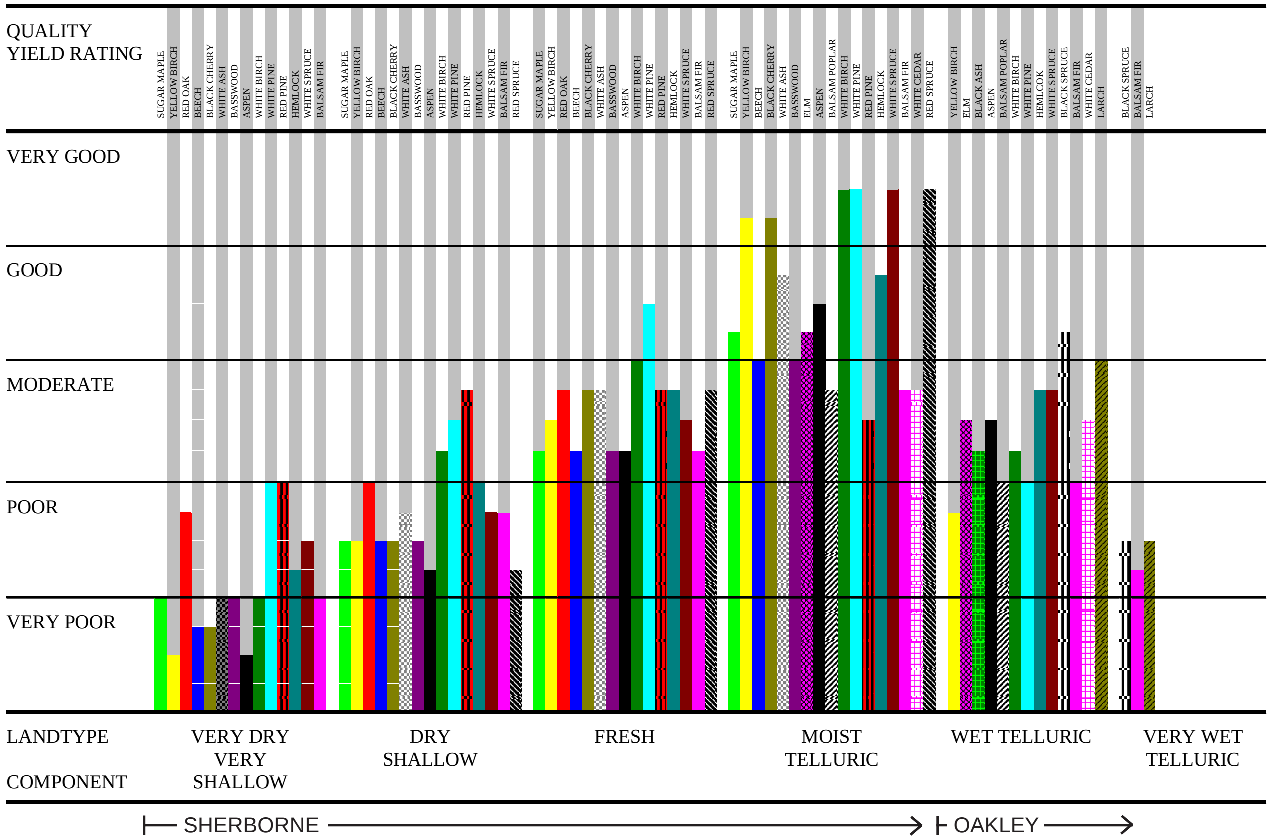


Figure 2.2 Production of quality wood on the Sherborne and Oakley (telluric) Landtype (Modified from Hills and Brown 1955).

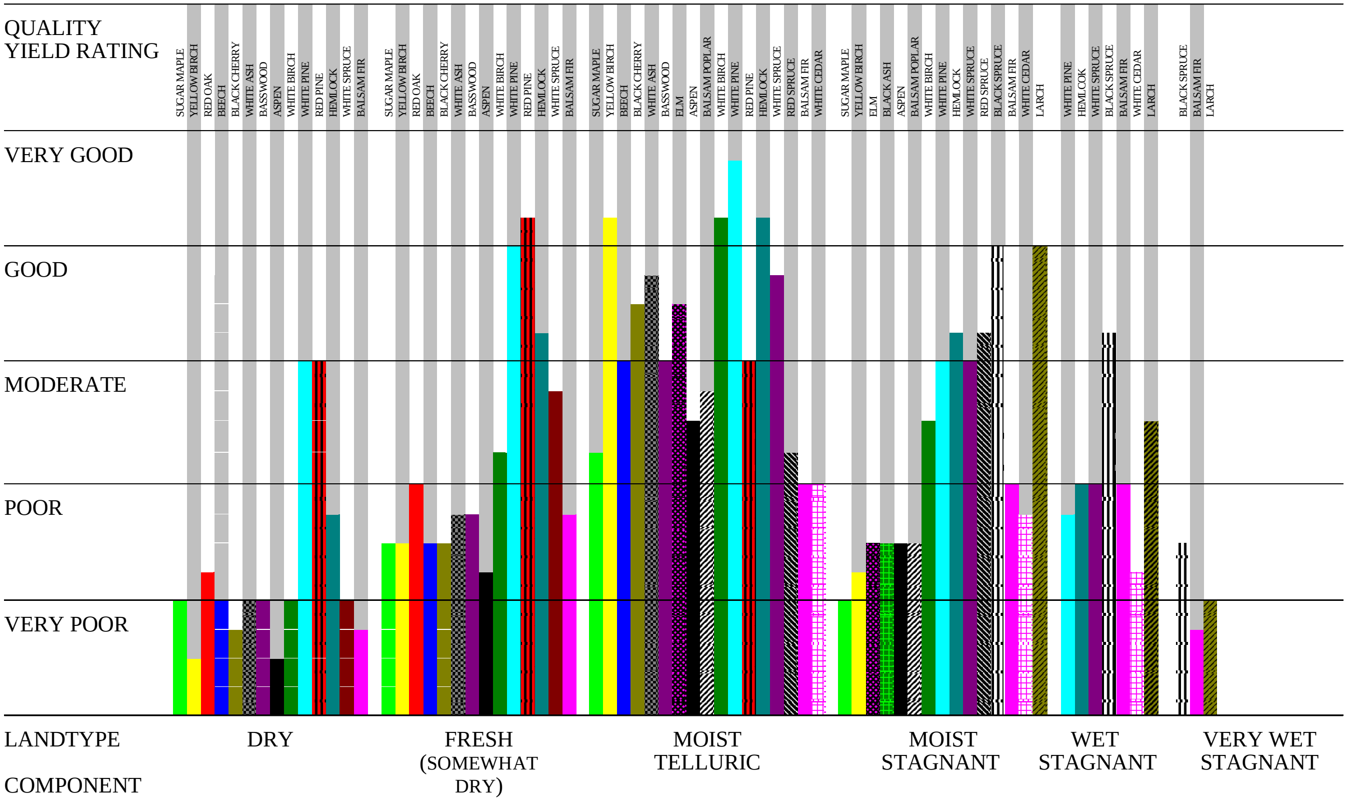


Figure 2.3 Production of quality wood on the Petawawa and Oakley (stagnant) Landtype (modified from Hills and Brown 1955).

3.0 Choosing the right tree to leave

Original work: Anderson and Rice (1993)—adapted by M. Walsh, S. Reid, and A. Corlett

The ability to consistently choose the right tree to leave or to harvest will develop from an understanding of the current forest condition, and from a broader understanding of the principles of tree and wildlife biology (Sections 2.0 and 4.0), silviculture, and forest economics. A stand assessment that identifies such factors as tree species, stand structure, density and age(s), as well as tree quality and health, and the availability of habitat will support the development of the stand-level silvicultural prescription. The tree marker will use these same variables to make "leave/cut" decisions about individual trees in the stand. An understanding of: risk indicators, tree classification systems, and the application of the relevant silvicultural system is critical at the stand and tree level.

3.1 Assessing individual tree potential for growth

The success of partial cutting practices relies on the marker's ability to anticipate the growth response of residual trees after treatment. Residual trees usually must be vigorous, or potentially so, to improve their timber value. However, even trees that are currently of lower vigour may increase in value if allowed to achieve and maintain their maximum vigour for sufficient time following treatment.

The growth potential and timber quality of a tree depend on a variety of factors ranging from individual tree attributes to stand level characteristics, all of which can interact to limit potential development. Consequently, the objective of marking is to optimize growth for all residual trees rather than attempting to maximize growth for a few individual trees. The following discussion will focus on tree vigour, risk, and quality, some of the principal attributes used in making comparisons among trees during the decision-making process, and in providing an indication of potential stand development.

3.1.1 Potential tree vigour

Indicators of potential tree vigour

Vigour potential may be defined as *the relative capacity of a tree to increase in size* (OMNR 1990). An understanding of the crown (position, size, architecture, and quality), bark character, and degree of competition is required to properly assess tree vigour. The marker uses these features to select crop trees that have the highest potential for future growth and timber value. Vigour characteristics are described and illustrated below.

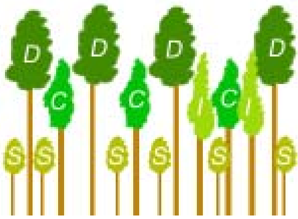
Crown position

Growth rates of individual trees vary within a forest stand. Some trees encroach on the growing space of others, increasing in size at the expense of neighbouring trees (Oliver and Larson 1990). This results in a process of crown differentiation. Crowns usually develop in a single layer or stratum in even-aged, single species stands. However, stands of mixed intolerant species may develop several strata. Uneven-aged stands of shade-tolerant species often have a continuous vertical distribution of foliage (canopy) because suppressed trees have reduced height growth but do not die (Oliver and Larson 1990).

Natural disturbances as well as disturbances resulting from silvicultural activities often expose the lower crown classes of uneven-aged tolerant hardwood stands to overhead sunlight. This allows the understorey trees to accelerate their height growth for a brief period and may promote gradual entry of the tree’s crown into the upper-canopy stratum.

Classifying a tree by its crown position in relation to the forest canopy provides an indication of the amount of direct sunlight reaching the crown; an important factor that influences photosynthetic rates and subsequent diameter and height growth of the trees. Table 3.1 describes four crown position classes.

Table 3.1 Crown position classification (adapted from Trimble 1969).

 Crown class	Position in canopy	Amount of sunlight received
Dominant (D)	Tree is taller than its immediate neighbours. Crown extends above the general level of the crown canopy.	Receives full light from above and considerable light from the sides.
Codominant (C)	Tree with crown formed at the general level of the crown canopy.	Receives full light from above but comparatively little from the sides.
Intermediate (I)	Tree is shorter than dominants or codominants but with crown extending into the canopy formed by them.	Receives some direct light from above but none from the sides.
Overtopped or Suppressed (S)	Tree with crown entirely below the general level of the crown canopy.	Receives no direct light.

Crown size

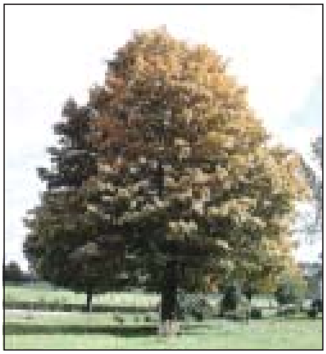


Figure 3.1 Long crown.

The length and width of tree crown is an index of the leaf surface area available for photosynthesis, which produces the resources necessary for tree growth. Live crown ratio (LCR), an index of tree vigour, is the ratio of live crown length to total tree height, expressed as a percentage. Well-balanced crowns have a LCR of 30–50%, with a crown diameter of 60–100% of crown length (Oliver and Larson 1990; Arbogast 1957). The LCR tends to be greater for shade-tolerant species (Lorimer 1983). For mid-tolerant to intolerant species, the LCR is inversely related to stand density (Ward 1964). For most tolerant hardwood species, a tree with a crown diameter of 0.2–0.25 metres per centimetre of dbh will grow at close to maximum rate (Anderson 1985; Smalley 1975; Gevorkiantz 1956).

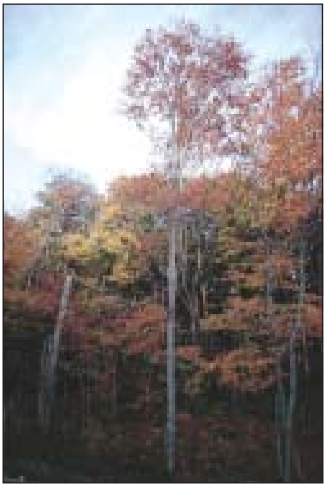


Figure 3.2 Short, narrow crown.

Crown efficiency varies with crown size and its ability to respond to release. Long crowns (Figure 3.1; LCR = 86%) produce wood volume inefficiently since they shorten merchantable bole length, while wide crowns seldom respond to release. Short, narrow crowns (Figure 3.2; LCR = 24%) produce timber of desirable size slowly, even after release (Gevorkiantz 1956). Trees with well-balanced crowns (Figure 3.3; LCR = 47%) often produce high quality, merchantable timber.

Crown architecture

For any species, at the same crown size, trees with the greatest leaf area within the main crown usually will be the most vigorous (Arbogast 1957). Studies have indicated that the arrangement of leaves in the crown is influenced by the shade-tolerance characteristics of the individual species (Horn 1975). At low light levels endured by shade-tolerant species, an ideal crown should intercept all available light at the highest possible intensity. This is achieved by having a narrow layer of leaves in a shell around the crown surface (a monolayer type). At high light intensities commonly associated with shade-intolerant species, the ideal crown should have leaves distributed throughout the total branch volume, and interior leaves should receive enough light to balance their own metabolic needs (a multilayer type). In the open, monolayered trees, with their lesser leaf area, are competitively inferior to multilayered trees. Conversely, deep shade may cause mortality of interior leaves of multilayered trees, placing them at a disadvantage.

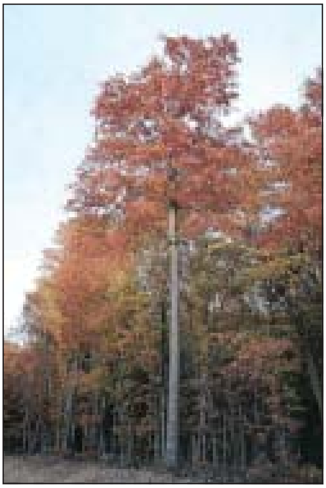


Figure 3.3 Ideal crown size.

Crown quality

High-quality crowns are symmetrical, showing balanced development on all sides with little evidence of crowding damage. In forest conditions, vigorous trees will usually exhibit fine branching, with numerous branchlets and twigs indicative of a dense crown with a large leaf area (Figure 3.4). In their juvenile years, vigorous trees tend to demonstrate strong apical dominance (i.e., no forking). Less vigorous trees exhibit coarse branching (exceptions are species with compound leaves e.g. white ash which is naturally coarse branched), with some dead limbs and a discontinuous leaf canopy (Figure 3.5). They may also have undersized or discoloured leaves, low leaf density, and a flat-topped profile. Crown breakage resulting from wind, snow, or felling damage may reduce growth potential, especially in sugar maple, pine, and white ash trees with forked stems (Figure3.6). Forked stems in conifers are undesirable except as potential raptor nest sites. However narrow forks in the upper crown may be acceptable.

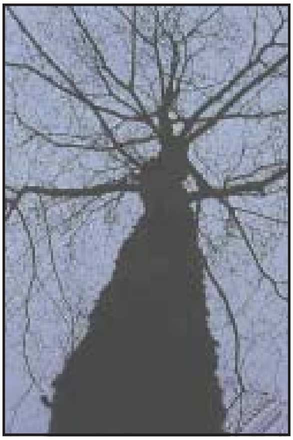


Figure 3.4 Branching pattern of high vigour trees.

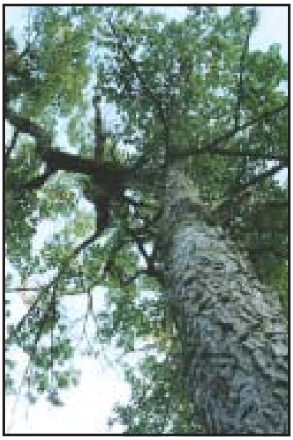


Figure 3.5. Branching pattern of low vigour trees.

Figure 3.6. Severe crown damage.

In conifers, decline symptoms are expressed by a loss of needle density, which gives the crown an unusual transparency with large portions of the bole and branches within the crown often visible (Figure 3.7).

Care must be exercised in evaluating crown quality when trees are in a leafless condition. Declining trees may be difficult to distinguish from healthy trees and may lead to over-cutting or wrong marking selections.

Bark character

The vigour of some tree species can be determined by examining the firmness of the bark and the nature of the bark fissures and ridges (Arbogast 1957). The bark of vigorous trees must actively grow in circumference to accommodate rapidly growing stem diameters, and consequently, trees with high vigour express different bark characteristics than less vigorous trees. The bark characteristics of low and high vigour trees are described below and are summarized in Table 3.2.

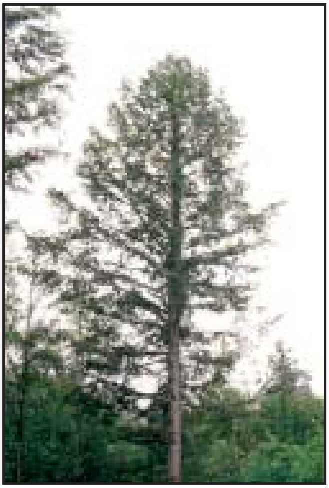


Figure 3.7 Unhealthy crown in conifers.

Outer bark thickness and furrow depth are the most consistent vigour indicators for rough-barked species, such as sugar maple and white pine (Figure 3.8).

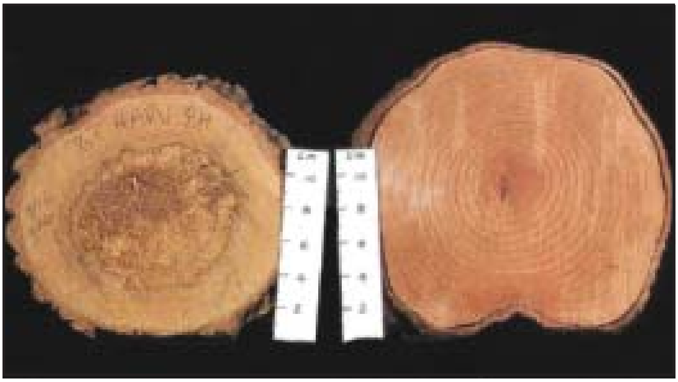


Figure 3.8 Trunk cross sections from low vigour (left) and high vigour (right) sugar maple trees. Note the ridged, thick bark on the low vigour tree and the smooth, thin bark on the high vigour tree.

Young sugar maple trees (polewood) will retain a smooth, juvenile, thin bark when they have maintained a continuous state of high vigour, as illustrated in Figure 3.8. Vigorous, mature maples display vertical furrows that are caused by splitting of the outer bark during rapid diameter growth (Arbogast 1957). The furrows of vigorous trees have a prominent vertical pattern, are relatively narrow (with a V- or U-shaped profile), and are often less than 1.3 cm deep for mature sugar maple. Vigorous trees are characterized by the light colour of the new inner bark in the base of the furrows. This feature is useful in assessing the growth response of sugar maple to previous release treatments.

Vigorous trees also have firm plates or ridges, which tend to be much broader than the furrows. In less vigorous trees, ridges are soft and corky in texture, and cross-breaks are common in the vertical pattern of the furrows. The furrows in low vigour trees are also much broader than the plates (Sajdak 1967). Some examples of bark vigour indicators for sugar maple are shown in Figure 3.9. Similar bark features indicative of vigour status can be recognized in red oak, white ash and black cherry Figure 3.10) (Cummings and Zarger 1953; Burkle and Guttenberg 1952).

In smooth-barked species such as yellow birch and beech, external bark characteristics reflect age and relative growth rate (Clausen and Godman 1969). Trees with smooth or peeling bark tend to be younger and therefore faster-growing for their size (Figure 3.11). However, bark appearance does not reflect vigour status in all tree species, for example the long-lived and shade tolerant hemlock.

Table 3.2 Bark characteristics indicative of high and low tree vigour potential.

Species	Indicators of high vigour	Indicators of low vigour
Rough-barked species (sugar maple and red oak; to a lesser extent white ash and black cherry)	Furrows are: ● prominently vertical in pattern ● relatively narrow ● V-or U-shaped in profile ● less than 1.3 cm deep ● light in colour at base ● less broad than plates or ridges Ridges are: ● firm	Furrows are: ● often marked with cross-breaks in their vertical pattern ● much broader than plates or ridges Ridges are: ● soft and corky
Smooth-barked species (yellow birch, beech)	● smooth, thin and, if peeling, then very thin strips (more likely for younger and therefore faster-growing trees for their size)	● rough, with large flaky plates

Low vigour	Medium vigour	High vigour
 dbh 16.5 cm D-Incr. (20) = 2.49 cm	 dbh 17.3 cm D-Incr. (20) = 5.43 cm	 dbh 18.0 cm D-Incr. (20) = 12.53 cm
 dbh 22.7 cm D-Incr. (20) = 2.19 cm	 dbh 22.6 cm D-Incr. (20) = 5.33 cm	 dbh 30.2 cm D-Incr. (20) = 12.95 cm
 dbh 42.7 cm D-Incr. (20) = 3.30 cm	 dbh 44.2 cm D-Incr. (20) = 8.13 cm	 dbh 58.5 cm D-Incr. (20) = 13.90 cm

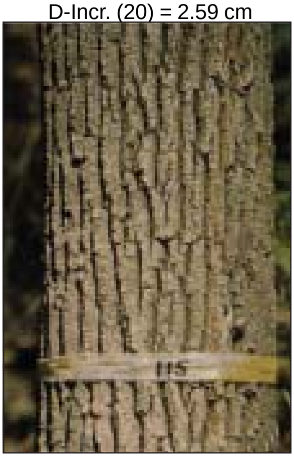
Figure 3.9 Bark vigour characteristics for sugar maple—indicative of low, medium and high vigour based on 20-year dbh growth and contrasting different size classes.

Low vigour		High vigour

dbh 26.0 cm
D-Incr. (20) = 2.59 cm

Red oak

dbh 29.2 cm
D-Incr. (20) = 7.69 cm



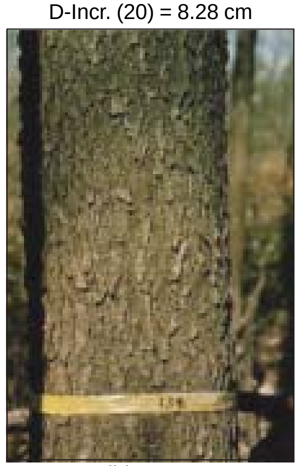
dbh 21.5 cm
D-Incr. (20) = 1.62 cm

White ash

dbh 29.2 cm
D-Incr. (20) = 8.28 cm

dbh 26.3 cm
D-Incr. (20) = 2.81 cm

Black cherry



dbh 27.2 cm
D-Incr. (20) = 12.27 cm

Figure 3.10 Bark vigour characteristics for red oak, white ash and black cherry—indicative of low and high vigour based on 20-year dbh growth.

Low vigour | **High vigour**

Yellow birch

dbh 40.0 cm
D-Incr. (20) = 4.25 cm

dbh 41.0 cm
D-Incr. (20) = 17.12 cm

Beech

dbh 21.1 cm
D-Incr. (20) = 3.46 cm

dbh 28.2 cm
D-Incr. (20) = 9.28 cm

Hemlock

dbh 30.0 cm
D-Incr. (20) = 3.46 cm

dbh 49.7 cm
D-Incr. (20) = 16.72 cm

Figure 3.11 Bark vigour characteristics for yellow birch, beech, and hemlock—indicative of low and high vigour based on 20-year dbh growth.

Degree of competition

The density of competing trees affects the current growth rate of potential crop trees. Removal of neighbouring trees will provide opportunity for accelerated growth and improved quality of residual trees. Growth response depends upon the genetic and physical attributes of the tree and the silvical characteristics of the species. For instance, sugar maple is an elastic species, capable of adjusting its growth rate to the available growing space. Even badly suppressed trees can respond to release both in height and diameter growth. Black cherry, however, is inelastic and responds poorly, if at all, to release from severe suppression (Ellis 1979). Species that respond favourably to release from competition will have higher tree vigour potential (refer to Table 2.3 and Table 2.4).

Ability to respond to release

Poor - Cb

Moderate - Be, By, Ce, Pw

Good - Aw, Bd, He, Mh, Or, Pr, Sr, Sw

Marking to improve vigour

Dbh is the best practical indicator of growth potential in young, even-aged, single species stands (Trimble 1969). A combination of dbh and crown position (Table 3.1) provides a better measure of tree potential in older, more diversified even-aged stands. As an example, crop tree selection in the medium and large sawlog classes of mature white and red pine stands is based on relative dbh and crown position and quality, since those features reflect both apparent seed production and volume growth potential.

Dbh is a poor indicator of growth potential in uneven-aged stands at an early stage of management because tree ages tend to vary widely (sometimes by more than 100 years) within a narrow range of dbh (Blum 1961; Gibbs 1963). Tree markers should assess the current crown position and the probability of its improvement if competing trees were removed. Bark characteristics will indicate those trees with higher potential vigour. Table 3.3 provides a useful classification of vigour, expressing the ability of a tree to grow rapidly and compete successfully with its neighbours (Trimble 1969, 1960). This system combines crown and bark attributes into four classes of vigour. This system is applicable to a wide range of species and has been adapted successfully in Ontario to uneven-aged stands (OMNR 1983).

Individual tree vigour must be considered in the context of the overall management objectives for wildlife habitat, stand density, structure, and species composition. Tree markers will decide what trees to remove based on the silvicultural prescription, which identifies the desired stand structure, stocking targets, and wildlife habitat goals. Marking will optimize, rather than maximize, the performance of individual trees to meet the objectives for the stand.

Table 3.3 Tolerant hardwood tree vigour classification (from OMNR 1983; Trimble 1969).

Tolerant hardwood vigour classification

Vigour class	Identification
I (GOOD)	A tree in this vigour class has a large, healthy, full crown in a dominant or codominant position. Half the crown or more is exposed to direct sunlight. The crown is dense, with no evidence of disease or injury. Crown quality and position are more important than total length. The bark and twigs have good colour and vigorous appearance.
II (MEDIUM)	A tree in this vigour class has a medium-sized crown in a codominant position. Less than half the crown is exposed to direct sunlight. The crown is less dense and not as perfect as that of a Vigour I tree. This class may also include a large-crowned tree that fails to meet the requirements of Vigour I because of mechanical injury or dying limbs.
III (FAIR)	A tree in this vigour class has a medium to small crown, usually in a mid-canopy position. Only the tip is exposed to direct sunlight. The crown may be open, with some dead or broken limbs, or thinly foliated. This class also includes trees with medium to large crowns in a codominant position that cannot meet the requirements for a Vigour II tree.
IV (POOR)	A tree of this class usually has a small, spindly, flattened crown in an overtopped position. This class includes all living trees that fail to meet the requirements of higher-vigour trees.

3.1.2 Potential tree risk

Tree markers must evaluate a range of vigour characteristics, with emphasis on features that indicate potential decline. Residual trees must survive and grow through the subsequent cutting cycle, in order to meet timber production objectives. Cutting cycles in the GLSL forest normally range from 15 to 25 years, depending upon site productivity and length of growing season, thus a tree's likelihood of dying within that time may be defined as its risk potential. High-risk trees are those that may either die or deteriorate significantly in quality before the next harvest, due to decay development, structural defects, damage, and/or other factors (OMNR 1990). It is noteworthy that even high-quality stems may be at risk because of crown breakage or excessive lean.

Some trees with high risk, low vigour, or major defects will be retained for wildlife habitat (e.g., cavity trees) or to meet biodiversity concerns (e.g., rare species in stand). However, most wildlife guidelines recommend retaining trees with relatively low risk and high vigour (e.g., mast trees, solitary conifers) because these trees will last longer and thus provide habitat longer.

Occasionally, especially in previously high-graded stands, trees of modest quality may be retained for maintenance of stand stocking targets. The risk status of such "storage" trees must be carefully evaluated, since little timber production purpose is served if they do not survive (Anderson and Rice, 1993).

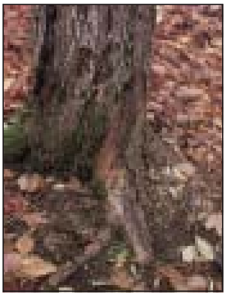
Some of the defects that cause tree decline or conditions that contribute to increased tree risk are illustrated and described in Table 3.4.

Table 3.4 Defects or conditions leading to increased risk potential and possibly decline.

Beech bark disease

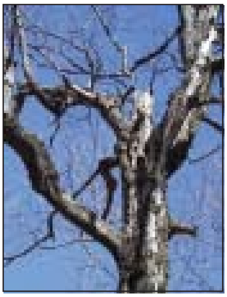
Nectria coccinea var. faginata

- infection of trees occurs following primary feeding injury by beech scale aphids
- disease is usually fatal within 10 years of infection



Root injury during harvesting

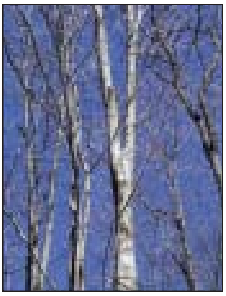
- can predispose sugar maple to infection by root-rot fungi and sapstreak, a fatal disease caused by *Ceratocystis* spp. (Mielke and Charette 1989)
- extensive root damage weakens trees, resulting in possible decline, windthrow and reduces potential product quality



Crown dieback
Broken or dead tops

(also see Figure on page 197)

- broken or dead branches are ubiquitous on forest trees; they are a serious decay hazard only if more than 7.6 cm in diameter. Yellow birch has a slightly higher risk from this factor than do other tree species
- bears can also cause crown damage when they forage for food
- well-healed branch stubs, if they are not swollen, are a sign of vigour



Forks

- frequently result from the death of the terminal bud or leader of oppositely branched species or species with whorled branching
- decay further weakens these trees and makes them more susceptible to breakage
- a higher risk is associated with V-shaped forks than U-shaped forks The narrow angle between two major branches of a V-shaped fork can prevent the normal development of bark and cambium layers, and subsequent pinching action can kill this zone as the branches grow (Pirone *et al* 1988). A weak union results that can split when stressed by heavy wind or ice-storms.
- the splitting of forks in maple is due to its opposite branching and the occurrence of broad (weak) ray tissue etc. across the crotch
- U-shaped forks are formed at more of a right angle making them less susceptible to splitting or breaking

Coppice stems

- a shoot (sprout) originating from a stump
- coppice sprouts are vulnerable to rot transfer from the parent stump unless they originate at or below the stump root collar
- red oak and basswood are especially prone to sprout development

3.1.3 Potential tree quality

The potential development of high quality timber products is constrained by the presence of value-limiting defects. Such defects are considered to be either scalable defects such as seams, rot, or shake that reduce the sound, usable volume or durability, or grade defects such as knots or stain that reduce strength or utility. Sound trees may be unsuitable for some grades, while defective trees may contain high grade material, depending on the type and placement of the defect.

Some value-limiting defects are difficult to discern, however methods to estimate defect from external features have been developed. External indicators of internal defects are categorized as biotic (defects attributable to the action of organisms) or abiotic (defects associated with injuries arising from various non-biological origins). These indicators are critical tools used during the tree selection process of a marking program.

Major, moderate, and minor defects of hardwood trees are listed and described in Table 3.5, Table 3.6, and Table 3.7 respectively. Major, moderate and minor defects of conifer trees are listed and described in Table 3.8, Table 3.9, and Table 3.10 respectively. Additional information on decay fungi is provided in Basham (1991).

Biotic and abiotic defect indicators

Biotic	Abiotic
false tinder fungus	spiral seams
mossy top fungus	open seams
spine tooth fungus	fluxing seams
coal fungus	bark seams
eutypella canker	mechanical damage
nectria canker	lightning wounds
shoestring root rot	fire scars
punk knot	barrelling
clinker fungus	forks
artist's conk	broken tops
black knot	broken branches
sugar maple borer	burls
white pine blister rust	crooks
white pine weevil	sweep
all root rots	
red ring rot	
animal feeding	

Table 3.5 Major defects that reduce quality potential in hardwoods. Trees with these defects will degrade rapidly.

Spine tooth fungus

(Climacodon septrionalis)

IDENTIFICATION: Large, soft fruiting body (conk) that occurs on trunk as shelf-like clusters; conk has spines or teeth on its underside. Annual conks are killed by frost, but a white blotch on trunk indicates previous location. Mainly infects sugar maple. Hedgehog fungus (*Hericium erinaceous*) causes a rot similar in other hardwoods.

RELEVANCE TO TREE QUALITY: Conk indicates a cull tree. Decay usually 4–5 metres above and below conk.



Punk knot

(Inonotus glomeratus)

IDENTIFICATION: Black, cinder-like plugs that form at old branch stubs; often become swollen by callus growth. Fungus does not fruit on living trees. Can produce linear, sunken cankers that retain the bark through which black stroma may eventually erupt to form a *black seam*. Infects sugar maple and beech.

RELEVANCE TO TREE QUALITY: Several conks indicate a cull tree. Decay is usually 1.5–2.1 metres above and below conk.



Table 3.5 Major defects that reduce quality potential in hardwoods.Trees with these defects will degrade rapidly.—continued.

Coal fungus

(Hypoxylon deustum)

IDENTIFICATION: At the butt of infected trees. Often inconspicuous on a seam or scar on maples and beech. Thin, crust-like, black carbon-like fruiting body.

RELAVANCE TO TREE QUALITY: Decay found 1–2.7 metres above conk. A serious butt rot. Is implicated as a major source of infection from stumps to sprout stems.

Yellow cap fungus

(*Pholiota* spp.)

IDENTIFICATION: Yellow cap mushrooms form annually in late summer, and are not visible in winter. Yellow, sticky, somewhat scaly stems and caps occur in clusters at wounds or seams.

RELEVANCE TO TREE QUALITY: Mushrooms indicate significant rot mainly on maple and yellow birch. Produces a yellow-brown stringy rot.

Table 3.5 Major defects that reduce quality potential in hardwoods.Trees with these defects will degrade rapidly.—continued.

Shoestring root rot

(*Armillaria* complex)

IDENTIFICATION: Honey-coloured mushrooms appear in late summer in clusters at the base of infected trees but are short lived. May also be recognized by tough, dark brown, stringy *rhizomorphs* (shoestrings) under the bark and on roots, or an exaggerated trunk flare.

RELEVANCE TO TREE QUALITY: Appears to be virulent only on trees weakened by stress and is often cited as a contributing factor in tree decline. Flare or barrelling may indicate a hollow butt with rot extending above the swelling by as much as 2–3 metres. Causes butt and root decay in many hardwoods and conifers. Trees can be prone to windthrow.

False tinder fungus

(*Phellinus igniarius*) (*P. tremulae*)

IDENTIFICATION: On sugar maple it is a hoof-shaped perennial conk. Upper surface is grey-black with whitish outer rim; lower surface rust-coloured, with small, round pores. On beech, the conk may be shelf or bracket-shaped. A related variety occurs exclusively on yellow birch (var. *laevigatus*) and the conk is more flattened against the trunk. Found on maple, beech and yellow birch. P. tremulae is found on poplars.

RELEVANCE TO TREE QUALITY: A major heart rot. A single conk usually indicates a decay column of 5 metres often representing 50% cull.

Table 3.5 Major defects that reduce quality potential in hardwoods.Trees with these defects will degrade rapidly.—continued.

Clinker (cinder) fungus

(Inonotus obliquus)

IDENTIFICATION: Large plugs that are initially yellow but become black, rough, hard and cinder-like; may form a canker. Found almost exclusively on yellow birch.

RELEVANCE TO TREE QUALITY: Decay will be from 1.5–1.8 metres above and below the conk. More than a single, protruding conk usually indicates a cull tree.

Eutypella (cobra) canker

(*Eutypella parasitica*)

IDENTIFICATION: On trunk; cobra-head shaped swelling around canker. Canker has a sunken centre, with bark firmly attached, surrounded by strongly flared callus folds. Found on sugar, red and Manitoba maples.

RELEVANCE TO TREE QUALITY: Decay about 1½ times canker length. High risk of breakage. Kills trees by progressively girdling the stem. Infected trees often suffer wind breakage before girdling is complete.

Nectria (target) canker

(*Nectria galligena*)

IDENTIFICATION: On trunk; canker is usually free of bark with concentric callus ridges. Black fruiting bodies. Can infect all hardwoods.

RELEVANCE TO TREE QUALITY: Decay hazard. High risk of breakage. Kills trees by progressively girdling the stem, although infected trees often suffer wind breakage before girdling is complete.

Table 3.5 Major defects that reduce quality potential in hardwoods.Trees with these defects will degrade rapidly.—continued.

Artist's conk

(*Ganoderma applanatum*)

IDENTIFICATION: Perennial and shelf-like conks found mainly on the lower bole. Upper surface is grey or brown marked with concentric ridges. The undersurface is white and chalky, turning brown when touched, with visible pores. Infects most tree species.

RELEVANCE TO TREE QUALITY: Normally a scavenger rot found on dead or dying trees. Rotten wood appears white with mottles. White underside is easily etched on, hence the name artist's conk.

Butt flare (barrelling)

IDENTIFICATION: Unusual change in taper of lower bole. Nearly always accompanied by hollow butt. Found on sugar maple, yellow birch, and some conifers.

RELEVANCE TO TREE QUALITY: Barrelling is a morphological reaction to physical stresses (e.g., wind-sway) on the tree, resulting from internal rot.

Black bark

IDENTIFICATION: Black discoloration on bark. Usually associated with fluxing seam. Internal gas pressures, associated with bacterial wet wood and decay, force sap through the seam onto the bark. Mould fungi grow on sap discharge. Commonly found on sugar maple.

RELEVANCE TO TREE QUALITY: Indicative of internal wet wood infections that are often associated with advanced decay and extensive cull.

Table 3.5 Major defects that reduce quality potential in hardwoods.Trees with these defects will degrade rapidly.—continued.

Large darkface scar > 900 cm^2

IDENTIFICATION: Grey-black, moist, somewhat spongy surface usually associated with a trunk wound such as that caused by logging or by sugar maple borer. Wounds with ground contact generally become dark-faced. All hardwood and conifer species are susceptible.

RELEVANCE TO TREE QUALITY: The larger the wound the greater the decay column. Scars on yellow birch only need to be 60% of the above size to indicate major decay.

Fire scar

IDENTIFICATION: Butt scars with *church door* appearance and some residual charcoal. Wounds face the same direction on all associated stems indicating the direction of fire movement. Most hardwood and conifer species are susceptible.

RELEVANCE TO TREE QUALITY: Usually associated with large butt rot column. Structurally weakens the tree. Considered a major defect when wound is large and has a column of rot.

Table 3.6 Moderate defects that reduce quality potential in hardwoods. Trees with these defects will degrade slowly.

Mossy top

(*Oxyporus populinus*)

IDENTIFICATION: White, soft, spongy perennial conks that appear water-soaked. Usually has green moss or algae on upper surface. Lower surface is white and contains pores. Frequently occurs on lower butt in clustered layers. Mainly found on sugar maple.

RELEVANCE TO TREE QUALITY: Decay usually 1–1½ metres above and below conks. Often associated with other defects such as open seams, sunscald, and fire scars.

Sugar maple borer

(*Glycobius speciosus*)

IDENTIFICATION: Open “J” shaped wound caused by larvae burrowing between bark and wood tissue. Larvae tunnels often seen in a horizontal pattern across wound. Bark exfoliation may take 5–10 years. Callus growth often conceals old damage. Sugar maple is the only host.

RELEVANCE TO TREE QUALITY: Often attacks low vigour trees. Decay may be found 60 cm above to 30 cm below wound. Some risk of breakage. Otherwise healthy, vigorous trees may heal over in time. The tree is UGS if the scar is dark-faced and soft.

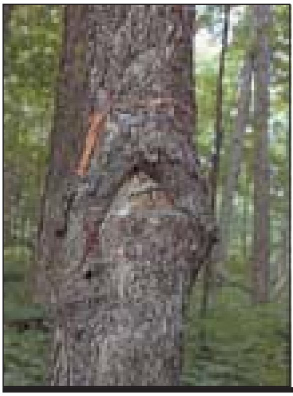


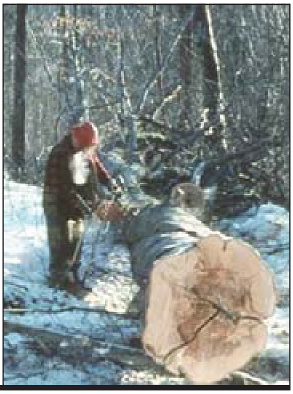
Table 3.6 Moderate defects that reduce quality potential in hardwoods. Trees with these defects will degrade slowly—continued.

Spiral seam

IDENTIFICATION: A seam or crack, which spirals around the bole to the point where it may affect half of a face or more. Affects most hardwood species but is prevalent on beech.

RELEVANCE TO TREE QUALITY: Little decay hazard in a vigourous tree. Indicates major cull if seam is infolded or open with rot present. If seam is tight, it indicates a vigorous tree but will represent significant grade defect for certain products (such as veneer and lumber), due to mechanical limitations on production.





Frost cracks and seams

IDENTIFICATION: A crack or seam on bole.

RELEVANCE TO TREE QUALITY: Frost cracks are produced in trees that have an internal core of moist mineral stain. The outside living tissue near the bark shrinks in cold weather while the inner moist, stained wood will freeze and expand like a block of ice. These opposite forces cause the outer bark and wood to split to relieve the pressure.

- Open seams indicate low vigour trees or repeated frost action. These seams are prone to infection, and usually indicate internal stain and rot.
- A tight seam on vigorous trees usually indicates limited internal defect.
- Fluxing seams, with the associated *black bark* condition, are sure signs of internal wetwood infections, advanced decay and extensive cull.
- Infolded seams reflect deep cavities in the stem and indicate cull trees unless very small.

Bark seams, photo below right, are not associated with wounds and do not indicate decay.



Table 3.6 Moderate defects that reduce quality potential in hardwoods. Trees with these defects will degrade slowly—continued.

Small darkface scar < 900 cm^2

IDENTIFICATION: Grey-black, moist, somewhat spongy surface usually associated with a trunk wound such as that caused by logging or by sugar maple borer. Wounds with ground contact generally become dark-faced. All tree species are susceptible.

RELEVANCE TO TREE QUALITY: The larger the wound the greater the decay column.

Sunscald

IDENTIFICATION: A dead patch of wood indicating killed bark. Scar created when alternate warming of tissue (by sun's reflection from snow) during the day and freezing at night kills bark. Primarily on younger, thin-barked trees on exposed sites. Always on the southwest side of the tree.

RELEVANCE TO TREE QUALITY: Vigorous trees will grow new bark over the dead patch (although this may cause an infolded bark seam).

Black knot

(*Apiosporina morbosa*)

IDENTIFICATION: On black cherry, appear as black cankerous swellings on twigs of seedlings, saplings, and mature trees.

RELEVANCE TO TREE QUALITY: Canker girdles twigs and small branches. Severe infection may cause crown dieback, reducing competitive ability, and response to release. If more than 50% of the crown is affected, then consider it unacceptable growing stock (UGS).

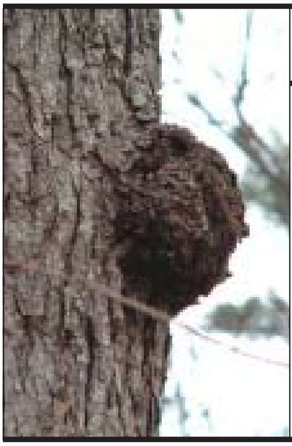
Table 3.6 Moderate defects that reduce quality potential in hardwoods. Trees with these defects will degrade slowly—continued.

Lean

IDENTIFICATION: Tree leaning more than 10°. Root system may be partially exposed. In the example photo, the tree is leaning 28°.

RELEVANCE TO TREE QUALITY: Susceptible to windthrow particularly in stands that are thinned heavily.

Table 3.7 Minor defects that reduce quality potential in hardwoods. Trees with these defects will maintain quality over cutting cycle.



Burl

IDENTIFICATION: A burl is a sound, hard, woody protrusion or knobby bump on the bole of a tree, with no protruding limbs, twigs, or stubs. They can occur on hardwoods and conifers.

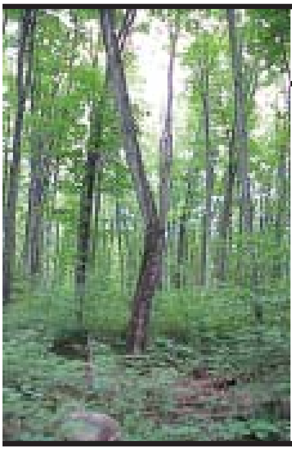
RELEVANCE TO TREE QUALITY: Arise from obscure origin and represent deformation of bole. Can result in a log grade defect if abundant, but do not indicate presence of decay.

Epicormic branching

IDENTIFICATION: Branches arising from buds in bark along mainstem, below the tree's normal crown position. Most commonly occurring in trees under crown stress; also known as watersprouts.

RELEVANCE TO TREE QUALITY: May indicate additional problems (e.g., dieback). Usually a result of too little or too much sunlight.

Table 3.7 Minor defects that reduce quality potential in hardwoods. Trees with these defects will maintain quality over cutting cycle—continued.



Crook and sweep

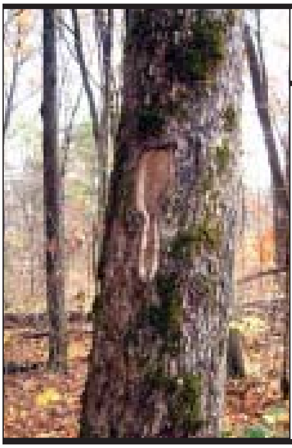
IDENTIFICATION:

Crook is an abrupt bend in the main stem of a tree probably caused by injury from another tree falling into the stem during early years

RELEVANCE TO TREE QUALITY: Does not indicate decay. Root system may be stressed due to crown weight imbalance. Affects length and quality of merchantable log.

Sweep is a gradual, but pronounced, bend in the main stem likely a result of the tree's reaction to overhead competition.

RELEVANCE TO TREE QUALITY: Does not indicate decay. Root system may be stressed due to crown weight imbalance. Affects length and quality of merchantable log.



White face scar

IDENTIFICATION: A dry, casehardened surface usually associated with localised stain and very limited decay, if any. They are neither ground-contact nor cupped to retain water. Probable cause is an early injury from another tree falling into the stem or from logging equipment.

RELEVANCE TO TREE QUALITY: Does not indicate internal decay.

Table 3.8 Major defects that reduce quality potential in conifers. Trees with these defects will degrade rapidly.

Fomes root rot

(*Heterobasidion annosum*)

IDENTIFICATION: Individual trees or a group of trees show signs of decline, yellowing of foliage and tree death. Conks form at the root collar of trees, in the litter layer. The conks are perennial with a greyish-brown to dark brown zoned upper surface and lighter-coloured sterile margin. The lower surface is biscuit coloured with small pores. Wood rot at the base of the tree is common and trees break at the root collar.

RELEVANCE TO TREE QUALITY: Spreads via root grafts and exposed surfaces (stumps and wounds) of any conifer. Trees will gradually decline then die. Remove infected trees as well as adjacent healthy stems where crowns are touching. In previously harvested areas, look for logging damage wounds.

Shoestring root rot

(*Armillaria* complex)

IDENTIFICATION: General decline in tree growth and poor vigour; premature yellowing and undersized or scanty foliage; branch dieback, and decayed bark or wood in the root collar area plus fan shaped, white, mycelial felts and dark-brown or black ***rhizomorphs*** (shoestrings) between bark and wood or in soil. When the tree is dead or almost so, clusters of honey-coloured mushrooms will develop at the root collar or on roots near the soil surface in the autumn months. Advanced decay may produce an exaggerated flare indicating a hollow butt.

RELEVANCE TO TREE QUALITY: Appears to be virulent only on trees weakened by stress (often cited as a contributing factor in ***decline***). Trees can be prone to windthrow. Found on many hardwoods and conifers.

Tomentosus root rot

(*Inonotus tomentosus*)

IDENTIFICATION: Conks develop on the ground near the roots of an infected tree or on the butt of the tree. Conks on the ground are stalked with a thin circular cap, and those on trees are usually thicker and shelf-like. Both are yellowish-brown with a velvety or plush-like upper surface. Infection can occur on any size of tree and is spread through soil and root contacts or grafts.

RELEVANCE TO TREE QUALITY: Root rot caused by Tomentosus advances slowly in the root system and results in trees with excessive branch mortality in the lower crown, reduced height and lateral increment, and general thinning of the crown. Infected trees are prone to windthrow. Found on most conifers, but is most common on spruces.

Table 3.8 Major defects that reduce quality potential in conifers. Trees with these defects will degrade rapidly—continued.

White pine blister rust

(*Cronartium ribicola*)

IDENTIFICATION: Small yellow to reddish-brown spots appear on the needles at the point of infection. Infection spreads through the needles into the twigs. Twig bark becomes yellow to orange and forms honey-yellow to brownish fruiting bodies which later become dark coloured like clotted blood and are visible throughout the year. They are called pycnial scars. A mass of orange-yellow aeciospores later ruptures the bark through the pycnial scars. Excess resin flow is common. Death of tissue beyond the lesion usually results in the formation of brown, dead foliage. Dead branches are called ***flags***. The fungus cannot spread from pine to pine, but rather requires the alternate host, *Ribes*, to complete the infection cycle.

RELEVANCE TO TREE QUALITY: Normally classed as a major defect when found on the main stem, but can be a moderate defect if found only on lateral branches. Small trees are killed quickly, whereas on larger trees, branches are killed and cankers girdle the stem.

Velvet-top fungus

(*Phaeolus schweinitzii*)

IDENTIFICATION: Annual conks usually form on old wounds on the butts of infected trees, or on the ground, coming up from a decayed root. On the tree, thin brackets grow one above the other. On the ground, the conks are circular in shape, sunken in the centre and tapering to a short thick stalk. Conks appear in late summer and fall. When fresh, the upper surface is velvety, concentrically zoned and reddish-brown with a light yellow-brown margin. The lower surface is dirty green becoming red-brown when bruised and consists of numerous large pores with irregular outlines.

RELEVANCE TO TREE QUALITY: Causes a brown cubical rot in the heartwood of living trees. Old trees suffer most from infection, but the fungus can be parasitic on young trees. Infection is largely through basal wounds from fire, logging, soil compaction, or root injury. Fungus may also spread through the soil to infect roots and infection may occur through root grafts. Extreme decay frequently results in breakage or windthrow.

Table 3.8 Major defects that reduce quality potential in conifers. Trees with these defects will degrade rapidly—continued.

Red ring rot

(*Phellinus pini*)

IDENTIFICATION: Perennial conks found on the **underside of dead branch stubs** of living trees are the most reliable indicator of infection. Conks may look like thin shell-shaped to bracket-like and hoof-shaped structures. The upper surface is dull greyish or brownish black, rough with concentric furrows parallel to the lighter brown margin. The underside is light brown to brownish-gold, and velvety in texture.

RELEVANCE TO TREE QUALITY: Of major significance in mature and overmature pines. Infected trees suffer a loss of merchantable volume, as well as being structurally weakened. Although the disease does not kill trees, it is best to salvage infected trees before merchantability is lost. In trees less than 100 years old, the rot extends an average of 2.5 metres above and below a single conk. In trees 100–200 years old, it extends as much as 7.5 metres above and below a conk.

See Table 3.5

Butt flare (Barrelling)

Table 3.9 Moderate defects that reduce quality potential in conifers. Trees with these defects will degrade slowly.

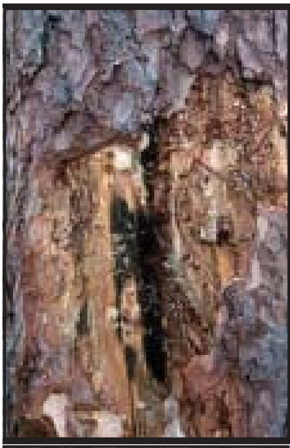
White pine weevil

(*Pissodes strobi*)

IDENTIFICATION: White pine is the most common host, but all pines and spruces may be attacked. In young trees, the leader and top whorl withers and dies from the attack, seriously affecting tree form and commercial value. In older trees, past damage is indicated by deformed, and/or multiple stems.

RELEVANCE TO TREE QUALITY: Affects form and merchantability of the main stem. Crucial to leave suitable crown closure in regeneration cuts to prevent future weevil damage in the regenerating stand.

Table 3.9 Moderate defects that reduce quality potential in conifers. Trees with these defects will degrade slowly—continued.

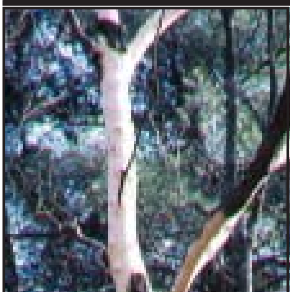


Pine engraver beetles

(*Ips pini*)

IDENTIFICATION: Yellow or reddish boring dust is found in bark crevices, around entrance holes, or on the ground beneath. Attacked trees have discoloured foliage, usually going from green to yellow, reddish, and then reddish brown. Insects usually attack near the top of the trunk, and frequently girdle the tree, causing dead tops.

RELEVANCE TO TREE QUALITY: Adult insects may attack trees over 5 cm in dbh and can kill trees 5 to 20 cm dbh and kill tops of larger trees. If there is a quantity of fresh slash or debris available for breeding purposes, population levels of the beetle may rise, leading to attacks on surrounding living trees.



Feeding damage

Porcupine (*Erethizon dorsatum*)

Yellow-bellied sapsucker (*Sphyrapicus varius*)

IDENTIFICATION: The porcupine feeds on the bark of many species of trees. Feeding usually takes place high in the tree and girdling can result in dead tops (left photo shows damage).The yellow-bellied sapsucker, a member of the woodpecker family, can attack living trees to feed on the sap and bark tissues (bottom photo shows damage). Oozing sap, from the feeding holes, may attract other animals to feed on the bark.

RELEVANCE TO TREE QUALITY: Porcupine damage is usually a moderate defect. Depending on the severity of the damage, the tree could be either classed as unacceptable growing stock (UGS) or acceptable growing stock (AGS).Heavy sapsucker feeding (50 or more holes in a band or patch) can lower wood quality, reduce tree growth, result in decay fungi invasion, and in extreme cases cause mortality. A moderate defect but tree defect class will be either AGS or UGS depending on severity and position.

Mechanical damage

(Stem wounds)

IDENTIFICATION: A dry, case-hardened surface, usually associated with localized stain and very limited decay, if any. Probable cause is an early injury from another tree falling into the stem or from logging equipment.

RELEVANCE TO TREE QUALITY: Wounds are considered a major or serious tree defect when they cover a surface area greater than the square of the dbh, for trees ranging in size from 10 to 31 cm dbh. All wounds larger than 1000 cm^2 (32 x 32 cm) are considered serious regardless of the tree's size. The chance of decay increases further when the wound has ground contact.

Table 3.9 Moderate defects that reduce quality potential in conifers. Trees with these defects will degrade slowly—continued.

Broken or dead top crown dieback

IDENTIFICATION: Broken or dead tops resulting from dieback, felling, wind, or ice damage indicate potential top rot that is usually limited to the upper crown. Broken tops that are frayed or broom-like offer high infection possibility and indicate a greater risk than a clean break. Crown dieback may be symptomatic of decay elsewhere in the tree. Dieback signs to look for are reductions of foliage density, foliage discolouration, and dead branches in the upper crown.

RELEVANCE TO TREE QUALITY: If more than 50% of the crown is affected, class the tree as UGS. The main cone-bearing zone of conifers is in the upper crown. Trees with broken or dead tops will produce less seed than trees with healthy tops.

Lightning injury

IDENTIFICATION: There are several possible injuries associated with lightning hitting a tree. The woody part of the tree may be shattered and may burn. A thin line of bark down the length of the bole may be stripped off and the wood singed. The tree may show no external signs but have internal tissues burned, or the roots may be the only area damaged. Some trees may be killed immediately, while others may exhibit just the scars from the strike. The scars offer an entrance to fungal spores.

RELEVANCE TO TREE QUALITY: Each tree must be assessed for damage severity. In many cases, especially with red pine, the lightning hit tree will not be the only casualty. The lightning will flash through the tree, into the roots, and will affect plants surrounding the target tree. In red pine the strike will travel through root grafts and injure or kill neighbouring trees. These pockets of dead trees can be mistaken for *Fomes* infections. Look for a struck tree to be sure. Another concern, if the affected trees are not removed, is the possible build-up of other pests, such as *Ips pini*.

See Table 3.4 **Root wounds**

See Table 3.5 **Fire scar**

See Table 3.6 **Lean > 10º**

Table 3.10 Minor defects that reduce quality potential in conifers. Trees with these defects will maintain their quality over time.

Burl

IDENTIFICATION: Burls are abnormal swellings of the main stem or branches of a tree. They can vary considerably in size, reaching 1 metre or more in diameter in some cases. Burls result from the abnormal development in number or size of wood cells following disturbance to the cambial layer, the cause of which is unknown.

RELEVANCE TO TREE QUALITY: Burls are not known to be indicators of decay. Burls will add volume to a log but are unsuitable for lumber production. Burl wood, because of the appealing grain structure, can demand a premium market price when used for specialty products.

Crook and sweep

IDENTIFICATION: A form defect that gives trees an arched look. Can be present on entire stem or in one log portion of the stem.

RELEVANCE TO TREE QUALITY: Probable cause is an early injury from another tree falling into the stem, or a tree bending to the light. Considered a minor defect related to form only. May disqualify a tree from the utility pole market if sweep is greater than that allowed by standards.See Table 3.7 for an example of crook.

3.1.4 Summary of potential vigour, risk and quality

Table 3.11 provides a summary of the guidelines to use when evaluating key indicators of vigour, risk and quality.

3.2 Tree classification systems

Tree classification systems, in combination with other crop tree selection criteria, are a means of assessing the ability of individual trees to increase in volume, form, quality, and value after release. Tree defect indicators are grouped into categories of major, moderate, and minor importance to tree quality. Using such guidelines, markers can evaluate candidate cut/leave trees for either their potential to contribute to long-term habitat values, or to ensure higher long-term quality and yield development.

Table 3.11 Guidelines for crop-tree selection (adapted from Anderson and Rice 1993).

Tree Potential	Key Features
Potential vigour is likely to be **high** if:	• no recent stress events (e.g., defoliation, drought, frost, pollution) • species responds favourably to competition and release from competition • no serious infections or diseases • symmetrical crown, with numerous fine branchlets and twigs • half the crown or more is exposed to direct sunlight • for most tolerant hardwoods, a crown diameter of 20–25 cm per centimetre of dbh • dense crown with no evidence of disease or injury • firm bark, including plates and ridges • light colour of new inner bark in base of furrows or smooth, peeling bark (for smooth-barked species)
Potential risk is likely to be **low** if:	• no canker infections, insect borer wounds, beech bark disease, root infections, crown dieback or decline, severe leaning, forks, yellow-bellied sapsucker feeding holes, or crown damage from foraging black bears • low risk of windthrow, splitting, breakage of limbs due to tree location, condition, site features
Potential quality is likely to be **high** if:	• few, if any biotic indicators of decline • few, if any abiotic indicators such as broken or dead tops, burls, seams, scars, stain, or cavities

Two tree classification systems are employed in managing forests in Ontario. The first system classifies trees as either acceptable growing stock (AGS) or unacceptable growing stock (UGS) as described in Table 3.12. Trees can be classified as AGS or UGS based on their defects as outlined in Table 3.13 for hardwoods and in Table 3.14 for conifers. The second system is more detailed and uses four or six tree classes (Figure 3.12). The four-class system is easier to learn than the six-class system and is applicable to most marking operations. The six-class system (Table 3.15) has been recommended for purposes of pre-cut cruising and subsequent stand analysis in order to provide a comprehensive database for future monitoring of treatment efficacy. To allow comparison with historical data and to bridge between the most common current systems, the six-class system can be collapsed into four classes, and ultimately into two classes. Similarly, a five-class system would comprise A1, B1, A/B, C and D classes and a three-class system would comprise A1/B1, A/B, and C/D classes.

Utility of tree classification systems

- Helps to identify those combinations of tree attributes that will control the future growth and quality of residuals
- Supports the development of appropriate silvicultural prescriptions
- Functions as a tool to monitor the quality potential of stands
- Aids in management planning by indicating the type and degree of effort needed to regulate the future timber supply

Table 3.12 A simple two-class tree classification system for determining residual trees in tolerant hardwood forests.

Tree Class	Class Description
Acceptable Growing Stock (**AGS**)	*AGS trees exhibit form and appearance that suggests they can reasonably be expected to maintain and/or improve their quality and can be expected to contribute significantly to future crops in the form of vigorous, high quality stems.* • Contain or may potentially produce high or medium quality logs. • Will maintain or improve in quality within the next cutting cycle. • Will produce high quality sawlogs, veneer logs or sawlogs for dimensional lumber (medium quality).
Unacceptable Growing Stock (**UGS**)	*UGS trees are high risk and are expected to decline during the next cutting cycle. UGS trees may also be of poor form and/or low quality and cannot reasonably be expected to improve in quality.* • High risk, or are expected to decline within the next cutting cycle. • Contain or have the potential to produce low quality logs but no better. Such trees are often used for pulpwood, poker poles, or fuelwood but are not normally considered as crop trees. • May contain cavities. Some trees in this category are retained for their wildlife value, when necessary to meet cavity guidelines (although wildlife trees showing low risk and high vigour are normally given priority for retention).

Table 3.13 Tolerant hardwood defect classification.

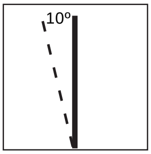
Importance of various defect indicators		
MAJOR DEFECT (tree will degrade rapidly) (**Always UGS**)	**MODERATE DEFECT** (tree will degrade slowly) (**UGS if severe**)	**MINOR DEFECT** (tree will maintain quality over cutting cycle) (alone, these defects rarely influence classification)
Spine tooth fungus	Mossy top fungus (always UGS)	Burl
Punk knot		Crook & sweep
Clinker (cinder) fungus	Sugar maple borer (if healing whiteface, class as AGS) (if darkface, class as UGS)	Epicormic branching
Coal fungus		Whiteface scar
Yellow cap fungus		
Shoestring root rot	Spiral seam	
False tinder fungus	Frost cracks and seams	
Eutypella canker (*cobra*)	Sunscald	
Nectria canker (*target*)	Black knot (on black cherry) (UGS if more than 50% of the crown is affected)	
Artist's conk		
Butt flare (*Barrelling*)	Small darkface scar *less than 900 cm^2* *(less than 12 x 12 inches)*	
Black bark		
Large darkface scar *greater than 900 cm^2* *(greater than 12 x 12 inches)*	Lean >10º 	
Fire Scar		

Table 3.14. GLSL conifer defect classification.

Importance of various defect indicators		
MAJOR DEFECT (tree will degrade rapidly) (**Always UGS**)	**MODERATE DEFECT** (tree will degrade slowly) (**UGS if severe**)	**MINOR DEFECT** (alone, these defects rarely influence classification)
Fomes root rot	White pine weevil damage	Burl
Shoestring root rot	Pine engraver beetles	Crook & sweep
Tomentosus root rot	Root wounds	
White pine blister rust	Feeding damage (porcupine, sapsuckers)	
Velvet-top fungus	Broken or dead top Crown dieback (if more than 50% dieback, class as UGS)	
Red ring rot		
Butt flare *(barrelling)*	Lean (more than 10º)	
	Fire scar	
	Lightning injury	
	Mechanical damage (stem wounds)	

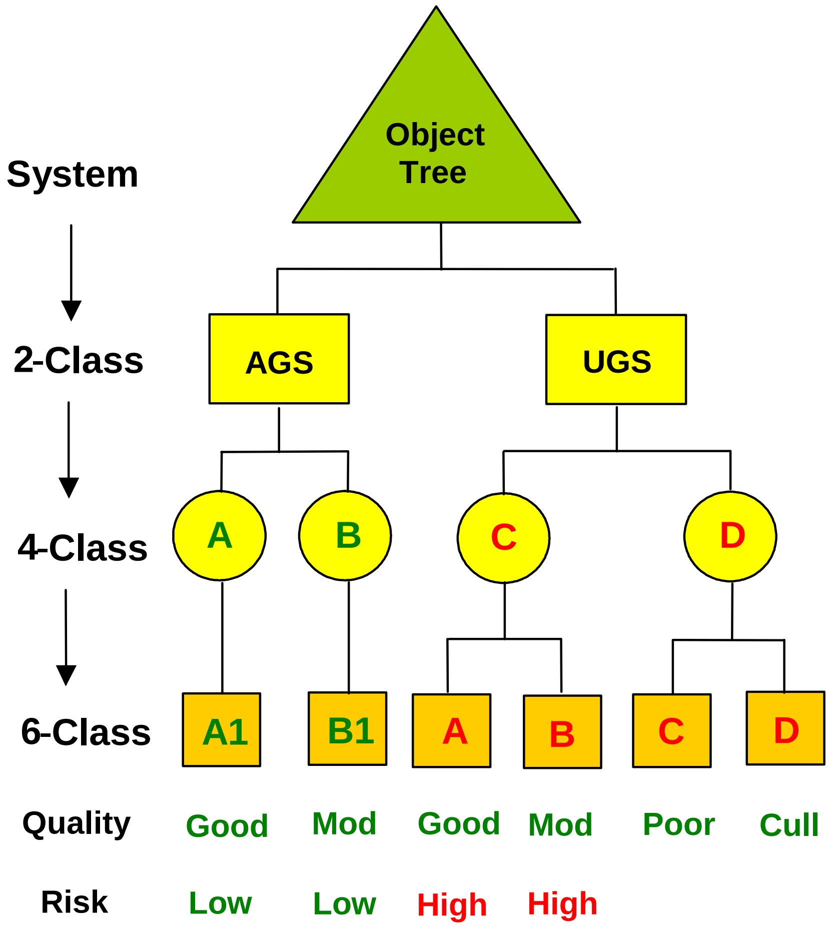


Figure 3.12 Relationships among two-, four-, and six-class tree quality classification systems.

Table 3.15 Detailed six class system for classifying tolerant hardwood trees.

	CLASS A1	CLASS A	CLASS B1	CLASS B	CLASS C	CLASS D
class description	Trees that contain or are potentially capable of producing high-quality logs and that are expected to at least maintain their present quality for a 20-year period. Such trees would normally be considered crop- tree producers of high-quality sawlogs or veneer logs.	Trees have bole quality equal to Class A1 trees, but that are of high-risk or are expected to decline within a 20-year period. Such trees are normally best harvested immediately.	Trees that contain or are potentially capable of producing medium quality logs and that are expected to at least maintain their present quality for a 20-year period. Such trees would normally be considered crop-tree producers of sawlogs for dimension lumber.	Trees have bole quality equal to Class B1, but that are of high-risk or are expected to decline within a 20-year period. Such trees are normally best harvested immediately.	Trees that contain or having the potential to produce low-quality logs but no better. Such trees are often used for pulpwood, poker poles, bolter logs or fuelwood but are not normally considered as crop trees.	Cull trees by Crown Forest Sustainability Act standards: with no sawlog potential but which may be used for pulpwood or fuelwood if a strong market exists.
Criteria						
dbh	>9 cm	>35 cm	>9 cm	>30 cm	>25 cm	
tree vigour	High vigour; well-developed crown; wounds healing well.	May be low vigour.	Good vigour; crown capable of responding to release; wounds healing.	May be low vigour.	May be low vigour.	May be low vigour.
RISK: lean	Allowed if < 5°, no root damage.	No limitation.	Allowed if < 10°, no root damage.	No limitation.	No limitation.	No limitation.
RISK: broken top, canker, dieback	Not allowed.	No limitation.	Not allowed.	No limitation.	No limitation on large trees (30 cm+); not allowed on trees smaller than 30 cm.	No limitation.
wounds (includes mechanical injuries, fire scars, maple borer).	Whiteface <500 cm^2, dry, hard; well above the root collar.	Whiteface <1000 cm^2, but with little evidence of decay in best log. Sound lumber can be sawn on three faces. No limitation on secondary log.	Whiteface <1000 cm^2, dry, hard.	Darkface <500 cm^2, with evidence of decay in best log; sound lumber can be sawn on two faces. No limitation on secondary log.	Darkface >500 cm^2, with evidence of widespread interior decay on trees 30 cm and larger. Trees smaller than 30 cm must be structurally sound.	No limitation.

Table 3.15 Detailed six class system for classifying tolerant hardwood trees—continued.

	CLASS A1	CLASS A	CLASS B1	CLASS B	CLASS C	CLASS D
seams, cracks	Relatively straight, tight, shallow; no evidence of internal decay.	Relatively straight, deep; little evidence of internal decay.	Max. 1/3 stem spiral per log; tight, shallow, little evidence of internal decay (no infolding callus growth).	Max. 1/3 stem spiral per log; deep, some evidence of internal decay.	Heavy spiral will necessitate boltwood manufacture; may be evidence of internal decay.	No limitation.
cavities (includes hollow butt)	Small, upper cavity only; stem structurally sound.	Hollow butt not permitted; no cavities normally allowed within 2 m of best log.	Medium-size, upper cavity only; stem structurally sound.	Hollow butt permitted; no cavities normally allowed within 1 m of best log.	Large trees: at least 60% of the bole must be free of (major) cavities; holes not allowed on trees smaller than 30 cm.	No limitation.
dead limbs or branch stubs (>7.5 cm diam); live branches	Three faces of best log should be free of live branches. No limitation on upper bole or on small trees. No stubs >7.5 cm on merchantable bole	Three faces of best log should be free of live branches. No limitation on upper bole.	Two faces of best log should be free of live branches. No limitation on upper bole.	Two faces of best log should be free of live branches. No limitation on upper bole.	No limitation.	No limitation.
bumpy surface, twisted or spiral grain	Not allowed on best log.	Not allowed on best log.	Not allowed if pronounced on best log.	Not allowed if pronounced on best log.	No limitation.	No limitation.
sweep	Allowed if straight logs are recoverable.	Allowed if straight logs are recoverable.	Allowed if straight logs are recoverable.	Allowed if straight logs are recoverable.	Heavy sweep will necessitate boltwood manufacture.	No limitation.
crook, major fork	Normally minimum 4 m logs; tree must be structurally sound; no cracks allowed at forks or rot at crooks.	Normally minimum 4 m log	Minimum 2.5 m logs; tree must be structurally sound; no cracks allowed at forks or rot at crooks.	Minimum 2.5 m logs.	No limitation.	No limitation.
major rot conk	Not allowed.	Not allowed.	Not allowed.	Allowed on upper log only.	More than 2 conks not allowed.	No limitation.
minor rot conk	Not allowed.	Not allowed within 2 m of best log.	Not allowed.	Not allowed within 1 m of best log.	At least 1 log free of conks	No limitation.

NOTE:
No “Major” defects are allowed in classes A1 or B1.
Major, Moderate, and minor defects are outlined in Table 3.13.

3.3 Stand considerations

Information provided to this point has focused on the use of external indicators of vigour, risk, and quality in making individual tree decisions. However, it is equally important that the tree marker appreciate critical stand level parameters—species composition, crown closure, as well as stand density, stocking and structure. These traits dictate how and when to harvest the stand, and directly influence stand growth and development, cutting cycle length, and opportunities for regeneration. In this section, stand level information is described in the context of uneven-aged and even-aged forests so that the tree marker may use that knowledge to adjust marking patterns when stand characteristics vary unexpectedly.

The following descriptions reflect the common usage of the terms important to prescription writers and tree markers:

- **Species composition** is the percentage, based upon basal area, of each tree species comprising the stand.
- **Percent crown closure** refers to the area covered by the canopy of green leaves and branches formed by the crowns of all trees in a forest, expressed as a percent of the total area.
- **Structure** is the distribution of age and/or size classes within the stand.
- **Density** refers to stem frequency per hectare.
- **Stocking** as explained in OMNR (1990), is a relative term, considered in relation to the stand desired for best growth (Bickford *et al*. 1957) and commonly expressed as a percentage. It is in this traditional sense that the term is used in even-aged management discussions. However, in the following discussion of uneven-aged management, the term *stocking level* is used synonymously with *density level* to reflect the common local usage of the term. Thus, stocking levels are often expressed in terms of basal area per hectare when considering selection management.

3.3.1 Uneven-aged stands

Uneven-aged stands have three or more age classes (Smith 1986), and are frequently composed of a diversity of tree species. Some stands may have over 16 different species of trees represented, with each requiring special consideration.

In silvicultural prescriptions, guidelines for retaining or promoting certain species may be specified. This can be particularly relevant in providing habitats for specific wildlife species or maintaining biodiversity. Management of uneven-aged forests involves periodic harvests of trees of all sizes and species at a specific interval or cutting cycle (Davis and Johnson 1987).

Stocking and density

Optimal post-harvest stocking conditions for uneven-aged hardwood forests have been developed and expressed for various regions of the GLSL and deciduous forests (OMNR 1998a, 2000), and are summarized in Table 3.16.

Maximizing timber growth

Annual basal area growth in tolerant hardwood stands can vary widely across Ontario over a 20-year period. Under optimal conditions of stocking, structure, and residual tree health, basal area growth averages 0.3 metres squared per hectare per year (m^2/ha/yr) along the north shore of Lake Huron, and 0.4 m^2/ha/yr in the southern portion of site region 5E (M. Woods, OMNR, personal communication, 2000). Greater yields in site regions 6E (0.36-0.47 m^2/ha) and 7E (0.59-0.71 m^2/ha) are a result of more favourable growing conditions (refer to Table 7.2.2 in OMNR (2000)).Stand growth of tolerant hardwoods over a 20-year cutting cycle in the Algonquin portion of site region 5E is maximized at residual basal area of about 20 m^2/ha in trees 10 cm dbh and larger (OMNR 1983). Sawlog production in site regions 6E and 7E is maximized at 20 m^2/ha as well (OMNR 2000), although better growth rates permit shorter cutting cycles. Stand growth in the northern transitional forest is maximized at about 18 m^2/ha due to the harsher climate (Rice *et al*. 1998).

An essential factor in achieving optimal growth rates is to maintain the correct stocking level of healthy, vigorous stems following harvest. If higher than recommended stocking levels are retained, the crowding of residuals and competition-induced mortality over the cutting cycle will result in reduced stand growth. Lower than optimal stocking levels may promote the development of poorer quality stems with reduced merchantable heights and many low limbs, while a substantial reduction in stocking may lead to decline as a result of exposure to sun and wind. It is often necessary to retain some UGS trees, especially in previously high-graded stands, in order to maintain stocking targets (as well as critical wildlife habitat values).

Some variation in targeted residual stocking levels is acceptable within individual prescriptions in order to:

- encourage development of younger age classes
- accelerate removal of UGS
- meet wildlife habitat or biodiversity objectives
- accommodate gaps in certain diameter groupings, and to
- encourage recruitment of mid-tolerant species

Any adjustments to the stocking level targets will have an impact on anticipated future volume available for harvest, and cutting cycle length. Lower residual stocking targets would reduce yield expectations if cutting cycles were not lengthened. Conversely, when harvest cycles are shortened, residual-stocking levels should be increased, to ensure the same future yield (OMNR 1990).

Table 3.16 Recommended residual stocking levels by size class, for maximizing sawlog production (adapted from: Arbogast 1957; Anderson and Rice 1993; Rice et al. 1998).

dbh Size Class	Southern Ontario 7E		Southern Ontario 6E		Central Ontario 5E		Algoma/North Shore**	
	Basal Area m²/ha	Trees/ha	Basal Area m²/ha	Trees/ha	Basal Area m²/ha	Trees/ha	Basal Area m²/ha	Trees/ha
Polewood (10-24 cm)	4	206	4	184	6	312	6	325
Small Sawlog (26-36 cm)	5	67	5	70	6	81	6	74
Medium Sawlog (38-48 cm)	5	33	6	40	5	33	4	28
Large Sawlog* (50 cm and larger)	4	15	5	22	3	14	2	10
X-Large Sawlog (62 cm and larger)	2	7						
Totals	20	329	20	316	20	440	18	437
*(50-60 cm only when using the X-Large size class)	Data based on q-value of 1.125, using 2-cm diameter classes.		Data based on q-value of 1.1, using 2-cm diameter classes.		Data based on q-value of 1.16, using 2-cm diameter classes.		Data based on q-value of 1.18, using 2-cm diameter classes.	

** Values for the Algoma/North Shore are provisional and work is on going to verify these values. The large sawlog class value incorporates stocking levels needed for the maintenance of habitat values (Rice *et al*. 1998).

Stand structure

Examining the structure of a stand can provide the marker with an immediate picture of the stand's history, and an indication of how efficiently growing space is being utilized. In the long term, failure to consider structure could lead to wood supply shortages and forest management that is not sustainable. Sustained timber production in uneven-aged forests will occur only when the distribution of dbh-classes or stand structure is balanced.

Q-Factor: a mathematical expression of the shape of the reversed J-shaped curve – calculated by dividing the number of trees in each size class by the number of trees in the next largest size class.

A balanced structure can be characterized by the inverse "J" diameter distribution as depicted in Figure 3.13. This distribution occurs when the density of trees in each size class decreases exponentially with increasing tree size (dbh), and is often a chief target in silvicultural prescriptions.

Depending on stand management objectives and site potential, the balanced structure may follow one of several curves, dictated by maximum desired dbh, targeted residual basal area and specified "q" factor.

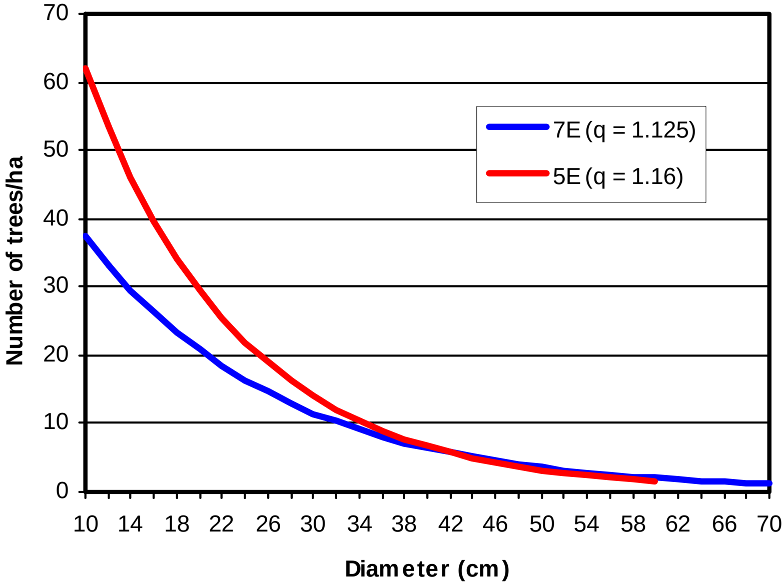


Figure 3.13 Examples of two stand structure curves that would be suitable for site region 7E of southern Ontario and site region 5E of central Ontario, with q's based on 2-cm dbh classes. See Table 3.16 for other data sets.

Structural targets

Well-structured stands are rarely encountered during the early stages of management, and the process of modifying stand structure to this idealized condition may take two or more cutting cycles. Poorly structured, or unregulated tolerant hardwood stands are often comprised of slow-growing, suppressed saplings and over-mature dominants, interspersed with variable numbers of vigorous, immature stems. If relatively undisturbed, such stands may be associated with a stand condition of "zero net timber growth" in which cull development and mortality offset the growth achieved by the healthy-tree component.

The manager must compare the actual structure of the stand to that of an optimal condition, and express the strategy for moving it to a more regulated structure in the prescription. Expressing both the optimal and actual condition within several size threshold classes is the easiest way to identify size classes that are over- or under-stocked. Table 3.16 provides stocking conditions by size class groupings for optimizing sawlog production within uneven-aged hardwood forests in various regions of the GLSL and deciduous forests (OMNR 1998a and 2000). Table 3.16 presents recommended targets for site regions 7E, 6E and 5E.

Stand structure targets optimized to meet other objectives are identified in OMNR (2000).

Long-term effect of disregarding structure when marking stands.

Stand structure may be negatively affected when there is pressure to mark and subsequently harvest the most marketable (generally larger) stems. Over several cutting cycles, stand growth becomes concentrated in the smaller and less marketable diameter classes, with clear impacts on availability of high value forest products. Ben Roach (in Marquis 1994) provides an excellent case study of the development of such a situation, and cautions that trees harvested under the selection system must be taken from across all the diameter classes.

The diameter class groupings identified in previous guides (OMNR, 1998a) have been slightly modified such that the 38 cm diameter class is included in the medium sawlog size class grouping, and there is now an optional extra-large (XL) diameter size class, that includes trees larger than 62 cm dbh. This additional size class grouping may be used for situations where an old-growth objective is to be addressed, or where more-productive forests occur, as in southern Ontario. These modifications will affect the way that structure targets are expressed to markers, but do not represent a change in the way that selection management is implemented.

Sustainable growth of the managed forest will depend on:

- The degree to which stand structure is regulated.
- The future growth of residual released trees, which must ultimately replace larger, more mature individuals removed during harvests.
- The recruitment of seedling and sapling stock (< 9 cm dbh) in sufficient quantity to adequately supply new growth to the stand.

3.3.2 Even-aged stands

An even-aged stand is one in which relatively small age differences exist between individual trees. An even canopy, a narrow range of diameter classes, and often a higher component of mid-tolerant species would characterize such a stand.

Managers may decide to move even-aged stands dominated by shade tolerant species toward an all-aged condition by taking advantage of regeneration occurring at each management intervention. However, most even-aged stands are grown as an entity from establishment to harvest for a specified rotation period, often with a series of partial harvests before final removal of the overstorey.

Species composition

Species composition can be quite variable in even-aged stands. Tree markers should recognize and adapt to stand conditions where two or more species having dramatically different niches occur, e.g., shade-tolerant (sugar maple) beneath mid-tolerant (red oak), or mid-tolerant (white pine) beneath intolerant (large-toothed aspen). Where regeneration of the less tolerant species is desired, a shift in silvicultural approach including both harvest intensity and follow-up treatment may be indicated. Interestingly, the productivity of such stands tends to be higher than stands containing species that exploit similar niches, making it important to take advantage of such opportunities (Oliver and Larson 1990).

Tree markers also must account for the optimum growing-space requirements for each species during stand interventions leading up to the regeneration stage. The concept of relative density is useful for this purpose. Relative density values are based on the estimated minimum growing space required by trees of different sizes and species, and are expressed in units of area. Equations were developed to express these requirements for three different species groups (Mh/Be, Or/By/He, and Cb/Aw) by Marquis *et al*. (1984), and illustrated in Figure 3.14 to show the wide variability in growing space requirements between species.

In general, sugar maple and beech trees require more space for optimum growth than many associated species. In fact, the basal area of undisturbed black cherry stands has been found to be more than 1.5 times greater than sugar maple stands of similar average diameter (Stout 1987), supporting the suggestion that black cherry is less demanding in terms of growing space requirements than sugar maple. Optimal residual-stocking targets may vary throughout a stand as species composition varies. The tree marker must be aware that targeted residual basal areas, which assume a sugar maple/beech dominant

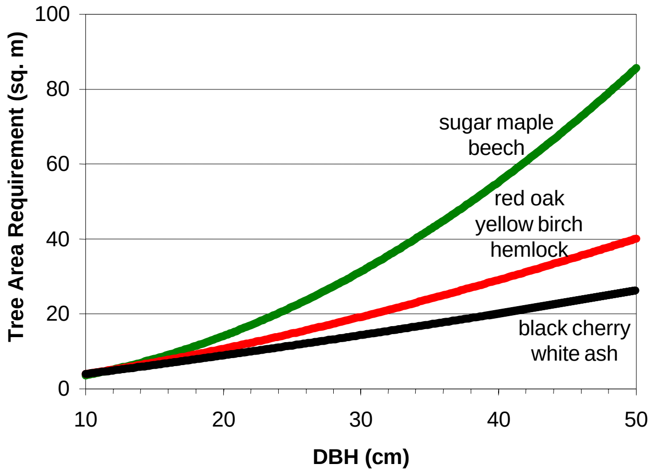


Figure 3.14 Relationship between crown radius and dbh for three GLSL species groups. (adapted from Marquis et al. 1984).

condition, can be adjusted to a higher level if patches of red oak, yellow birch, black cherry, basswood, or eastern hemlock are encountered.

Stand stocking and density

Achieving optimum growth rates following harvest depends in large part on maintaining the correct density of healthy, vigorous stems. The timing and degree of thinning required in even-aged, single species plantations, or natural forests dominated by red or white pine, can be determined using density management diagrams (DMD). Stocking charts are more commonly used to control density in even-aged stands dominated by tolerant hardwoods, or mixed stands with a hemlock component. These management tools emulate the natural thinning process that occurs as a stand matures.

Density management diagrams (DMDs)

There is a limiting relationship between number of trees per hectare and mean diameter in fully stocked even-aged stands. This mathematical principle led to the development of density management diagrams for species such as white and red pine. These diagrams allow comparisons between five stand parameters: 1) average tree volume, 2) density, 3) average tree height, 4) average diameter, and 5) stocking. From the assessment of these measurements by means of the diagrams, one can infer whether the stand is understocked, optimally stocked, or overstocked at various stages in its development. Procedures for the use of the DMDs are found in *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario* (OMNR 1998b).

Stocking charts

Stocking charts also represent the limits of stocking and density for full site utilization. These charts are based on the growing space required by forest-grown and open-grown trees, but are more commonly used to control stem density in even-aged stands of hardwood species. These multi-element depictions illustrate the relationship between four stand parameters: 1) basal area; 2) density; 3) average diameter; and 4) stocking. The charts provide a quick assessment of available growing space, indicate when growing space is limited and suggest when thinning should be implemented to maintain optimum stand growth. Stocking charts cannot be successfully applied to uneven-aged stands.

The stocking charts that have the most relevance to the tolerant hardwood forest species are provided in *A Silvicultural Guide for the Tolerant Hardwood Forest in Ontario* (OMNR 1998a), along with directions for their use. A stocking chart for hemlock is provided in *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario* (OMNR 1998b).

Stand structure

Achieving a balanced structure is to some extent more critical to the sustainability of uneven-aged forests than meeting density and stocking criteria, but the reverse seems to be true for even-aged stands. Even-aged stands tend to contain trees of similar size, creating a size-class distribution or structure that tends to plot as a bell-shaped curve (Figure 3.15). However a forest composed of many even-aged stands of varying age managed in a regulated series will exhibit an reverse J-shaped curve rather than a normal one (Smith, G.E. 1960). Group selection is an alternative to single tree selection that allows the establishment of a mosaic of even-aged patches within an uneven-aged stand.
Unlike that of uneven-aged stands, the structure of even-aged stands is dynamic over the rotation, with the average diameter constantly increasing. The rate of increase is greatly influenced by the type of thinning employed; i.e., crown thinning (from above), low thinning (from below), selection thinning, or row thinning (Erdmann 1987).

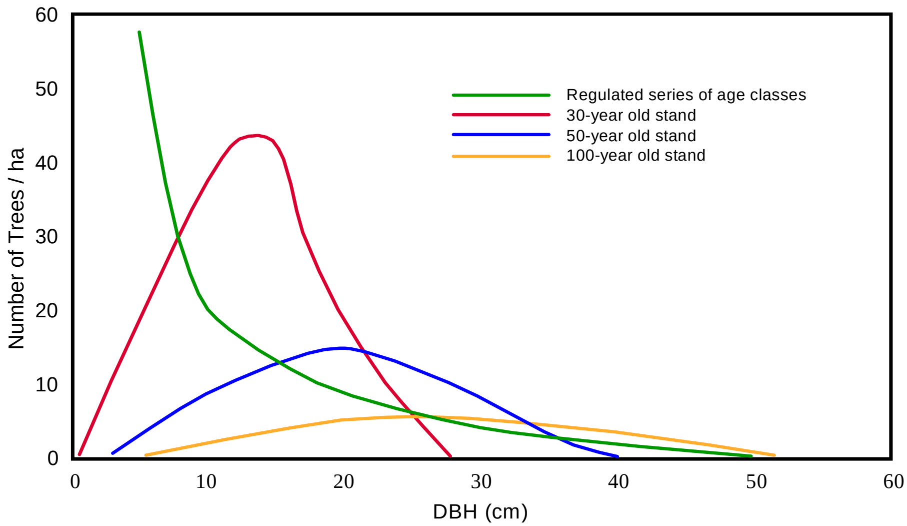


Figure 3.15 Stand and forest-structure developed under a regulated even-aged system (from Smith 1960).

Variations of this bell-shaped distribution may occur in some even-aged stands, particularly when the overstorey is dominated by intolerant species and the understorey is composed of shade tolerant species. For instance, some even-aged black cherry stands may develop a reverse-J distribution as a result of recruitment of shade-tolerant sugar maple. Oak stands also often exhibit a negative exponential structure with sugar maple (Figure 3.16) developing in the understorey, but neither cherry nor oak can be regenerated under the selection system as an uneven-aged forest; both must be developed using even-aged techniques.

Crown closure

While density management diagrams and stocking charts are used to manipulate stands over their cutting cycle, management of crown closure takes on an important role during the final harvests in the rotation of even-aged stands dominated by mid-tolerant species.

Mid-tolerant species, such as white pine, yellow birch, red oak and to some extent white ash, growing as even-aged elements of stands, require specific reproduction methods (uniform shelterwood and group selection) to ensure renewal. Emphasis is placed on residual tree spacing and canopy density (and resultant shade) combined with appropriate site manipulation.

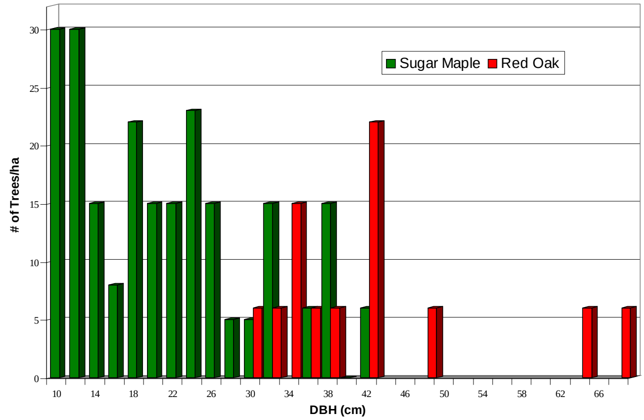


Figure 3.16 Size-class distribution of a 90-year-old red oak stand. Notice the bell-shaped distribution of red oak compared to the reverse-J distribution of sugar maple, indicating the differing niches they are occupying.

Targets for canopy closure and residual tree spacing are stipulated in silvicultural prescriptions involving the uniform shelterwood system. Prescribed residual crown closure generally ranges from 35 to 80%, depending on species (OMNR 1990). While only the shade-tolerant species will maintain themselves at low light levels, most species growing in the GLSL forest will grow well at 45% of full light (Logan 1965, 1973).

Measuring crown closure

The most practical non-subjective way to estimate crown closure involves a point-sampling prism cruise, in which each tree counted represents a specific number of trees per hectare. The crown size to dbh class relationship varies from one species to another, so values are required for individual species or groups of similar species. For instance, beech and red oak may achieve 50% closure at 8 m^2/ha. White ash may achieve 50% closure at 18 m^2/ha (Kelty 1987), and sugar maple and yellow birch occupy an intermediate position between these two extremes. White pine may achieve 50% crown closure at 16 m^2/ha.

Table 3.17 (adapted from Godman and Tubbs 1973; Bentley 1996) illustrates the relationship between dbh and crown closure for several common GLSL species. The table includes basal area per tree, and the number of trees per hectare represented by each tree tallied in a Basal Area Factor (BAF) 2 metric prism sweep. By summing the percent crown closure for all trees counted, the total crown closure for the stand may be estimated. The relatively significant impact that smaller diameter trees have on the resultant crown closure level, serves to emphasize the importance of their removal during a regeneration cut.

Caution: white pine crown size is sensitive to stocking level, and much of the data in Table 3.17 was developed from well-stocked young stands. The conversion figures should only be applied to well-stocked stands of about 100–120 years old. Values for species other than hemlock are variable across dbh classes. However, since shelterwood marking is from below, with the smaller diameter stems removed and the larger trees of desirable species and good seed bearing potential retained, trees retained will generally be within a relatively narrow range of diameters. If the approximate average diameter of the residual stand can be estimated, it will help in establishing an approximate basal area target that could be used by the tree marker along with established crown spacing guidelines.

Table 3.17 Estimates of percent crown closure (% CC) per tree counted in a point sample prism cruise–BAF 2 —adapted from Godman and Tubbs 1973 (tolerant hardwoods, hemlock) and Bentley 1996 (poplar, birch, spruce, fir, and white pine).

			Po Bw		Spruce/fir		Pw		Tol hdwds		Hemlock	
dbh (cm)	No. trees/ha per tree tallied	Basal area (m^2/tree)	Crown area (m^2/tree)	% CC	Crown area (m^2/tree)	% CC	Crown area (m^2/tree)	% CC	Crown area (m^2/tree)	% CC	Crown area (m^2/tree)	% CC
10	254.6	0.0079	14.22	36.2	4.28	10.9	7.69	19.6	6.99	17.8	1.53	3.9
12	176.8	0.0113	16.18	28.6	5.67	10	9.66	17.1	8.77	15.5	2.21	3.9
14	129.9	0.0154	18.06	23.5	7.19	9.3	11.72	15.2	10.7	13.9	3	3.9
16	99.5	0.0201	19.85	19.7	8.83	8.8	13.86	13.8	12.87	12.8	3.92	3.9
18	78.6	0.0254	21.58	17	10.59	8.3	16.06	12.6	15.27	12	4.96	3.9
20	63.7	0.0314	23.26	14.8	12.46	7.9	18.32	11.7	17.75	11.3	6.13	3.9
22	52.6	0.038	24.89	13.1	14.43	7.6	20.65	10.9	20.53	10.8	7.41	3.9
24	44.2	0.0452	26.48	11.7	16.49	7.3	23.03	10.2	23.52	10.4	8.82	3.9
26	37.7	0.0531	28.03	10.6	18.66	7	25.46	9.6	26.55	10	10.35	3.9
28	32.5	0.0616	29.54	9.6	20.91	6.8	27.93	9.1	29.86	9.7	12.01	3.9
30	28.3	0.0707	31.03	8.8	23.26	6.6	30.45	8.6	33.58	9.5	13.78	3.9
32	24.9	0.0804	32.48	8.1	25.69	6.4	33.02	8.2	37.4	9.3	15.68	3.9
34	22	0.0908	33.91	7.5	28.2	6.2	35.62	7.8	41.31	9.1	17.7	3.9
36	19.6	0.1018	35.32	6.9	30.8	6.1	38.27	7.5	45.3	8.9	19.85	3.9
38	17.6	0.1134	36.7	6.5	33.47	5.9	40.95	7.2	49.33	8.7	22.12	3.9
40	15.9	0.1257	38.06	6.1	36.23	5.8	43.67	7	54.04	8.6	24.5	3.9
42	14.4	0.1385	39.4	5.7	39.05	5.6	46.42	6.7	58.88	8.5	27.02	3.9
44	13.2	0.1521	40.73	5.4	41.95	5.5	49.21	6.5	63.86	8.4	29.65	3.9
46	12	0.1662	42.03	5.1	44.93	5.4	52.03	6.3	68.97	8.3	32.41	3.9
48	11.1	0.181	43.32	4.8	47.97	5.3	54.87	6.1	74.19	8.2	35.29	3.9
50	10.2	0.1963	44.6	4.5	51.08	5.2	57.75	5.9	79.52	8.1	38.29	3.9
52	9.4	0.2124	45.86	4.3	54.26	5.1	60.66	5.7	84.95	8	41.41	3.9
54	8.7	0.229	47.1	4.1	57.51	5	63.6	5.6	90.46	7.9	44.66	3.9
56	8.1	0.2463	48.34	3.9	60.82	4.9	66.56	5.4	97.29	7.9	48.03	3.9
58	7.6	0.2642	49.56	3.8	64.2	4.9	69.56	5.3	103.04	7.8	51.52	3.9
60	7.1	0.2827	50.76	3.6	67.64	4.8	72.57	5.1	110.27	7.8	55.13	3.9

4.0 Tree marking for wildlife habitat and biodiversity

by B. Naylor, B. Crins, W. Dunlop

In the 1980s, integration of timber and habitat management focused on socio-economically important vertebrates such as game fish, moose, and white-tailed deer. Adoption of an ecosystem management philosophy in the 1990s has directed forest managers to consider the impact of their actions on all wildlife (Figure 4.1) and biodiversity at a variety of spatial and temporal scales (Naylor 1998a,b).

Figure 4.1 Pink lady's-slipper. Wildlife includes all things wild and living (OWWG 1991).

Every decision made by tree markers affects habitat for some species of wildlife, and thus biodiversity, at some scale. Moreover, markers find critical and sensitive habitats such as hawk nests or patches of rare plants before any operations take place and are best positioned to implement mitigative measures. Thus, they are the eyes and ears of biologists and ecologists, and are responsible for ensuring that wildlife habitat and biodiversity considerations are integrated into forest management practices at the scale of individual stands in the marked forests of Ontario.

Some general principles and specific practices for conserving biodiversity and wildlife habitat are described below. This is not a definitive discussion (refer to the original OMNR guides for further information). The focus is primarily on the habitat needs of the 200+ species of birds, mammals, reptiles, and amphibians, 90+ species of fish, and a handful of rare vascular plants that either directly or indirectly depend on, or are potentially affected by activities within, the GLSL forest of central Ontario. It is hoped that the needs of the vast array of other wildlife species (e.g., invertebrates) will be at least partially addressed by providing the compositional and structural habitat diversity needed by vertebrates and rare plants.

Meeting the habitat needs of all these species can seem a daunting task. Markers can help accomplish this by 1) practising good silviculture, 2) protecting critical and sensitive habitats, and 3) maintaining special habitat features. Details of this approach are discussed in the following sections.

Integrating timber and biodiversity/habitat concerns is an evolving science. As new knowledge becomes available guidelines will undoubtedly be refined and new considerations may be added. Moreover, within a specific forest management plan, direction from this guide may be modified, or additional concerns may be identified, based on local considerations.

4.1 General principles for addressing biodiversity concerns

The term biodiversity has been defined in many ways, but is generally accepted to be an expression of the variety and variability of life (Box 4.1). Conservation biologists often discuss diversity at the species, ecosystem, and gene levels (DeLong 1996).

> **Box 4.1 What is biodiversity ?**
>
> *Biodiversity is an expression of the variety and variability of life at numerous levels. It includes:*
>
> - the variety of forest types on the landscape
> - the variety of tree species and structural components (e.g., cavity trees) within stands
> - the variety of wildlife species within stands and across the landscape
> - the genetic diversity of trees and other wildlife species

Species diversity. Initial interest in biodiversity originated from concern about the loss of species through the process of extinction (i.e., loss of species diversity). Decisions tree markers make about individual tree retention and the conditions they create for regeneration directly influence the current and future tree species diversity within stands and across landscapes. Markers also directly influence the diversity of wildlife species when they protect critical or sensitive habitats of rare species (see Section 4.2), and indirectly when their actions help to conserve ecosystem and genetic diversity (see below).

Ecosystem diversity. The diversity of wildlife species found within stands and across landscapes is generally related to the diversity of habitat (ecosystem) conditions at these scales. Markers can help ensure that the full suite of habitat types (even those with low inherent diversity) is maintained across the landscape by implementing silvicultural systems that are appropriate for the stand and site conditions encountered. Moreover, within stands, markers should strive to maintain and perpetuate a natural mix of tree species and special habitat features (see Section 4.3).

Genetic diversity. Genetic diversity plays an important role in maintaining the viability of populations of individual species and ensuring their ability to adapt to changing environmental conditions. Marking potentially influences the genetic diversity of both the residual overstorey and the regenerating understorey. Poor practices such as diameter-limit cutting and high-grading can have a large impact on genetic composition (Anderson and Nielsen 1998). Correct application of the marking principles for selection and shelterwood management should conserve genetic diversity of common tree species. However, genetic diversity can be lost when the abundance of a rare species is reduced below its critical threshold of viability (low abundance can also lead to increased self-fertilization and reduced seed production; Ledig 1992). Loss of genetic diversity is a concern for many regionally rare tree species in the deciduous forest (see list in OMNR 2000:93). Species such as red spruce, white oak, white elm, butternut, and bitternut hickory in the GLSL forest, tolerant hardwoods and hemlock in the transition forest, and white pine and red pine in the boreal forest are of particular concern. These species may be found only as small isolated populations because they have reached the northern (or southern) limit of their range, are naturally rare, or have been reduced in abundance as a consequence of pests or past practices (Pinto *et al*. 1998). The threshold of viability is generally assumed to be about 100 sexually mature individuals capable of interbreeding (Pinto *et al*. 1998). Most pollen falls within 15–30 m of the parent tree; trees further than 50 m from their neighbours have a low probability of being pollinated (Tubbs *et al*. 1987). Thus, the 100 individuals forming a viable population must occur within an area of not more than 25 ha. However, greatest opportunities for pollination likely occur when the 100 individuals occupy 10 ha or less. Therefore, when dealing with an isolated stand of a regionally rare species, retain at least 10 individuals per hectare and a total of 100 or more individuals in the stand unless the stand is already satisfactorily regenerated or will be regenerated with seed collected within the appropriate seed zone.

Marking can also indirectly influence the genetic diversity of wildlife. Maintaining a natural mix and pattern of habitats across the landscape will encourage large, healthy, widely dispersed populations with lower probability of loss of genetic diversity through inbreeding or genetic drift.

Biodiversity objectives. Creating more biodiversity or more habitat for a certain species of wildlife is not always desirable. For example, increasing species diversity by introducing new species into an ecosystem may result in dramatic changes to established ecological processes (e.g., host-pathogen relationships), ultimately leading to loss of native species (e.g., white elm, chestnut). Moreover, increasing habitat for one species will invariably reduce habitat for another. As a guiding principle, markers should strive to emulate natural processes. In other words - think like Mother Nature. The general objective is to create or maintain forests with a mix of tree species and structural components that would likely have been created by natural processes such as tree aging and death, windthrow, and fire. Furthermore, within forest management plans, specific biodiversity objectives may identify the need to increase (or decrease) the amount of certain forest types based on their historic abundance.

4.2 Protecting critical or sensitive habitats

Critical or sensitive habitats are tied to a specific geographic location. These include stick nests, special habitats for moose and deer, interior forest, old growth, riparian forest, small streams, seepages, and woodland pools, wetlands, patches of rare vascular plants, and locations of species at risk. On Crown land, some of these features may be designated as areas of concern (AOC) and protected by modifying timber management activities following specific guidelines.

4.2.1 Stick nests

Stick nests are platforms made of sticks and twigs that are used by large birds for nesting (Figure 4.2). Stick nests are an important feature for wildlife because they may be used repeatedly by the birds that built them (even for decades). Once abandoned by their builders, stick nests may be used by birds that do not build their own nests, such as owls.

Trees containing stick nests are relatively rare habitat features. Stick nesting birds generally prefer to build their nests in trees greater than 40 cm dbh, and as well, typically select trees with unusual forks or crooks. Thus, all trees containing stick nests should be considered valuable components of wildlife habitat.

Figure 4.2 Large nests made of sticks and twigs are used by herons and birds of prey. Trees capable of holding stick nests are rare and valuable habitat components.

Some stick nests will be known before markers enter a stand (especially those of eagles, ospreys, and herons), but most will be found for the first time during the marking operation (especially those of hawks and owls). A local data collection arrangement, consistent with the *Forest Information Manual* (OMNR 2001a: 40 [or as revised from time to time]), should be developed that clearly outlines the role of tree markers (and SFL and OMNR staff) in the identification, protection, and reporting of new stick nests.

When new nests are found, a person with appropriate knowledge (see Box 4.2) should verify the identity and status of the nest (see below). Verification may be conducted by any person specifically identified as a qualified verifier in the local data collection arrangement. Qualified verifiers may include tree markers, staff from OMNR, or other persons employed by an SFL holder, another forest resource licence holder, or a third party. Verification should follow the timelines prescribed in the *Forest Information Manual* (OMNR 2001a: 51 [or as revised from time to time]).

Box 4.2 Persons qualified to verify stick nests must have the following skills:

- ✔ Ability to identify hawks, falcons, owls, crows, and ravens by sight and call
- ✔ Ability to identify nest builder based on characteristics of nest, nest tree, and nesting habitat
- ✔ Ability to identify evidence that a nest is currently being used or was recently used for breeding
- ✔ Familiarity with habitat prescriptions, reporting requirements, and all aspects of the local data collection arrangement
- ✔ Must be acceptable to both the OMNR and SFL

Identity of stick nest users. The identity of the species that built or is using a nest determines which guideline must be applied to protect a nest. Positive identification of species is easiest to make when the birds using a nest can be seen or heard. Nests of different species can also be distinguished by a variety of clues such as diameter and depth of nest, size of sticks, density of nest, type of decoration, location of nest in tree, species of nest tree, and type of habitat. See Szuba and Naylor (1998) for details.

Activity status of nests. Active nests require more protection than inactive ones (see Naylor 1998a,b). Nests of species of special concern (see below) that are known to have been used within the past five years should be considered active (regardless of whether they are currently being used). The status of any new nests found during the breeding season can be determined using evidence listed in Box 4.3. When nests of species of special concern are located outside the breeding season, activity status should be judged from evidence of previous use. Nests showing compelling evidence of use during the previous breeding season (Box 4.4) should be considered active (or verification may be deferred until the next breeding season).

Box 4.3. Evidence that a nest is currently being used (i.e., occupied) when found during the breeding season.

Any one of the following suggests a nest is currently being used for breeding:

- Bird on nest or bird flies off nest
- Bird perched in nest tree or adjacent tree
- One or more eggs in nest
- One or more chicks in nest
- One or more chicks perched in nest tree or adjacent tree
- Bird delivering food to nest
- Down feathers on nest
- Abundant fresh (green) decoration on nest
- Lots of whitewash on nest or near base of nest tree
- Eggs shells near base of nest tree

Two or more of the following suggest a nest is currently being used for breeding:

- Bird behaving aggressively in vicinity of nest*
- Small amount (one or two sprigs) of fresh (green) decoration on nest
- Prey remains (butcher block) in vicinity of nest
- A few splotches of whitewash on nest or near base of nest tree
- One or more molted feathers near base of nest tree
- Nest in good repair (e.g., new material added to nest—look for freshly broken sticks on nest)

*includes calling repeatedly, circling overhead, or flying toward an observer

> **Box 4.4. Compelling evidence that a nest was used during the previous breeding season.**
>
> If a nest is found outside the breeding season:
>
> Any of the following suggests a nest was used during the previous breeding season:
>
> - Down feathers on nest
> - Abundant fresh (green) or old (dry and brown) decoration on nest
> - Lots of whitewash on nest or near base of nest tree
> - Egg shells near base of nest tree
>
> Two or more of the following suggest a nest was used during the previous breeding season:
>
> - Small amount (one or two sprigs) of fresh (green) or old (dry and brown) decoration on nest
> - Prey remains (butcher block) in vicinity of nest
> - A few splotches of whitewash on nest or near base of nest tree
> - One or more molted feathers near base of nest tree
> - Nest in good repair (e.g., new material added to nest—look for freshly broken sticks on nest)

Protecting nests. Bald eagles, ospreys, great blue herons, red-shouldered hawks, Cooper's hawks, and northern goshawks are stick nest builders of special concern in central Ontario. In all cuts, marking should be modified around nests of these species based on the appropriate guidelines (see Naylor 1998a,b; Szuba and Naylor 1998). Nests of great gray owls could also potentially be encountered while tree marking in the GLSL forest. This species is very rare, so its nest sites should also be protected. Since there is no formal guide for this species, those for the red-shouldered hawk could be applied.

Three other hawks (broad-winged hawk, red-tailed hawk, sharp-shinned hawk), three other owls (barred owl, long-eared owl, great horned owl), merlins, and common ravens also build or use stick nests. Unlike the species of special concern, most of these birds are relatively common. Their nest sites are only identified as specific AOCs if they are being used (i.e., occupied) and could be negatively affected by forest management operations.

Generally, for common species, forest management activities should not be conducted within 150 m of occupied nests. Moreover, in selection and shelterwood cuts (other than final removals), nest trees and trees with crowns touching the nest tree should be retained (Naylor 1998a,b). This protects nest trees from damage during felling, reduces the chance of nests blowing out of trees, and ensures a relatively high canopy closure immediately adjacent to nests.

In clearcuts and shelterwood final removal cuts, individual trees containing small nests (< 75 cm diameter) of common species (e.g., broad-winged hawk, sharp-shinned hawk) should be retained and will contribute to targets for residual tree retention required by the *Forest Management Guide for Natural Disturbance Pattern Emulation* (OMNR 2001b [or as revised from time to time])(see Section 4.3.7). Trees containing large nests (≥ 75 cm diameter) of common species (e.g., red-tailed hawk, raven) in good repair or inactive nests of rare species (red-shouldered hawk, Cooper's hawk, goshawk, great gray owl) should also be retained and should be protected within residual patches of forest at least 0.25 ha in size (30 m radius). Large nests in small residual patches may be reused by stick-nesting birds of early successional forest (e.g., red-tailed hawk, great horned owl) and will contribute to targets for residual patch retention required by the *Forest Management Guide for Natural Disturbance Pattern Emulation* (OMNR 2001b).

American crows also build stick nests. Since they are extremely common their nests are not protected by current legislation. However, when other stick nests are in short supply, crow nests may be retained since they can be used by merlins or long-eared owls.

Figure 4.3 Bear nests are loose bundles of broken branches created by bears feeding on tree fruits or leaves.

Not all accumulations of twigs in trees are stick nests requiring retention. Squirrels make nests comprised of twigs and leaves. Bears can create loose bundles of broken branches (*bear nests*) in beeches, oaks, poplars, and black cherries when feeding on their fruits or leaves (Figure 4.3). Witches' brooms occasionally may be mistaken for stick nests. These three features are not considered critical wildlife habitats.

Stick nests (especially small ones) may degrade quickly after abandonment. When accumulations of sticks are no longer recognizable as nests (and their identity cannot be determined), specific protection and reporting are not required. However, these trees may be retained if they are healthy, have good forks, and there are few other stick nests in the vicinity. In addition, dead trees containing inactive stick nests of hawks, owls, merlins, or ravens do not need to be retained or reported since they will rarely be re-used.

Reporting stick nests. All stick nests considered AOCs must be accurately mapped (GPS location) and reported by the verifier (see raptor nest form, Appendix K) following the timelines outlined in the *Forest Information Manual* (OMNR 2001a: 51 [or as revised from time to time]). Location (and identity) of other stick nests may also be reported to facilitate compliance monitoring. Reporting requirements should be described in the local data collection arrangement.

Marking stick nests. Markers should avoid placing obvious marking that might attract predators or curious people (e.g., colourful flagging tape or paint) on nest trees. However, a small painted blue "N" low on the trunk can help facilitate relocation of nest trees (especially if nests have deteriorated).

4.2.2 Winter cover for deer and moose

Conifer-dominated forest is extremely important habitat for wildlife in the GLSL forest; although it represents only about one-third of the forest, it is preferred habitat for about 130 of the 190 species of forest-dependent birds, mammals, reptiles, and amphibians (Naylor 1998b). Deer are particularly dependent on conifer cover during winter because it provides both thermal shelter and improves access to food (Figure 4.4).

Figure 4.4 Conifer cover provides thermal shelter for deer during winter. It also moderates snow depth, influencing the ability of deer to reach browse.

Thermal cover. Conifer forest provides important thermal shelter for deer during winter because it blocks wind and typically has higher ambient night-time air temperatures and lower daily temperature fluctuations than other forest types (Pruitt and

Pruitt 1987). By bedding in sites with high conifer cover, a deer's energy expenditure associated with thermo regulation is reduced.

Not all conifer cover is equally valuable as thermal shelter. Stands must be mature (trees at least 10 m tall) and relatively dense (at least 60% conifer canopy closure)(Voigt et al. 1997). Stands dominated by hemlock or cedar can provide excellent thermal cover. Stands dominated by white pine, white spruce, balsam fir, or upland black spruce can provide acceptable thermal cover. Those dominated by red pine, jack pine, or lowland black spruce typically provide poor thermal cover (Bellhouse and Naylor 1997).

Within deer yards, stands providing critical thermal cover should be identified as part of a forest or deer yard management plan (usually 10–30% of the forest in each yard). Stands providing critical thermal cover that are dominated by pine, spruce, or balsam fir will generally be deferred from harvest. In contrast, some cutting in hemlock or cedar stands providing critical thermal cover may be permitted since cutting encourages the production of browse. However, marking must retain at least 60% conifer canopy closure (about 24 m^2/ha) in trees at least 10 m tall. Clumping of residual conifers (i.e., 3–5 trees with interlocking crowns) provides better thermal cover and snow interception than uniform spacing of residuals. Where possible, species that provide the best thermal cover should be preferentially retained (Box 4.5)(Voigt et al. 1997, Naylor 1998b).

Box 4.5 Tree species to retain for thermal and access cover.

Best	**Good**	**Poor**
hemlock	white spruce	lowland black spruce
red spruce	balsam fir	red pine
cedar	white pine	jack pine
	upland black spruce	

Markers may encounter other components of deer habitat, such as bedding sites, where high conifer canopy closure must be maintained (Voigt et al. 1997). Deer usually bed in dense conifer cover on ridges or knobs (often on south-facing slopes). A conifer canopy closure of at least 80% should be retained at known and high potential bedding sites. Appropriate conditions can be provided by retaining a clump of 3–5 trees (at least 10 m tall) with interlocking crowns surrounded by forest with a conifer basal area (BA) of at least 24 m²/ha within a tree length radius of the bedding site.

High conifer canopy closure (80%) should also be maintained along well-used travel corridors (Voigt et al. 1997). Appropriate conditions can be provided by retaining all conifers with crowns directly over the trail, and a conifer BA of at least 24 m²/ha within a tree length of both sides of the trail.

Winter marking is recommended in deer yards so bedding sites and travel corridors can be efficiently identified.

Access cover. Conifer cover intercepts snow in its foliage. Some of this trapped snow sublimates (converts from solid snow directly into water vapour) on warm days, resulting in a lower depth of snow below conifer cover. Snow that falls to the ground is generally denser and more capable of supporting the weight of deer (Verme 1965). Snow depth and density determine the area of a yard that is accessible to deer (and thus the amount of food available to deer) and the energetic cost of travelling to acquire this food. Both factors may influence the survival of deer through winter and possibly the survival of fawns the next summer (Voigt *et al*. 1997)

When harvest blocks are expected to contribute to the supply of winter food in yards, marking should be modified to maintain access cover.

Selection cuts in hardwood stands will produce abundant winter browse for deer (group selection openings will further enhance food supply). However, the abundance and dispersion of conifer cover will dictate how much of this browse is accessible. Pockets of conifer at least 0.04 ha in size (i.e., 20 m x 20 m) provide both thermal and access cover in hardwood stands. They should be marked to maintain at least 60% conifer canopy closure and to encourage regeneration of the conifer cover. This may involve removing all competing hardwoods. However, this should be done only if felling of the hardwoods will not damage the residual conifers (Naylor 1998a).

Clumps of three or more conifers, 10 m or more in height, and with interlocking crowns can also provide access cover in hardwood stands. Deer will travel to these clumps and browse within a radius of about

30 m of the clump when snow is deep. Some conifers in these clumps may be marked but a minimum of 3–5 trees of appropriate species (Box 4.5) should be retained. Residual trees should be at least 10 m tall and should have touching crowns to maximize their snow interception capabilities. Clumps should be ideally 10 to 30 m, and no more than 60 m apart (Naylor 1998a).

Even solitary scattered conifers can be important to deer in hardwood stands. Deer will use these conifers when moving between pockets or clumps of conifers. Thus, scattered conifers that appear to link shelter patches should be retained (Naylor 1998a).

Shelterwood cuts and clearcuts in conifer stands will also produce abundant winter browse for deer. Shelterwood preparatory and regeneration cuts will generally maintain adequate access cover. Shelterwood removal cuts and clearcuts should retain clumps of 3–5 conifers (at least 10 m tall) with interlocking crowns spaced 10 to 30 m, and no more than 60 m apart unless regeneration is at least 10 m tall (5 m for hemlock or cedar).

For more details on managing food and cover in deer yards see Voigt et al. (1997) and Naylor (1998a,b).

Moose winter cover. Because of their larger body size and longer legs, moose are not as adversely affected by cold weather and deep snow as are deer. However, when snow depth exceeds about 60 cm, moose movement becomes restricted and they will begin to use dense conifer cover (Figure 4.5) (Jackson *et al*. 1991). Moose may be confined to dense conifer stands when snow depth exceeds about 90 cm. Forest conditions that provide good thermal cover for deer (see above) also generally provide good thermal cover for moose. Thus, in stands identified as important winter cover, application of the guidelines for deer will likely conserve cover values for moose (Naylor 1998b).

Figure 4.5 Moose begin to use dense conifer cover when snow depth exceeds about 60 cm.

4.2.3 Moose summer habitat

During summer, moose avoid heat stress by bedding in mature (10+ m tall) stands of lowland conifers or hardwoods (Jackson *et al*. 1991). When stands are identified as critical summer thermal shelter, markers should attempt to maintain a high residual canopy closure (80+%) (Naylor 1998a,b).

In early summer, moose feed extensively on floating and submerged plants in sites known as aquatic feeding areas (Figure 4.6) (Fraser et al. 1980). Moose aquatic feeding areas (MAFAs) generally receive a 120 m AOC that is intended to provide a travel corridor, visual screening, hiding cover for moose calves (while cows are feeding in the MAFA) and cool bedding sites for adult moose (Naylor 1998a,b).

Figure 4.6 In early summer, moose feed on floating and submerged plants in sites known as aquatic feeding areas.

Some selection or shelterwood cutting within the AOC can be beneficial, as it will encourage the development of a dense understorey that can improve lateral screening. Specific direction will be provided in the marking prescription based on the quality of the MAFA, type of silviculture, and amount of aquatic habitat on the landscape (see Naylor 1998a,b). Within pockets of lowland forest in the AOC, markers should try to maintain at least 80% canopy closure to provide dense cool sites that moose can use for thermoregulation during summer (Naylor 1998a,b).

4.2.4 Edges, ecotones, and interior habitat

An edge is the place where two different plant communities meet (Hunter 1990). Edges may be hard (e.g., boundary between mature forest and agricultural field) or soft (e.g., boundary between mature maple forest and poplar forest). Edges may also be relatively permanent (e.g., lake/forest edge) or transitory (e.g., young forest/old forest edge). Some wildlife species are commonly associated with edges because they use the resources that are found in the plant communities on both sides of the edge. For example, moose is considered an ‘edge species’ because it feeds in young forest that contains a high amount of browse, but almost always within close proximity to mature forest that provides cover (Jackson *et al*. 1991). Similarly, deer is an edge species that uses fields and meadows for feeding and adjacent forest for cover.

Environmental conditions associated with an edge (e.g., greater sunlight and wind penetration) may influence the vegetation community on both sides of an edge creating an area known as an ecotone (Hunter 1990). The nature of the edge influences the width and character of the ecotone. Some wildlife species find preferred habitat in the unique conditions within ecotones (Hunter 1990) and ecotones frequently have a greater diversity of wildlife than is found in the plant communities on either side of the edge (Thomas *et al*. 1979).

However, not all species benefit from edges and associated ecotones. For some songbirds, nest predation and parasitism may be higher, or pairing success may be lower, within 100–300 m of hard forest edges (Brittingham and Temple 1983, Wilcove 1988, Van Horn 1990). These species are typically associated with mature forest and show a strong preference for habitat that is not influenced by the edge (i.e., forest interior habitat).

The amount of forest interior habitat is strongly influenced by the nature of the edge and the size and geometry of patches of mature forest. Large patches have more interior habitat than small patches of the same shape (Figure 4.7). Circular or square patches have more interior habitat than long thin patches of the same area.

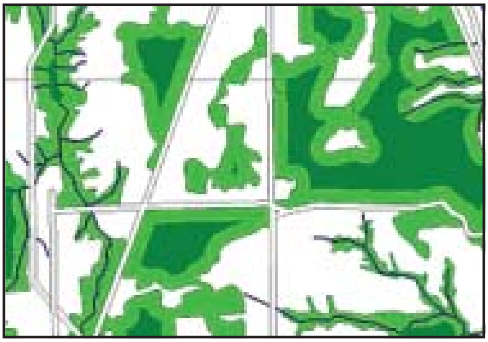


Figure 4.7 Forest patches that are small or relatively linear have lots of edge habitat (light green) but very little interior habitat (dark green). Farmland and road rights-of-way are white. Edge effect is assumed to extend 100 m into forest patches.

The unique conditions provided by forest interior habitat can be adversely affected by timber harvest. For example, creating openings greater than twice the height of the stand can result in increased parasitism of songbird nests (Brittingham and Temple 1983, Paton 1994, Suarez *et al*. 1997).

Protection of forest interior habitat is primarily a concern where edges are abrupt (forest/farmland edges), woodlots are small and widely dispersed, and <20–30% of the landscape is forested (Andren 1994; Fahrig 1997, 2003). In these situations, uncut buffers (up to 30 m depending on vegetation density and aspect) should be maintained adjacent to hard edges to reduce windthrow, maintain the integrity of interior habitat, and minimize invasion of non-native species (OMNR 2000). Patches of forest that contain >90 ha of wooded habitat that is >100 m from hard edges represent significant cores of interior habitat and are extremely valuable to forest interior birds such as the ovenbird and wood thrush (Burke and Nol 2000). In woodlots that contain all or part of these significant cores of interior habitat, timber harvest should be precluded or tree marking should be modified to maintain habitat for interior species. In the latter case, marking within the forest interior (>100 m from a hard edge) should be restricted to single tree selection with a high residual basal area (20+ m^2/ha) and canopy closure (70+ %) (OMNR 2000). Openings in the canopy should generally be small and should not exceed twice the height of the stand. Moreover, a 30 m uncut buffer should be maintained adjacent to all hard edges.

4.2.5 Old growth forest

All forest development stages are important habitats for some wildlife species (e.g., see Bellhouse and Naylor 1997). However, late successional or old growth forest tends to be especially valuable because of its relative rarity (Figure 4.8). Some old growth forest should be maintained on our landscapes in a protected, unharvested condition to provide unique wildlife habitats and serve as ecological benchmarks.

Figure 4.8 Old growth stands are characterized by multi-layered canopies (including supercanopy trees), high tree species diversity (including mid-tolerants), and an abundance of large diameter living and dead trees, cavity trees, and downed woody debris.

However, it may be possible to harvest some older stands and retain some of the key habitat and aesthetic features of old growth forest. For example, selection management tends to emulate the gap phase processes dominant in old growth hardwood forest. However, it produces forest with a lower total BA, a smaller average and maximum tree size, more uniform gap sizes, a lower canopy residence time, fewer dead and declining trees, and less downed woody debris than found in old growth forest (Frelich and Lorimer 1991, Keddy 1994, Dahir and Lorimer 1996, McGee et al. 1999, Seymour et al. 2002). Prescriptions might be modifed in certain stands to maintain more old growth characteristics. The following is an example of the type of prescription that might be used.

Total basal area. To maintain a higher total BA throughout the life of a stand, retain a residual BA of at least 20 m^2/ha and do not harvest stands until BA exceeds 28 m^2/ha.

Stand structure targets. To increase average tree size and retain some very large trees, add an extra large sawlog size class and use a lower Q-factor (e.g., 1.13) to create a stand structure target along the lines of the following:

Canopy gaps. To create more variability in canopy gap size, create some group openings from 0.02 to 0.20 ha in size (see Section 6.2).

Canopy residence time. To increase canopy residence time decrease the proportion of BA removed in each stand entry or increase the length of the cutting cycle.

Size Class	Residual basal area	
	Current ideal target	Old growth target
Poles (10-24 cm dbh)	6 m^2/ha	5 m^2/ha
Small logs (26-36 cm dbh)	6	5
Medium logs (38-48 cm dbh)	5	5
Large logs (50-60 cm dbh)	3	3
X-large logs (> 60 cm dbh)	0	2

Dead and declining trees. To maintain more dead and declining trees, retain at least 12 cavity trees/ha, with at least half of these 40+ cm dbh (see Section 4.3.1). Where feasible and practical, girdle marked and unmerchantable stems to create snags to replace those knocked down during harvest operations.

Downed woody debris. To maintain more downed woody debris, follow suggestions for the retention of dead and declining trees since these trees represent future downed woody debris. Require operators to leave unmerchantable wood at the stump to the extent practical and feasible. Large cull pieces (40+ cm diameter and 2+ m long) left on landings might be skidded back into the cut block.

Small patches of mature forest should also be retained in most cut blocks and allowed to become islands of old growth. At this time the *Forest Management Guide for Natural Disturbance Pattern Emulation* (OMNR 2001b) suggests that 10 to 36% of each clearcut and shelter-wood cut block (where there is not an acceptable break as defined in the guide) be retained as peninsular or internal residual patches (0.25 to 50+ ha in size). Some peninsular and internal residual patches will likely be identified during preparation of a forest management plan. However, many internal patches will be identified during field operations. Internal patches should be linked to existing AOCs or anchored to other important habitat features such as stick nests, small streams, seeps, woodland pools, or patches of rare plants whenever possible. See OMNR (2001b) for more detail on the composition, size, and placement of internal residual patches.

4.2.6 Riparian forest and fish habitat

Riparian forest bordering lakes, rivers, streams, and creeks is an important component of the habitat of both terrestrial and aquatic wildlife (Figure 4.9) (Hunter 1990). From an aquatic perspective, riparian forest affects fish habitat through its influence on sedimentation, water temperature (via shading), and provision of cover in the form of fallen logs. Riparian forest also provides inputs of organic matter that form the basis of the food webs of some aquatic ecosystems. From a terrestrial perspective, riparian forest represents a juxtaposition of water and forest and thus provides habitat for wildlife

Figure 4.9 Riparian forest bordering lakes, rivers, streams, and creeks is an important component of the habitat of both terrestrial and aquatic wildlife.

such as eagles, ospreys, and wood ducks that hunt or forage in aquatic ecosystems but nest in forest. Riparian forest may also function as a travel corridor. Moreover, the growing conditions that exist in riparian areas often produce unique forest communities that may support a greater diversity or abundance of wildlife than in adjacent upland forest.

On Crown land in Ontario, activities within riparian forest are currently guided by the *Timber Management Guidelines for the Protection of Fish Habitat* (OMNR 1988b) and the *Code of Practice for Timber Management Operations in Riparian Areas* (OMNR 1991). Riparian forest adjacent to lakes and streams representing significant fish habitat is considered to be an AOC (OMNR 1988b). The width of the AOC ranges from 30 to 90 m based on slope. The amount and type of marking permitted in the AOC is determined by the characteristics of the adjacent aquatic ecosystem (i.e., type of fish community), as well as by the presence of significant fish (e.g., spawning beds) or other wildlife habitats (e.g., moose aquatic feeding areas). Specific direction will be provided in the marking prescription.

OMNR (1988b) and OMNR (1991) are currently being revised and amalgamated. The *Forest Management Guide for the Protection of Fish Habitat* will incorporate the new understanding of the habitat requirements of fish and the impacts of forest management activities. It is anticipated that this new guide will change the amount and type of marking permitted within some riparian forest.

Within riparian AOCs, markers should be vigilant for nests of eagles, ospreys, herons, and merlins (see Section 4.2.1). Retention of cavity trees (see Section 4.3.1) is important for hole-nesting waterfowl such as wood ducks and common goldeneyes. Retention of supercanopy trees (see Section 4.3.6) provides nest, roost, and perch sites for eagles and ospreys.

4.2.7 Small streams, seepages and woodland pools

Some riparian forest may not be associated with significant fish habitat and thus may not be identified as an AOC as per the *Timber Management Guidelines for the Protection of Fish Habitat* (OMNR 1988b). This includes forest surrounding small (typically intermittent) streams (not providing spawning habitat), seepage areas, and woodland pools (some of these habitats may be addressed in the new *Forest Management Guide for the Protection of Fish Habitat*.)

Many small streams typically do not support fish populations because they are either too shallow, too warm, have too little oxygen, dry out during some part of the year, or freeze completely during winter. However, these streams may contribute to water quality and may also be important habitats for wildlife such as the northern two-lined salamander (Figure 4.10).

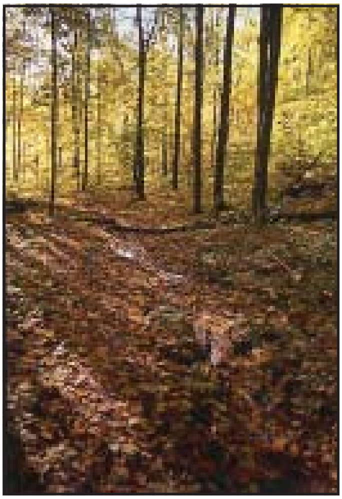


Figure 4.10 Intermittent streams are valuable habitat for some salamanders. They generally flow less than nine months of the year and are characterized by a poorly defined stream channel.

Seeps are small areas of groundwater discharge, typically located along lower slopes of hills (Figure 4.11). Soils remain saturated for much of the growing season giving rise to productive growing conditions. Seeps tend to green-up early in the spring and are thus used at this time of the year by a variety of wildlife species such as black bears (Elowe 1984). Seeps adjacent to brook trout streams may help maintain coldwater conditions throughout the summer (Meisner *et al*. 1988). Seepage areas may also be ideal habitats for some rare plants such as American ginseng.

Woodland pools are small depressions that fill with spring melt-water but may be dry during some part of the growing season (Figure 4.12). They generally have no well-defined inlet or outlet. During dry periods, they appear as a depression with matted leaves and water lines on trees (Kittredge and Parker 1996). Woodland pools are important breeding sites for many forest frogs (e.g., wood

Figure 4.11 Seepage areas are important habitats for a variety of wildlife because they support a diversity of plant species and green-up early in spring.

Figure 4.12 Woodland pools are important breeding habitat for many amphibians.

frog) and salamanders (e.g., yellow-spotted salamander).

Large woodland pools are generally more valuable than small ones since large pools last longer and subsequently tend to support a greater richness and abundance of breeding amphibians (Figure 4.13). Research from Algonquin Park suggests that pools with a surface area of about 200 m^2 (approximately 20 metres x 10 metres) or more generally persist for at least two months (Figure 4.13), long enough to be considered valuable to wildlife (Kittredge and Parker 1996). This threshold may vary regionally.

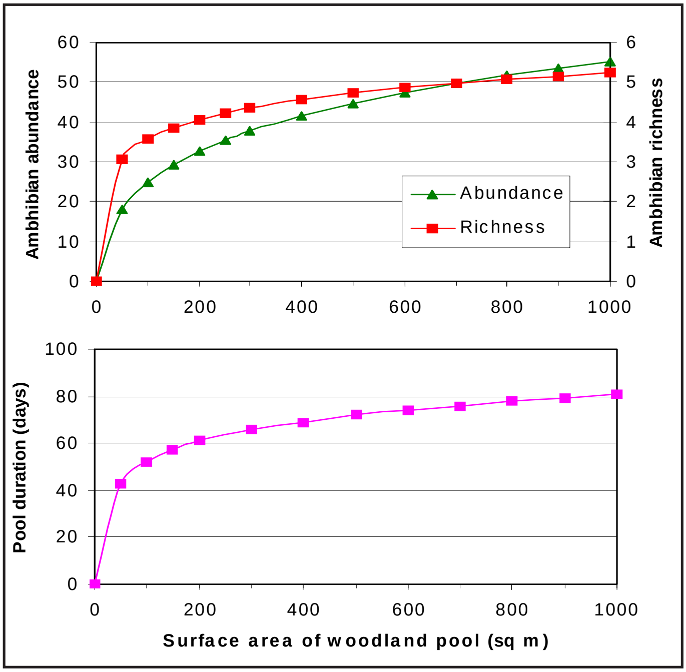


Figure 4.13 Duration of woodland pools and amphibian richness and abundance in relation to surface area (m^2) (Lisa Enright Cornish, unpubl. data).

Forest management operations should be conducted in a manner that maintains the integrity of small streams, seepages, and woodland pools. Avoid marking trees that are within or right on the edge of small streams and large (>200 m^2 surface area) seeps and woodland pools to maintain high canopy closure (70%+) (Naylor 1998a,b; OMNR 2000). Moreover, within a tree length of large woodland pools, retain at least 50% stocking (i.e., BA of at least 15 m^2/ha in hardwood stands and 20 m^2/ha in conifer stands) unless based on other biodiversity or habitat objectives. In parts of southern Ontario where forests are highly fragmented and large woodland breeding pools are relatively rare, this should be a no-cut buffer (OMNR 2000). When lower basal area (or a larger opening) is required to meet other biodiversity or habitat objectives (e.g., for regeneration of yellow birch or butternut), locate these areas on north or east sides of woodland pools.

Markers should map small streams that are not depicted on forest resource inventory maps and large seeps and woodland pools to help ensure that skid trails and landings can be located so they avoid these features. Reporting requirements should be outlined in a local data collection arrangement.

4.2.8 Wetlands

Wetlands are areas that are seasonally or permanently covered by shallow water and support water-tolerant plants. Wetlands include marshes, shrub and tree-dominated swamps, fens, and bogs (Env. Can. 1987). Wetlands play a critical ecological role in the GLSL forest of central Ontario. They influence water quality, protect shorelines, aid in flood control, provide spawning and nursery sites for fish, and are habitat for many other wildlife species (James 1985). For example, in central Ontario, shrub swamps are used by 59 species of birds, mammals, reptiles, and amphibians, shallow marshes by 45 species, and bogs and fens by 40 species (Bellhouse and Naylor 1997).

Wetlands providing significant fish, waterfowl, or moose aquatic feeding habitat, containing active heron colonies or osprey nests, or designated as provincially significant should be identified as AOCs. Marking should be modified to protect the appropriate values (see prior sections and Hickie 1985).

In some parts of the GLSL forest, abandonment of beaver-controlled wetlands as a consequence of declining food supplies is a local concern. When other values will not be adversely affected, markers may be directed to create some large openings ($\geq$ 40 m wide) adjacent to specific wetlands containing beaver lodges (OMNR 1986, Naylor 1998a,b). Openings should be located as close to the shore as possible and preferably within pockets of intolerant hardwoods on low slopes.

Marking in forested wetlands (e.g., silver maple/black ash swamps), should be modified to consider the autecology of the desired species, the sensitivity of the site (see OMNR 2000), and other habitat concerns (e.g., moose summer thermal shelter, see Section 4.2.3).

4.2.9 Rare vascular plants

Numerous species of rare vascular plants (mainly flowering plants and ferns) are found in the GLSL forest region (see the Natural Heritage Information Centre (NHIC) website for a complete listing). The diversity of species in this region is second only to that of the limestone/ dolostone-based areas of the province south of the Precambrian Shield. Many of the rare plants in this region are found in habitats that would not be directly affected by forest management activities (e.g., wetlands, shorelines, rock barrens). Below we describe four rare species that might be encountered when marking in pine and tolerant hardwood forests in central Ontario. For additional information on identification, distribution, or autecology, we recommend contacting staff at the NHIC, OMNR district ecologists, or local botanical experts.

Braun's holly fern. Braun's holly fern is a striking, dark green, clump-forming fern with closely spaced brown scales along the stalk of each frond (blade) (Figure 4.14). The tip of each division of the blade is sharp with a short bristle. The blades of this fern can be up to one metre long. Braun's holly fern is usually found in dense mature fresh to moist tolerant hardwood forest (Ecosites 28.2, 29.2, and 35). The soils in which it grows usually are rich, have substantial organic matter, are neutral to somewhat basic in soil reaction, and often have rock outcrops. It can also occur in deeply shaded ravines and on terraced floodplains on silty soils. It usually is found around the edges of

Figure 4.14 Braun's holly fern.

small depressions, where competition from herbs and other ferns such as ostrich fern is reduced. Fewer than 30 populations of this plant are known in central Ontario.

Ram's-head lady's-slipper. Unlike the common pink lady's-slipper, which has only two leaves right at ground level, this species has several well-developed leaves on its stem. The lower lip of its showy flower is whitish with very conspicuous red or purple veins (Figure 4.15). This lower lip is densely haired, and is strongly bent near the end, with a downward-angled, cone-shaped pouch. It flowers in late May and June.

Figure 4.15 Ram's-head lady's slipper.

Ram's-head lady's-slipper may be found in two types of habitats. It may occur in cool, dry, sandy mixed stands of white, red, and jack pines (Ecosites 11.1 and 13.1) with slightly acidic to neutral soils, and a thick layer of pine needles. In this habitat type, it prefers northern exposures or depressions within the forest where the microclimate is cooler than the surrounding conditions (Case 1964). It may also be found in wet, mossy, coniferous swamps (Ecosite 32). Fewer than 20 populations of this plant are known in central Ontario.

American ginseng. American or wild ginseng is very similar to the common wild sarsaparilla in appearance, and may even occur with it (Figure 4.16). The flowering and fruiting structures are held on a stalk that originates from the central junction point of the leaves, rather than on a separate stalk as in wild sarsaparilla.

Figure 4.16 American ginseng.

It is relatively frost-sensitive, so that the above-ground parts of the plant wither with the first frost.

This species occurs in fresh to moist tolerant hardwood forest (Ecosites 24.2 and 26.2), especially where the soils are rich in organic matter, circumneutral (pH 7) or somewhat basic, relatively well drained, and where marble (or limestone/dolostone) occurs in outcrops or is relatively close to the surface (White 1988). It prefers relatively mature forests with fairly closed canopy, but may tolerate a low level of forest management activity, including single tree selection and sugar-bush management. However, excessive opening of the canopy during forest operations may result in lower fruit production.

American ginseng has been severely depleted throughout much of its range in recent years due to harvesting for commercial medicinal purposes and is currently officially designated as *Endangered* by COSEWIC (COSEWIC 2003). Fewer than 20 populations are known in central Ontario.

Pine-drops. Pine-drops has brownish, reddish, or purplish, relatively succulent stems that are up to 1 m long, with small, scale-like, poorly developed leaves that are scattered along its length (Figure 4.17). The flowers are white to reddish and vase-shaped, with the petals spreading backwards. They are usually spread out along the upper third of the stem. It flowers during July and August and the old, dried fruiting stems can persist into the following growing season.

Figure 4.17 Pine-drops.

Pine-drops may be found in dry white pine forests (Ecosites 11.1 and 14.1), usually in areas with relatively thin soils, or on sandy, forested dunes (Gillett 1972). It appears to be a saprophyte (using its root system to extract nutrients from decaying plant material), although it has been suggested that it may be somewhat parasitic on pines. Fewer than five populations of pine-drops are known in central Ontario.

Protection. All four of the above species either require high canopy closure or are sensitive to disturbance of the forest floor associated with skidding or site preparation. Consequently, if there is no prescription in the forest management plan it is recommended that markers establish a reserve that extends one tree length from the perimeter of patches of these plants. Sightings of all four species should be reported to the local OMNR ecologist or biologist who will pass this information along to the NHIC. Reporting requirements should be outlined in a local data collection arrangement. **Locations of patches of American ginseng should otherwise remain confidential.**

4.2.10 Species at risk

Some species at risk, such as bald eagles and red-shouldered hawks, directly benefit from direction provided in earlier sections (e.g., Section 4.2.1). Maintaining ecosystem diversity at the landscape (by conserving interior forest, old growth, riparian, and wetland habitats) and stand levels (by maintaining cavity trees, mast trees, supercanopy trees, and veteran trees) indirectly conserves habitat for many other species at risk. In addition, markers should be aware of the species at risk that occur in their local area, their habitat requirements, local direction for their protection, and any legal obligations they may have associated with legislation such as the *Endangered Species Act* (RSO 1990). New sightings of species at risk should be reported to local OMNR biologists or ecologists. Reporting requirements should be outlined in a local data collection arrangement.

4.3 Maintaining special habitat features

Some stands will contain critical or sensitive habitats, others will not. Markers are also responsible for maintaining the many special habitat features that are not site-specific. These include cavity trees, mast trees, conifers in hardwood stands, hardwoods in conifer stands, supercanopy trees, and veterans.

4.3.1 Cavity trees

About a quarter of all birds and mammals use holes or cavities in trees for nesting, denning, roosting, resting, feeding, or hibernating (Naylor 1998a,b). These include animals that make their own holes such as woodpeckers and those that cannot such as northern saw-whet owls, wood ducks, eastern bluebirds, bats, squirrels, American martens, fishers, raccoons, and black bears.

Cavities are generally found in either standing dead trees (snags) or in living trees that are declining. There appears to be a super abundance of habitat for cavity users in many of our stands today. However, there is a concern that habitat for cavity users may decline in the future as many snags are removed during timber harvest operations to comply with the *Occupational Health and Safety Act* (RSO 1990). As well, a more rigorous application of silvicultural systems (such as single tree selection) leads to a lower proportion of the growing stock in declining and low vigour trees (Naylor 1998a,b).

The pileated woodpecker was identified (by the *Class Environmental Assessment by the Ministry of Natural Resources for Timber Management on Crown Lands in Ontario*) as an indicator of the needs of our forest-dwelling cavity users. Guidelines have been developed that are intended to provide habitat for pileated woodpeckers and other cavity users (Naylor *et al*. 1996). These guidelines require the retention of at least six living (with one exception noted below) cavity trees per hectare (0.5 to 1.0 m^2/ha) in all harvest blocks. Factors to consider when selecting cavity trees for retention are discussed below.

Type of cavity

Type of cavity is the most important factor to consider when retaining cavity trees (Box 4.6). Trees with the following high value cavities provide habitat for the greatest variety of cavity-using wildlife and thus should be favoured for retention.

Box 4.6. Priority for retaining cavity trees.

Cavity trees are to be retained in the following order of priority based on the type of cavity they contain,

1. Pileated woodpecker roost cavity
2. Pileated woodpecker nest cavity
3. Other woorpecker nest cavity or natural nest or den cavity
4. Escape cavity
5. Woodpecker feeding cavity
6. High potential to develop cavities

Pileated woodpecker roost cavities. First priority for retention are trees with cavities used by pileated woodpeckers for roosting (Figure 4.18). These are large diameter trees (usually 40+ cm dbh) that are hollow and have at least two excavated entrance holes. Entrance holes excavated by pileated woodpeckers are somewhat oval and are about 7.5–10 cm wide and

10–12.5 cm high. Entrance holes to roost (or nest) cavities differ from excavations made while feeding. Feeding excavations are rectangular or irregular in shape (instead of a symmetrical oval shape), have very rough edges (instead of clean smooth edges), and extend 5–20 cm into the tree then stop (they do not lead into a large chamber suitable for roosting or nesting). Because roost trees are rare and extremely valuable to pileated woodpeckers (and other species), all living and dead standing roost trees should be retained unless they have degraded to such a point that they no longer appear to provide suitable roosting habitat. When a standing dead roost tree is to be retained, it must have a tree length reserve placed around it to comply with the OH&SA.

Figure 4.18 Pileated woodpecker roost tree.

Pileated woodpecker nest cavities. Second priority for retention are living trees with pileated woodpecker nesting cavities (Figure 4.19). These are large diameter trees (usually 40+ cm dbh) in which pileated woodpeckers have excavated one or more nest chambers and associated entrance holes. Nest and roost trees can be distinguished by the number of entrance holes and tree condition. Roost trees may have 2–10+ entrance holes and entrance holes may be less than 1 m apart. Although pileated woodpeckers will nest in the same tree more than once, it is rare to find a tree with more than two nest holes and when multiple nest holes are encountered, they are generally more than 1 m apart (because nest chambers may be up to 75 cm deep). Condition is probably the best clue to separate nest and roost trees. Pileated woodpeckers excavate nest cavities in trees with white spongy heart rot (typically associated with

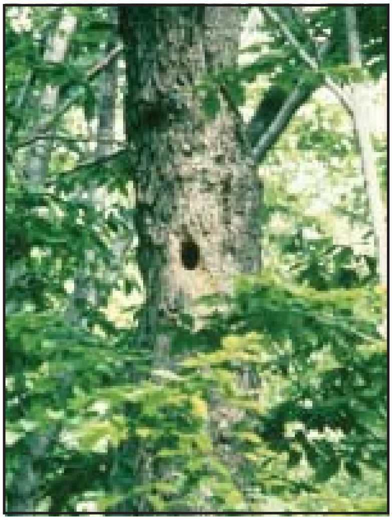


Figure 4.19 Pileated woodpecker nest tree.

false tinder fungus) rather than in trees with existing hollows. Roost cavities are in hollow trees (look for indicators of defect such as open seams, church doors, and barrelling to indicate hollowness).

Other woodpecker nest cavities or natural nest or den cavities. The third priority for retention are living trees with cavities excavated by other woodpeckers (e.g., yellow-bellied sapsucker, hairy woodpecker, northern flicker) for nesting (Figure 4.20) or cavities suitable for nesting or denning (by secondary cavity users) that formed from natural decay processes. Nests created by pileated woodpeckers can be distinguished from those created by other woodpeckers by the size and shape of the entrance hole. Entrance holes created by other woodpeckers are generally circular (instead of oval) and are smaller (less than 10 cm in diameter). Entrance holes to other woodpecker nest cavities differ from woodpecker feeding excavations because they are generally symmetrical and circular, have smooth clean edges, and lead into a chamber and thus look dark. Feeding excavations are typically rectangular or irregular in shape, have rough edges, and do not lead into a cavity and thus appear relatively light.

Figure 4.20 Yellow-bellied sapsucker nest cavity.

Natural nest or den cavities are hollow chambers associated with an entrance hole formed by branch mortality or wounding (Figure 4.21). In contrast to woodpecker nests, entrance holes to natural nest cavities are rarely perfectly symmetrical and are often rimmed with callus tissue. Active cavities may show gnawing by mammals on the callus.

It is unusual to find six high value cavity trees on every hectare. Thus, trees with the following low value cavities may also be retained.

Figure 4.21 Natural nest cavity formed from an old branch stub.

Escape cavities. The fourth priority for retention are living trees with natural cavities that are not ideal nest or den sites for most species, but could be used by wildlife as temporary shelter or escape from predators (Figure 4.22). Cavities in these trees are usually not ideal for nesting or denning because of the location, size, or orientation of the cavity. Examples include: (i) trees with a cavity at ground level (little protection from predators); (ii) hollow trees with a large open seam (little protection from predators or weather); (iii) trees with a cavity whose entrance hole faces up and collects rain and snow (little protection from the weather); and (iv) trees that are hollow from top to bottom and thus have no platform to support eggs or young.

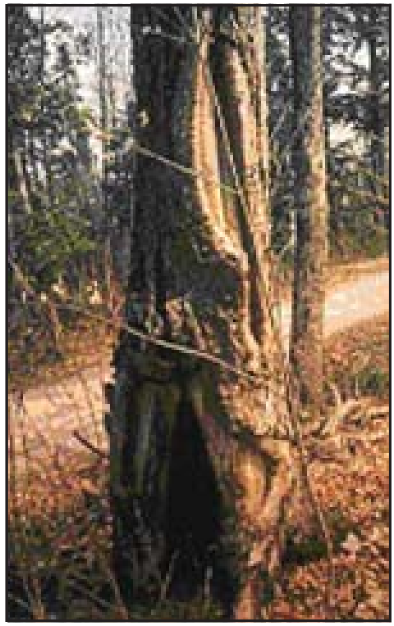


Figure 4.22 Escape cavities such as the church door opening in the base of this yellow birch, provide rest or roost sites but are not good nest or den sites for most wildlife.

Woodpecker feeding excavations. Living trees with feeding excavations created by pileated or other woodpeckers are the fifth priority for retention (Figure 4.23). Trees that are riddled with feeding excavations are likely past their most useful stage and are thus not the best candidates for retention. When retaining feeding trees, keep trees with a small number of fresh looking feeding holes.

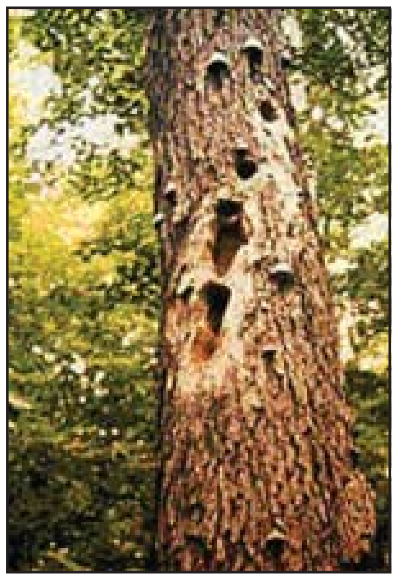


Figure 4.23 Feeding excavations. made by a pileated woodpecker.

High potential to develop cavities. When an average of six trees with existing cavities cannot be left per hectare, retain living trees with high potential to develop into cavity trees in the future (Figure 4.24). This includes trees with evidence of advanced heart rot in the bole (e.g., conks). Trees with large plates of loose bark that might provide habitat for roosting bats are also included in this category.

Other considerations when retaining cavity trees

Worker safety. Do not retain cavity trees with obvious safety hazards such as large dead limbs or dead tops. Place a tree length reserve around dead roost trees being retained.

Figure 4.24 This poplar has false tinder fungus conks along the length of its bole, suggesting it is an excellent potential cavity tree.

Size of tree. Bigger is better. Pileated woodpeckers generally nest and roost in trees at least 40 cm dbh and feed in trees at least 25 cm dbh. Moreover, small cavity-users can usually find holes in large trees but the reverse is not true. Thus, at least one of the six cavity trees per hectare should be a medium or large sawlog-sized tree. The other five cavity trees should be at least 25 cm dbh.

Species of tree. The majority of good nest or den cavities will be found in living hardwood trees. Retention of some living conifers with escape or feeding cavities is recommended since conifer (especially pine) cavity trees provide other wildlife values and, when dead, will provide long-lasting standing dead trees that may be used by a variety of wildlife, including roosting bats. When selecting among species of hardwoods for retention, consider rate/ease of cavity formation and cavity longevity. For example, poplars rot at an earlier age than maples and their wood is generally more conducive to excavation by woodpeckers. However, once formed, cavities in maples will have a longer life expectancy. Moreover, dead limbs on tolerant hardwood trees such as red oaks are generally a lower potential safety hazard than similar-sized dead limbs on intolerant hardwoods, especially white birch.

Dispersion. Since most cavity users are territorial, retain a relatively uniform distribution of cavity trees throughout each cut block. Some variation from six trees per hectare is expected since existing trees with cavities are rarely evenly distributed across a stand. Thus, some parts of a cut block may have as few as three cavity trees per hectare while other parts may have as many as nine cavity trees per hectare. The primary concern is that all cavity trees do not end up concentrated on one small portion of the cut block with the result that they are defended and exclusively used by relatively few cavity-users.

At the scale of the individual hectare, cavity trees do not need to be evenly spaced. Some clumping is acceptable and may even be advantageous. This is especially true for cavity trees retained on final removal cuts or clearcuts as clumping may reduce the risk of windthrow.

Risk and defect. Trees containing cavities will generally be classified as *unacceptable growing stock* and thus may have high risk or major defects. When selecting among cavity trees to retain, choose those with relatively low risk so they will stand and provide cavity habitat over the next 20 years. Also, select cavity trees with the least serious defects when possible. For example, when trees have equally good cavities, retain those with black bark, mossy top fungus, or false tinder fungus instead of those with spine tooth fungus, target canker, or cobra canker.

Multiple wildlife benefits. All things being equal, retain cavity trees that provide multiple wildlife benefits. For example, oak, beech, black cherry, and basswood cavity trees will also provide mast for a wide range of wildlife (see Table 4.1). Conifer cavity trees will provide thermal and access cover and will eventually form long-lasting standing dead trees when they die. Trees with loose bark may provide roosting habitat for bats.

Marking cavity trees in blue. Marking cavity trees to be retained with a small blue “W” is highly recommended. This will enable the marker to keep track of the number of wildlife trees retained, and makes the rationale for retaining the tree obvious to an auditor or logger.

4.3.2 Tree species diversity

Tree species diversity can influence the diversity of other wildlife groups in a stand (e.g., Menard *et al*. 1982). Markers should strive to maintain and perpetuate a mix of tree species within each stand through time that reflects the site conditions, the prevailing species association, and the species composition that would be created by natural disturbance processes (Box 4.7). This involves maintaining acceptable numbers of sexually mature individuals of each species to provide viable seed and creating the appropriate conditions for regeneration success (e.g., creating some group

Box 4.7 General principle for maintaining species diversity.

When selecting among trees of similar quality or spacing, favour retention of less common species (if they would be present following natural disturbance).

selection openings in a maple stand to encourage regeneration of mid-tolerant hardwoods).

While all tree species contribute to stand diversity, three groups of tree species have special importance to wildlife and are discussed in more detail (mast trees, scattered conifers, scattered hardwoods).

4.3.3 Mast trees

The term mast refers to the edible fruits of both overstorey and understorey plants. Soft mast, such as blueberries and cherries, and hard mast, such as acorns and beech nuts, are consumed by about 25% of birds and mammals within the GLSL forest (Table 4.1) (Naylor 1998a,b). Availability of these foods can have important implications for wildlife. For example, the abundance of soft and hard mast influences weight gain, reproductive rate, and cub survival in black bears (Rogers *et al*. 1988).

*Table 4.1 Selected wildlife species that consume mast. Symbols reflect the % of diet comprised by the mast species: + = < 2%, * = 2 to 5%, ** = 5 to 10%, *** = > 10% (data from Martin et al. 1951).*

Wildlife	Oak	Beech	Cherry	Hickory	Basswood	Walnut	Ironwood
Deer	***	+		+			
Black bear	***	***	***	+			
Raccoon	***		*	+			
Red squirrel	**	**	*	***	+	*	+
Grey squirrel	***	**	+	***	+	*	
Chipmunk	**	**	*	**	**		
Mice	**	+	+	+	+		+
Wood duck	***	*		**			
Ruffed grouse	***	**	**				
Wild turkey	***	*	+	*			
Downy woodpecker	+	+					+
Rose-breasted grosbeak	+	*	**	*			+
Cedar waxwing			***				
White-breasted nuthatch	***	+		+			
Blue jay	***	*	+	+			

A minimum of eight mast trees should be retained per hectare (0.5 to 1.5 m^2/ha) in all cuts when available (Naylor 1998a,b). However, a greater number may be retained to meet specific habitat or timber objectives. For example, stands with a large number of bear nests are likely important feeding areas for bears and thus mast production should be a key objective. Higher numbers of mast trees should also be retained in stands adjacent to deer yards (Voigt *et al*. 1997). Specific direction may be provided in the tree marking prescription.

When selecting mast trees for retention, consider the following seven criteria:

Species of tree. Red oak is the single most important mast-producing tree found in the GLSL forest. In order of relative importance, other suitable mast-producing trees to leave include other oaks, beech, black cherry, hickory, basswood, walnut (or butternut), and ironwood. A mix of species in each stand will minimize the chance of a total mast-crop failure.

Size of tree. Bigger is generally better. On productive sites, mast trees should be at least 25 cm dbh and ideally medium or large sawlog-sized trees. Ironwoods at least 10 cm dbh can be considered mast trees. On very shallow sites where mast trees may not attain a large dbh, leave the biggest trees available.

Crown position. Mast trees should be dominant, or better codominant trees.

Crown condition. Mast trees should have healthy, wide, deep, symmetrical crowns with lots of fine branches and few dead branches (Figure 4.25).

Figure 4.25 Good mast trees have wide, deep, symmetrical crowns with lots of fine branches and few dead branches. The beech on the left is a good mast tree, the one on the right is not.

Evidence of mast production. Trees of similar size and crown quality may vary inherently in mast production capability. When marking during the fall or early winter, look for evidence of mast (fruits or husks) in the crowns.

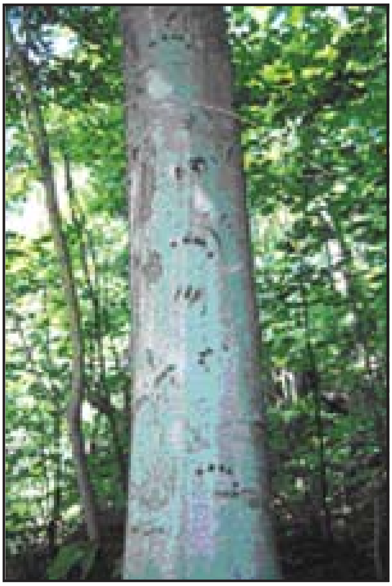


Figure 4.26 Many sets of bear claw marks may indicate that a tree is a consistent mast producer.

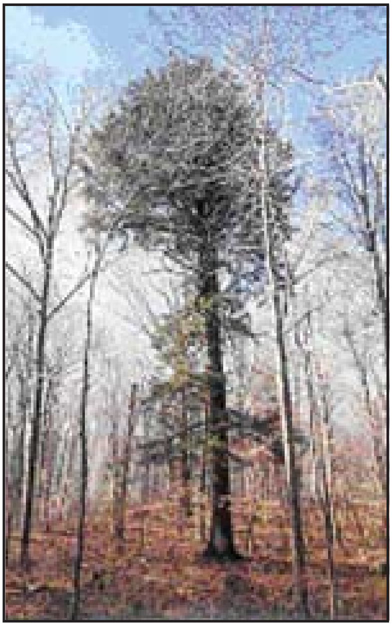


Figure 4.27 Solitary conifers are an important component of the habitat for about 10% of wildlife that inhabit tolerant hardwood forest.

Evidence of wildlife use. Look for trees with evidence of previous use by wildlife, such as beech trees with bear claw marks or bear nests (Figure 4.26). Trees with evidence of many years of use may be the most productive and consistent mast producers. However, bears can love some trees to death. The crown of some trees may be so severely damaged by bears that they would probably not be good choices to retain for mast production.

Risk and vigour. Leave trees that will stand and produce mast for at least 20 years. The best mast trees will be healthy, vigorous trees, usually without major defects. However, trees with major defects may have very healthy crowns and thus may still be good candidates to retain.

4.3.4 Scattered conifers in hardwood stands

Scattered conifers are used by about 10% of all the vertebrate wildlife that inhabit tolerant hardwood forest (Figure 4.27) (Naylor 1998a). For example, large scattered conifers are important as refuge trees and bedding sites for bears, especially in beech stands or hardwood stands near wetlands (Rogers and Lindquist 1992). Barred owls that nest and hunt in hardwood forest, roost in conifers during the day. Some songbirds such as the black-throated green warbler inhabit hardwood forest but need conifer clumps or solitary conifers for nesting. Even a few solitary conifers per hectare will increase the diversity of birds in a stand (Naylor 1998a).

In hardwood cuts, retain at least ten large conifers per hectare (0.5 to 2 m^2/ha). When there are fewer than ten conifers per hectare, mark to remove conifers only when they have high risk or low vigour and their retention will have a significant impact on habitat or silvicultural objectives.

When selecting solitary conifers for retention, consider the following four criteria:

Species of tree. Retain long-lived conifers such as hemlock, red or white spruce, white pine, or cedar where available. Rare species should be favoured (see Sections 4.1.1 and 4.3.2)

Size of tree. Retain trees at least 25 cm dbh, preferably medium or large sawlog-sized trees.

Risk and vigour. Retain trees with high vigour and low risk unless retained to meet cavity tree objectives.

Dispersion. Trees in clumps (three or more) are especially valuable. Solitary conifers within sight of large conifer pockets are likely less valuable than those isolated in a sea of hardwoods.

4.3.5 Scattered hardwoods in conifer stands

While scattered conifers in hardwood stands are an important consideration for wildlife, so too are scattered hardwoods in conifer stands. All mast-producing trees are hardwoods. High value nest and den cavities tend to be found in living hardwood trees. Moreover, about 5% of vertebrates that Heinhabit conifer stands use hardwood trees for some other purpose (Naylor 1998b). For example, male poplars produce big flower buds that are the staple diet of ruffed grouse during winter. Bears will climb large poplars in the spring to feed on the flushing buds. Many raptors nesting in conifer stands will preferentially select hardwood trees as nest sites (Figure 4.28).

Thus, retaining some hardwoods in conifer stands benefits a variety of wildlife species. However, while retention of some hardwood trees is

Figure 4.28 Scattered hardwoods in conifer stands provide mast, cavities, and nest sites.

beneficial, most trees retained in conifer shelterwood cuts should be those conifer species (e.g., white and red pine) that would have survived an understorey fire and regenerated the new stand.

In most cases, correct application of the stick nest, cavity tree, and mast tree guidelines should provide an adequate number of hardwood trees in the residual overstorey of conifer stands.

4.3.6 Supercanopy and veteran trees

Supercanopy trees are large (generally 60+ cm dbh) living trees that emerge above the main canopy of a stand (Figure 4.29). They create vertical structural diversity in the forest. Supercanopy white pines are commonly used by black bears as refuge trees and bedding sites (Rogers and Lindquist 1992). Their open crowns make them ideal nest, roost, or perch sites for large birds such as bald eagles, ospreys, turkey vultures, red-tailed hawks, and ravens (DeGraaf *et al*. 1992, Rogers and Lindquist 1992). Supercanopy trees are also aesthetically desirable, often viewed as *character trees*.

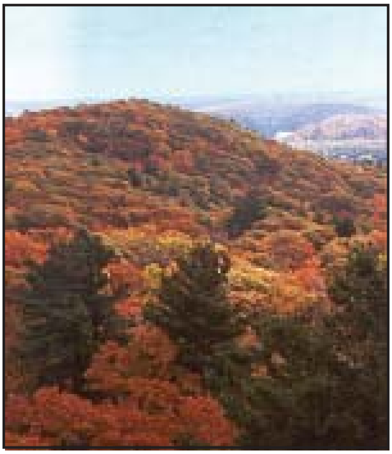


Figure 4.29 Supercanopy trees, such as these white pines emerging above the tolerant hardwood canopy, are aesthetically pleasing and provide nest, roost, and perch sites for a variety of large birds.

Supercanopy trees are often *veterans* that survived stand initiating disturbances. For example, residual pines that survive low to moderate intensity fires eventually become supercanopy trees as the new forest regenerates (Pinto *et al*. 1998).

Some supercanopy trees should be retained in all cuts. Current guidelines require the retention of at least one supercanopy tree (trees 60+ cm dbh) per four hectares when available (Naylor 1988a,b).

On final removal cuts and marked clearcuts, markers must also retain some trees that will become the supercanopy trees of the future (*veterans*). The number of *veterans* to be retained should be based on locally-relevant data (see Pinto *et al*. 1998) but should be at least ten per hectare if available. Veteran trees should have the following characteristics:

Species of tree. In tolerant and mid-tolerant hardwood stands, veterans may be any long-lived species. In pine and mixedwood stands, veterans should be long-lived species capable of surviving fires such as white pine, red pine, hemlock, white spruce, cedar, or red oak. On all sites, short-lived species like poplar, white birch, and balsam fir should not be retained as veteran trees.

Size of tree. Veterans should be dominant or codominant trees at least 25 cm dbh.

Condition of tree. Veterans should be sufficiently healthy and windfirm so they can reasonably be expected to live for another 50–100 years.

Overlap with other wildlife tree guidelines. Cavity trees, mast trees, scattered conifers, and supercanopy trees retained on final removal cuts or marked clearcuts (see previous sections) may be acceptable veterans if they meet the above characteristics.

4.3.7 Residual trees in clearcuts and shelterwood final removal cuts

The *Forest Management Guide for Natural Disturbance Pattern Emulation* (OMNR 2001b) requires the retention of a minimum average of 25 living or dead trees (≥10 cm dbh and ≥3 m in height) per hectare in all clearcuts and shelterwood final removal cuts (where there is not an acceptable break, as defined in the guide). At least six of these residual trees must be large diameter, living, high-quality cavity trees, or those with potential to form cavities. Application of the stick nest, cavity tree, mast tree, solitary conifer, supercanopy tree, and veteran tree guidelines described in this guide, in concert with the retention of seed trees, unmerchantable trees, and dead trees that are not a safety risk, should generally satisfy these requirements in marked clearcuts and shelterwood final removal cuts.

4.4 Reporting new values

Not all forest values encountered by a tree marker will have been identified during development of the forest management plan or the forest operations prescription. It is every tree marker's responsibility to report previously unidentified forest values and take appropriate action. A local data collection arrangement should be in place prior to marking a stand to enable rapid and smooth two-way communication of the value's physical features and enable a timely decision on the appropriate protection or mitigation measure.

4.5 Summary

Guidance for conserving biodiversity and wildlife habitat is summarized in Table 4.2.

Table 4.2 Summary of tree marking direction for the provision of wildlife habitat and the conservation of biodiversity.

General principles for conserving biodiversity	Ecosystem diversity	• apply silvicultural practices that perpetuate the natural diversity of forest communities across the managed landscape (i.e., maintain oak forest on oak sites, hemlock forest on hemlock sites etc.) • maintain a natural mix of tree species within each stand—when selecting among trees of similar quality and spacing, favour retention of the less common species
	Species diversity	• protect critical and sensitive habitats for rare species • maintain special habitat features required by rare and common species
	Genetic diversity	• apply correct marking principles (e.g., retain appropriate crop trees) • for isolated stands of regionally rare tree species (e.g., red spruce), retain at least ten individuals per hectare and at least 100 individuals per stand
Protecting critical and sensitive habitats	Stick nests	• stick nests belonging to bald eagles, ospreys, great blue herons, red-shouldered hawks, Cooper's hawks, northern goshawks, and great gray owls must be protected by appropriate guidelines • retain trees containing stick nests belonging to common species (broad-winged hawks, red-tailed hawks, sharp-shinned hawks, barred owls, long-eared owls, great horned owls, merlins, or ravens), and adjacent trees with touching crowns in selection and most shelterwood cuts • in clearcuts and shelterwood final removal cuts, retain individual trees containing small nests (< 75 cm dia) of common species; retain nest tree within a residual patch at least 0.25 ha in size for large nests ($\geq$ 75 cm dia) of common species in good repair (or inactive nests of rare species) • as a minimum, accurately map (GPS) and report (Appendix K) stick nests considered AOCs
	Winter cover in deer yards	• defer from harvest or maintain at least 60% conifer canopy closure (about 24 m^2/ha) in trees 10 m or greater in height in stands providing critical thermal cover—hemlock, red spruce,and cedar provide the best cover—some clumping of residuals is better than a completely uniform spacing • maintain at least 80% canopy closure over bedding sites and well-used travel corridors (24 m^2/ha of conifer BA within a tree length radius) • in hardwood selection cuts, to maintain access to food: - maintain at least 60% canopy closure in pockets ($\geq$ 0.04 ha) of conifers - retain clumps of 3–5 conifers (at least 10 m tall) spaced 10–60 m apart - retain solitary scattered conifers when they link shelter patches • in shelterwood removal cuts and clearcuts, to maintain access to food: - retain clumps of 3–5 conifers (at least 10 m tall) spaced 10–60 m apart, unless regeneration is 10 m tall (5 m for hemlock or cedar)
	Moose winter cover	• follow guidance for deer (above) to maintain thermal cover for moose
	Moose summer habitat	• maintain high residual canopy closure (80%+) in patches of summer thermal shelter • follow prescription for marking within AOC surrounding aquatic feeding areas
	Edges, ecotones, and interior habitat	• maintain a high residual basal area (20+ m^2/ha), a high canopy closure (70+%), produce only small canopy openings, and maintain a 30 m uncut buffer along hard edges in woodlots that contribute to the supply of significant interior habitat in highly fragmented landscapes
	Old growth forest	• to retain more of the key habitat and aesthetic features of old growth hardwood forest: -maintain a higher BA throughout the cutting cycle -adjust stand structure to maintain a larger mean and maximum tree size -create more variability in canopy gap size by including some group selection openings to encourage regeneration of mid-tolerant hardwoods -increase canopy residence time by reducing the proportion of BA removed in each cut or lengthening the cutting cycle -retain more cavity trees -retain more downed woody debris on site

Table 4.2 Summary of tree marking direction for the provision of wildlife habitat and the conservation of biodiversity—continued.

Protecting critical and sensitive habitats	Riparian forest and fish habitat	• modify marking within 30–90 m of waterbodies providing fish habitat based on slope and type of aquatic ecosystem • retention of stick nests, cavity trees, and supercanopy trees is especially important in riparian areas
	Small streams, seepages, and woodland pools	• avoid marking trees within or on the edge of small streams, seepages, and woodland pools (retain 70%+ canopy closure) • retain at least 50% stocking within a tree length of significant (> 200 m^2 surface area) woodland pools
	Wetlands	• apply guidelines for fish, waterfowl, moose aquatic feeding areas, ospreys, and herons as appropriate • create some larger openings (40+ m wide) adjacent to some wetlands containing beaver lodges • for forested wetlands, consider autecology of tree species, sensitivity of site, and other habitat concerns
	Rare vascular plants	• report and protect patches (tree length reserve) of Braun's holly fern, ram's-head lady's-slipper, American ginseng, and pine-drops
	Species at risk	• markers should be aware of the species at risk that occur in their local area, their habitat requirements, local direction for their protection, and any legal obligations they may have associated with legislation such as the *Endangered Species Act* • report new sightings of species at risk to local District biologists or ecologists
Maintaining special habitat features	Cavity trees	• retain at least six living cavity trees per hectare (0.5 to 1 m^2/ha) based on the following order of priority—trees with 1. pileated woodpecker roost cavities 2. pileated woodpecker nest cavities 3. other woodpecker nest cavities or natural den cavities 4. escape cavities 5. woodpecker feeding cavities 6. high potential to develop cavities • retain a mix of species • trees should be at least 25 cm DBH (at least 1/ha medium or large sawlog-sized), with no obvious safety hazards
	Mast trees	• retain a minimum of eight mast trees per hectare (0.5 to 1.5 m^2/ha) • oaks are best—beech, black cherry, and hickory are good— basswood, walnut, butternut, and ironwood are fair—a mix of species is good • retain dominant or upper codominant trees at least 25 cm DBH and preferably medium or large sawlog-sized • retain trees with wide, deep, symmetrical crowns with lots of fine branches and few dead branches • retain trees with evidence of use by wildlife (e.g., bear claw marks) if crowns are in good condition
	Scattered conifers in hardwood stands	• retain at least ten large conifers per hectare (0.5 to 2 m^2/ha) • retain long-lived conifers such as hemlock, red spruce, white spruce, white pine, or cedar that are at least 25 cm DBH and preferably medium or large sawlog-sized
	Scattered hardwoods in conifer stands	• follow guidelines for stick nests, cavity trees, and mast trees to maintain some hardwoods in all conifer stands
	Supercanopy trees	• retain at least one supercanopy tree (60+ cm DBH) per four hectares
	Veterans	• on clearcuts and final removal cuts, retain at least ten vigorous dominant or codominant trees per hectare capable of becoming future supercanopy trees • retain long-lived species that can grow for another rotation such as tolerant hardwoods, oaks, white pines, red pines, white spruces, cedars, and hemlocks
	Residual trees on clearcuts and final removal cuts	• retain an average of 25 living or dead trees ($\geq$ 10 cm dbh and > 3 m tall) per hectare in clearcuts and final removal cuts (where necessary, as described in the guide) • at least six must be large-diameter living cavity trees or have future potential to form cavities • other trees may include stick nests, mast trees, solitary conifers, supercanopy trees, veterans, seed trees, unmerchantable trees, and dead trees that are not a safety risk

5.0 Developing and interpreting silvicultural prescriptions

by E. Boysen, S. Reid

A silvicultural prescription is a site and stand-specific operational plan that describes the forest management objectives and activities for an area. It prescribes a series of silvicultural treatments that will be carried out to establish or maintain a free growing stand in a manner that accommodates other resource values such as wildlife habitat and the conservation of biodiversity.

Prescriptions are developed through a series of steps. The first step of development deals with gathering information about the stand such as species composition, tree diameters, wildlife habitat and tree quality. This information is then analysed to formulate objectives and prescribe appropriate treatment.

5.1 Analysing the stand

All forest stands should be analysed **prior** to developing either the long term or short term objectives for that stand. This is accomplished through the process of timber cruising, which can involve anything from an extensive walk-through to an intensive survey, depending on the complexity of the stand and the consequences of an inaccurate assessment.

Data collected can be stored as a record of the stand condition prior to harvest, and then compared with data collected in the future to verify that the relative proportion of AGS stock is increasing, or that species composition targets are being met.

An example of a stand analysis field tally, suitable for most purposes is provided in Appendix B. Table 5.1 provides the type of stand and tree level information normally required for prescription setting.

Sampling intensity, cruise organization and data analysis

An individual with a sound silvicultural background should inspect the stand before commencing the tree marking operation. This allows for the necessary verification and ground-truthing of the tree marking prescription.

Table 5.1 Information gathered during a forest inventory.

Stand level information	Tree level information
• observable site features, e.g., landform, topography, soil depth, drainage features	• tree species
• access, e.g., winter or all season roads, trails, etc.	• quality class, i.e. AGS or UGS
• moisture conditions, e.g., dry, fresh, wet	• size class, i.e. polewood, small/ medium/large/(and for some treatment objectives) very large sawlogs
• regeneration by species and abundance: Little <10% ground cover Moderate 10% - 30% ground cover Ample 31% - 60% ground cover Heavy >60% ground cover	• note: If volume estimates are required, the tree level data should be collected by 2 cm dbh classes. An estimate of stand height is also required for even-aged stands.
• wildlife attributes observed - record location of stick nests if present	
• other observations that may help to define the appropriate silvicultural system, and to develop the prescription, e.g., season of operation (all season, winter only)	

An extensive survey or reconnaissance survey, usually sampling less than one percent of the stand area, can be used to verify marking prescriptions. An intensive survey is recommended for prescription development, in which case a 2–5% sample will usually suffice, depending on the variability of stocking and species composition. When sampling for volume estimates, it may be necessary to sample 10% of the stand.

To ensure a proper stand analysis, gather the information required using a BAF 2 metric prism. This is the simplest and quickest method. Instructions for use of the wedge prism (basal area estimation) and the clinometer (height estimation) are found in Appendix C. Fixed area plots of different sizes can be used where the prism provides less accuracy (such as in young plantations or dense hardwood stands where it is not possible to distinguish individual stems), or for intensive surveys where a permanent record of the forest is required. When using fixed area plots, circular plots are recommended—for a 200 m^2 plot, plot radius is 7.99 m; for a 400 m^2 plot, plot radius is 11.28 m.

The steps to follow when planning an operational cruise include:

1. Lay out all cruise lines in the office before going to the field.
2. Regardless of the sampling method used, establish one sample point for every two hectares in the stand, with a minimum of ten sample points per stand.
3. For stands greater than 20 hectares, add a sample point for every additional five hectares. Gathering data from an **even** number of plots when sampling with a BAF 2 prism will make the subsequent stand analysis calculations easier.
4. On the stand map, lay out the sampling or cruise line so that it provides samples from the entire stand. If aerial photos show that the stand is **not** uniform, delineate each unique area, and sample them as separate units.
5. Begin the sample line at an easy-to-find point on the map and in the field.
6. Keep a minimum of 40 m away from any stand edge.
7. Keep sample points approximately 80 m apart. This will ensure that you do not sample the same large tree from two different sampling points.
8. When sampling many stands, lay out the cruise lines to minimize the amount of *off-setting*, or travel time between sampling lines.
9. Mark the location of each plot centre on the ground with flagging tape. Use a more permanent marker if the plot will be re-measured at some point in the future.
10. Record the tree level attributes on the tally sheet using the dot tally method (one dot for each tree sampled).
11. Accumulate all data gathered for the stand on a single tally sheet.
12. Be sure to record plot numbers, as this will be critical in the calculation of the stand's basal area.
13. For borderline trees, a plot radius table (calculated with the following formula) can be used to determine whether the tree is actually in the plot. A plot radius table is provided in Appendix D. Alternatively, tally every other borderline tree where precision is less critical.

$$\text{Distance(m)} = \sqrt{\frac{0.25 \text{ x } dbh^2(cm)}{BAF}}$$

14. Using the tally sheet in Appendix B, total the number of trees tallied—by species in the right hand column, and by quality class/ size class at the bottom of the tally.
15. Calculate the basal area/ha using the formula shown on the tally sheet.

5.2 Developing the prescription

The stand analysis should provide sufficient information to set long and short term objectives. Once those objectives are established, an appropriate prescription can be developed.

The long-term objective should describe the desired future forest condition including the state of relevant values (aesthetics, habitat, and timber quality) at the stand and landscape level and the choice of silvicultural system to be followed. The management practices required over the longer term should also be specified (site preparation, planting, tending, and protection). Short term objectives will describe specific stand targets to achieve in the next five years which include desired residual stocking and structure, species composition, harvesting considerations, stand level habitat and biodiversity concerns, and marking restrictions in areas of concern. Objectives are defined in the forest management plan.

The following steps will help in the development of a prescription.

- Compare the actual basal area, by size class, to the stand structure targets to determine surpluses or deficits in the desired stand structure or quality classes.
- Use the forest inventory information to access the appropriate treatment key, and follow the recommended decision path as a guide.
- A prescription is not a ruling doctrine but should be viewed as a working hypothesis; i.e., a best estimate based on available information. At the same time, it must be realized that any treatment that is applied now is likely to restrict the choices available in subsequent treatments (Smith 1962). Keep in mind that while the prescription is usually based on a sample of less than 5% of the stand, the tree markers will see 100%. The prescription should be flexible enough to allow the markers to react and adjust to unanticipated stand conditions or features.

- Each prescription should refer to the appropriate wildlife habitat and biodiversity concerns summarized in Table 4.2. The tree marking direction shown in Table 4.2 represents the minimum requirement but managers may choose to increase certain values within their area. For example, a prescription dealing with cavity trees, mast trees and solitary conifers might recommend retention of ten of each of these values in their prescriptions, even though Table 4.2 recommends 6, 8, and 10 respectively.

An example of how the information required in a typical tree marking prescription can be organized is shown in Appendix E.

5.3 Overstorey treatment keys for silvicultural prescriptions

by S. Reid, J. Leavey, A. Stinson, K. Webb, F. Pinto

A series of overstorey treatment keys for partial cutting management systems are provided for even-aged plantations, white and red pine forests, eastern white cedar, hemlock, spruce, jack pine, and the tolerant hardwoods (Figures 5.1–5.7 respectively). The intent of the keys is to provide some guidance to the marker in situations where a condition is encountered that was not anticipated in the silvicultural prescription.

To effectively apply treatment keys, tree markers must be aware of the tree species composition, basal area, stand quality (AGS/UGS), and treatment objectives for the stand. All silvicultural systems developed using these keys must be consistent with established guidelines, ground rules, and policies (examples include OMNR 1997, 1998a & b; Szuba and Naylor 1998; and OMNR 2000).

The tree marker should be aware of the limitations under which forest management activities may take place, as outlined in the forest management plan. When tree markers are uncertain of these limitations, they should consult with the prescription writer or forest management plan author. Any modifications to the prescription should be reported to the prescription writer so that required follow-up silvicultural work can be incorporated into the annual work schedule.

Stand objectives: To optimize quality and growth on crop trees, while addressing habitat and biodiversity guidelines wherever possible in even-aged plantations.

<table>
<tr><th colspan="3">CONIFERS</th></tr>
<tr><td colspan="3">Refer to A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario (1998b) (see Density Management Diagrams in Appendices B and G) or other appropriate silvicultural guides for thinning recommendations.</td></tr>
<tr><th colspan="3">COMMERCIAL THINNING STAGE</th></tr>
<tr><th>1ST</th><th>2ND</th><th>Subsequent Thinning</th></tr>
<tr><td>Row or strip thinning: usually mark every fourth row for removal. This initial thinning is needed to gain access to the entire plantation. It may include some selective low thinning in remaining rows; maximum basal area (BA) reduction is 33%, i.e., 25% from selected row and 8% maximum from remaining rows. Marking must concentrate on the removal of suppressed and low quality stems in the middle three rows.</td><td>Marking should concentrate on removing any remaining suppressed, sub-dominant or poorly formed trees.

Should also include a light to moderate crown thinning that favours the better stems within the stand. Maximum of 20% BA reduction, which if done correctly would translate into about a 30 to 35% reduction in the number of stems.

Special Consideration:
Larch plantations require a heavier crown thinning to give the larch crop tree crowns additional space to develop.</td><td>Moderate crown thinning to further release the better crop trees.

Special Consideration:

Larch plantations should have moderate to heavy crown thinning to ensure adequate space for larch crown development.

In later stages of growth the selected larch crop trees are virtually isolated, or at least have free growing space for crown expansion.</td></tr>
<tr><th colspan="3">HARDWOODS</th></tr>
<tr><td colspan="3">No detailed rules can be laid down for the thinning treatment of hardwood plantations other than those described for conifer plantations. There are very few hardwood plantations in the GLSL forest region, and each case must be judged on its own merits. With an objective of growing high quality timber, poor quality trees, however large, should be removed early to ensure a better quality residual crop. Light thinning should be the rule until straight stems and reasonable height growth have been obtained. Subsequent opening up of the stand may begin at rates varying with the crop species, desired products, and particularly with their ability to tolerate shade. Relevant habitat and biodiversity guidelines should be applied.</td></tr>
<tr><th colspan="3">MIXTURES</th></tr>
<tr><td colspan="3">In mixed crops the forest manager is able to exercise control over the composition and development of the mixture through well-planned thinning.

With an objective of growing high quality timber, the general rule should be to encourage the best-formed trees, regardless of species, and to eliminate all wolf trees and whips. In some cases the mixed plantation may have groups within the stand where one species dominates the mixture, while in other areas another species performs better. These groupings can be favoured within the plantation and in the end there will be a satisfactory mixed crop, in a patchy configuration.

In most cases, trying to release badly suppressed or weak subdominant trees at the expense of thriving dominants is seldom successful.

See Section 6.5 for additional discussion on thinning practices.

(Adapted from The Thinning of Plantations. 1955. Forestry Commission, Forest Operations Series No. 1. London. Her Majesty’s Stationery Office).</td></tr>
</table>

Figure 5.1 Treatment of even-aged plantations.

Stand Objectives: Maintain or enhance the abundance of white and red pine.

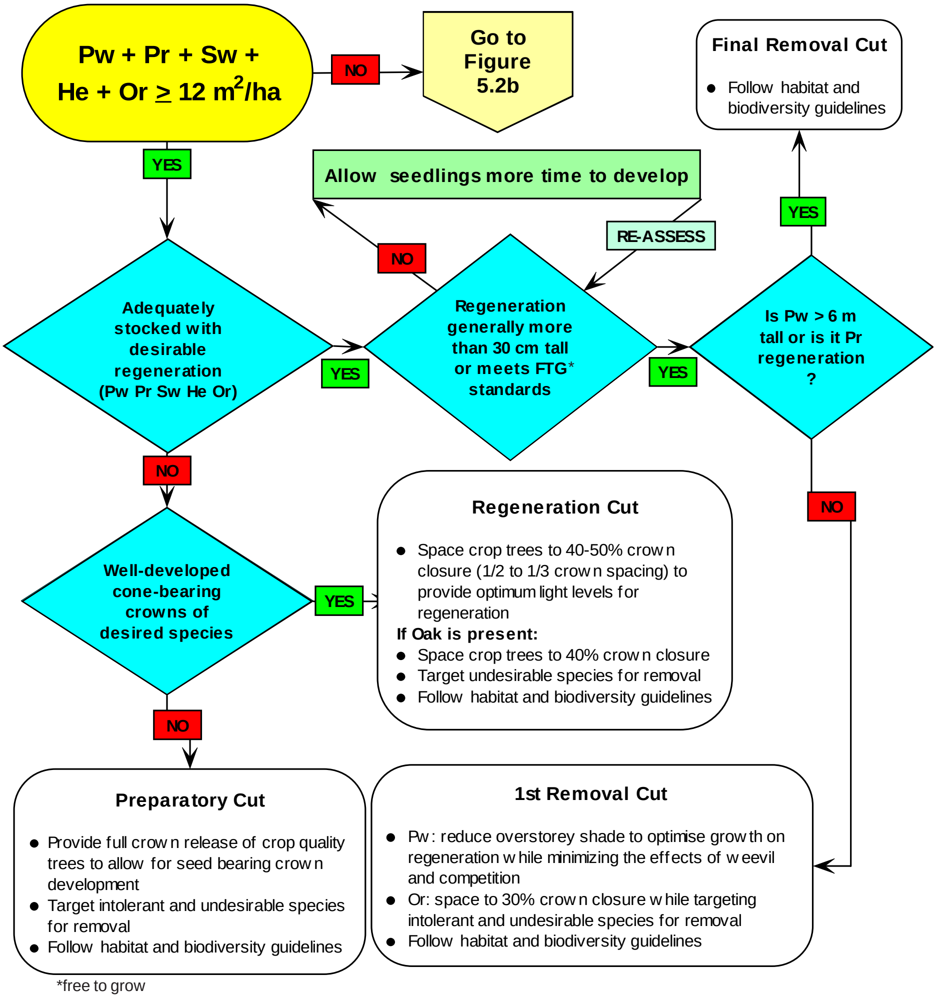


Figure 5.2a Overstorey treatment key for Pw and Pr where dbh > 10 cm. and Pw, Pr, Sw, He and Or component ≥ 12 m²/ha.

Stand Objectives: Maintain or enhance the abundance of white and red pine.

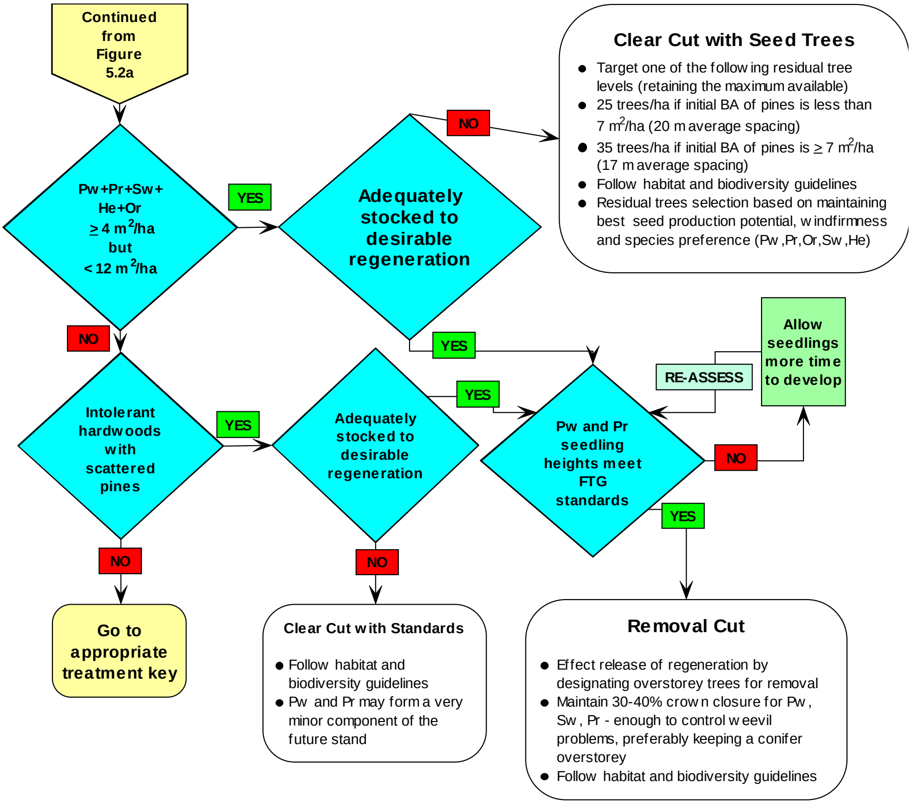


Figure 5.2b Overstorey treatment key for Pw and Pr where dbh > 10 cm., and Pw, Pr, Sw, He and Or component < 12 m²/ha

Stand Objectives: Maintain or enhance the abundance of white cedar.

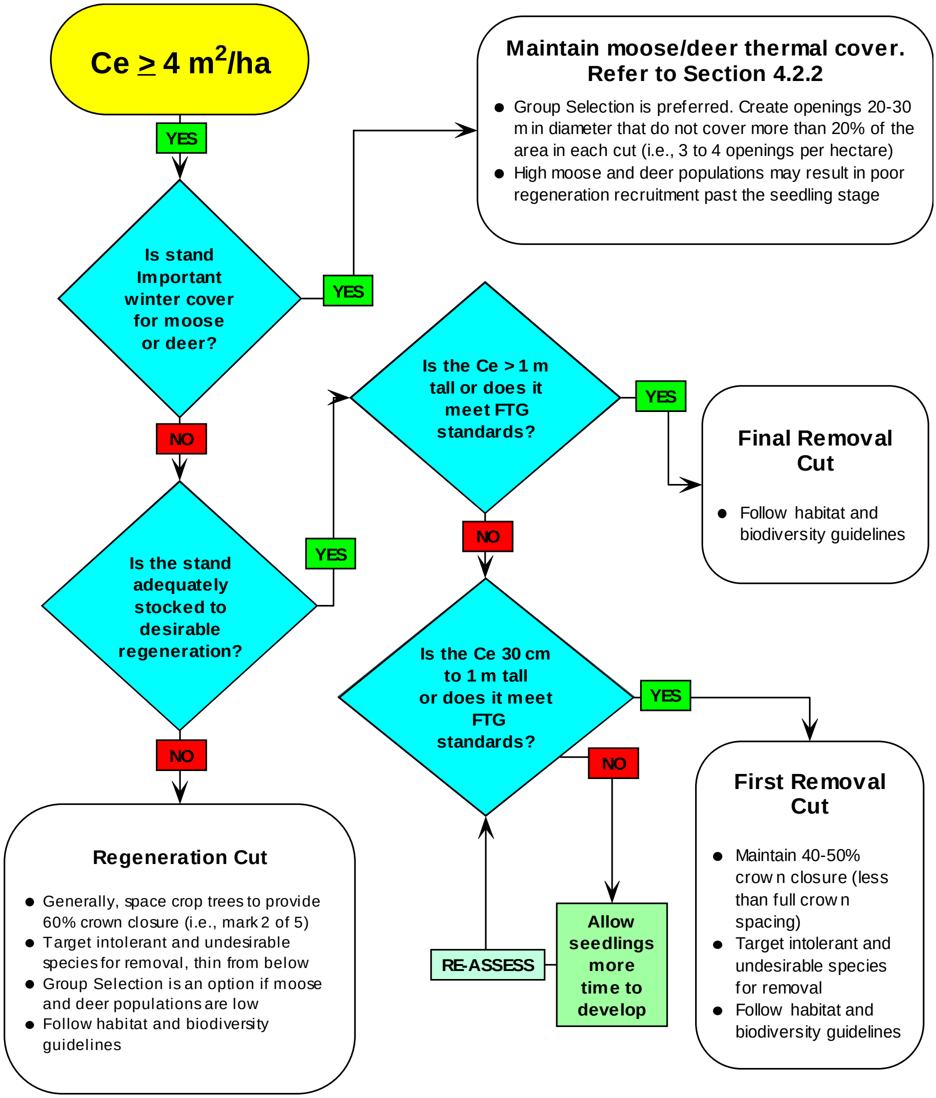


Figure 5.3 Overstorey treatment key for Ce where dbh > 10 cm.

Stand Objectives: Maintain or enhance the abundance of hemlock.

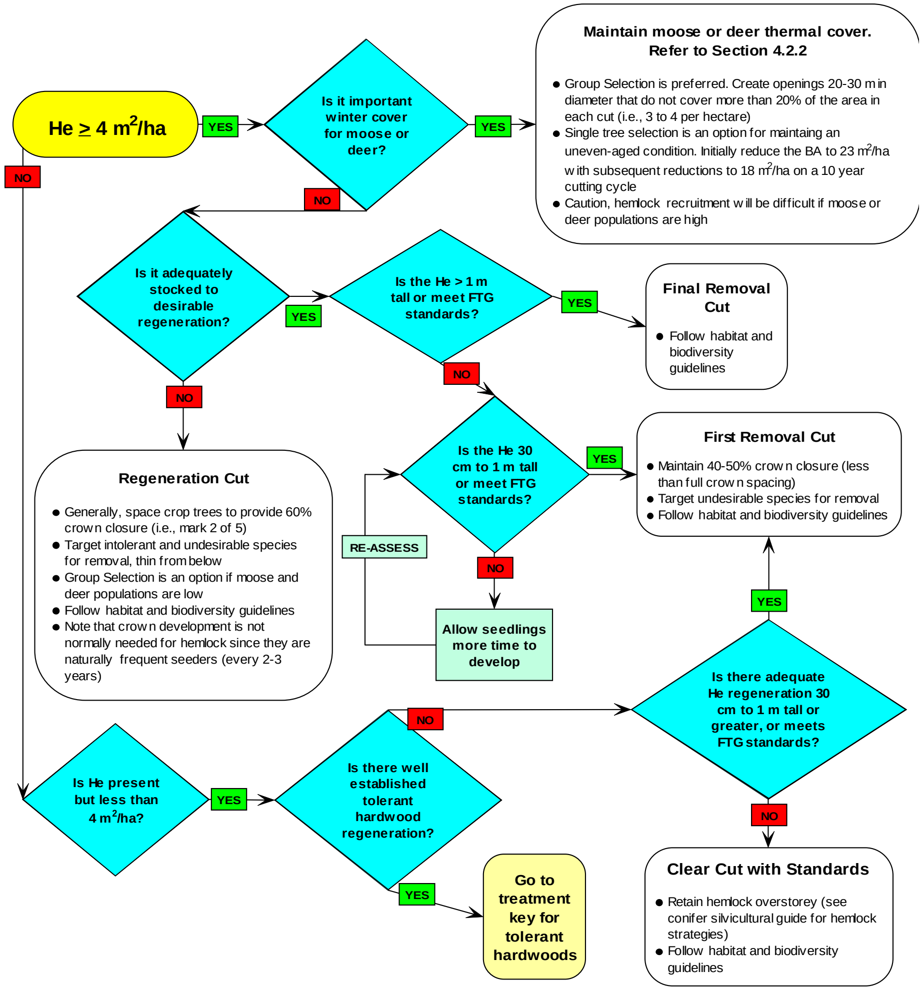


Figure 5.4 Overstorey treatment key for He where dbh > 10 cm.

Stand Objectives: Maintain or enhance the abundance of spruce.

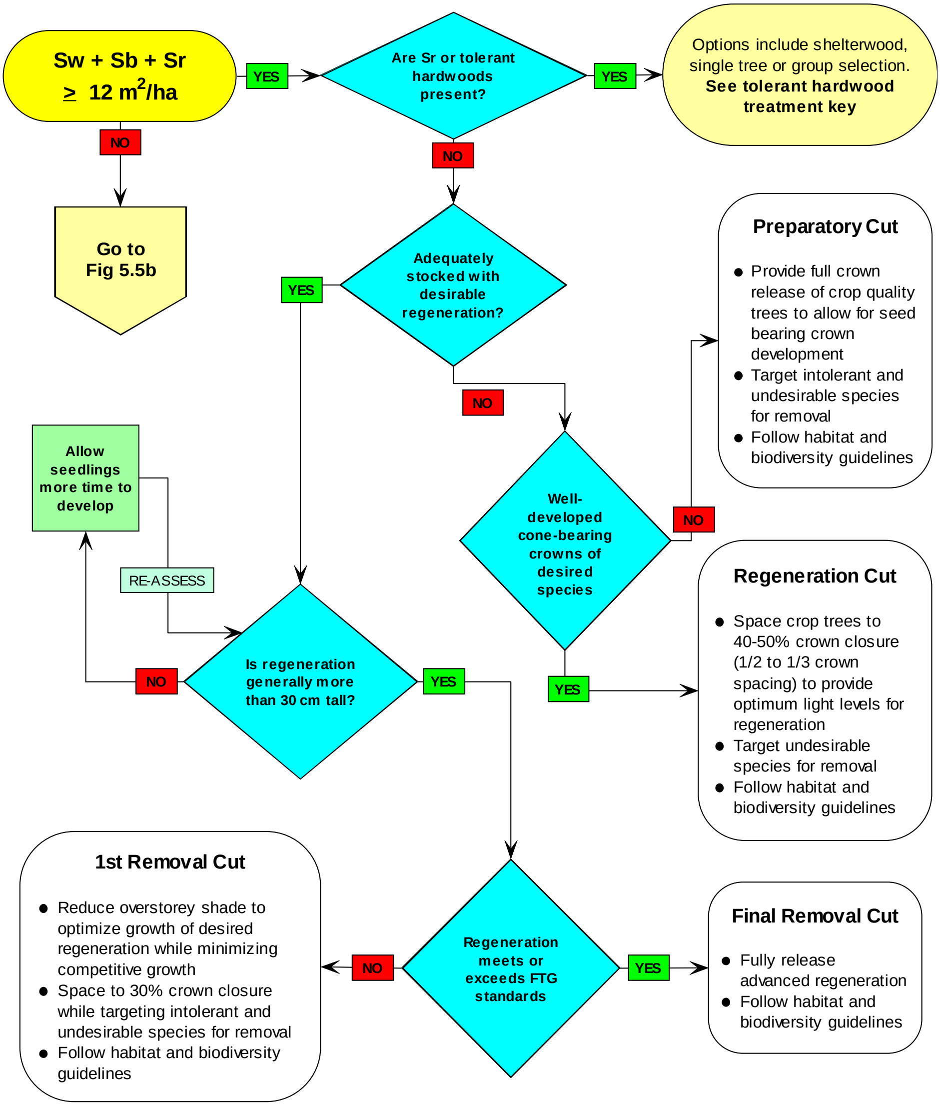


Figure 5.5a Overstorey treatment key for spruce where dbh > 10 cm and spruce component ≥ 12 m²/ha.

Stand Objectives: Maintain or enhance the abundance of spruce.

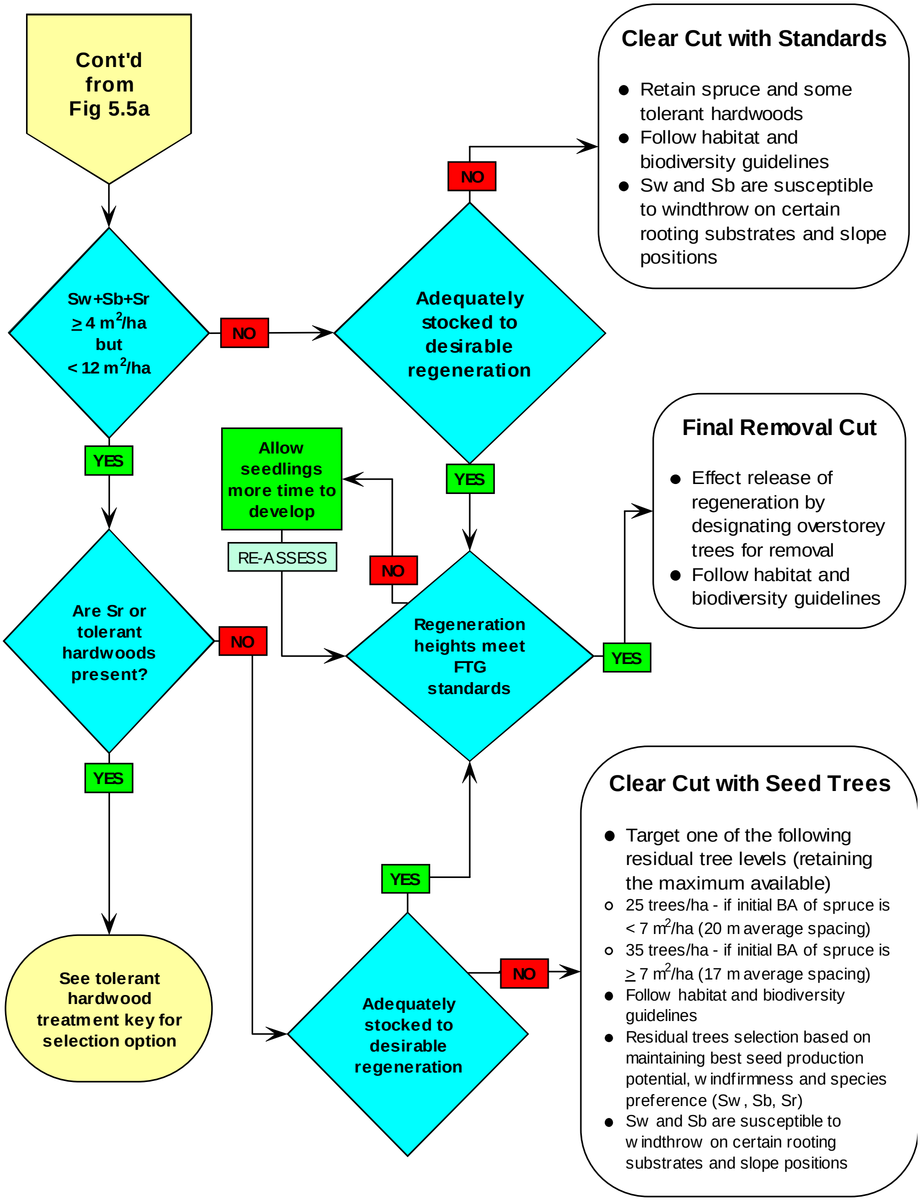


Figure 5.5b Overstorey treatment key for spruce where dbh > 10 cm and spruce component < 12 m^2/ha.

Stand Objectives: Maintain some of the structural components of the original stand and naturally regenerate jack pine.

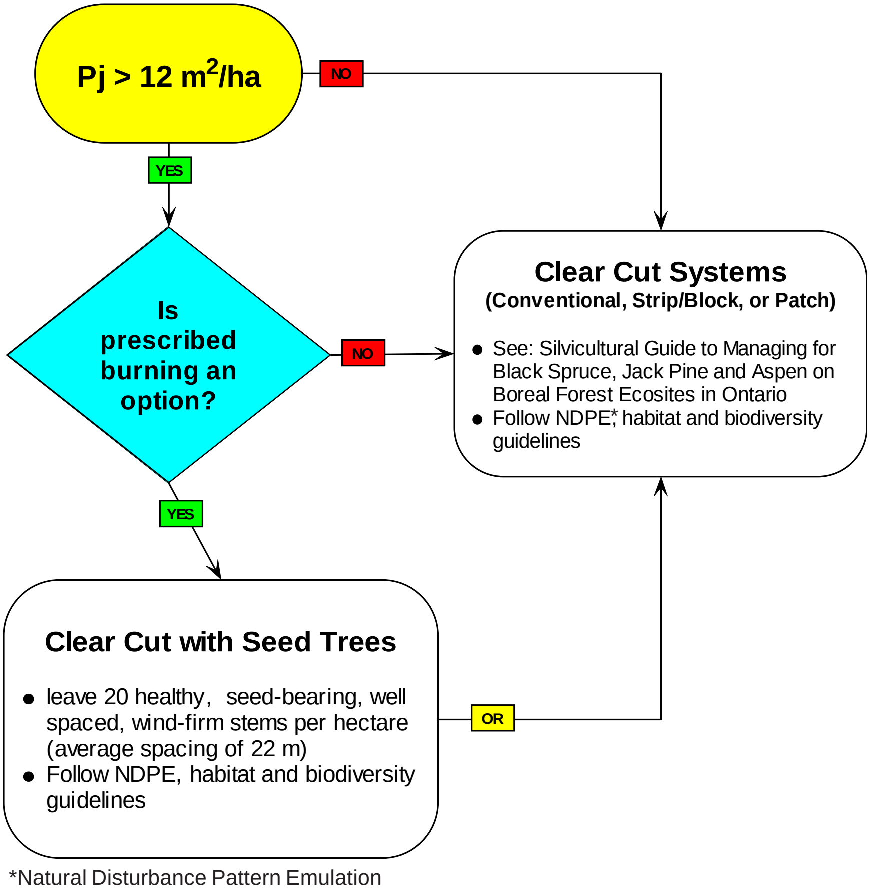


Figure 5.6 Overstorey treatment key for jack pine where dbh > 10 cm regenerate jack pine.

Stand Objectives: Maintain or enhance the quality and abundance of tolerant hardwoods.

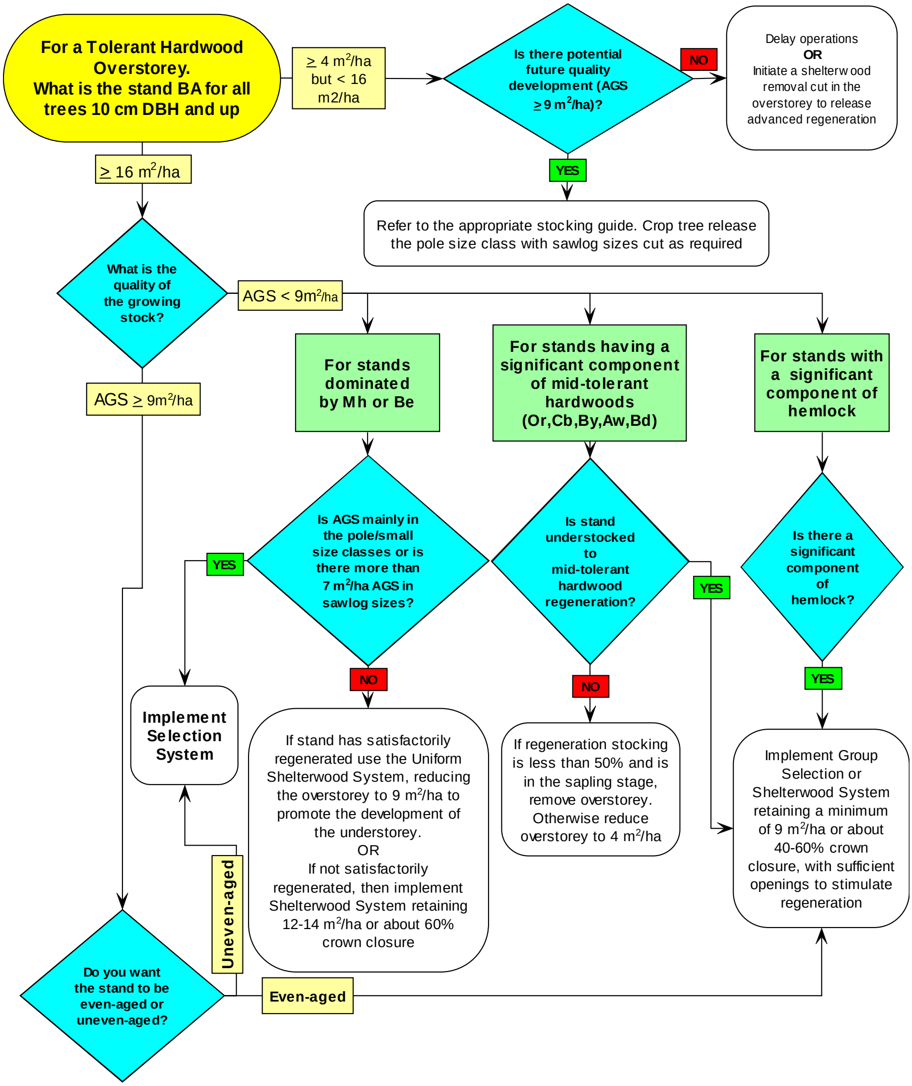


Figure 5.7 Overstorey treatment key for tolerant hardwood forests where dbh > 10 cm (including red spruce).

6.0 Implementing tree marking prescriptions

Achieving the objectives of a silvicultural prescription ultimately relies on decisions tree markers make in the forest. Tree markers must apply the prescription to the best of their ability, under the conditions they encounter as they traverse the stand. Often conditions change; stocking levels, species composition, forest structure and health are all quite variable. Therefore, a tree marking crew must be attentive and ready to adjust marking patterns to suit newly encountered forest conditions. Information in this chapter will help tree markers effectively implement a silvicultural prescription by providing marking guidance for a variety of prescription types and silvicultural systems.

6.1 Single tree selection

by A. Corlett, K. Wright

Single tree selection is a silvicultural technique used to encourage the development of all-aged forests dominated by shade tolerant species. Emphasis is placed on controlling the levels of residual stocking, stand structure and individual tree quality through the tree marking process. NOTE: selection management should not be confused with *selective cutting*. Selective cutting involves the selection and harvesting of individual trees with few if any control measures in place. The process is also known as *high-grading*.

What is single tree selection?
A periodic partial-cutting, controlled by basal area, using vigour and risk characteristics to determine individual tree selection. An uneven-aged silvicultural system.

6.1.1 Where is single tree selection appropriate?

On sites suited to shade tolerant species, single tree selection is one of the most effective systems for the production of high quality sawlogs and veneer. The manager's decision to adopt the single tree selection approach is based on:

The shade tolerance of the targeted species. The desired species must be *shade tolerant*, well adapted to regenerate and grow in low light conditions. A related asset is the capacity to respond to periodic release, sometimes following many years of suppression (such species as sugar maple are referred to as *elastic* in their ability to respond to release).

Site quality. Growth and quality development for tolerant hardwoods are optimized on productive, relatively deep, well-drained upland sites. Markers should be aware of the implications of site variance within a stand: e.g., sites with a rooting limitation (high water table or bedrock) are often more suited to mid-tolerant species such as red oak, white ash or yellow birch; which will not perform as well under a single tree selection approach.

Quality of the overstorey. A minimum of 9 m^2/ha AGS in trees 10 cm dbh and larger, or 7 m^2/ha in trees 24 cm dbh and larger is usually considered adequate for the effective application of the selection system. The system may be applied in areas with a lower AGS level if other forest objectives (aesthetics, habitat, etc.) take priority over timber production, but anticipated sawlog volume and quality development will be reduced.

Other considerations:

- High levels of crown closure will discourage the establishment and survival of mid-tolerant species. Modifications to the system (e.g., larger canopy openings using group selection), and often site preparation, must be carried out to accommodate the maintenance of a mid-tolerant species component within a stand dominated by shade tolerant species. Recognizing and acting on those opportunities to maintain other species groups is an example of site specific, intensive management.

- The first entry of the selection system is usually a *stand improvement cut*, following one (or more) historical unregulated harvests. Such a harvest normally includes a high component of low value material. Markets for the marked but less marketable material (the fuelwood/ pulpwood component of the harvest) will dictate the cost of treatment, or even the manager's ability to meet the complete silvicultural objective. **It is important that tree markers focus on sound silvicultural principles, keeping the health and sustainability of the forest in mind at all times, and allow the manager to address challenges in the marketplace.**

6.1.2 Tree marking for a single tree selection harvest

Single tree selection is one of the most difficult systems to apply. Tree markers must focus on both the long and short-term objectives of management while remembering:

- Selection is an all-aged approach. Growth is optimized only when the dbh class distribution or stand structure is balanced.
- The degree of harvest is based on a basal area target. The basal area target will contribute to the optimization of stand growth if set at a level that reflects site potential.
- Selection of individual trees to retain or harvest is based on vigour and risk indicators. AGS trees tend to respond more quickly to release and increase in volume and value at a much faster rate than UGS trees.

The critical elements to consider when carrying out a single tree selection prescription are *stocking, stand structure,* and *quality*.

Stand stocking

When assessing pre-harvest stocking levels, tree markers should ask the following questions:

Has the stocking level reached a point normally consistent with the end of a cutting cycle and the scheduling of a harvest (normally, at least 25 m²/ha)?

Stocking levels lower than this may indicate a need to delay harvesting for a few years. An alternate solution is to consider reducing the level of harvest. This approach will protect long-term quality development but will reduce financial returns from the current harvest operation.

How variable are stocking levels across the stand?

Usually a function of past management, this condition may also be the result of site variability. Tree markers must ascertain the intent of the prescription writer. Should a defined residual stocking level be rigidly adhered to throughout the stand, or to what degree can the marker adjust post-harvest basal area as quality and initial stocking vary?

Does the targeted residual basal area (BA) meet the requirements of all species desired as a component of the future forest?

For example, localized hemlock concentrations may dictate a higher residual basal area while the existence of areas suited to the regeneration of a mid-tolerant species such as yellow birch or black cherry may dictate a lower residual basal area.

Tree markers should focus on the targeted residual basal area specified in the silvicultural prescription. The residual stocking level is one of the principal factors influencing future stem quality (clear bole length), growth potential of residual trees and ultimately the volume and quality that can be sustainably harvested. Tolerant hardwood marking prescriptions will specify a target residual basal area, often in the range of 18–20 m^2/ha.

Figure 6.1 roughly illustrates the projected growth response patterns for an idealized stand harvested to a range of residual stocking levels. The original data for this chart (see OMNR 1983) included the sawlog component (trees > 24 cm dbh) only. That information was modified to include the assumed contribution of the polewood component. While some error was no doubt introduced, the information should allow managers to relate the information more readily to a typical prescription specifying all trees >10 cm dbh. Retention of a higher or lower stocking level than the optimal will have the following consequences:

- At higher residual basal areas, most tolerant hardwood stands are overstocked, with little room for crown expansion. Potential growth is restricted due to crowding.
- At lower residual basal areas no suppression occurs. Individual tree growth may be high, but the growing space is underutilized. Not only is stand growth reduced but quality can also be adversely affected due to higher incidence of sunscald, epicormic branching, and shorter clear bole lengths.

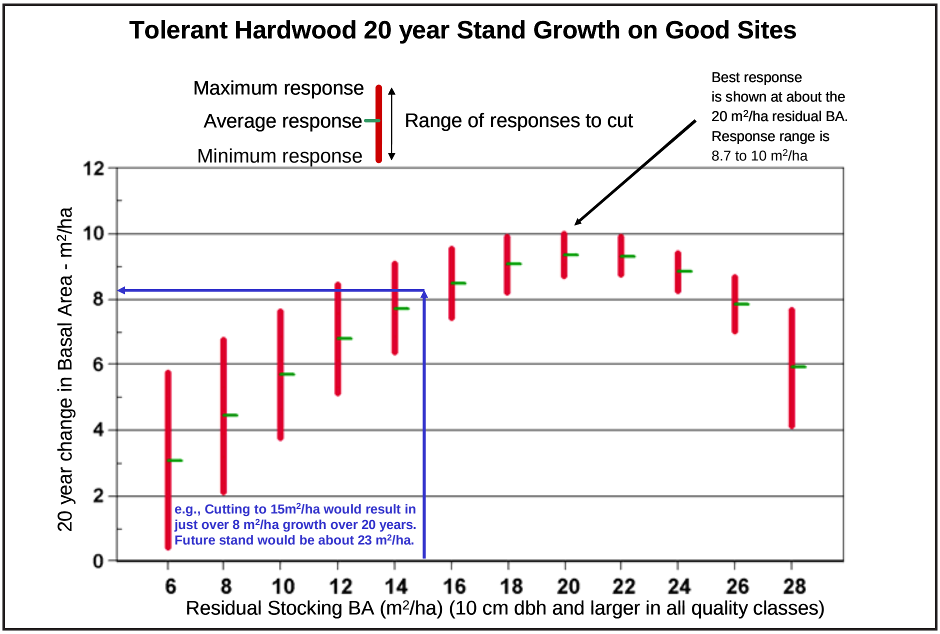


Figure 6.1 Basal area growth of tolerant hardwoods related to residual stocking (adapted from Algonquin Park data, OMNR (1983)).

The red bars in Figure 6.1 represents the expected range of growth response and reflects variation in the original stand structure and composition, as well as local site quality. More favourable growing conditions, such as those found in site regions 6E and 7E, will permit more rapid replacement of harvested trees, thus a shorter cutting cycle. Reduced growth is expected on marginal sites, therefore cutting cycles will be longer although the initial residual basal area is the same.

Residual basal area targets for individual stands may vary with species composition, stand structure and quality distribution (Table 6.1). Depending on stand objectives, the prescription writer may retain a higher residual basal area but schedule an earlier return (shortened cutting cycle) or lower the residual basal area target and use an extended cutting cycle.

It is appropriate and usually unavoidable to have some basal area variance within the stand, but an average targeted basal area should be achieved across the entire stand. Reducing the basal area by more than one-third at either the site or stand level is not recommended, assuming that single tree selection continues to be the objective, because of the

Table 6.1 Single tree selection basal area targets.

Species	Suggested Basal Area Targets in trees > 9 cm dbh	Other Considerations
sugar maple beech	20 m^2/ha or 18 m^2/ha on the North Shore	A residual BA of 20 m^2/ha or 1/3 of the pre-harvest BA, whichever is higher, is usually appropriate. Operationally, a residual BA of 18–20 m^2/ha is normally acceptable, while lower residual BA's will likely have implications to cutting cycle length and stem quality.
yellow birch	16 m^2/ha	Single tree selection has not been applied successfully as a yellow birch management system. Regeneration may establish, but it later succumbs to shaded conditions as overstorey crowns close. Successful establishment and growth of yellow birch would depend on shortened cutting cycles that may not be practical to implement. Yellow birch can be maintained as an even-aged mosaic in an uneven-aged selection forest. Creating canopy openings with diameter equal to the height of the stand but never exceeding 50 m (0.2 ha opening) has been an effective management option (***see*** OMNR 1998a; Section 9.3—Page 8).
hemlock	23 m^2/ha (OMNR 1990)	Optimal seedling height growth occurs at 50–55% of full sunlight or greater with the slowest growth at 20% of full sunlight or lower. Hemlock responds well to release from overstorey competition. (***see*** OMNR 1998b; Section 3.4—Page 26). Pre-harvest BA is often quite high, especially where the hemlock component is high. At the regeneration stage, BA should not be reduced below 23 m^2/ha, or by more than 1/3 of total BA, whichever is higher.
red spruce		Red spruce is very shade tolerant. Maximum height growth occurs in full sunlight. However, seedlings and saplings are able to withstand severe suppression and still respond to release. (***see*** OMNR 1998b; Section 3.4 - Page 24)
black cherry red oak, white ash, basswood	Not Applicable	These four mid-tolerant species require overhead light to survive and grow. Single tree selection is not suitable if the objective is to maintain any of these species as a stand component.
white cedar	26 m^2/ha	Cedar is shade tolerant and can withstand suppression for long periods of time. Seedling height reaches a maximum at approximately 50% of full sunlight. (***see*** OMNR 1998b; Section 3.4—Page 31) Single tree selection has not been proven as an effective management system for white cedar.

risk of overexposure and invasion of undesirables. Some prescriptions therefore identify a specific basal area target (such as 18–20 m^2/ha), or a one-third reduction in basal area, whichever is higher. Tree markers must be flexible and exercise judgement in meeting stocking objectives. Significant variance from the prescribed basal area should be discussed with the prescription author. Because residual stocking is so critical to the successful implementation of the single tree selection system, markers should periodically *calibrate* themselves by carrying out a basal area prism sweep.

Figure 6.2 (adapted from OMNR 1983) is a conceptual model illustrating the theoretical stocking development projection for an ideal stand that has been harvested to 20 m^2/ha.

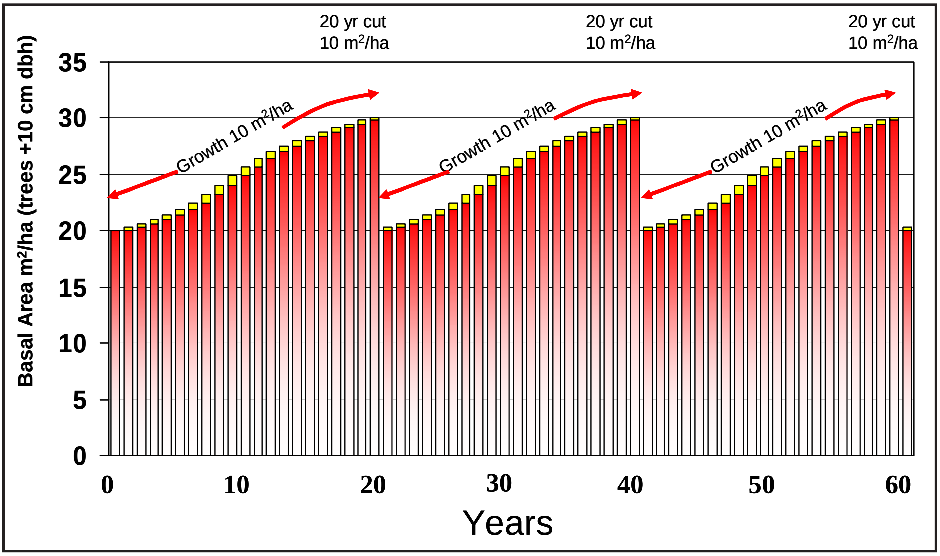


Figure 6.2 Theoretical stocking development projection.

Assuming an average annual growth rate of 0.5 m^2/ha/year, the net periodic growth (accretion) for the following 20 year period would be approximately 10 m^2/ha. A volume of wood equal to the accretion may then be harvested and the process repeats itself indefinitely. This model assumes minimal damage during harvest, favourable site conditions, and optimal residual stocking and structure. Actual values in previously unmanaged stands often range from 0.3 to 0.4 m^2/ha/year.

Stand quality

Forests previously managed in an unregulated manner will likely have lower than ideal levels of AGS. This presents significant management challenges for the forest manager and for the tree marker.

Tree markers should think about the following conditions when entering a stand:

How much AGS material is present in the pre-harvest condition?
A basal area of 9 m^2/ha of AGS in trees larger than 9 cm dbh is usually considered sufficient to implement selection management. However, a lower level may be acceptable if other stand objectives take priority over volume and quality production.

How is the AGS material distributed across the size classes?
An even distribution of size classes normally makes implementation of the selection system easier for the tree marker. If the AGS material is concentrated in one or two size classes, an alternative silvicultural system may be considered.

Which UGS trees should be retained?
It is rarely possible and never desirable to remove all UGS material from a stand. Doing so may compromise objectives related to residual stocking, habitat and/or biodiversity. Since some UGS will be retained, the priority is to remove trees with major infectious diseases as outlined in Table 3.13 and Table 3.14, and those UGS trees that are most impeding the development of AGS stock. Retention of a tree with one of the major *infectious* defects will normally be considered as an infraction in a tree marking audit. Good cavity trees often have major defects, so when given a choice, markers should leave cavity trees with defects that are the least infectious and could be expected to survive for an extended period.

Tree markers should keep in mind that UGS refers to tree potential, not current value. An emphasis on stand improvement through priority removal of UGS trees does not equate to removal of low value material only. Although showing signs of decline, some marked UGS will contain sawlog or veneer quality material. High value AGS trees must sometimes be marked to release other AGS trees.

Stand structure
The size class distribution of trees in a stand is termed stand structure. Uneven-aged stands are generally composed of trees of many ages and sizes that are spatially intermixed. Their growth is optimized when a balance is achieved in growing space captured by all diameter classes.

Typically, the relationship of the number of the trees by diameter class forms a reverse-J distribution in uneven-aged stands. It is most practical to describe the current and desired structure to the tree marker in diameter class groupings (poles, small, medium and large sawlogs). Using this format, the prescription writer and the tree marker can more easily visualize and discuss the diameter class groupings that have stocking surpluses or deficits. Written direction regarding the desired modifications to stand structure can be given to the marking crew as follows:

Mark—

- one out of five trees from the polewood size class
- one out of three trees from the small sawlog size class (and so on to the large or extra large sawlog classes).

In practice, tree markers can use direction regarding structure to help make individual tree decisions, especially if considering priority for retention while comparing trees of equal quality but in different size classes.

6.1.3 A single tree selection example

The structure and quality of a typical sugar maple dominated forest in central Ontario before and after a single tree selection harvest are outlined in Table 6.2 and Table 6.3, and shown graphically in Figure 6.3.

Table 6.2 Example central Ontario tolerant hardwood stand: pre-harvest condition.

Size class (cm)	**Poles 10–24**		**Small sawlogs 26–36**		**Medium sawlogs 38–48**		**Large sawlogs 50+**		**Total**	
Quality	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS
BA (m^2/ha)	3.6	2.5	6.0	3.6	3.4	3.2	.9	4.2	13.9	13.5
Total BA (m^2/ha)	6.1		9.6		6.6		5.1		27.4	
Ideal BA (m^2/ha)	6		6		5		3		20	

Table 6.3 Example central Ontario tolerant hardwood stand: condition following single tree selection harvest.

Size class (cm)	**Poles 10–24**		**Small sawlogs 26–36**		**Medium sawlogs 38–48**		**Large sawlogs 50+**		**Total**	
Quality	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS
BA (m^2/ha)	3.5	2.0	5.0	1	3.1	1.5	0.9	2	12.5	6.5
Total BA (m^2/ha)	5.5		6.0		4.6		2.9		19	
Ideal BA (m^2/ha)	6		6		5		3		20	

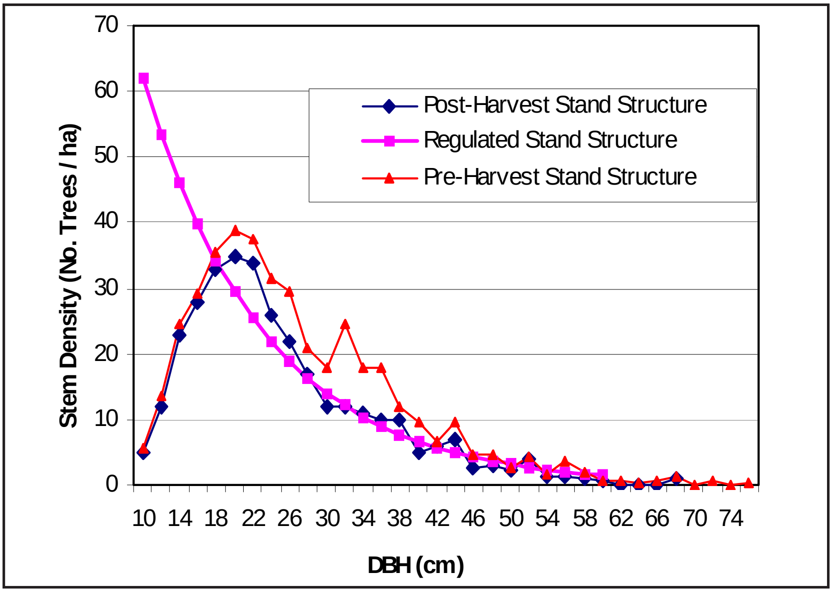


Figure 6.3 Structure of a typical central Ontario tolerant hardwood stand before and after single tree selection harvest.

In developing the prescription for this particular stand, the following stand conditions would have to be considered:

- The stand structure is somewhat irregular, resulting from a history of unregulated harvest practices. The most significant surpluses are in the small and large sawlog size classes, and while the stocking of poles is close to the ideal residual level, few understorey trees are progressing into the size class.
- Stocking is greater than 27 m^2/ha. This, plus the fact that there is little in-growth into the pole size class, indicates that there has been little recent activity and that a harvest is now warranted.

- Almost 70% of the AGS are in the pole and small sawlog classes, and much of the surplus in the larger size classes is UGS. This is typical of stands with a history of unregulated harvest practices, and indicates high cost operations in the immediate future but the potential for high value returns in the long run, assuming the application of appropriate silvicultural effort.
- The current AGS level is 13.9 m^2/ha, or approximately 51% of the total stand BA.
- 80% of the stand BA is made up of shade tolerant sugar maple. The remaining 20% are composed of a mix of species including yellow birch, beech, basswood, white ash, red oak, hemlock, red maple, ironwood, black cherry, white birch, and black ash.
- This upland hardwood site is well drained and productive, thus capable of producing high-quality sawlogs and veneer.

Prescription criteria
The combination of a species composition dominated by shade tolerant hardwoods, a relatively high level of AGS, and a structure which, while irregular, can be seen to approach the reverse-J, all point to the selection system as the most viable management approach for this stand. The resultant selection system tree marking prescription would then typically require that objectives be set relevant to species priority, residual stocking and structure, residual level of AGS and habitat values. The example that follows will specify the silvicultural objectives of the prescription. Directions related to cavity trees, stick nests, scattered conifers and the maintenance of species diversity are a critical part of the original prescription, but not repeated here. In this simplified example:

- species priority was identified as follows:
    - when comparing trees of equal quality (and assuming no overriding species diversity concerns in this example), the priority for retention is: (i) yellow birch and red oak, (ii) sugar maple, (iii) beech and (iv) red maple
- the targeted residual basal area is 19 m^2/ha
- movement towards the ideal stand structure will be accomplished by focusing removal in the small and large sawlog size class, with trees in other size classes harvested when required to remove individuals with major defects, or those which would provide greatest benefit or release to AGS trees selected for retention

- direction to the markers relevant to stand structure adjustment was as follows:
  mark for removal:
  - one out of ten trees in the pole size class
  - one out of three trees in the small sawlog size class
  - one out of four trees in the medium sawlog size class
  - two out of five trees in the large sawlog size class

These structural directions are not to override considerations of quality or stocking, but rather to assist when comparing trees of different size with roughly equivalent potential.

- target an increase in the proportion of AGS from the current 51% to approximately 66% in the post-cut stand; priority is to remove:
  - trees with major defects
  - those with minor or moderate defects that are competing with high potential AGS trees
  - and AGS trees that are in an overstocked condition and will provide release to better quality AGS if removed

Post harvest observations

In this forest, the following post-marking stand condition was observed:

- As illustrated in Figure 6.3, stands previously managed in an unregulated manner usually cannot be moved to an ideal structure in a single harvest. While the post-cut structure is much closer to that of the ideal reverse-J distribution, some large diameter UGS trees have been retained into the next cutting cycle to maintain stocking. Also, note that polewood recruitment will take several cycles to attain balance, and that ongoing monitoring to track improvement is necessary.
- The uniform canopy openings created by harvest will allow the understorey to develop. Through a series of careful harvests the stand will eventually approach an “ideal” structure.
- The proportion of AGS in the residual stand has increased by 15%. This is a reasonable and expected gain for this stand. A larger gain in the proportion of AGS could not have been accomplished in this stand without compromising the residual basal area objective. The UGS level has been reduced to 34% and will be reduced further during the next harvest.

Figure 6.4 Before (top) and after (bottom) harvesting a tolerant hardwood stand marked to a single tree selection prescription.

6.2 Group selection

by A. Corlett, K. Elliott, K. Webb

Group selection is a silvicultural technique that can be used to encourage the development of mid-tolerant species within uneven-aged tolerant hardwood forests. Emphasis is placed on matching the size of the canopy gap to the light requirements for establishment and growth of the desired species. This is achieved by marking and harvesting several companion, dominant trees.

What is group selection?
A modification of the selection system in which trees are removed in small groups rather than as individuals.

6.2.1 When is group selection appropriate?

Tree marking for group selection is principally applied where there is an objective:

- to develop an all-aged stand made up of a mosaic of even-aged patches representing the full range of age classes, over the period of a rotation, or alternatively;
- to develop a mosaic of even-aged patches of mid-tolerant species at appropriate locations within a stand managed primarily for shade tolerant species under the single-tree selection system.

The first approach is applied where forests,
- are dominated by mid-tolerant species but where uniform shelterwood has not been the first choice due to aesthetic, habitat or social considerations, or small stand size,

or

- have a high component of shade tolerant species which have low potential quality due to disease (e.g., beech bark disease) or site condition compared to the mid-tolerant species growing in the stand

The second approach is more typical of the situation in the GLSL forest, where sites are variable, management for the tolerant hardwoods is generally desirable, but the maintenance of a mid-tolerant hardwood component is ecologically and economically important.

A third and less common application of the system has been to create an interspersion of food and cover for deer or moose in cedar or hemlock stands.

6.2.2 Stand selection

Stands in which group selection is typically prescribed in central Ontario tend to be dominated by sugar maple, but with a strong component of mid-tolerant hardwood species. Species such as yellow birch, basswood, white ash, and/or red oak are common and often represent approximately one-third of the basal area. Some stand conditions to look for include:
- A history of partial cuts indicated by a multi-aged structure. At least one heavy cut took place at some point to initiate the development of the mid-tolerant species, but more than one age class is represented. (A single age class resulting from a clearcut could lead the manager to consider continuation of an even-aged system, possibly uniform shelterwood, rather than group selection).

- There should be sufficient acceptable growing stock (> 9 m^2/ha) to make the selection system viable. While gaps will be created in order to initiate mid-tolerant species within the stand, a significant proportion of the total area would normally be managed for shade tolerant species under a single tree selection approach.
- Quality and growth potential of the mid-tolerants should be equivalent to or better than the associated tolerant hardwoods, particularly in those micro-sites where gaps will be established.

6.2.3 Placement of canopy gaps

- Place gaps using a *worst first* approach—where potential growth or value returns are low compared to elsewhere in the stand. Such locations include groups of mature trees, off-site species, or poor quality trees that exhibit relatively low potential growth or financial return (Miller *et al*. 1998). Gaps can often be located in those areas within the stand where AGS levels drop to 4–6 m^2/ha so that few immature AGS trees have to be sacrificed.
- Attempt to place gaps close to mature seed producers, preferably so that seed producing trees border the gap. The resulting higher concentrations of seed may improve regeneration success (Figure 6.5).
- Place gaps where desired regeneration (especially difficult to establish regeneration such as red oak or basswood) is present and requires release.
- Place gaps adjacent to openings established during previous operations, so as to avoid retention of narrow and less operable strips of mature timber.
- Look for site indicators suggesting superior quality and growth potential of mid-tolerant species compared to tolerant hardwoods. This is often noted in areas having

Figure 6.5 Canopy gap 0.18 ha (or approximately 1.5 tree lengths in diameter) in a Mh-Or-By stand adjacent to numerous red oak seed producers.

some restrictions to root growth such as in areas of shallow soil (ridges with a red oak or white ash component) or a high water table (mid to lower slopes with a yellow birch component). Sometimes indicator species can be used to suggest suitable sites for mid-tolerant species. For example, common hobblebush or ground hemlock may indicate favourable site conditions for yellow birch within a stand that is predominantly well suited to the tolerant hardwoods.

Considering topography

The impact of crown openings on light, temperature, and moisture at ground level is strongly affected by residual-tree height, gap orientation and shape, and latitude or sun angle (Canham *et al*. 1990; Marquis 1965). In particular, the amount of light in canopy openings created by group selection is linked to both opening size and aspect, as illustrated in Figure 6.6.

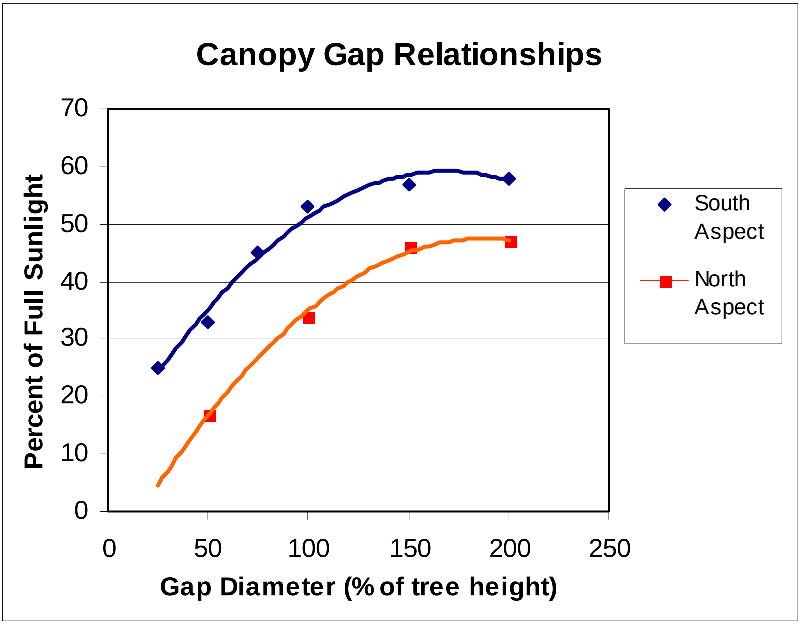


Figure 6.6 Effect of gap location on light levels. Gaps located on north-facing slopes must be about double the size of those on south-facing slopes in order to achieve comparable light levels (adapted from Minckler 1961).

6.2.4 Determining canopy gap size

The correct matching of patch size to species is especially important when managing the mid-tolerant species. Group openings normally range between 0.02 ha and 0.2 ha (circular patches 16 m–50 m in diameter, or one to two times the canopy height), depending on the light requirements of the target species. Larger openings tend to support greater proportions of intolerant species, fewer shade tolerant species and more competition from shrubs and herbaceous species. Groups should not exceed 0.2 ha in size because there is no silvicultural benefit to tolerant or mid-tolerant species and larger openings may in fact encourage the establishment of intolerant species. Table 6.4

Table 6.4 Recommended gap sizes for the regeneration of the principal GLSL species.

Species	Gap size	Other considerations
Sugar maple & beech	0.0–.03 ha, diameter < 20 m or one large tree crown.	Very shade-tolerant species such as sugar maple and beech may germinate and survive beneath an intact canopy (but require a gap for entry into canopy).
Yellow birch	Normally 0.04–0.05 ha, and not to exceed 0.2 ha. Diameter range of 22–50m	Retain 5–12 seed trees/ha (depending on crown size) within the stand and particularly near canopy gaps. Smaller gaps must be expanded during subsequent harvests to maintain yellow birch height growth. Site preparation timed with a seed year is critical.
Red oak	At least 1.5 times height of adjacent trees. Minimum gap size about 0.1 ha, or 36 m in diameter	Does not require a prepared seedbed and can become briefly established under considerable shade, but must be released soon after germination in order to have a chance of surviving and growing adequately. Canopy openings of 1–2 times tree height have been most successful in terms of species, tree numbers, and growth (Minckler and Woerheide, 1965). Cut stumps will contribute to regeneration target. Additional details in OMNR 1998a.
Basswood	Gap diameter at least 1.5 times height of adjacent trees. (see red oak)	Regeneration from seed is unreliable, but basswood is a prolific stump sprouter. Cut stumps will contribute to regeneration target. Additional details in OMNR 1998a.
White ash	Gap diameter at least 1.5 times height of adjacent trees. (see red oak)	Does not require a prepared seedbed and can become briefly established under considerable shade, but must be released soon after germination in order to have a chance of surviving and growing adequately.
Black cherry	.1–.2 ha	Does not require a prepared seedbed and can become briefly established under considerable shade, but must be released soon after germination in order to have a chance of surviving and growing adequately.
Hemlock	0.03–0.07 ha Max diameter = height of the stand, usually 20–30 m. diameter	Openings not to cover more than 20% of the block during each cut. Distribute openings uniformly over the cut block. At least 60% of the stand must be over 10 m in height if the stand is important to deer and moose. Log in the summer to create site disturbance necessary for regeneration.
Red spruce	Max diameter = height of the stand	Retain dominant and codominant red spruce in the stand and especially in the vicinity of the group opening as a seed source. Ideally, harvest in the frost-free season so that the humus layer can be exposed.
White cedar	Max diameter = height of the stand	Use procedures described for hemlock.

recommends specific gap sizes required to regenerate relevant species within the GLSL forest, as well as additional considerations of which the tree marker should be aware.

Effects of gap size

- Little direct sunlight reaches the forest floor within small gaps.
- The zone of direct sunlight is largest on the north side of larger gaps.
- The potential duration of direct sunlight is generally brief even in large gaps (1000 m^2); less than four hours (Canham *et al*. 1990).
- Species that grow in small gaps will often occur in shaded portions of a large gap (Oliver and Larson 1990).
- Survival of mid-tolerant species, such as yellow birch, is poor in small openings where the gap diameter is less than about 50% of tree height; a result of rapid canopy closure by residual trees.
- Consider crown lateral expansion rates when calculating group-opening size. As an example, yellow birch crowns grow approximately 15 cm per year (Hibbs 1982).

6.2.5 How to mark group selection openings

The following marking pattern can be used to identify group openings in the field (Figure 6.7):

Figure 6.7 Identifying group location for follow up site preparation and monitoring. (Erdmann et al, 1982)

- Using blue paint, mark the perimeter of the plot on residual trees.
- Paint the plot number (in blue) on a few residual trees at the edge of the group opening
- Below the plot number, mark a species code (e.g., By, Or, Cb, Aw) to indicate the species targeted for management within the opening.
- If site preparation is required, mark “S” for “site preparation”, below the species code.

- Place an orange or yellow "X" on the trees to be removed within the group opening.
- All marked trees require a butt mark for cut control.

6.2.6 Regulating the group selection harvest

When implementing group selection prescriptions, resource managers risk over-harvesting unless they make a conscious effort to consider and pre-plan the size and number of canopy gaps, as well as the residual basal area between gaps (Figure 6.8). Regulation procedures are summarized briefly here and are detailed in several documents, including OMNR (2000, 1998), Miller *et al*. (1998), and Miller *et al*. (1995).

The *area control method* is recommended where harvesting will occur almost entirely within the created gaps and the total area harvested per cutting cycle remains constant and is likely to be 10% or less of the stand area.

Figure 6.8 Size and distribution of forest clearings created through group selection.

However, if the silvicultural prescription specifies that only a few openings will be created or group selection openings are being implemented together with a single-tree selection prescription (on the portions of the stand between openings), harvest regulation should be calculated by basal area control. In this case, the residual basal area between the gaps must be maintained at a higher level than is recommended in Table 6.1 to compensate for the openings that will have a basal area of zero following the cutting. The priorities as far as which trees to remove are the same (See Section 3.0 *Choosing the right tree* to leave).

For the group selection system to be effective in regenerating mid-tolerant species, it is essential that all non-crop trees be removed in group openings.

- Remove all stems, even if AGS, down to diameters of 2 cm dbh to prevent growth suppression of desired regeneration (Miller *et al.* 1995). Retention of non-crop trees will only encourage rapid crown closure, favouring growth of tolerant species. If too much AGS is being sacrificed, perhaps the patch was poorly located.
- Follow-up maintenance to ensure adequate stocking by the crop species is critical in achieving long-term goals.

6.3 Uniform shelterwood

by A. Corlett

Uniform shelterwood is a silvicultural system recommended for establishing an even-aged cohort of regeneration throughout an entire stand. The system involves marking and harvesting to adjust the overstorey crown closure to satisfy the light, moisture and temperature requirements for establishment and growth of the desired regeneration.

What is uniform shelterwood?

An even-aged system in which mature timber is removed in a series of two or more cuts for the purpose of obtaining natural regeneration under the shelter of the residual stand.

6.3.1 Where is uniform shelterwood appropriate?

The uniform shelterwood system is an appropriate approach for managing stands of mid-tolerant species and in certain circumstances, can be the best choice for managing shade tolerant forests. The manager’s decision to apply the shelterwood system is based on three factors:

- The shade tolerance of the targeted species—what level of light will give the desired species a competitive advantage for regeneration and growth?
- Site quality—does the site have the potential for long term production of high value products?
- Quality of the existing overstorey—is selection management currently an option, or is it more efficient to regenerate the area and manage the new crop under shelterwood to achieve a balance of products?

The shelterwood system is an effective approach for managing white pine forests because it closely mimics natural disturbances, like fire, to which the species is adapted. When correctly applying the shelterwood system, tree markers ensure:

- the presence of a seed source
- sufficient shade to assist with vegetation control
- sufficient light for good height growth in seedlings
- and some protection from insect (e.g., white pine weevil) and disease (e.g., blister rust) damage to white pine regeneration (Figure 6.9).

Figure 6.9 160-yr. old white pine stand after a uniform shelterwood regeneration cut, Elliot Lake area.

Opportunities for the application of the shelterwood system exist in tolerant hardwood forests as well, whether to encourage a mid-tolerant component to manage the more tolerant species on sites not suitable for selection management, or to regenerate productive areas currently supporting a low-quality overstorey.

Tree markers accustomed to working in all-aged tolerant hardwoods must modify their marking patterns when implementing the shelterwood system for a variety of reasons.

- Shelterwood is an even-aged management approach, **not** all-aged.
- Marking is based on percent crown cover, **not** basal area.
- The intent at the regeneration cut stage is to retain mature and vigorous seed producing individuals while removing the smaller diameter stems, **not** to establish an even distribution of size classes.
- The seedling, sapling and pole component of high-graded or undisturbed mid-tolerant stands are often composed primarily of shade tolerant species. These tolerant species may interfere with the growth and development of targeted mid-tolerant regeneration, thus **not** contributing to the achievement of the stand level objective.

6.3.2 Tree marking for a uniform shelterwood harvest

Some of the elements that must be considered when implementing a uniform shelterwood prescription are stand structure, overstorey stem quality, species composition, and crown closure.

Stand structure and quality
When examining stand structure before marking, check for the following:

- A pattern in the distribution of age classes that will suggest how the stand has developed since initiation, and potential management challenges.
- Similarity to a bell-shaped curve (normal distribution of tree diameters) which indicates an even-aged condition, or similarity to the reverse-J distribution which indicates an uneven-aged condition.
- Determine if smaller diameter trees are the same age as the large diameter trees. Small trees may be slow growers with little potential to increase in vigour or size and require removal—or they may be younger, indicating a separate regeneration event and a need for release.
- Determine whether some species are concentrated in one or two size classes, or whether there is uniformity in the species composition across all size classes.
- Determine whether the dominant trees of seed-bearing age, and therefore capable of contributing to the attainment of a regeneration objective.
- Assess whether some dominant trees are older than other trees. This may suggest the survival rate following the past stand-disturbances. Markers may use this information to retain veterans.

Today, most shelterwood harvests in Ontario are at the regeneration cut stage. The typical objective is to establish regeneration that can be released through subsequent harvests. The intent then is to thin from below, retaining larger and higher quality trees for seed and shelter, while removing smaller diameter stems, which are often the same age but poorer growers. The post-harvest stand structure is similar to that resulting from naturally occurring understorey fires, where smaller trees are more likely to be killed and larger trees more likely to survive. The removal of smaller stems can occur either during the harvest or during site preparation when even smaller undesirable trees are removed.

In many stands, irregular treatments in the past have led to the development of a variety of age classes and variations in stand structure. This makes it necessary for tree markers to adjust their marking patterns to accommodate different stages of shelterwood management within the same stand as areas at different stages of development are encountered. An understanding of stem and crown vigour indicators for the species being managed will make it easier to distinguish between small diameter, low vigour trees, and high vigour trees that are small because they are younger than the predominant stand condition.

Species composition

The species targeted for regeneration will normally be the species with priority for retention in the overstorey as noted in the silvicultural prescription. In some cases, adjustments to the targeted crown closure level will be required. Some points to remember when selecting species for retention include:

- The odds of successful natural regeneration increase with greater density of good quality seed producers of the desired species, especially for difficult to regenerate mid-tolerant species such as red oak, white pine, or light-seeded tolerant species such as hemlock.
- Consider the entire silvicultural objective when using species criteria to select crop trees for retention. Trees selected for retention should meet objectives related to crown closure, seed production potential, contribution to habitat, and for some species, modification of the environment in order to reduce insect damage. Retention of a lower priority species (e.g., retaining a poplar instead of a white pine in a white pine seeding cut) may satisfy a crown closure target but will not contribute to seed production or white pine weevil management objectives. Less desirable tree species should only be retained when desirable trees are not available.
- Individuals of species that will not contribute to the long term forest objectives are given lower priority for retention.
- Be aware that the crown size to dbh relationship varies from one species to another (refer to Table 3.17).

Crown closure

While density management diagrams and stocking charts are used to manipulate stands over their cutting cycle, management of crown closure takes on an important role during the later harvests in the rotation of an even-aged stand dominated by mid-tolerant species.

Targets for crown closure and residual tree spacing are stipulated in silvicultural prescriptions involving the uniform shelterwood system.

Residual crown closure ranging from 35–80%, depending on species, is usually prescribed (Table 6.5) (OMNR 1998a and 1998b). While only the shade-tolerant species will maintain themselves at low light levels, most species growing in the GLSL forest will grow well at 45% of full light (Logan 1965, 1973) which can be achieved at about 40% crown closure (Figure 6.10).


Figure 6.10 Canopy view showing 40-50% crown closure of white pine following a shelterwood regeneration cut.

Tree markers have to look at the crowns (adjusting for crown size, spacing, and species composition) while implementing a shelterwood prescription, and not depend solely on a residual BA target. Experienced markers can make accurate ocular estimations of residual crown cover with training, and by reviewing post-cut stands. Non-subjective approaches to estimating crown closure involve point sampling with tools such as a spherical densiometer, or a point sample prism cruise using crown area tables. That approach is explained in Section 3.3.2.

6.3.3 Stand selection

Conifer forests managed under the uniform shelterwood system are typically mid-tolerant of shade (Pw, Sw, and Ce) or light-seeded and very tolerant (He and Sr). Specific stand conditions that would lead to a decision to implement the shelterwood system are detailed in the Overstorey Treatment Keys (Section 5.3). Hardwood forests managed under the uniform shelterwood system usually have an insufficient level of AGS for the application of the selection system, or are better quality stands with a strong component of mid-tolerant species such as oak, ash or basswood, or are growing on inadequate sites for the selection system.

6.3.4 Recognizing and implementing the correct stage of shelterwood harvest

Most applications of the shelterwood system in Ontario focus on establishing regeneration, thus the regeneration stage is usually

Table 6.5 Recommended crown closure levels for regeneration of the principal GLSL species.

Species	Targeted crown closure levels	Other considerations
Sugar maple	Seeding cut from below retaining 60% canopy closure	Two-cut uniform shelterwood if new regeneration is required. Overstorey removal when regeneration is well established (>1 m in height, approximately 12,400 stems per hectare) (OMNR, 1990).
Beech	Not Applicable	Beech generally does not regenerate well where stands have been opened excessively (shelterwood areas for example), although prolific root suckering may result if roots are damaged during logging (OMNR, 1998a).
Yellow birch	50–60% canopy closure on scarified sites. 60–70% canopy closure on burned sites	Two-cut uniform shelterwood recommended; overstorey removal when seedlings are 1.8–2.4 m tall (OMNR, 1998a).
Red oak	For 1st seeding cut, target residual crown closure of 70% on sites with severe understorey competition, or 50% on sites with minimal competition	If regeneration present but not well established and crowns have closed, it may be necessary to carry out more than one removal cut. Delay final overstorey removal until advanced growth is dominant and well established (root-collar calliper of 1.3 cm or height of 1.2 m) (Dey and Parker, 1996; OMNR, 1998a).
Basswood	40–50% residual crown closure following regeneration cut	Difficult to regenerate from seed. Suggested that a heavy seed crop is required two years before harvest (Stroempl, 1972).
White ash	40–50% residual crown closure following regeneration cut	Often regenerates in association with red oak.
Black cherry	30–40% residual crown closure following regeneration cut	Overstorey removed when regeneration is 1 m tall (Hornbeck and Leak, 1991).
White pine	40–50% residual crown closure following regeneration cut 20–35% residual crown closure following first removal	1/2 to 1/3 crown spacing, or space trees to 40% of total height. Reduce crown closure to 40% if oak component is desired. Time site preparation with a seed year. At 1st removal cut, retain 20–35% closure, favour best quality residuals to maximize growth and value increment. Retain veterans and wildlife trees in removal final cuts (OMNR 1998b).
Red pine	20–30% residual crown closure following regeneration cut	Full crown spacing should provide approx. 22% closure. Time site preparation with a seed year. Removal cut once seedlings are 30 cm in height, and stocking and density targets are met (OMNR 1998b).
Hemlock	60–70% residual crown closure following regeneration cut	Three cut shelterwood normally recommended. First removals when regeneration is 30 cm–1 m in height and stocking and density targets are met. Closure reduced to 40–50% after 1st removal (OMNR 1998b).
White spruce	Follow procedures as applied to the principal associated species (often white pine).	Follow procedures as applied to white pine. Silvical requirements are very similar to white pine, so apply the same approaches where possible (OMNR 1998b).
Red spruce	Follow procedures as applied to hemlock.	Follow procedures as applied to hemlock (OMNR 1998b).
White cedar	Follow procedures as applied to hemlock.	Follow procedures as applied to hemlock (OMNR 1998b).

prescribed. However, tree markers may need to adjust their marking to apply a different stage of shelterwood when species composition and structure change within a stand. For example, a stand dominated by a low quality sugar maple overstorey, but with abundant advance reproduction, may require a liberation cut (often termed a one-cut shelterwood). The schematic in Figure 6.11 provides an idealized overview of stand development as the shelterwood system progresses in a white pine forest. The illustration should help the tree marker to visualize the initial stand condition and management objective at each stage.

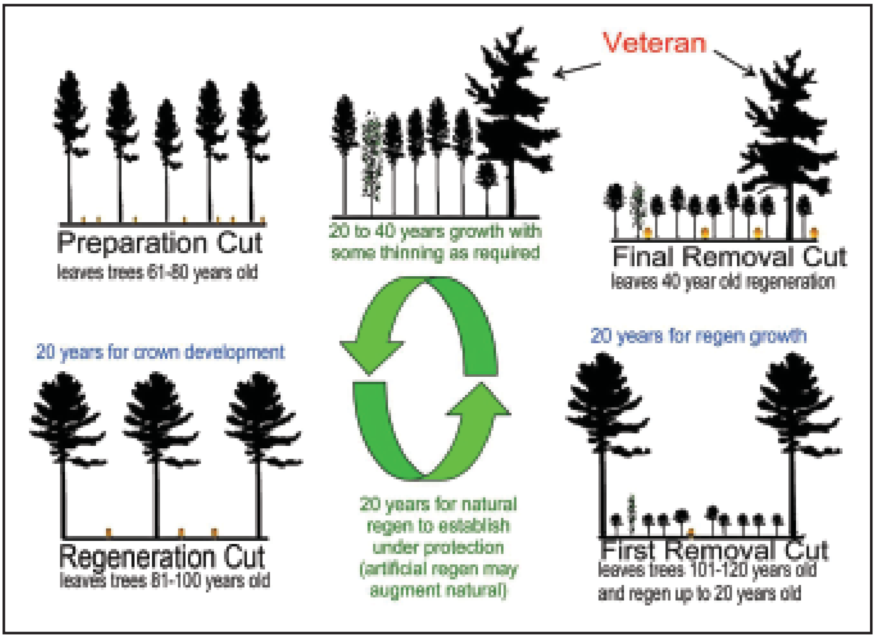


Figure 6.11 Flow diagram illustrating the stages of the uniform shelterwood system.

Fully developed crown concept

The fully developed crown concept is used to determine whether a stand is ready for a regeneration cut or requires a preparatory cut first. Regeneration cuts can be applied when the trees are fully developed and have reached their prime age for seed production. White pine that are ready for a regeneration cut tend to have a crown width equivalent to approximately 30–35% of the crown height, or with crown diameters averaging 6–8 metres. Open grown white pine may develop a crown width equivalent to 40% of its height and a crown depth of 50% of its height, however this condition is seldom achieved in dense, unmanaged stands.

Shelterwood marking criteria

Table 6.6 provides more prescriptive information related to the various shelterwood stages illustrated in Figure 6.11. White pine has been used to illustrate the stages of management, but the same principles would apply to other forest types, with appropriate modifications for stand condition, crown spacing, etc.

Selecting crop trees

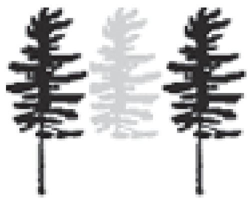
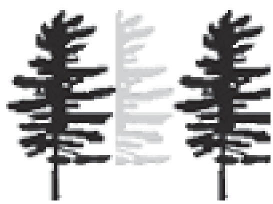
The term *crop* tree is used throughout these guidelines. They are essentially the better quality stems in any stand. A crop tree may very well be, but is not necessarily, the largest diameter tree in the stand. A crop tree selected in one location may be of much lower quality than a crop tree selected in another location. However, they are the best to be found and are selected for retention, to be harvested later.

The silvicultural prescription will provide a species priority listing for selecting crop trees. In pine (Pw/Pr) dominated forest units, white pine, red pine, red and white spruce (possibly hemlock) and associated species with similar site and silvical characteristics such as red oak are usually identified. Species that may be sensitive to sudden exposure (e.g., dieback prone white birch) are usually not maintained as crop trees, unless regeneration from those species is a priority and some mortality is acceptable.

A crop tree would ideally have most of the following characteristics.

- Dominant or codominant crown class; with dominants having priority over codominants—all other features being equal.
- A healthy upper crown capable of future seed production, and ideally, some evidence of past seed production.
- Disease free; no evidence of diseases such as blister rust (on white pine), or Eutypella canker (on sugar maple), which may lead to mortality before the next harvest, and increased infection of regenerating stems.
- Straight single bole. Low forks on the butt log are not acceptable, although higher forks may be accepted if the risk of splitting is judged to be minimal. Avoid high “v” forked stems with large diameter limbs.

Table 6.6 Shelterwood management stages: objectives, stand condition, marking criteria.

Stage of management	**Stand condition**	**Marking criteria**
Polewood thinning Intent to maximize merchantable volume production on highest quality stems, capture potential mortality.	Average dbh 9–24 cm. Stand may be ready for either a commercial or non-commercial thinning at this point.	Refer to relevant stocking guides in the silvicultural guides for appropriate residual basal area targets.
Preparatory cut Intent is to promote crown expansion of potential seed producers so as to facilitate later regeneration efforts. Moving stands to the point where they are ready for regeneration is a continuous process from early thinnings through to the initiation of the regeneration cut.	Diameter of dominant stems 25–40 cm dbh or stands *above* 40 cm dbh which do not have fully developed crowns. White pine crown diameters are often in the 4–5 m range. Dominant stems are either not of optimal seed bearing age, or have not reached commercial or ecological maturity.	Space the residuals to full crown spacing between white pine residuals *or*bole spacing (30% of height); e.g., if dominant stand height is 24 m, spacing of crop trees at 30% x 24 m = 7.2 m. Emphasis is placed on the removal of undesirable seed-source species and low-quality individuals, along with the proper spacing of crop trees. 
Regeneration cut Further canopy reduction carried out to create proper light conditions for the establishment of regeneration and subsequent seedling development.	Average dbh of dominant white pine greater than 42 cm. Dominant stems have fully developed crowns capable of producing abundant seed. Absence of desired regeneration.	Targeted residual crown closure usually 40–50%. Usually achieved through: 1/2 to 1/3 crown spacing *or* bole spacing 40% of height. 
Removal cut(s) Residual stand is removed in one or more harvests, to release well-established regeneration.	Desired regeneration is well established and ready for release. Normally regeneration is at least 0.3 m in height, free from competition and adequately stocked.	*First removal* cut is applied uniformly if protection to the regeneration is still required (e.g., white pine weevil protection, or moderation of temperature or moisture extremes). Stand is opened to 20–35% crown closure. *Final removal* cut provides complete release of the understorey and improves growing conditions for regeneration. At least 10 veterans/ha are retained.
Wildlife habitat and biodiversity guidelines are to be followed at all stages of the system.		

- Well-balanced crown with a live crown ratio of 30–50%, and a crown diameter of 60%–100% of crown length. Potential to develop a bole free of dead branches for the first two logs (10 m).
- Well-formed crown. Fine branching is preferred.
- Healthy green foliage. Yellowing or discoloured foliage or multiple dead branches in the crown will indicate a stressed condition (disease infection, off-site location, or animal damage).
- Thrifty bark characteristics, i.e., small tight bark flakes vs. large platy flakes of over mature trees.
- No excessive butt flare.

Spacing reminders

- Allow for flexibility in spacing of residuals within the stand. The quality of the crop tree is more important than a rigid spacing guideline.
- Leave trees on the edge of openings (outcrops, wetlands, landings, etc.).
- Remember to thin from below. This involves removing the smaller trees and retaining the larger trees that have the best potential to produce seed. With this principle in mind, think about how residual trees will develop following the harvest. It may be very appropriate to retain small areas of well-stocked saplings or poles that are periodically encountered as they represent areas of the stand that have already been regenerated, and the competition between trees may ensure good stem development. However individual, low density, scattered saplings or poles will not develop straight clear boles if retained, and may inhibit the development of desired regeneration. Such trees should be removed.
- Trees with butt wounds and associated decay may be acceptable as crop trees and would be given priority for retention over an adjacent otherwise healthy tree with a small, weak crown as long as the defect does not interfere with the trees' ability to produce high quality seed and required shelter. Butt wounds will often result from mechanical injuries, as opposed to defects that might indicate a genetic predisposition to that problem. Retaining such trees while consistently removing better quality, more valuable trees will, however, lead to serious long-term problems. There may well be an impact on the manager's ability to implement subsequent removal

cuts if there is an abundance of low quality material left on site that make operations economically unfeasible.
- Retained wildlife trees must be considered part of residual crown closure and a factor in spacing.

Table 6.5 recommends crown closure levels for regeneration of selected species, as well as additional considerations the tree marker should be aware of.

6.3.5 A white pine regeneration cut example

The structure of a typical white pine dominated 110-year-old stand in central Ontario before and after a regeneration cut shelterwood harvest is illustrated in Figure 6.12. While even-aged stands are expected to have a size-class distribution that plots as a bell-shaped curve, an understorey dominated by shade tolerant species has caused this stand to exhibit a reverse-J distribution more typical of an all-aged condition. In preparing the prescription for this particular stand the following points were noted:

- Smaller diameter stems are not significantly younger than the larger overstorey stems.
- Very few white pine have been able to establish under the closed canopy of the overstorey white pine.
- The understorey is dominated by sugar maple, and to a lesser degree by red maple, balsam fir, and other species. Whether this stand was harvested in an unregulated manner, or if there was no logging and the area was protected from natural disturbances, the existing understorey species would in time dominate the overstorey.
- The overstorey white pines are mature with well-developed cone producing crowns.

According to the uniform shelterwood prescription,
- the best quality dominant and codominant white pine (and some incidental white spruce) have been spaced out to ½ crown spacing—approximately 12 metres between residual stems, with a resultant 40% crown closure, and a basal area of 15.5 m^2/ha (reduced from 38 m^2/ha)
- the understorey stems, primarily sugar maple, red maple, balsam fir, white birch and poplar, have been removed

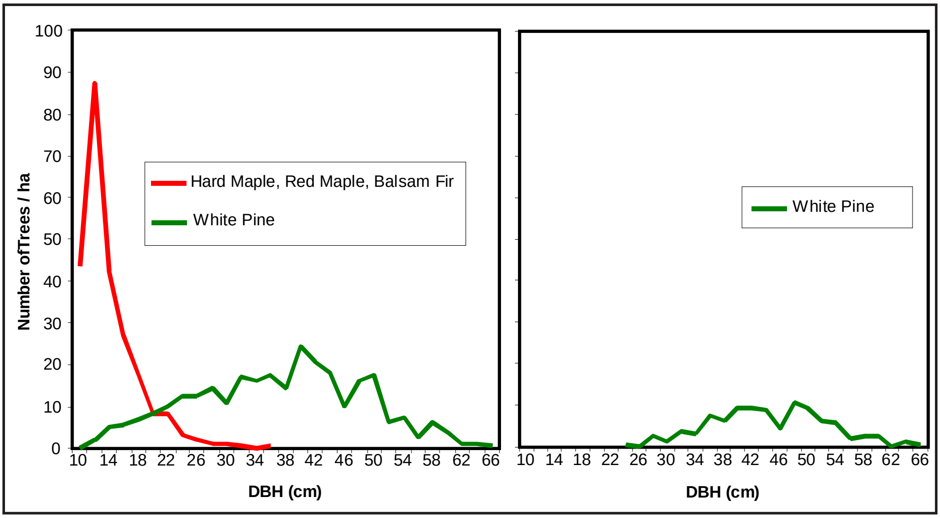


Figure 6.12 Pre-(left) and post-(right) harvest stand structure, white pine dominated, 110-year-old stand managed to a shelterwood regeneration cut prescription.

- the smaller diameter Pw and Sw have been removed where better quality seed producers are competing for the same growing space
- good quality Pw and Sw have been removed to release seed producers of equal quality competing for the same growing space
- the average stand diameter (quadratic mean diameter or diameter of the tree of average basal area) has increased from approximately 30 cm to 45 cm

Red and sugar maple can be expected to stump-sprout somewhat following harvest. Balsam fir has potential to regenerate prolifically from seed dispersed by residual trees that are not killed, or from surrounding stands. Correctly marking and harvesting the stand is critical in the implementation of the shelterwood silvicultural system, but these two steps are only the start in the process of establishing and nurturing the regenerating stand. Follow-up treatments such as mechanical and/or chemical site preparation are often necessary to control non-crop regeneration.

6.3.6 Rationale for 50% crown closure in white pine stands

By F. Pinto

White pine is considered a mid-tolerant species because it has adaptations that allow it to grow well under partial shade. White pine seedlings and saplings produce more foliage in partial shade, and reach their maximum rate of photosynthesis at 45% of full sunlight. Other species such as aspen, birch, pin cherry or understorey plants such as raspberry are able to use increasing levels of light for photosynthesis. While they cannot grow as well as young pines in a partially shaded environment, they can make efficient use of higher light levels for growth. Where available light is greater than 50% of full sunlight, these plants tend to grow quickly and can cause competition-related mortality in neighbouring white pine seedlings.

White pine do not store seed in the forest floor, in cones on the tree, or reproduce vegetatively, thus managers must rely on an adequate and timely seed crop if natural regeneration is desired. In addition, varying levels of mortality of the pine seedlings will result from natural causes, or because of logging activity. High seedling densities are therefore necessary to ensure the understorey is adequately stocked with healthy saplings once the removal cuts are complete.

It is occasionally possible to get a high density of pine seedlings from seed produced by very few parent trees; however, the successful replication of this result is very irregular. Experimental work (Figure 6.13) suggests that the number of seedlings that establish after harvest is directly proportional to the number of parent trees retained after harvest. A marked reduction in the number of seedlings/ha has been noted as spacing of residuals is taken from the uncut condition, to full crown spacing and then to a two crown spacing.

Partial shade conditions can have a positive influence on the health of established seedlings. The retention of partial cover is one measure used to reduce the incidence of damage to seedlings and saplings from white pine blister rust (Hodge *et al* 1990), an introduced pathogen that is particularly damaging to white pine.

The white pine weevil is a native insect that can reduce stem quality and value by 20–60%. Its population may be controlled to some extent by naturally occurring predators. Cavity trees, down woody debris and

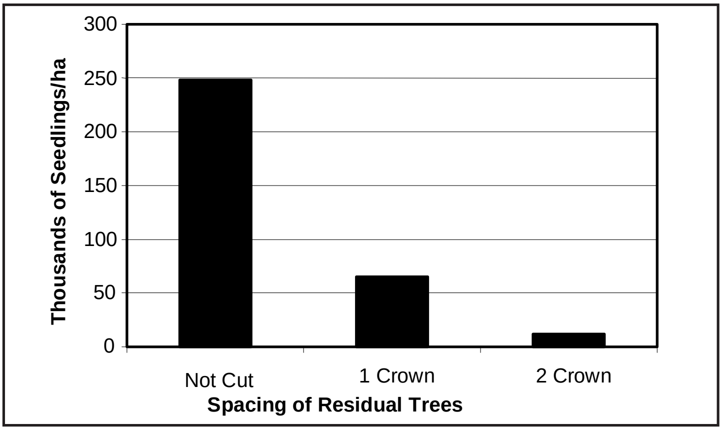


Figure 6.13 Number of seedlings per hectare after thinning and site preparation during an excellent seed production year in 1996 (Burgess et al 2000). The stands that were not cut have about 80% crown closure, one crown spacing resulted in 37% crown closure and two crown spacing resulted in 16% crown closure.

shade provide structural and microclimatic conditions that can maintain the habitat for these predators (Szuba and Pinto 1991). Figure 6.14 shows the level of damage to white pine regeneration under four different levels of residual tree retention. Weevil damage to white pine regeneration is most frequent in heavily thinned stands and can be controlled by maintaining a residual basal area from 14–18 m^2/ha, or half crown spacing.

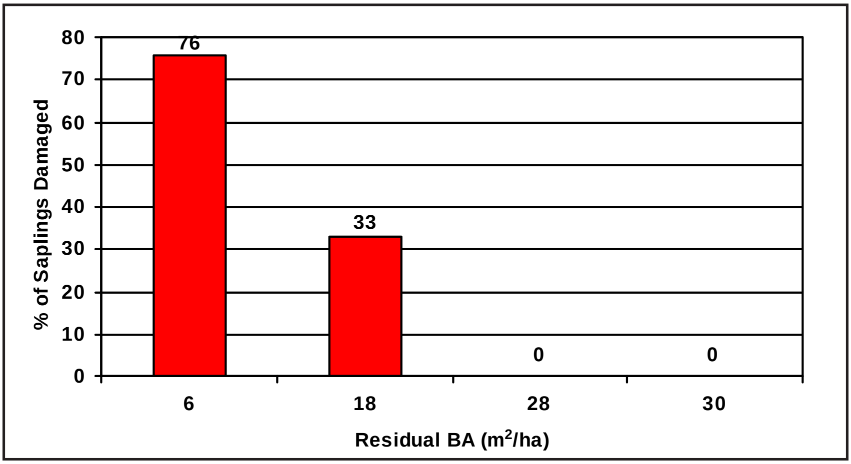


Figure 6.14 Occurrence of white pine weevil damage at varying levels of basal area (D'Eon 2000). Note that damage to white pine seedlings becomes apparent at the lower basal areas.

6.4 Clearcut with seed trees

by A. Corlett

The clearcut with seed-trees approach is a basic silvicultural treatment normally used to meet one of the following objectives:

- regeneration of shade intolerant species adapted to fire or other wide-spread disturbance patterns (e.g., red pine forests)
- restoration or maintenance of mid-tolerant species which are too under-stocked for application of the shelterwood system

> **What is a clearcut with seed trees?**
> *A modification of the clearcut system in which a small number of seed-bearing trees are left singly or in small groups. The objective is to create an even-aged stand.*

The genetic diversity objectives for the forest must be considered when prescribing this treatment. It may be inappropriate to emphasize a clearcut with seed trees approach for small isolated stands where the opportunity for in-flow of pollen is small and number of trees are below or approaching the critical level for population viability.

Success has been variable, with treatment failures usually resulting from inadequate numbers and fecundity of seed trees, or the failure to invest in required site preparation following harvest.

6.4.1 Shelterwood or seed-tree?

There are visual similarities to the shelterwood system, especially at higher seed-tree retention levels. However, the differences between the two systems are significant:

- the scattered trees left in seed-tree operations are insufficient to modify the microclimate and thus to protect the site or regeneration to any significant extent
- the potential increase in value of the residual trees is not an important consideration
- for most species, reduced numbers of retained seed producers means reduced seed production and lower odds of regeneration success

Tree markers are often required to shift from a seed-tree to a shelterwood approach within a stand for which clearcut with seed-trees is the prescription. This is done in order to capitalize on any opportunities to increase the chances of natural regeneration. The decision pathway illustrated in Figure 5.2a and 5.2b was initially developed to assist tree markers in the application of the clearcut with seed-trees system in a typically variable white pine/poplar/white birch mixedwood of central Ontario. This forest condition is also quite common in northwestern Ontario.

The decision pathway uses measures of basal area and species composition to suggest a shift in silvicultural treatment. Once that decision is made, tree marking considerations are based on crop tree quality, spacing and crown closure targets. Some losses due to windthrow may follow any harvesting operation, further reducing the number of seed producers. Markers should endeavour to retain as many high quality seed trees as possible.

6.4.2 Crop tree selection

Crop trees must be selected with care, as they are the source of a seed supply that is likely limited. Individuals selected for retention as seed trees must be windfirm and capable of producing viable seed. Therefore, use the following guidelines to select crop trees for retention:

- Crown class. Retain dominants and codominants (dominants have priority).
- Windfirm. Retain individuals with wide, deep crowns, and relatively large live crown ratios.
- Avoid retaining species that are prone to windthrow. White spruce may be retained to augment diversity within a red or white pine seed tree cut, and may produce seed and regeneration in the years immediately following the harvest, but tree markers should recognize that these trees may have low long-term survivability.
- Evidence of past seed production.
- Select seed trees that are mature and capable of producing abundant, fertile seed (optimum seed bearing age for both white and red pine is from 50–150 years).
- Do not select suppressed trees with weak, feathery crowns.
- Attempt to confine choices to the best phenotypes. Where good phenotypes are not available, retain individuals that developed imperfectly due to random environmental influences.
- Understand the seed dispersal capability of the targeted species to guide selection and spacing of residuals:

- White pine—retain 10–35 trees per hectare, well distributed across the site. Since ***more is better***, we recommend 25–35 trees per hectare wherever possible (Figure 6.15).
- Red pine—space seed trees one tree length apart where available (since red pine seed is usually distributed within one tree length of the parent tree).
- Yellow birch—seed trees evenly distributed at 50–60 m intervals throughout the area.

Figure 6.15 Clearcut with seed-trees: 34 seed trees/ha retained, 8/ha subsequently lost to windthrow.

6.5 Thinning and improvement

by S. Reid, S. Munro

Forest managers develop thinning and improvement prescriptions for stands that have trees growing at excessively-high densities or that are undesirable in size or quality. These treatments increase future economic returns, maintain good growth, and improve forest health.

The final spacing and density of the residual trees will vary with stand conditions species composition, site quality, tree size and quality, current rate of growth, stand health (incidence of insect or disease problems), tree defects, available markets for expected products, and landowner objectives. Section 7.5 (pages 5-12) of A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario (OMNR, 1998b) contains information regarding the types of thinning systems available, thinning intensity, timing of thinning and thinning control. These topics are especially important for developing a marking prescription for plantations, either pure or mixed, conifer or hardwood. Further direction for areas outside of site regions 4E and 5E may be found in the other relevant silvicultural guides (OMNR 1997 and 2000).

6.5.1 Thinning

Any plantation managed properly through timely and appropriate thinnings will evolve into a forest condition similarly found in natural, even-aged stands of the same species. Once the stand has reached this stage, marking prescriptions normally treat the stand as if it were natural, i.e., shelterwood or selection style marking prescriptions are employed.

What is thinning?

Thinning is the removal of a portion of trees in an even-aged stand to provide more growing space for the remaining crop trees. The main objective of thinning is usually to maximize stem growth and quality development in the long term while maintaining a regular supply of wood products in the short term (adapted from Rollinson 1988).

What is improvement?

Improvement cuts are applied to stands past the sapling stage to improve stand composition and tree quality by removing trees of undesirable species, form, or condition, from the main canopy. Improvement cuts are typically done in uneven-aged stands of tolerant hardwoods as a component of the selection system. This operation can yield a low volume of sawlogs, but most products are derived from poor-quality trees, and provide firewood or pulpwood only.

Thinning intensities will vary no more than 15% of the target thinning intensity. Failure to achieve the desired intensity of thinning can result in over cutting which reduces profitability, or under cutting which can result in little growth response in the crop trees. The precision of tree marking for thinning will depend upon the expertise and resources available, as well as the nature of the crop being managed.

Types of thinnings

Thinnings can be categorized as *selective* or *systematic* (Table 6.7). Selective thinning is based on the principle of improving selected crop trees and involves marking individual trees for removal. Systematic thinning involves marking rows for removal, focusing on improving growth of all trees adjacent to the row removed. In plantations, rows are often visible and are easily selected and marked for removal, however in

Table 6.7 Thinning approaches in plantations (adapted from Forestry Comm. 1955).

Thinning type	Marking guidelines
Selective low thinning/ thinning from below	Trees are removed from the lower canopy. These trees tend to be the smaller diameter suppressed and sub-dominant trees. Benefits dominant and codominant trees by removing smaller and weaker stems that are using significant amounts of water and nutrients. This type of thinning can be made throughout the rotation of the stand. Generally a 2^{nd} thinning or lightly combined within a first thinning. The marker should concentrate on removing the smaller diameter classes and any trees of poor form or quality. It may be combined with a light crown thinning where crop trees require spacing. The 2^{nd} thinning should be the last time small, low quality trees need to be removed.
Selective crown thinning/ thinning from above	Trees are removed from the dominant and codominant canopy to space the potential crop trees. Suppressed and trees likely to die before the next thinning are also removed. Lower crown classes are using insignificant amounts of nutrients. Competition is between the dominants and codominants. This type of thinning cannot be maintained throughout the rotation of the stand since too few competing trees would remain to give reasonable thinning yield. Can be included within a 2^{nd} thinning, but generally is applied to subsequent thinnings. This type of thinning can be distinguished as light, medium, or heavy crown thinnings, although these intensities are usually applied within the same prescription depending on stand stocking. In light crown thinning a minimal number of dominant trees are removed in any one operation, the goal being to reduce crown competition among the better dominants while maintaining some inter-competition, i.e., 2 sided crown release. In a heavy crown thinning a specified number of the best dominants, about 250 per hectare, are released from all crown competition by cutting out any tree that touches the crown of a selected tree. A moderate crown thinning is somewhere between these two intensities.
Systematic thinning/ row or strip or chevron thinning	Rows or strips of trees are removed regardless of individual tree characteristics. A method of performing an inexpensive thinning treatment if the saving in cost is greater than the likely loss of future revenue from more selective thinning methods. This type of thinning is usually reserved for first thinnings as it does not permit consideration of the merits of individual trees. For thinning predetermined rows at regular intervals, a mark at the end of the rows and periodic marks within the rows may be all that is required. It is crucial in this instance that the logging operation only cuts the prescribed rows. If a selective cut is included in the first thinning, it may be necessary to mark all trees in the rows to avoid errors in tree cutting. All selective cuts must be fully marked.

natural conifer forests, rows must be forced into the stand at specified intervals. In most cases a combination of the selection and systematic thinning will be used to obtain the desired residual basal area. The thinned rows serve as access routes within the entire stand for harvesting or forwarding machinery.

When is thinning appropriate?

Factors that affect decisions to proceed with thinning include:

- the stand condition (stocking density, diameter distribution, tree quality, and crop tree distribution)
- the owner's objectives (timber values, aesthetics, wildlife, etc.)
- present markets (pulp, small dimension logs, etc.)
- projected future markets (product trends)
- wind-firmness (dangers of wind damage depending on thinning intensity, species and site)
- costs (access, tree marking, harvesting, etc.) (cost/benefit analysis)

The choices to be made before thinning include:

- desired species composition (single species versus species mixtures)
- timing of first thinning (age, density of the stand)
- the type of thinning (row, selection)
- the thinning intensity (basal area control, number of trees per hectare)
- the thinning cycle (expected timing of the next thinning)
- expected thinning yields (cubic metres per hectare by product type)
- the age thinning should cease (stage of stand development, planned rotation length)

Thinning stages

Pre-commercial thinning (spacing)

Pre-commercial thinning involves the removal of some trees in a young stand to reduce competition for water, nutrients and light and to accelerate commercial growth on the remaining trees. Trees removed have little or no commercial value. This thinning stage is usually not required in a properly spaced plantation, but may be appropriate in natural stands. A plantation consisting of two or more species in mixture, one that is unlikely to reach commercial size or value, would be an example of a situation requiring pre-commercial thinning. In such a case, it would be advantageous to remove some or all of these trees to provide more growing space for the residual trees. In all cases an effort should be made to market the thinned material.

First commercial thinning

First thinnings provide pulpwood sized material and are applied to stands between 20 and 30 years old, depending on species and site. If access for current and future harvests is a concern, first thinnings are likely to be systematic, with the thinning regime described in the prescription, e.g., every fourth row to be removed (Figure 6.16). Rarely are two adjacent rows removed in one thinning.

Figure 6.16 Red and white pine plantation showing a one in four row thinning in the foreground, with young plantations above.

Sometimes rows of trees converge within the stand and small adjustments in marking are necessary to maintain the width of uncut rows. Special adjustments may also be necessary to deal with topographical restrictions (e.g., orient the marking up/down the slope where rows run parallel to a steep slope). Such adjustments may involve a forced row thinning approach where the marking maintains the desired space between cut rows. Cut rows should not be wider than necessary for machine access. Standard marking procedures at both eye and stump level are applied throughout the stand.

Second commercial thinning

Second thinnings may provide a variety of products: pulpwood, small sawlogs and poles. Access to the whole stand is likely assured if earlier thinnings were systematic, so selective thinnings are most appropriate. Thinning is from below but some minor crown thinning may take place as well. Establishing a desired residual basal area target is critical, but at a maximum, only 33% of the existing basal area should be removed.

The focus is to retain the best individual trees, removing the smaller diameter or poorly formed stems. Trying to release badly suppressed or weak subdominant trees at the expense of thriving dominants is seldom successful.

If the stand is a mixture of more than one species, the general rule is to encourage the best-formed trees, regardless of species. In some cases, the mixed plantation may have areas within the stand where one species dominates the mixture, while in other areas another species may perform better. These groupings can be favoured within the plantation and eventually a satisfactory mixed crop in a patch-like configuration can result.

Commercial thinnings—subsequent thinnings

Having completed the first two thinnings successfully, the following conditions should be evident:

- access and landings are well established
- most, if not all, poor quality trees have been removed
- best crop trees have been released and all trees are well spaced
- there are few impediments to logging with little possibility of residual damage

A maximum of 33% of the standing basal area will be removed in any subsequent thinnings, with the release of crop trees and spacing of the residuals the priority. If any poor quality or insect or disease-affected trees are present, they should removed now. Some of the later thinnings will have the same basic objective as a uniform shelterwood preparatory cut, and the marker should be aware through the prescription, of the regeneration plan for the stand. In this way the marker can favour the best seed producers if natural regeneration is proposed for the future.

6.5.2 Improvement

Stand improvement operations are intended to meet a variety of objectives, from improving overall forest health, to optimizing long-term development of specific products. Sections 3.1 (Assessing individual tree potential for growth) and 3.2 (Tree Classification Systems) will assist the tree marker in making the tree and site level decisions critical to the implementation of this activity.

General characteristics of trees targeted for removal in an improvement cut

- *suppressed trees that are of high risk and that will not survive until the next stand entry*
- *trees too crooked, forked, or have too many limbs to make sawlogs.*
- *high risk forked crowns (V-forks)*
- *trees with fire scars or injuries from insects, diseases, or mechanical damage*
- *off-site species showing low vigour*
- *over-mature trees*
- *wolf trees that occupy too much growing space*

General characteristics of trees to retain in the stand in an improvement cut

- *high quality trees*
- *vigorously growing trees*
- *mast and cavity trees for wildlife*
- *supercanopy and solitary conifers*
- *trees necessary for retention for stocking requirements*

Marking guidelines

As with thinning or single tree selection, the maximum basal area reduction should not exceed 33% in any one cut. We do not recommend reducing the basal area to less than 12 m^2/ha. For improvement cutting in even-aged tolerant hardwoods follow the recommended stocking guides in the relevant silvicultural guides (OMNR 1998a,b).

Most of the information on commercial and pre-commercial thinning addresses pole-sized material greater than 18 cm dbh, including the stocking guides provided in the silvicultural guides. Thinning of smaller diameter material has had a lower priority because for most species it is important to delay release until self-pruning along the first log is completed. Thinning of small diameter trees is justified for species such as yellow birch and red oak that show significant growth response following careful release.

Cautions:

- Do not select and release crop trees until they have attained crown closure.

- Thinning too heavily may have a negative effect on height growth, particularly for less tolerant species such as black cherry and red oak (Miller 2000).
- Yellow birch poles with restricted crowns are sensitive to excessive exposure following heavy cutting and will commonly develop epicormic branches from dormant buds.
- Epicormic sprouting increases with intensity of release but is not a serious problem in managed stands periodically thinned after crown closure (Erdmann and Peterson 1972). Sprouting is usually more profuse just beneath the live crown than further down the stem.
- Mid-tolerant and suppressed trees feather out more than dominant and codominant ones.

The following information is adapted from Erdmann *et al*. (1982), and Erdmann and Peterson (no date), and is specific to yellow birch:

Crop-tree selection priority
- dominants and codominants
- capable of producing high quality sawlogs or veneer logs
- potential two-log tree
- straight and well formed, without crooks or sweep
- no major forks (high U-shaped forks are acceptable)
- no major defects (stem cankers, splits, seams, large wounds, heavy sapsucker damage, and dead branches in the butt log)
- clean bole for half height (small live branches—less than 2.5 cm in diameter—in the second log are acceptable)
- full-crown with dense foliage
- well spaced throughout the stand

Management strategy (even-aged, yellow birch dominated stands, 10–18 cm dbh)
- select up to 250 crop trees/ha, spaced 6–7 metres apart. This should produce approximately 185 final harvest trees per ha
- crown release the 250 crop trees for 2 m (Figure 6.17)
- leave adjacent tree crown(s) to correct forks
- retain an equally good quality stem nearby
- cut main canopy, high risk and cull trees
- do not create holes larger than 4.5 m in the canopy

- cut low vigour, low-quality, leaning, crooked, forked, and cankered trees from below
- thin dense pockets of high quality stems
- do not reduce stocking below the minimum stocking curve
- leave a uniformly thinned stand of the best dominants and codominants

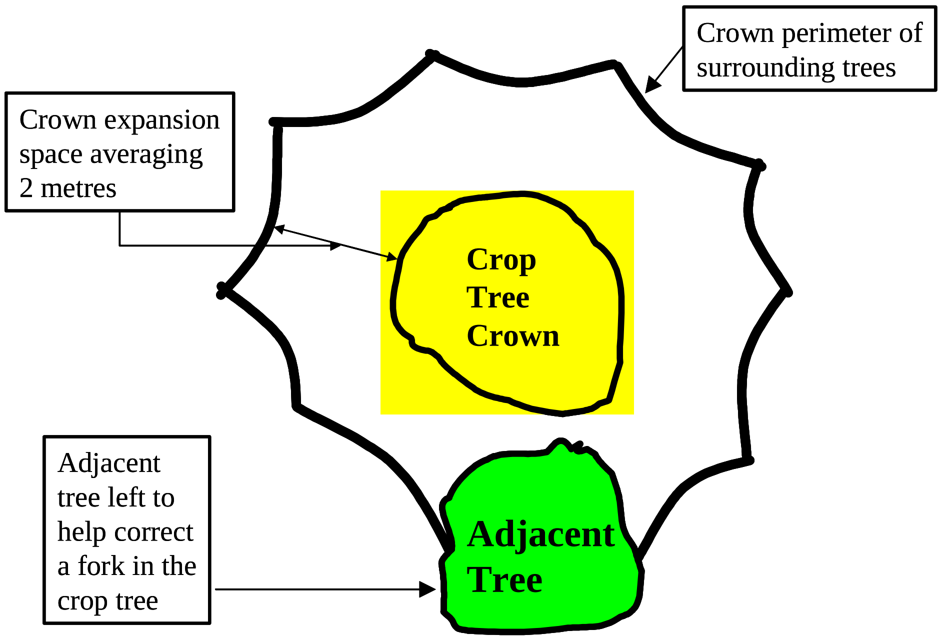
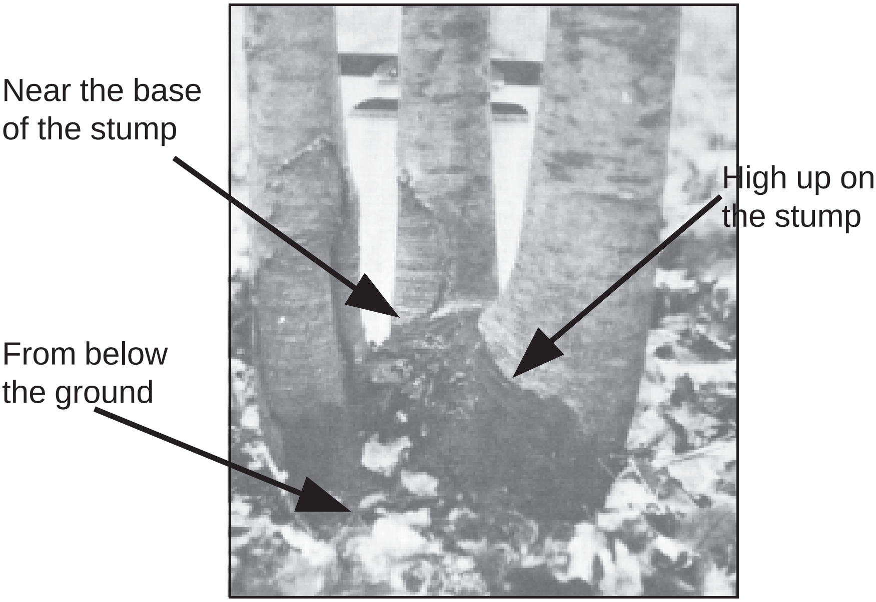


Figure 6.17 Crop tree crown release.

Thinning northern hardwood stump sprouts (adapted from Stroempl [1983])

Tolerant and mid-tolerant species such as basswood, red and/or silver maple (soft maples), sugar maple, white ash, red oak and black cherry have the ability to reproduce from stump sprouts or coppice and will respond well to sprout-thinning treatments. Stump sprouts originate from concealed dormant buds that are stimulated to grow when the tree is cut. Sprouts can originate either:

Table 6.8 Sprouting facts and related marking suggestions.

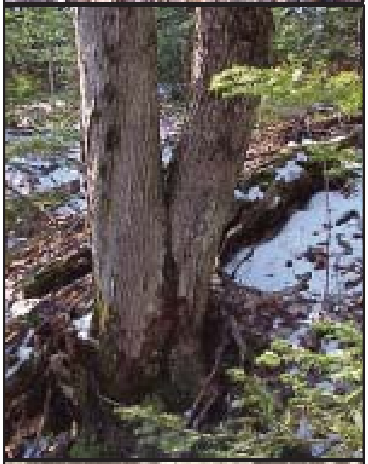


Sprouting facts…	When thinning stump sprouts, tree markers should…
• sprouts that originate closest to the ground will have less chance of rotting as the parent stump deteriorates	• retain sprout(s) that originate closest to the ground
• younger stems have greater sprouting frequency and capacity than older stems • as stump diameter increases, sprouting frequency and capacity decreases • thick bark and low tree vigour restrict the emergence of dormant buds from cut stumps	• favour stems originating from younger stumps rather than older stumps • do not rely on old and larger diameter stumps for quality coppice regeneration
• one (sapling) sprout generally assumes early dominance in a clump	• favour the most aggressive and best quality stem(s) in the cluster

Table 6.9 Marking guidelines for stump sprouts.

U-Type

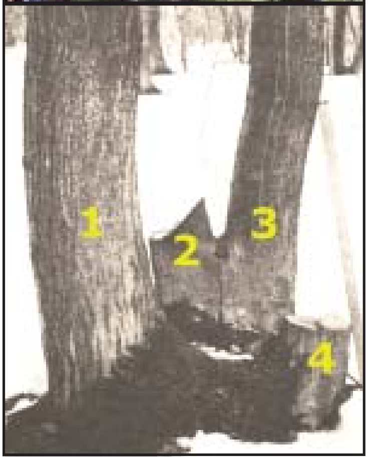
- two or more sprouts will remain separated by space or sapwood
- treat as two separate stems
- little risk of disease movement between trees
- ensure paint does not splash on adjacent stem(s), (possible result could be the removal of the wrong tree)



V-Type

- disease may move between stems at the contact zone
- treat as one stem, mark or retain the entire clump
- ensure painted stump marks indicate two stems
- if only one stem is cut, there is a risk of rot entering the remaining stem
- the longer the cutting cycle, the greater the risk of rot moving into the residual stem
- resistance to decay of the species as indicated:

  greatest **Or > Mh > Be > Ms** least



How not to thin a clump•

red oak stems #2 and #3 should have been cut and stem #4 left

In Practice:

U-Type connections between two stems should take precedence for retention over **V-Type** connections when thinning clumps

6.5.3 Marking crop trees for pruning

The selection and marking of crop trees for pruning should only be carried out in stands growing on productive sites and where active management practices such as regular thinnings are being carried out. Before crop tree marking, a stand thinning regime must be set and documented. This will help to eliminate the potential of removing marked and pruned crop trees in future thinnings.

Criteria for selecting crop trees for pruning

AGS trees with the following attributes:

- *crown position is dominant or codominant*
- *crown is full, round, and finely branched*
- *leader is well-developed*
- *tree is free of disease and insects*
- *bole is straight with no stem defects or injuries*

The number of crop trees to mark is based on the expected stem density of a well stocked stand at its rotation age. Up to 370 polewood size trees per hectare are typically selected. A program of maintaining identification marks (blue) through to harvest must be implemented to ensure that the true value of pruned trees is recovered.

6.6 Implementing prescriptions in areas of natural disturbance

by F. Pinto, C. Nielsen

Tree markers often encounter small areas or entire stands that have been affected by ice or wind storms. This section provides an overview of each of these disturbance types and the factors to consider when adjusting marking to suit the conditions encountered.

6.6.1 Understanding ice storm impacts

Ice storms are an important and recurring natural disturbance within our forests, although their occurrence in any one location is spotty and unpredictable. Major ice storms, with a return time of 20–100 years, are considerably more frequent than similar natural disturbances such as windstorms or fire which have a return time of 100–1,000 years (Melancon and Lechowicz, 1987; Smith and Musser, 1998).

Ice storms can advance succession in some stands and retard it in others, depending upon individual stand structure, species composition, landscape features, as well as storm intensity. Canopy gaps of varying size may be created, crown or stem breakage may occur, and stem decay may result. The tree marker will generally be required to encourage conditions such that potential damage to the forest is minimized, or take remedial action in stands that have already been impacted.

Conditions affecting the degree of damage

Landscape position

Ice storm damage is usually patchy because numerous geographic and climatic factors affect them: 1) elevational differences; 2) proximity to bodies of water; 3) inclination and aspect of slope; 4) composition of the ground surface; 5) direction and velocity of the wind (Bruederle and Stearns 1985).

Where is ice storm damage most severe?

- *On northern and eastern slope exposures where there is a colder microclimate.*
- *Where trees are likely to develop asymmetrical crowns that accumulate ice and snow unevenly.*
- *In open grown areas, or along forest edges.*
- *On windward exposures; damage can be intensified by strong winds.*

Species composition

Species susceptibility is related to such characteristics as crown form, fineness of branching, branch angle, crown size, and to some extent the mechanical strength of wood (Bruederle and Stearns, 1985; Boerner *et al.* 1988). Conifers generally suffer less damage than hardwoods (Table 6.10) (Dueber 1941; Carvell *et al.* 1957). Species with broad, flat crowns (e.g., white elm) expose a large surface area of branches and usually suffer severe damage. Large crowns, or those that protrude from the canopy also have an increased exposure to glaze and suffer more damage (Bruederle and Stearns 1985; Hauer *et al.* 1993).

The type of damage is dependent on the size of twigs. Small twigs are relatively flexible and tend to bend with ice accumulation. Glaze

Table 6.10 Susceptibility of common trees in Ontario to crown damage caused by ice storms.

Susceptible	Mid-tolerant	Resistant
White elm	Beech	Balsam fir
Basswood	Ash (white and green)	Eastern hemlock
Birch (white and grey)	Bur oak	Ironwood
Black cherry	Eastern white cedar	Spruce
Butternut	Red oak	
Jack pine	Red pine	
Poplar	Sugar maple	
Red maple	Tamarack	
Scots pine	White oak	
Silver maple	White pine	

remains on the twigs and the weight is concentrated onto the larger branches that may break under the stress (e.g., sugar maple, elm species, and beech). Large twigs, such as those found on hickory or ash, accumulate less glaze per unit diameter, but are less flexible, and tend to snap at the ends more readily than fine branches (Dueber 1941; Bruederle and Stearns 1985).

Tree size and condition

Saplings and small polewood become badly bent. Poles in many instances break below the crown. As average tree diameter increases, the proportion of bent trees in the stand is reduced while the rate of actual breakage is increased.

Larger trees suffer mainly from loss of branches and breakage of the main stem within the crown. The presence of decay increases their susceptibility to ice damage. In severe cases all side branches can be stripped leaving only the main trunk. Older trees are more susceptible to injury due to an increase in crown size, internal decay, and a decrease in the flexibility of branches (Bruederle and Stearns 1985).

Tree marking in stands damaged by ice storms

Tree markers will use their knowledge of tree quality potential to categorize damaged trees into an AGS or UGS classification. Most of the rules are the same as explained in Section 3.0 (Choosing the right tree to leave) but the marker must also appraise relatively recent physical damage, often without the usual defect indicators like conks, and cankers.

Indicators of tree survival potential

Crown damage

The survival and response of an individual tree to injury involves many factors including the pre-storm condition of the tree as well as tree vigour, site quality and additional stresses that trees are subjected to in the years immediately following the storm. The expectations of recovery for an individual tree can be related to the amount of crown loss due to breakage (Table 6.11).

Table 6.11 Expected impacts on hardwoods damaged by the 1998 ice storm in Ontario (adapted from Nyland 1994).

Crown loss	Probability of survival[1]	Growth suppression	Wood degradation[1]
<30%	excellent	minimal	minimal
30%–50%	very good	short-term	variable
50%–75%	good	variable, may be long-term	variable, worse for injuries with split forks and torn bark
>75%	poor	severe, long-term	severe, especially in dying trees attacked by insects

Crown loss is estimated by examining the tree from several angles and visualising the intact crown based on the shape of the crown remaining as well as any material on the ground under the tree. The marker then estimates how much of the crown is remaining to the nearest 10%—subtract this from 100 to arrive at an estimate of percent crown loss. Figure 6.18 demonstrates a range of percent crown loss.

Hardwood trees are seldom killed by crown damage. When a tree suffers crown damage it re-allocates carbon reserves to increase efficiency in the remaining leaves and to produce leaves from dormant buds. Even completely broken tops of some species will sprout new branches prolifically and allow the tree to recover (Table 6.12).

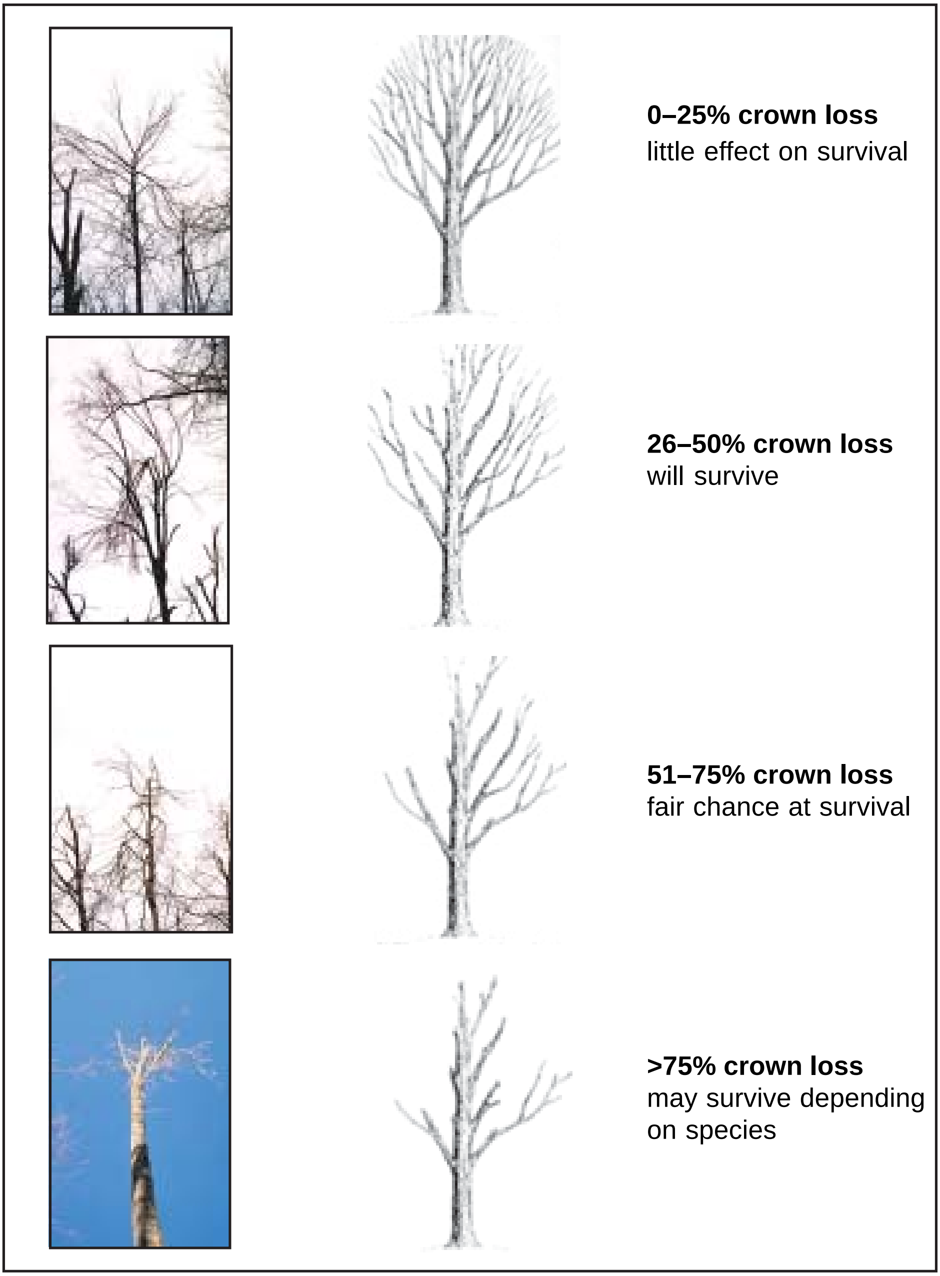


Figure 6.18 Varying levels of crown loss and effect on survivability.

Table 6.12 Crown recovery potential for hardwood species.

Species	Crown recovery potential
White ash	Prolific crown sprouting. Crown replacement within 2–3 years of severely damaged trees.
Basswood	Prolific crown sprouting. Crown replacement within 2–3 years of severely damaged trees.
Sugar maple	Moderate crown sprouting—trees with greater than 50% crown loss die progressively.
Beech	Moderate crown sprouting—enough to allow tree to survive.
Black cherry	Good crown regeneration.
Red oak	Low crown regeneration—50% growth reduction and 42% mortality if severely damaged.

Conifers that do not survive ice storms tend to be broken below the live crown or have a majority of crown loss (Williston 1974; Whitney and Johnson 1984; Boerner *et al*. 1988). Interestingly, pines only require as few as three remaining live limbs to have a greater than 75% chance of survival (Barry *et al*. 1993). In cases of severe top breakage, a lateral branch will develop into a terminal, developing a crook where the break occurred (Barry *et al*. 1993).

Decay and stain

Breaks in the trunk and large branches provide points of entry for stain and decay fungi. Crown injuries that do not involve the main stem or large branches present a low decay hazard in all species (Campbell 1937). Broken branches less than 8 cm in diameter callus over quickly and present a low decay hazard (Hough 1965; Rextrode and Auchmoody 1982; Barry *et al*. 1993). Where large branches are broken, especially if shattered, the incidence of decay is high, particularly for red maple and beech. Black cherry and sugar maple seem to be somewhat resistant to decay following crown damage (Hough 1965; Rextrode and Auchmoody 1982), possibly due to the slow formation of heartwood in these species (Campbell 1937). In any species, split forked stems are particularly prone to infection because of the large surface area left exposed.

Wounds in the trunk are more serious than damage to branches in the crown (Shortle and Smith 1998b). Generally trunk wounds that do not penetrate more than 5 cm into the sapwood or that are less than 930 cm^2 in surface area will have only localized stain, but little decay. However, any trunk wounds in species such as red maple, beech, and yellow birch 20 years or older, constitute a high decay hazard (Campbell 1937). In more decay resistant species such as black cherry and sugar maple only large trunk wounds (regardless of tree age) constitute a high decay hazard. Remember that wounds in contact with the soil result in greater levels of decay.

The rate and degree of stain and decay development depends on tree species, wound size, wound location, individual tree vigour, and local pathogens and insects (Shigo 1984). Stain and decay progress only until the wound is overgrown, all things being equal. Significant rot does not develop in maple until a succession of fungi has infected the tree, and this may not occur for over a year. Mineral stain will impede or prevent the spread of infection and development of decay of maple. Observations from past ice storms have shown that decay from branch breaks that were less than 12 cm in diameter was limited to 15 cm from the wound in sugar maple, four years after damage occurred. Decay had progressed 76 cm from the wound location in black cherry after four years.

Degree of bending

Bent trees that have not recovered by late summer or early fall following an ice storm will not improve, and may eventually break or uproot. Birch, cherry, red cedar and willow do not recover from severe bending. Bent cherry saplings and small polewood will grow sprouts along the bole, limiting their future worth (Hough 1965).

Conifers bent more than 45 degrees will not recover (Sanzen-Baker and Nimmo 1941; Mckellar 1942; and Burton 1981), and trees that appear completely recovered may contain fractured stems or compression failures (Anon 1941; Cayford and Haig 1961; Barry *et al*. 1993). Compression failures are most common in young, tall trees with slightly tapered stems that are easily whipped by the wind. Dense pole timber stands are particularly subject to this injury if they have recently been thinned. Often, the only external evidence of damage in pine is pitch flow where the bark has been broken (Barry *et al*. 1993).

Epicormic branching
Many tree species will respond to crown damage and the increased exposure to sunlight following an ice storm by activating latent buds to produce epicormic branches. The extent of epicormic branching is dependent on the species. Sugar maple, beech, and yellow birch all respond to excessive exposure by sprouting epicormic branches from dormant or adventitious buds (Blum 1963). Yellow birch is the most prolific producer of epicormic branching followed by sugar maple and beech, at a ratio of 13:6:1. Based on a study conducted by Smith (1966) species were ranked according to degree of epicormic branching from most to least as follows: white oak, black cherry, red oak, hickory, red maple, sugar maple, and white ash.

The degree of crown loss has a greater effect on the level of epicormic branching than the degree of exposure to sunlight. Epicormic branch development is also dependent on the crown position of the tree, with more sprouts developing on mid-canopy and overtopped trees than on dominant and codominant trees. More sprouts develop on second logs than on first logs (Smith 1966; Erdmann and Peterson 1972; Stubbs 1986), with bole sprouting somewhat greater on poor sites (Smith 1966).

Sunscald
Sunscald is the death of cambial tissue on one side of a tree caused by rapid freezing of sun-thawed tissue. Sunscald injury is evidenced by dead bark, discoloured underlying wood, and sometimes disease infection (e.g., sap rot fungi). Generally, sunscald is common when smooth, thin-barked trees are exposed to direct sunlight (Spaulding and Bratton 1946). After a severe ice storm, beech with dbh less than 46 cm and sugar maple with dbh less than 15 cm are susceptible to sunscald. White ash and basswood with severe crown damage have not shown evidence of sunscald (Spaulding and Bratton 1946).

Reducing risk of damage in areas prone to ice storms
Measures to reduce risk of severe ice storm damage are synonymous with good silvicultural practices. Well-managed stands are the least susceptible to damage and most likely to recover after an ice storm. The following are prescription and marking guidelines for reducing risk of ice damage.

- Maintain recommended stocking levels. Lower than recommended stocking levels will encourage development of broad, deep crowns that are susceptible to ice damage.
- Remove no more than 1/3 of the basal area when implementing the selection system. Stands that have been heavily cut have a higher risk of ice damage until crown closure develops and tree stems have the opportunity to become windfirm.
- Maintain species diversity (e.g., retain a conifer component in hardwood dominated stands). Recognize that degree of damage is species dependent.
- Retain additional conifer on north and east slopes and favour hardwood species of lower susceptibility in areas prone to ice storms.
- Retain vigorous trees that are free of decay and dieback. Branch and stem breakage often occurs at locations previously weakened by decay.
- Target for removal trees with asymmetrical crowns, mid-stem forks, and multiple stems (which tend to break at the union), while following guidelines for wildlife habitat.
- Select straight trees for retention—leaning trees are more susceptible to stem breakage and tipping, in particular on steep slopes with north or east aspect.
- Attempt to maintain regular spacing to avoid asymmetrical crown development.
- Periodically thin even-aged polewood stands to promote lower height to diameter ratios. Such stands, if unthinned and overstocked, are more susceptible to damage; stands of small diameter, tall trees with a lack of vertical structure may show a domino effect once a few trees bend or break.
- Manage tolerant hardwood stands, with an adequate proportion of AGS stems, towards an uneven-aged structure. Vertical structure may reduce risk of damage.
- Ensure efficient road layout and orientation to reduce exposure of trees on windward side.

6.6.2 Understanding windthrow

Windthrow is the uprooting or breakage of trees caused by strong winds and is a natural process that plays an important role in forest succession. During a wind event a tree sways in an elliptical fashion. The forces of the wind are transmitted to the roots anchoring the tree. Crown and stem breakage or uprooting can occur when the forces from the wind event exceed the ability of the tree and soil to dissipate or resist the energy.

Wind events create conditions with the potential to promote stand renewal in the following ways:

- create pit and mound micro-topography, which in turn influences the rate of litter decomposition
- create seed beds suitable for seed germination of light-seeded species such as yellow birch and white spruce
- release advanced regeneration
- provide growing space to the trees that are more resistant or protected from windthrow

The role of the tree marker is to emulate small-scale wind disturbances in stands where this type of disturbance is the main cause of tree replacement. As well, tree markers should be aware of the factors that affect windthrow in order to minimize the potential that may result from poor application of a silvicultural prescription; e.g., incorrect orientation of a cut block, or excessive tree marking such that the residual stocking level is too low.

Conditions affecting the degree of damage

Species composition

Trees with dense wood and thick stems are less prone to breakage than a tree with wood of low density and a slender stem. Tolerant hardwoods tend to have dense wood and thick stems making them more resistant to windthrow. The pines are considered more resistant to windthrow than many other conifers. Balsam fir and black spruce are more susceptible to breakage than pines.

Landscape position

An individual tree's location on the landscape and the type of stand and site conditions may increase or decrease the likelihood of windthrow. Trees growing in exposed areas such as along lakeshores, hill crests, ridges or large clearings are more susceptible to windthrow than similar trees growing in other parts of the forest. In these areas, tree markers should recognize that windthrow risk might be increased immediately following logging by the intensity of tree removal, the timing of the removal, and the orientation of any openings in or near the stand.

A tree marker should study the location and position of the stand in relation to other stands and landscape features. Windthrow risk is greatest in stands located along the windward side of a hill (usually the western and northern slopes), along the eastern shore of a large water body, and along a ridge or crest of a hill. Examples of landscape features and associated windthrow risk are provided in Table 6.13.

Table 6.13 Landscape features: Indicators of windthrow risk and management implications (Mitchell 1995).

Low risk	**Moderate risk**	**High risk**	**Management in high risk zones**
valley bottoms lee middle slopes not parallel to predominant prevailing winds areas sheltered by high ground	valley bottoms parallel to prevailing winds mid slopes lee upper slopes	mid and upper slopes parallel to prevailing winds windward upper slopes ridges, hilltops valley bends and constrictions near windward shoreline of large water body	orient openings perpendicular to prevailing winds block harvest areas and schedule harvest by block to different years buffer harvest areas with unharvested areas

Forestry activities

- Logging and site preparation can sever roots or otherwise destabilize residual trees, and increase decay in the roots, stem and branches making affected trees more susceptible to windthrow and breakage.
- Windthrow may be more common immediately following thinning operations in dense stands.
- Juvenile thinning may reduce windthrow.

Site conditions

Soil depth and rooting zone will also influence risk of windthrow. White spruce is considered less vulnerable when growing on soils that allow it to produce strong descending roots, such as deep sands (Nienstaedt and Zasada 1990). Sugar maple growing on deep compacted till overlain with a shallow layer of dumped till may be uprooted in strong winds (microbursts) because the root system is confined to a shallow rooting zone.

During a wind event, the roots of a tree on the windward side are stretched and those on the leeward side are compressed. As the forces are transmitted to the soil around the roots, the soil mass is subject to shear forces. Soil shear strength is greater in sandy soils and lower in fine textured soils; shear strength increases as soil moisture content decreases (Busby 1965). Thus, trees on dry sandy soils will be less prone to windthrow than those on fine textured saturated soils.

Tree markers should observe the conditions of the stand, particularly for evidence of existing windthrow. Stands that already display evidence of windthrow probably have a moderate or high risk of further windthrow. Trees that are expected to die before the next entry are normally given priority for removal except where they need to be retained for biodiversity objectives. The tree marker should then set removal or retention priorities according to the following indicators of windthrow risk (Table 6.14).

Table 6.14 Site and stand factors affecting windthrow risk and management (Mitchell 1995, 1998).

Low risk	Moderate risk	High risk	Management in high risk zones
	Site factors		
-deep soils -well drained -sandy to loamy textured soils	-moderately deep soils -patches of moderate to poor drainage -high amount of coarse fragments	-shallow soils -poor drainage -fine textured soils -organic soils -exposed bedrock	-buffer cut areas with uncut blocks -removal levels should be low
	Stand factors		
-stand height less than 15 m -uniform height, low density -uneven height, moderate density -shade intolerants have live crown ratio greater than 70%	-stand height 15–25 m -uniform height, moderate density -uneven height, high density -shade intolerants have live crown ratio of 70–35%	-stand height 25 + m -uniform height high density -stem or root decay evident -shade intolerants have live crown ratio of less than 35%	-use partial cutting to create uneven height structure -retain dominant trees with little evidence of decay -removal levels should be low

6.7 Implementing prescriptions to facilitate careful logging

by J. Leavey

Carefully planned and implemented logging operations will allow for sustainable harvests of high quality timber products extracted in a manner that avoids injury to workers, minimizes damage to residual trees and conserves the complex relationships between forest life forms and the air, water and soil (OMNR 2000).

Careful logging is expressed as a set of principles and best management practices designed to ensure achievement of silvicultural objectives while mitigating or avoiding unnecessary damage to the forest ecosystem. Specific careful logging concerns include:

- damage to residual trees
- damage to regeneration
- destruction of wildlife habitat
- soil compaction
- soil rutting
- erosion
- disruption of water movement
- nutrient loss

This subsection relates to a tree marker's influence on a logger's abilities to minimize damage to residual trees, regeneration and wildlife habitat. The direction offered in this subsection should only be employed by tree markers with experience or sufficient knowledge of the subsequent harvesting job to avoid complicating or limiting it with poor decisions. Logging professionals will make the final decisions pertaining to worker safety, roads, landings, skid trail layout, and operability constraints such as weather, seasonal restrictions, steep grades, and marketability. Nevertheless, tree markers should consider factors that allow professional loggers to practice careful logging.

Tree markers can facilitate careful logging activity by:

- Ensuring proper paint application.
    - Tree marking paint should be visible from at least three sides to aid planning for skid trail layout and directional felling.
    - When using paint symbols that are not easily seen from different directions, apply the symbols consistently facing one direction.
    - Ensure that stump marks are applied and located in such a way that they will be clearly visible during post-harvest inspections.

- Assessing the characteristics (e.g., lean, crown size, proximity to other trees) of individual trees within the marking area, and considering the possible impacts of those trees on adjacent trees if felled.

  - Assess degree and direction of lean. If two competitors are otherwise equal, but one must be felled into an area of established regeneration, and the other may be directed into a natural opening, the marker should choose the least damaging option.
  - It may cause less damage to mark one tree with a large crown than several small-crowned trees, or vice versa.
  - Coppice stems or trees growing very close to desired residual trees may be very difficult to remove without causing stem or crown damage to residuals
  - Trees growing very close to immovable objects, such as rocks, present safety related challenges to the operator.

- Considering risks to personal safety or to significant natural values.
  - Trees that cannot be felled safely, such as trees on the edges of cliff faces, or trees overhanging utility lines, should be left unmarked, and an alternate choice made if possible.
  - Trees having excessive lean into an AOC, and that pose a significant risk to a physical (e.g., a stream) or habitat (e.g., a stick nest) feature, should be retained.
  - Trees within sensitive areas (e.g., seeps, riparian areas) should not be marked unless they can be removed with minimal impact to the site.

- Marking small diameter trees (at least those >10 cm dbh) even if locally unmarketable, to identify those trees that may be removed for silvicultural purposes during logging operations. An unmarked tree is a desired residual tree unless otherwise specified in the prescription and harvest license.
  - Undersized but marked trees may be targeted when felling adjacent stems (better to damage a marked UGS tree than an unmarked AGS), or used in laying out access trails or roads.
  - Marking undersized and unmerchantable trees facilitates subsequent regeneration treatments such as scarification for natural regeneration, or tending.

- Carrying out marking operations after roads and landings are constructed.
    - Trees damaged during road construction (broken crowns, severed roots, and scarred stems) will be more susceptible to decay causing infections and mortality, and may be marked.
    - Trees on the edges of openings may be retained at a somewhat higher density to reduce stresses to interior trees related to increase wind or over-exposure to sunlight.

Ultimately the person felling the trees is required to remove all overhead hazards from the work site before operating. A tree marker must use his or her best judgement when marking to avoid retaining trees that pose a worker safety hazard. A tree marker may also reduce the risk to forest workers by clearly identifying hazards that are to be left, or that are not readily visible to the operator. It may be viewed as simply a common courtesy to clearly mark the location of a bee's nest, or large precariously hanging limb, but it may also save somebody's life.

A tree marker's primary responsibility is to implement the prescribed silviculture treatment and integrate wildlife habitat and biodiversity considerations. However a tree marker may favour the removal of one tree over another if it facilitates safe felling and minimizes logging damage, assuming all other factors are equal. Quite often, a tree marking decision is made easier by taking the relative difficulty of felling and/or skidding into consideration.

7.0 Administering a tree marking program

by S. Munro, K. Webb

Information in this section will provide forest managers with guidance related to marking crew organization, marking technique and quality assurance.

7.1 Crew organization

To ensure a safe, effective and efficiently organized tree marking operation, program managers must consider staff training needs, optimal crew size, provision of adequate supervision, and any relevant health and safety requirements.

7.1.1 Training

The skills required for good tree marking have been recognized for many years (McLean 1976). Proficiency in those skills cannot be developed without extensive training and field experience. In recognition of the critical nature of the activity and following the Crown Forest Sustainability Act, tree markers must be certified, or must be in the process of becoming certified in order to mark Crown forests. Certification is only possible through successful completion of the Ontario Tree Marker Training Program.

The Tree Marker Training Program was developed specifically to ensure consistently high quality tree marking program delivery across the GLSL forest. Level I certification is the minimum level required to mark trees on Crown land in Ontario, and is the focus of this discussion. Advanced levels reflect the additional skills required of tree marking auditors, crew bosses, trainers, and prescription writers.

Level I training provides:

- a basic understanding of the silvicultural systems, and their relation to natural process and species adaptations
- an understanding of the silvics of the principal GLSL forest species
- the recognition of defect and vigour indicators, as well as the relevant quality classification systems
- habitat values and biodiversity considerations in hardwood and conifer forests
- marking crew organization
- stand analysis and prescription development, and

- marking to a selection and shelterwood prescription

Candidates are certified to mark Crown lands only after passing a written exam, several field examinations, and an operational field audit. Refresher courses are scheduled periodically, in cooperation with local managers, in order to provide markers with an opportunity to upgrade their skills, and receive training related to management issues relevant to local challenges.

This formal training program addresses only a portion of the knowledge required of a tree marker. Managers should not overlook the knowledge gained with field experience, or the value of providing a new marker with the opportunity to work with and learn from experienced markers.

7.1.2 Crew size

Crew size will depend on a number of constraints including the size of the area to mark, its location, access, time allotment, budget, and nature of the tree marking prescription. Usually three markers are an effective crew size; in addition, one tally person when a permanent record of the size and volume of marked trees is required (e.g., for a timber sale). Regardless of how many markers are in a crew, they must work as a unit, one person assuming the role of crew leader.

The crew leader should be slightly ahead of the second marker in the row and so on to the last marker. This helps to avoid missing trees. Communication is key to avoiding missed trees for removal. In dense forest cover, where it is difficult to see the upper bole of a tree, it is critical that markers assist each other to identify dead tops, diseased trees, cavities, or other non-timber values.

7.1.3 Supervision

To ensure that a tree marking operation functions efficiently and effectively, there should be a field manager or foreperson responsible for:

- assisting the forester, supervisor, or landowner in locating the stands designated for marking and in collecting required data on those stands
- securing maps, aerial photos, and prescriptions

- visiting the area to be marked ahead of time (with the prescription author or landowner) and discuss the prescription, management objectives and any areas of concern
- ensuring all private land boundaries, harvest boundaries and reserves are well marked to identify and protect these areas
- reserving vehicles, accommodation and other essential equipment
- supervising the marking tally and checking to ensure proper prescription application, documentation, etc.
- establishing the marking lines and ensuring full coverage of the prescribed area
- ensuring the markers are not too close together, or too far apart
- modifying or changing the prescription in unique or unusual local situations and reporting such variances to the forester/supervisor
- identifying and reporting any new forest values encountered and applying appropriate protection measures
- ensuring availability of sufficient tree marking paint
- ensuring availability of first aid supplies

7.1.4 Health and safety considerations

Working outdoors can present numerous hazards to the tree marker, and the following are general guidelines for safe working practices. Each practice is the responsibility of all involved.

- knowledge of safe working practices
- understanding of information contained in Material Safety Data Sheets (MSDS) i.e. tree marking paint
- knowledge of regulations under the Ontario Health and Safety Act (OHSA)
- ability to operate and maintain pertinent equipment
- experience in proper use of safety equipment, cardiopulmonary resuscitation (CPR) and first aid training
- prior knowledge of hazards on the job, i.e., remote locations, poison ivy

7.2 Marking style

7.2.1 Paint colour

Table 7.1 Tree marking paint colour and its meaning.

Paint colour		Meaning of colour
YELLOW or ORANGE		trees to be removed for harvest
RED		boundary line/reserve marking
BLUE		trees to be retained, e.g., crop tree, trees for wildlife
BLACK		when mistakes are made, cover up with black paint
WHITE		research plots

7.2.2 Paint application

One of the most important aspects of tree marking is the correct application of paint to the selected tree. Two distinct paint applications are required; a top mark and a butt mark (Figure 7.1). For safety reasons, apply the butt mark first, using an upstroke, to avoid inhaling the airborne paint. Ensure that enough paint is applied to offset any fading that may occur between applying the paint and the harvest operation.

Figure 7.1 Recommended application of top and butt marks.

Top mark

The top or stem marks need to be visible from all sides of the tree to enable the cutter and skidder operator to carefully plan their operations. This also enables the tree markers to follow their marking in the forest to ensure that no trees or areas are missed. Spray completely around the tree or at least mark the tree on three sides at eye level. In plantations to be row thinned, three dots are to be placed on either side of the trees at the start and end of the rows. Every 5th–10th tree is to be marked with a dot on either side of the tree to keep the harvester in the row.

Butt mark

Following the harvest, the butt or stump mark is inspected by auditors to ensure the correct tree was felled. Preferably place the butt mark in a seam or depression at the base of the tree (root collar) where it would be difficult to scrape off the mark with a skidder tire, or chafing logs or chains. Avoid applying paint on moss or ice. Marks should be a minimum 30 cm in length from the root collar.

7.3 Quality assurance

Quality assurance is the process by which a completed tree marking treatment is inspected prior to harvesting to ensure that it meets the objectives of the prescription for the stand and conforms to accepted standards. Tree marking audits are also performed to ensure consistency of marking across Crown Land and to help tree markers correct any potential problem areas before harvesting. Elements of the tree marking operation which are inspected include:

- accurate location and consideration of all boundaries (property lines or cut boundaries, areas-of-concern (AOC), non-timber values that occur as well as required buffers) according to the silvicultural prescription
- achievement of silvicultural objectives outlined in the prescription (basal area levels, number of trees per hectare, structural targets, AGS improvement level, etc.)
- selection of trees for retention or removal consistent with guidelines (species priority, spacing, tree quality class, structural, etc.) specified in the prescription
- paint application visible, correctly located and using the appropriate colour

- proper marking adjustment made for values (e.g., stick nests) or conditions (e.g. localized occurrence of desired advance regeneration) not noted in the prescription
- achieved biodiversity objectives outlined in the prescription (e.g., cavity and mast trees, solitary conifer in hardwood stands)

7.3.1 Audit procedure

Tree marking audits involve the installation of sample plots within which all trees larger than 10 cm dbh are assessed. Examples of tree marking audit forms and audit summaries are illustrated in Appendix F.

The auditor can manually summarize the data or the data can be transferred to an electronic version of the form for a computed summary. In either case, all appropriate fields must be filled in, and the *tree marking quality* (TMQ) must be calculated along with the overall rating of the tree marking operation.

TMQ is calculated for the stand and is based on the total of all sample plots. The overall percentage of TMQ is calculated using the formula included on the tally sheet. Local managers will set the TMQ at a level sufficient to meet their forest objectives, although the TMQ must be 90% or greater. The auditor will sign off or release the area to the logger if marking is satisfactory.

Equipment required

Plot system

A point sample using a prism or angle gauge is the sampling method of choice, for the following reasons:

- prism plots are quicker to install than fixed area plots since no plot layout is required
- the basal area calculation for hardwoods is simpler and quicker than the calculation required for fixed area plots
- the approach is standard in most OMNR districts, used on the provincial tree marking course and in silviculture guides

Plot layout
Data must be collected in a uniform manner across all sites and distributed evenly across the stand. Aerial photos are used to complete an unbiased stratification of the area. Plots are normally placed 80 m apart and 40 m from stand edges, although when the maximum dbh encountered is less than 60 cm, 60 m between plots may be acceptable. Plot centres are flagged and the plot number is recorded on the flag.

Number of plots required
To assess tree infractions, a minimum of 10 plots should be established for areas up to 20 ha, and one plot for every additional 5 ha. Stand infractions can be assessed by walking between plots, checking AOCs and *integrated resource management* (IRM) considerations.

Frequency of audits
Before assessing the tree marking, the auditor should review the prescription with markers, to resolve any misunderstandings early in the process. After the initial check the auditor should have a good understanding for how well the marking operation is progressing and can schedule future audits accordingly.

7.3.2 Infractions
Tree marking audits assess the quality of the marking by quantifying the number of infractions observed. Two types of infractions are assessed during an audit. These include tree infractions and stand infractions.

Tree infractions
Tree infractions are used to calculate and assess the correctness of individual tree decisions, i.e., removal/retention, species priority, size class, etc. These infractions are tallied on a plot by plot basis. Infractions of this type include the following:

- **Paint application:** Poor stump marks, and dbh marks that are not readily visible, faint, or subject to weathering. Paint application standards are usually set locally.
- **Spacing:** Improper spacing as it affects crown closure or improper release of crop trees. Both criteria are assessed for either excessive or insufficient levels of release/spacing. Standards are derived from

relevant silvicultural guides and specified in the silvicultural prescription.

- **Species priority:** Determined or set in the relevant silvicultural ground rules and clarified in the silvicultural prescription.
- **Quality (crop tree) priority:** The individual's manipulation of residual tree quality within each plot is judged according to the prescription and standards.
- **Size priority:** Targets are set for various diameter class groupings to meet stand structure objectives. This is true for both shelterwood and selection marking. Again, selection of residuals within the plot is assessed with the structural target in mind.

Stand infractions

Stand infractions are used to provide a stand level assessment of marking effectiveness, i.e., residual basal area, or overall integrated resource management considerations. Stand infractions are assessed on an overall stand basis, and an unsatisfactory rating in any of the following attributes will result in an unacceptable overall rating. Infractions in this category include:

- **Marking in reserves**: any unauthorized marking that could lead to removal of trees within a reserve is an infraction.
- **Marking outside the block**: any marking outside the approved allocation.
- **Integrated resource management (IRM) considerations:** IRM attributes are considered both within the plots and related to a stand level target, while traversing between plots. Within plots, cavity trees are appraised and related to a stand level target, while individual stand attributes are assessed wherever they are noted within the stand. For instance, the appropriateness of the treatment of areas surrounding critical stick nests will be appraised wherever the nest is noted. These overall attributes are judged based on stand-level habitat needs. Other examples of overall stand attributes are intermittent streams and seeps, mast trees, solitary conifer in hardwood stands, supercanopy trees, winter cover, treatment of poorly represented species, and moose calving sites.
- **Residual basal area:** This attribute is primarily a tool for assessing selection situations. On an individual plot basis, all trees are tallied by diameter class groupings, quality class, and whether they are

marked or residual stems. This information is summarized to calculate an overall residual basal area for the stand. The residual basal area is then compared to the target specified in the prescription, and if deemed to be within an acceptable range, is rated as satisfactory. A maximum 10% variance from the desired basal area is normally considered acceptable. In some cases, the auditor may accept greater than a 10% variance if the variance is justified silviculturally (i.e., if the operational cruise on which the prescription was based does not reflect actual stand conditions, or if the auditor basically agreed with the markers' decision making within each plot).

- **Residual crown closure:** This attribute is judged on a stand basis, with observations made throughout the stand and within the plots. These observations are made based on relative density factor, basal area/crown closure relationships, percent of stand height, or crown spacing. The technique used depends on approach most favoured by the local area. If overall objectives are not met, the treatment is deemed unsatisfactory.

8.0 Effectiveness Monitoring

The Ontario Tree Marking Guide is a companion document to the silvicultural guides for the Great Lakes–St. Lawrence, Deciduous, and Boreal Forest Regions of Ontario. It provides guidance to tree markers implementing the partial harvesting prescriptions as outlined in the silvicultural guides. Therefore, monitoring the effectiveness of this tree marking guide is closely tied to assessing the effectiveness of those treatments. Ontario has already developed a process to do this through the *Silvicultural Effectiveness Monitoring Manual for Ontario* (OMNR 2001).

Forest managers for each forest management unit in the province must collect an assortment of information to assess whether a particular area has met the regeneration objectives in the forest management plan. This information includes tree species, minimum height, time frame to reach free to grow, and stocking and/or density of trees. In the Great Lakes–St. Lawrence forest it also includes diameter distribution, as a surrogate for stand structure, and an indication of the quality of the residuals. Additional data may be needed to assess current stand and site conditions and track stand development over time toward the desired future forest condition. These might include the number of live cavity trees, number of seed trees, number of veteran trees or amount of major logging damage to residual trees or established regeneration on the site. This information and the subsequent analysis is reported in annual reports and the reports of past forest operations which are then used to write prescriptions in the next forest management plan.

Provincially, Ontario uses the data to report on the state of forest growth and regeneration and to analyze trends between forest units, management units, and site regions. This analysis serves many purposes, including providing background information when reviewing and rewriting silvicultural guides and their companion documents such as the Ontario Tree Marking Guide.

Similarly, the effects of this guide on wildlife population trends are monitored through the Ministry's Wildlife Population Monitoring Program. Condition 30 of the Forest Management Class Environmental Assessment outlines the requirements for the mandatory continuation of a Provincial Wildlife Population Monitoring Program. The intent of the program is to provide long-term trend data and to collect information to support the testing and analysis of the effectiveness of the forest management guides. The species that are to be monitored include moose; deer; pileated woodpecker; and species that use snags, dead and downed woody material, mature/overmature stands, and large areas in a similar successional stage. Any pertinent results of the analysis and the knowledge gained from this program will be used to help the MNR and the Provincial Forest Technical Committee review and revise this guide when necessary.

An informal, but important method of effectiveness monitoring will be through the experience of certified tree markers. Their extensive time in the forest to mark and audit marking, often on sites that were previously harvested, leads to an excellent understanding of how the techniques work and how they might be improved to achieve the intended goals.

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Appendix A—Common and scientific names of plant and wildlife species referred to in this guide.

Trees

COMMON NAME	SCIENTIFIC NAME	SPECIES CODES
balsam fir	*Abies balsamea* (L.) Mill.	Bf
balsam poplar	*Populus balsamifera* L.	Pb
basswood	*Tilia americana* L.	Bd
beech	*Fagus grandifolia* Ehrh.	Be
bitternut hickory	*Carya cordiformis* (Wang.) K. Koch	Hb
black ash	*Fraxinus nigra* Marsh.	Ab
black cherry	*Prunus serotina* Ehrh.	Cb
black spruce	*Picea mariana* (Mill.) BSP	Sb
black walnut	*Juglans nigra* L.	Wb
bur oak	*Quercus macrocarpa* Michx.	Ob
butternut	*Juglans cinerea* L.	Bn
chestnut	*Castanea dentate* (March.) Borkh.	Cd
eastern hemlock	*Tsuga canadensis* (L.) Carr.	He
eastern red cedar	*Juniperus virginiana* L.	Cr
eastern white cedar	*Thuja occidentalis* L.	Cw
European larch	*Larix decidua* Mill.	Le
green ash	*F. pennsylvanica* Marsh. var. subintegerrima	Ag
grey birch	*Betula populifolia* Marsh.	Bg
ironwood	*Ostrya virginiana* (Mill.) K. Koch	Id
jack pine	*Pinus banksiana* Lamb.	Pj
largetooth aspen	*Populus grandidentata* Michx.	Al
Norway spruce	*Picea abies* (L.) Karst.	Sn
pin cherry	*Prunus pensylvanica* L.f.	Cp
poplar	*Populus* L.	Po
red ash	*Fraxinus pennsylvanica* Marsh.	Ar
red maple	*Acer rubrum* L.	Mr
red oak	*Quercus rubra* L.	Or
red pine	*Pinus resinosa* Ait.	Pr
red spruce	*Picea rubens* Sarg.	Sr
Scots pine	*Pinus sylvestris* L.	Ps
shagbark hickory	*Carya ovata* (Mill.) K. Koch	Hs
silver maple	*Acer saccharinum* L.	Ms
sugar maple (hard maple)	*Acer saccharum* Marsh.	Mh
tamarack	*Larix laricina* (Du Roi) K. Koch	La
trembling aspen	*Populus tremuloides* Michx.	At
white ash	*Fraxinus americana* L.	Aw
white birch	*Betula papyrifera* Marsh.	Bw
white elm	*Ulmus americana* L.	Ew
white oak	*Quercus alba* L.	Ow
white pine	*Pinus strobus* L.	Pw
white spruce	*Picea glauca* (Moench) Voss	Sw
willow	*Salix* L.	Wi
yellow birch	*Betula alleghaniensis* Arnold	By

Shrubs

COMMON NAME	SCIENTIFIC NAME
beaked hazel	*Corylus cornuta*
bush honeysuckle	*Diervilla lonicera*
creeping snowberry	*Gaultheria hispidula*
dwarf raspberry	*Rubus pubescens*
fly honeysuckle	*Lonicera canadensis*
hobblebush	*Viburnum alnifolium*
Labrador tea	*Ledum groenlandicum*
leatherleaf	*Chamaedaphne calyculata*
leatherwood	*Dirca palustris*
low sweet blueberry	*Vaccinium angustifolium*
mooseberry	*Viburnum edule*
mountain fly honeysuckle	*Lonicera villosa*
mountain maple	*Acer spicatum*
northern wild raisin	*Viburnum cassinoides*
partridgeberry	*Mitchella repens*
prickly wild rose	*Rosa acicularis*
red currant	*Ribes triste*
striped maple	*Acer pennsylvanicum*
twinflower	*Linnaea borealis*
velvet-leaved blueberry	*Vaccinium myrtilloides*
wild red raspberry	*Rubus idaeus ssp. melanolasius*
willows	*Salix spp.*
wintergreen	*Gaultheria procumbens*

Herbaceous Vegetation

COMMON NAME	SCIENTIFIC NAME
American ginseng	*Panax quinquefolium*
blue cohosh	*Caulophyllum thalictroides*
bracken fern	*Pteridium aquilinium*
Braun's holly fern	*Polystichum braunii*
lady fern	*Athyrium filix-femina*
large-flowered bellwort	*Uvularia grandiflora*
oak fern	*Gymnocarpium dryopteris*
ostrich fern	*Matteuccia struthiopteris pensylvanica*
pine-drops	*Pterospora andromedea*
pink lady's-slipper	*Cypripedium acaule*
ram's-head lady's-slipper	*Cypripedium arietinumallium Tricoccum*
rose twisted stalk	*Streptopus roseus*
Schreber's Feathermoss	*Pleurozium schreberi*
sphagnum moss	*Sphagnum spp.*
spinulose wood fern	*Dryopteris carthusiana*
wild sarsaparilla	*Aralia nudicaulis*

Birds

COMMON NAME	SCIENTIFIC NAME
American crow	*Corvus brachyrhynchos*
bald eagle	*Haliaeetus leucocephalus*
barred owl	*Strix varia*
black-throated green warbler	*Dendroica virens*
blue jay	*Cyanocitta cristata*
broad-winged hawk	*Buteo platypterus*
cedar waxwing	*Bombycilla cedrorum*
common goldeneye	*Bucephala clangula*
common raven	*Corvus corax*
cooper’s hawk	*Accipiter cooperii*
downy woodpecker	*Picoides pubescens*
eastern bluebird	*Sialia sialis*
great blue heron	*Ardea herodias*
great gray owl	*Strix nebulosa*
great horned owl	*Bubo virginianus*
hairy woodpecker	*Picoides villosus*
long-eared owl	*Asio otus*
merlin	*Falco columbarius*
northern flicker	*Colaptes auratus*
northern goshawk	*Accipiter gentilis*
northern saw-whet owl	*Aegolius acadicus*
osprey	*Pandion haliaetus*
ovenbird	*Seiurus aurocapillus*
pileated woodpecker	*Dryocopus pileatus*
red-shouldered hawk	*Buteo lineatus*
red-tailed hawk	*Buteo jamaicensis*
rose-breasted grosbeak	*Pheucticus ludovicianus*
ruffed grouse	*Bonasa umbellus*
sharp-shinned hawk	*Accipiter striatus*
turkey vulture	*Cathartes aura*
white-breasted nuthatch	*Sitta carolinensis*
wild turkey	*Meleagris gallopavo*
wood duck	*Aix sponsa*
wood thrush	*Hylocichla mustelina*
yellow-bellied sapsucker	*Sphyrapicus varius*

Mammals

COMMON NAME	SCIENTIFIC NAME
American marten	*Martes americana*
beaver	*Castor canadensis*
black bear	*Ursus americanus*
deer mouse	*Peromyscus maniculatus*
eastern chipmunk	*Tamias striatus*
eastern grey squirrel	*Sciurus carolinensis*
fisher	*Martes pennanti*
moose	*Alces alces*
porcupine	*Erethizion dorsatum*
raccoon	*Procyon lotorr*
red squirrel	*Tamiasciurus hudsonicus*
white-footed mouse	*Peromyscus leucopus*
white-tailed deer	*Odocoileus virginianus*

Herptiles

COMMON NAME	SCIENTIFIC NAME
northern two-lined salamander	*Eurycea bislineata*
wood frog	*Rana sylvatica*
yellow spotted salamander	*Ambystoma maculatum*

Fish

COMMON NAME	SCIENTIFIC NAME
brook trout	*Salvelinus fontinalis*

Appendix B—STAND ANALYSIS FIELD SHEET

STAND ANALYSIS
FOR HARVEST OR INTERMEDIATE CUTTING

Management Unit:__________________________ Operation Unit: ___________________________
Township: _______________________________ Compartment Number: _____________________
OBM #: _________________________________ Stand Number: ___________________________
Licensee: ________________________________ WG (FRI): _____________ FU: _______________
Cruiser's Name: __________________________ Site Class: ________________________________
Date of Cruise: ____________________________ Ownership:______________________________

Prism Tally: BAF 2 metric

STATIONS TALLIED	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40

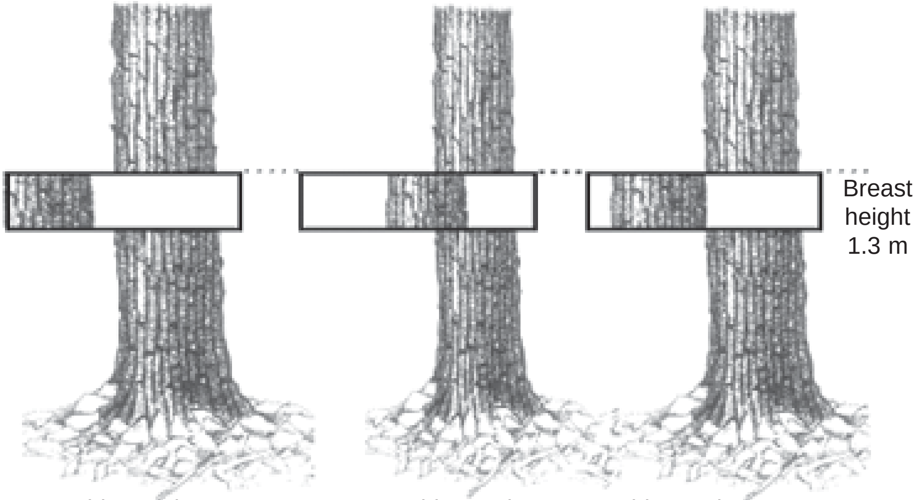
STAND ANALYSIS TALLY (by Species, Size Class and Quality Class)

Tree Size Class >>>>	**POLEWOOD 10 - 24 cm**		**SAWTIMBER SIZES SMALL 26 - 36 cm**		**MEDIUM 38 - 48 cm**		**LARGE 50 cm +**		**TOTAL ALL SIZES**	
SPECIES	**AGS**	**UGS**	**AGS**	**UGS**	**AGS**	**UGS**	**AGS**	**UGS**	**AGS**	**UGS**
Total Number of Trees										
BA (m^2/ha)*										
Total BA (m^2/ha)										
Target BA (m^2/ha)										
Ideal BA (m^2/ha)										

***Actual BA/ha = <u>Number of Trees x 2 (BAF)</u>**
Number of Prism Stations Tallied

<u>Other Site Information used for Prescription Development:</u>
Topography:____
Soil Moisture:____
IRM Considerations:____
Stand Access:____
Other Concerns: ____
Regeneration Notes: ____

Appendix C—TOOLS USED IN STAND ANALYSIS



- The prism may be held at any distance from the eye, but the prism must always be directly over the centre point of the plot. Rotate your body around this centre point. Do not stand on one spot and spin.
- Starting from an easily identified direction, all trees in a 360° sweep are viewed and counted, or not as the case may be. View each tree at *breast height*, 1.3 metres above ground level (See above graphic for determining which trees to count and where to aim.)
- Borderline trees may be alternately counted as half a tree or every second borderline tree counted as one tree. For exact determinations, use the limiting distance chart in Appendix D.
- Trees which are obscured can be viewed by temporarily moving the sampling point a sufficient distance at right angles to the direction of sighting. Maintain the same distance to the target tree to determine whether it is counted or not.

- Where, as in most cases, the object is to assess measurable, live basal area for silvicultural purposes, trees less than 9cm dbh and dead trees are often excluded.
- Basal area per hectare is the product of the prism Basal Area Factor (BAF) and the number of trees counted in a 360° sweep. For example, if the

number of trees counted is 14, and the BAF is 2, the basal area estimate will be 28 m^2/ha. The average BA of the stand is simply the average of all of the estimates combined.

- When sampling on sloping ground it is essential to increase the basal area estimates by multiplying by the factor (secant) given in column 2 of the following table appropriate to the angle of the slope. For example, given a basal area estimate of 28 m^2/ha assessed on a slope of 10^o, the corrected value will be: 28 x 1.0154 = 28.4 m^2/ha.

> If the horizontal distance is 40 metres, and the slope is 15^o, the distance to be measured up or down the slope and in the direction of the slope is:
> 40 x 1.0353 = 41.412 m

Correcting for slope requires the application of a correction factor (secant). For convenience, the length to be *added* to a standard 20 m measuring tape is given in column 3.

Angle of slope	Factor (secant)	Correction for 20 metres
(1) degrees	(2)	(3) metres
5	1.0038	0.08
7.5	1.0086	0.17
10	1.0154	0.31
12.5	1.0243	0.49
15	1.0353	0.71
17.5	1.0485	0.97
20	1.0642	1.28
22.5	1.0824	1.65
25	1.1034	2.07
30	1.1547	3.09
35	1.2208	4.42
45	1.4142	8.28
60	2.0000	20.00

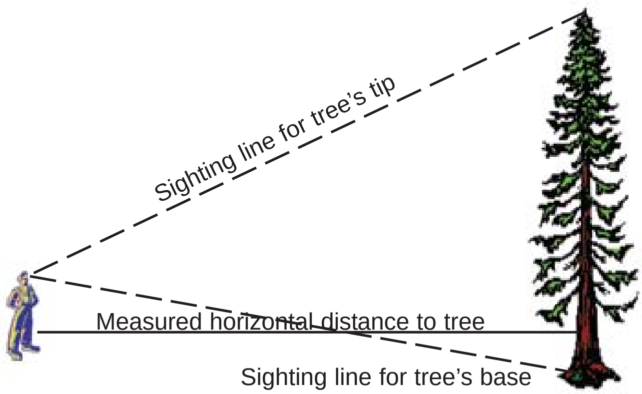
Adapted from Hamilton (1988)

Height measurement of individual trees

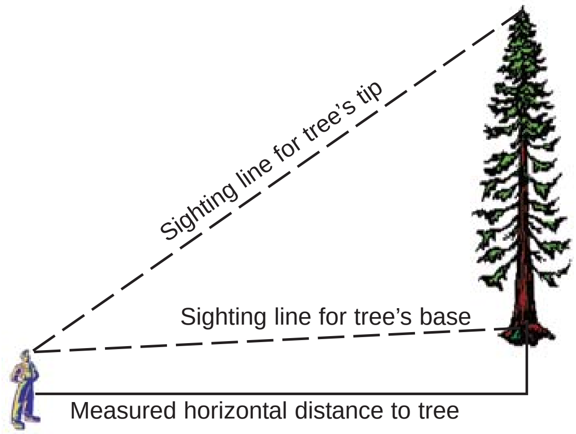
There are two expressions of tree height normally used in forestry. The first is total height which refers to the vertical distance from the base (where the tree meets the soil) of the tree to the uppermost tip of the tree. The second is merchantable height, which is the distance from the base of the tree to the highest point on the main stem where the diameter is considered the smallest diameter acceptable or at the lowest point in the crown at which no main stem is distinguishable.

Since it is not practical to measure tall trees using a tape measure, it is assumed here that a modern clinometer will be used to estimate height. Examples of these are Haga, Blume-Leiss, Relaskop, Abney Level, and Suunto. These instruments come with full instructions and those instructions should be referred to for using any particular instrument. All of these tools function based on trigonometrical principles that are simplified in the examples below.

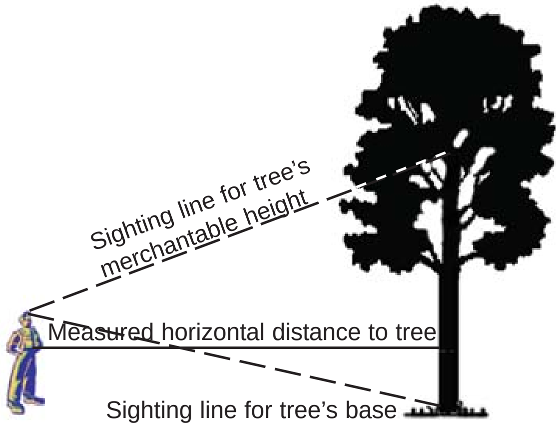
In the figures below, the observer stands the correct distance from the tree based on the clinometer in use. For example, if using a Suunto with a 20 scale, the observer would measure a distance of 20 metres from the tree in a horizontal plane. The observer then views the top of the tree (or merchantable heights if required, see
Example C) and records the result directly from the correct scale. The base of the tree is then sighted and the result recorded.



Example A: The tree base is below the observer's line of sight and the result will be a negative reading from the instrument's scale. Therefore to estimate the tree's total height you would add the two measurements together ignoring the negative sign. For example, the horizontal distance is 20 m, top reading from the 20 Scale is 19 and base reading is (-2), the estimated height would be 19 + 2 = 21.0 m.



Example B: The top and base results would both be positive numbers, so to estimate the tree's height you would take the top sighting result and subtract the base sighting result. For example, the horizontal distance is 20 m, top reading from the 20 Scale is 22.5 and base reading is 1.5, the estimated height would be 22.5 - 1.5 = 21.0 m.



Example C: When measuring merchantable heights, the observer sights the spot on the upper bole of the tree considered to be the minimum acceptable merchantable top diameter or where no main stem is distinguishable due to heavy branching. In this example, the observer is 20 metres from the tree, the merchantable height reading is 12 and the base reading is (-1.5), and the estimated merchantable height is 12 + 1.5 = 13.5 m.

- Visually check the tree for lean before measuring, a leaning tree could seriously affect your estimates. A tree with a 3^{o} lean would have a +5% to -5% affect on your estimate depending on the direction the tree is observed. For a 6^{o} lean the error would be as high as 11% either way.
- The distance of the observation point from the tree should be in the region of 1 to 1½ times the expected height of the tree. Errors can be sizeable where the observer is too close to the tree. The main difficulty in achieving the ideal position is that of being able to view the tops and bases of trees in dense stands.

Appendix D—PLOT RADIUS FACTOR

Horizontal Limiting Distance for Trees of a Given Diameter in Metres for BAF 2 Metric Prism

dbh (cm)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.00	0.04	0.07	0.11	0.14	0.18	0.21	0.25	0.28	0.32
1	0.35	0.39	0.42	0.46	0.49	0.53	0.57	0.60	0.64	0.67
2	0.71	0.74	0.78	0.81	0.85	0.88	0.92	0.95	0.99	1.03
3	1.06	1.10	1.13	1.17	1.20	1.24	1.27	1.31	1.34	1.38
4	1.41	1.45	1.48	1.52	1.56	1.59	1.63	1.66	1.70	1.73
5	1.77	1.80	1.84	1.87	1.91	1.94	1.98	2.02	2.05	2.09
6	2.12	2.16	2.19	2.23	2.26	2.30	2.33	2.37	2.40	2.44
7	2.47	2.51	2.55	2.58	2.62	2.65	2.69	2.72	2.76	2.79
8	2.83	2.86	2.90	2.93	2.97	3.01	3.04	3.08	3.11	3.15
9	3.18	3.22	3.25	3.29	3.32	3.36	3.39	3.43	3.46	3.50
10	3.54	3.57	3.61	3.64	3.68	3.71	3.75	3.78	3.82	3.85
11	3.89	3.92	3.96	4.00	4.03	4.07	4.10	4.14	4.17	4.21
12	4.24	4.28	4.31	4.35	4.38	4.42	4.45	4.49	4.53	4.56
13	4.60	4.63	4.67	4.70	4.74	4.77	4.81	4.84	4.88	4.91
14	4.95	4.99	5.02	5.06	5.09	5.13	5.16	5.20	5.23	5.27
15	5.30	5.34	5.37	5.41	5.44	5.48	5.52	5.55	5.59	5.62
16	5.66	5.69	5.73	5.76	5.80	5.83	5.87	5.90	5.94	5.98
17	6.01	6.05	6.08	6.12	6.15	6.19	6.22	6.26	6.29	6.33
18	6.36	6.40	6.43	6.47	6.51	6.54	6.58	6.61	6.65	6.68
19	6.72	6.75	6.79	6.82	6.86	6.89	6.93	6.97	7.00	7.04
20	7.07	7.11	7.14	7.18	7.21	7.25	7.28	7.32	7.35	7.39
21	7.42	7.46	7.50	7.53	7.57	7.60	7.64	7.67	7.71	7.74
22	7.78	7.81	7.85	7.88	7.92	7.95	7.99	8.03	8.06	8.10
23	8.13	8.17	8.20	8.24	8.27	8.31	8.34	8.38	8.41	8.45
24	8.49	8.52	8.56	8.59	8.63	8.66	8.70	8.73	8.77	8.80
25	8.84	8.87	8.91	8.94	8.98	9.02	9.05	9.09	9.12	9.16
26	9.19	9.23	9.26	9.30	9.33	9.37	9.40	9.44	9.48	9.51
27	9.55	9.58	9.62	9.65	9.69	9.72	9.76	9.79	9.83	9.86
28	9.90	9.93	9.97	10.01	10.04	10.08	10.11	10.15	10.18	10.22
29	10.25	10.29	10.32	10.36	10.39	10.43	10.47	10.50	10.54	10.57
30	10.61	10.64	10.68	10.71	10.75	10.78	10.82	10.85	10.89	10.92
31	10.96	11.00	11.03	11.07	11.10	11.14	11.17	11.21	11.24	11.28
32	11.31	11.35	11.38	11.42	11.46	11.49	11.53	11.56	11.60	11.63
33	11.67	11.70	11.74	11.77	11.81	11.84	11.88	11.91	11.95	11.99
34	12.02	12.06	12.09	12.13	12.16	12.20	12.23	12.27	12.30	12.34
35	12.37	12.41	12.45	12.48	12.52	12.55	12.59	12.62	12.66	12.69
36	12.73	12.76	12.80	12.83	12.87	12.90	12.94	12.98	13.01	13.05
37	13.08	13.12	13.15	13.19	13.22	13.26	13.29	13.33	13.36	13.40
38	13.44	13.47	13.51	13.54	13.58	13.61	13.65	13.68	13.72	13.75
39	13.79	13.82	13.86	13.89	13.93	13.97	14.00	14.04	14.07	14.11
40	14.14	14.18	14.21	14.25	14.28	14.32	14.35	14.39	14.42	14.46
41	14.50	14.53	14.57	14.60	14.64	14.67	14.71	14.74	14.78	14.81
42	14.85	14.88	14.92	14.96	14.99	15.03	15.06	15.10	15.13	15.17
43	15.20	15.24	15.27	15.31	15.34	15.38	15.41	15.45	15.49	15.52
44	15.56	15.59	15.63	15.66	15.70	15.73	15.77	15.80	15.84	15.87
45	15.91	15.95	15.98	16.02	16.05	16.09	16.12	16.16	16.19	16.23
46	16.26	16.30	16.33	16.37	16.40	16.44	16.48	16.51	16.55	16.58
47	16.62	16.65	16.69	16.72	16.76	16.79	16.83	16.86	16.90	16.94
48	16.97	17.01	17.04	17.08	17.11	17.15	17.18	17.22	17.25	17.29
49	17.32	17.36	17.39	17.43	17.47	17.50	17.54	17.57	17.61	17.64
50	17.68	17.71	17.75	17.78	17.82	17.85	17.89	17.93	17.96	18.00
51	18.03	18.07	18.10	18.14	18.17	18.21	18.24	18.28	18.31	18.35
52	18.38	18.42	18.46	18.49	18.53	18.56	18.60	18.63	18.67	18.70
53	18.74	18.77	18.81	18.84	18.88	18.92	18.95	18.99	19.02	19.06
54	19.09	19.13	19.16	19.20	19.23	19.27	19.30	19.34	19.37	19.41
55	19.45	19.48	19.52	19.55	19.59	19.62	19.66	19.69	19.73	19.76
56	19.80	19.83	19.87	19.91	19.94	19.98	20.01	20.05	20.08	20.12
57	20.15	20.19	20.22	20.26	20.29	20.33	20.36	20.40	20.44	20.47
58	20.51	20.54	20.58	20.61	20.65	20.68	20.72	20.75	20.79	20.82
59	20.86	20.90	20.93	20.97	21.00	21.04	21.07	21.11	21.14	21.18
60	21.21	21.25	21.28	21.32	21.35	21.39	21.43	21.46	21.50	21.53

Plot Radius Factor used: For each 1 cm in dbh allow 0.35355339 metres maximum distance to target.

Appendix E—TREE MARKING PRESCRIPTION

TREE MARKING PRESCRIPTION

Ownership: ______________________ Compartment: ______________________
District: ______________________ Forest Unit: ______________________
Management Unit: ______________________ W.G. ______________________
Township: ______________________ Forest Unit: ______________________
Photograph: ______________________ Site Class: ______________________
Stand Access: ______________________

OBJECTIVES

Long Term: ______________________

Short Term: ______________________

STAND INFORMATION:

Based on Stand Analysis Cruise

Species Composition: ______________________ Stand Area (ha): ______________________
Age Class: ______________________ Height (m): ______________________ Stocking: ______________________
Regeneration Notes ______________________

Stand Quality Notes: ______________________

Site & Topography Notes: ______________________

BASAL AREA DISTRIBUTION (m^2/ha):

Tree Size Classes (cm)	10-24	26-36	38-48	50+	TOTAL
Actual Basal Area (m^2/ha)					

STAND PRESCRIPTION

Treatment Instructions: ______________________

IRM Instructions: ______________________

RECOMMENDED BASAL AREA (m^2/ha)

DISTRIBUTION OF CUT

TREE	**ACTUAL BA**			**BA TO CUT**			**RESIDUAL BA**		
(cm)	AGS	UGS	Total	AGS	UGS	Total	AGS	UGS	Total
10-24									
26-36									
38-48									
50+									
TOTAL									

PRESCRIPTION PREPARED BY:

DATE:

PRESCRIPTION APPROVED BY:

DATE:

Follow-Up Recommendation: ______________________

Year Of Next Cut: ______________________

Appendix F—AUDIT SHEETS

TREE MARKING AUDIT REPORT

☐ PINE ☐ HARDWOOD

Area/District: _______________	Auditor: ___________________	Signature: __________________
Township: __________________	Auditor: ___________________	Signature: __________________
Stand Number: ______________	Contractor: _________________	Contract Number: ____________
Management Unit: ___________	Ownership: _________________	Date: ______________________

Stand Level Infractions (A to E)

Code		Satisfactory	Unsatisfactory
A	Marked in Reserve		☐
B	Marked Outside Block		☐
C	IRM Considerations	☐	☐
D	Residual Basal Area	☐	☐
E	Residual Crown Closure	☐	☐

Tree Level Infractions (1 to 5)

Code		Total Tree Infractions
1	Paint Application	
2	Spacing	
3	Species Priority	
4	Quality Priority	
5	Size Priority	
Total (TTI)		

Overall Rating Based on Stand and Tree Level Attributes

☐ Acceptable ☐ Unacceptable

Wildlife Tree Evaluations

Tree Marking Quality Assessment

TT: Total # of trees assessed

TTI: Total tree infractions recorded

TMQ% = (TT-TTI)/TT*100

TMQ = (___-___)/___*100 = ___%

Comments:

Plot Number		Poles 10-24 cm			Small Log 26-36 cm			Medium Log 38-48 cm			Large Log 50 cm +			Total All Sizes			Total	Tree Infractions						Comments
		A	w	**U**	**A**	w	**U**	**A**	w	**U**	**A**	w	**U**	**A**	w	**U**		1	2	3	4	5	Total	
1	M																							
	R																							
2	M																							
	R																							
3	M																							
	R																							
4	M																							
	R																							
5	M																							
	R																							
6	M																							
	R																							
7	M																							
	R																							
8	M																							
	R																							
9	M																							
	R																							
10	M																							
	R																							
Total M																								<< Totals
Total R																		Legend: M = Marked R = Residual						
BA - M																		A = AGS U = UGS w = wildlife tree tally						
BA - R																		Contractor: ______________________						
BA - M																		Signature: ______________________						
BA - R																		Date: ___________________________						

TREE MARKING AUDIT SUMMARY REPORT

☐ Conifer Audit

☐ Hardwood Audit

Area/District:______________ Auditor:_____________ Signature:________________

Township:________________ Auditor:_____________ Signature:________________

Stand Number:____________ Contractor:__________ Contract Number:__________

Management Unit:_________ Ownership:__________ Date of Audit:______________

Total Number of Prism Plots =

DBH Size Class	AGS		UGS		TOTAL	
Poles (10-24 cm)	Marked	Residual	Marked	Residual	Marked	Residual
Small Logs (26-36 cm)						
Medium Logs (38-48 cm)						
Large Logs (50 cm+)						
Total Number of Trees						
BA (m^2/ha)						
Total BA (m^2/ha)						
95% Confidence Intervals for the residual basal area (m^2/ha)			t-value = % BA Marked =		Lower Upper	

Wildlife Attributes

DBH Size Class	AGS		UGS		TOTAL	
Poles (10-24 cm)	Marked	Residual	Marked	Residual	Marked	Residual
Small Logs (26-36 cm)						
Medium Logs (38-48 cm)						
Large Logs (50 cm+)						
Total Number of Trees						
BA (m^2/ha)						
Total BA (m^2/ha)						
95% Confidence Intervals for the number residual per ha	Lower	Upper	Lower	Upper	Lower	Upper

Tree Infractions Summary & Tree Marking Quality (TMQ) Assessment

Number of Infractions	1 - Paint Application	2 - Spacing	3 - Species Priority	4 - Quality Class	5 - Size Priority	Total

TMQ = TT (total number of trees assessed) - TTI (total number of infractions recorded)/TT* 100

TMQ =	(TT	- TTI	/ TT	* 100	= TMQ
TMQ =					
95% Confidence Intervals for the TMQ				Lower	
				Upper	

Stand Level Infractions Summary and Overall Audit Rating

Code		Satisfactory	Unsatisfactory
A	Marking in reserves	N/A	______
B	Marked outside block	N/A	______
C	IRM Considerations	______	______
D	Residual Basal Area	______	______
E	Residual Crown Closure	______	______

Overall Ratings

Acceptable ________

Unacceptable ________

Comments

Plot #	Mark BA	Resid BA
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
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47		
48		
49		
50		

Appendix G—Fuelwood Volume Tables

IMPERIAL

Tree Diameter (dbh inches)	**No. Trees required to yield one cord (128 cubic feet)**	
	Hardwood (Deciduous)	Softwood (Coniferous)
5	35	-
6	20	-
7	15	20
8	11	13
9	8	10
10	6	8
11	5	7
12	4	6
13	3.5	4.5
14	3.0	3.7
15	2.5	3.0
16	2.0	2.5
17	1.7	2.1
18	1.5	1.9
19	1.3	1.6
20	1.2	1.5
21	1.0	1.4
22	.9	1.2
23	0.8	1.1
24	0.7	1.0
25	0.6	0.9
26	0.58	0.8
27	0.5	0.77
28	0.44	0.7
29	0.43	-

From OMNR 1980.

METRIC FUELWOOD VOLUME TABLE

dbhob (cm)	HARDWOODS		SOFTWOODS	
	m^3	Trees/ m^3	m^3	Trees/m^3
8	0.025	39.7	0.024	42.2
10	0.038	26.1	0.034	29.9
12	0.061	16.5	0.048	20.8
14	0.095	10.5	0.067	14.9
16	0.132	7.6	0.092	10.9
18	0.166	6.0	0.126	7.9
20	0.212	4.7	0.177	5.6
22	0.273	3.7	0.222	4.5
24	0.346	2.9	0.268	3.7
26	0.424	2.4	0.311	3.2
28	0.504	2.0	0.346	2.9
30	0.583	1.7	0.422	2.4
32	0.653	1.5	0.497	2.0
34	0.732	1.4	0.580	1.7
36	0.830	1.2	0.677	1.5
38	0.957	1.0	0.796	1.3
40	1.143	0.9	0.922	1.1
42	1.317	0.8	1.061	0.9
44	1.477	0.7	1.202	0.8
46	1.632	0.6	1.340	0.7
48	1.826	0.5	1.485	0.7
50	2.035	0.5	1.625	0.6
52	2.256	0.4	1.751	0.6
54	2.476	0.4	1.876	0.5
56	2.690	0.4	2.014	0.5
58	2.953	0.3	2.158	0.5
60	3.276	0.3	2.324	0.4
62	3.673	0.3	2.517	0.4
64	4.039	0.2	2.719	0.4
66	4.148	0.2	2.896	0.3
68	4.662	0.2	3.074	0.3
70	5.181	0.2	3.301	0.3
72	5.514	0.2	3.558	0.3
74	5.614	0.2	3.828	0.3

Appendix H—HARDWOOD LOG VOLUME TABLES

Cubic Metre Volume Table for Estimating the Approximate Volume of Standing Hardwood Trees

(Based on Ontario Log Rule, Form Class 79, and Smalian's Formula)
(Based on the regression formula from the complete data set)
Formula: (-0.06004)+(0.00004421*dbh*dbh*log length)+(0.00082319*dbh*log length)+(-0.00005349*dbh*log length*log length)

Merchantable Log Length in Metres

dbhob (cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	0.004	0.033	0.059	0.084	0.106	0.127	0.145	0.161	0.174	0.186	0.196	0.203	0.208	0.211	0.212	0.211	0.208	0.203	0.195
22	0.014	0.048	0.079	0.108	0.135	0.159	0.181	0.200	0.217	0.232	0.245	0.255	0.262	0.268	0.271	0.272	0.270	0.266	0.259
24	0.025	0.064	0.100	0.134	0.165	0.194	0.220	0.243	0.264	0.282	0.298	0.311	0.321	0.329	0.335	0.338	0.338	0.336	0.331
26	0.037	0.081	0.123	0.162	0.198	0.231	0.261	0.289	0.314	0.336	0.355	0.372	0.385	0.396	0.405	0.410	0.413	0.412	0.409
28	0.049	0.100	0.147	0.191	0.232	0.271	0.306	0.338	0.367	0.394	0.417	0.437	0.454	0.469	0.480	0.488	0.493	0.496	0.495
30	0.063	0.119	0.172	0.222	0.269	0.313	0.353	0.390	0.424	0.455	0.483	0.507	0.528	0.546	0.561	0.572	0.581	0.586	0.588
32	0.076	0.139	0.199	0.255	0.308	0.357	0.403	0.446	0.485	0.521	0.553	0.582	0.607	0.629	0.648	0.663	0.674	0.683	0.688
34	0.091	0.161	0.227	0.290	0.349	0.405	0.456	0.505	0.549	0.590	0.627	0.661	0.691	0.717	0.740	0.759	0.774	0.786	0.794
36	0.106	0.183	0.257	0.326	0.392	0.454	0.512	0.566	0.617	0.663	0.706	0.745	0.780	0.811	0.838	0.861	0.881	0.896	0.908
38	0.122	0.207	0.288	0.365	0.438	0.506	0.571	0.631	0.688	0.740	0.789	0.833	0.873	0.909	0.942	0.970	0.994	1.013	1.029
40	0.139	0.232	0.320	0.405	0.485	0.561	0.632	0.700	0.763	0.821	0.876	0.926	0.972	1.014	1.051	1.084	1.113	1.137	1.157
42	0.156	0.257	0.354	0.447	0.534	0.618	0.697	0.771	0.841	0.906	0.967	1.024	1.075	1.123	1.166	1.204	1.238	1.268	1.293
44	0.174	0.284	0.390	0.490	0.586	0.677	0.764	0.846	0.923	0.995	1.063	1.126	1.184	1.238	1.286	1.331	1.370	1.405	1.435
46	0.193	0.312	0.426	0.536	0.640	0.739	0.834	0.923	1.008	1.088	1.163	1.233	1.298	1.358	1.413	1.463	1.508	1.549	1.584
48	0.212	0.341	0.464	0.583	0.696	0.804	0.907	1.004	1.097	1.184	1.267	1.344	1.416	1.483	1.545	1.601	1.653	1.699	1.740
50	0.233	0.371	0.504	0.632	0.754	0.871	0.982	1.088	1.189	1.285	1.375	1.460	1.539	1.613	1.682	1.746	1.804	1.856	1.904
52	0.254	0.402	0.545	0.682	0.814	0.940	1.061	1.176	1.285	1.389	1.488	1.580	1.668	1.749	1.825	1.896	1.961	2.020	2.074
54	0.275	0.434	0.587	0.735	0.876	1.012	1.142	1.266	1.385	1.498	1.604	1.706	1.801	1.891	1.974	2.052	2.125	2.191	2.252
56	0.297	0.467	0.631	0.789	0.941	1.086	1.226	1.360	1.488	1.610	1.726	1.835	1.939	2.037	2.129	2.215	2.295	2.369	2.437
58	0.320	0.501	0.676	0.845	1.007	1.163	1.313	1.457	1.594	1.726	1.851	1.970	2.082	2.189	2.289	2.383	2.471	2.553	2.628
60	0.344	0.537	0.723	0.902	1.076	1.243	1.403	1.557	1.704	1.846	1.980	2.109	2.231	2.346	2.455	2.558	2.654	2.744	2.827
62	0.369	0.573	0.771	0.962	1.146	1.324	1.496	1.660	1.818	1.969	2.114	2.252	2.384	2.508	2.627	2.738	2.843	2.941	3.033
64	0.394	0.610	0.820	1.023	1.219	1.409	1.591	1.767	1.935	2.097	2.252	2.400	2.542	2.676	2.804	2.925	3.039	3.146	3.246
66	0.420	0.649	0.871	1.086	1.294	1.495	1.689	1.876	2.056	2.229	2.395	2.553	2.705	2.849	2.987	3.117	3.240	3.357	3.466
68	0.446	0.688	0.923	1.151	1.371	1.585	1.790	1.989	2.180	2.364	2.541	2.711	2.873	3.028	3.175	3.316	3.449	3.575	3.693
70	0.473	0.729	0.977	1.218	1.451	1.676	1.894	2.105	2.308	2.504	2.692	2.872	3.046	3.211	3.369	3.520	3.663	3.799	3.927
72	0.501	0.771	1.032	1.286	1.532	1.770	2.001	2.224	2.439	2.647	2.847	3.039	3.223	3.400	3.569	3.731	3.884	4.030	4.169
74	0.530	0.813	1.089	1.356	1.616	1.867	2.111	2.346	2.574	2.794	3.006	3.210	3.406	3.595	3.775	3.947	4.112	4.268	4.417
76	0.560	0.857	1.147	1.428	1.701	1.966	2.223	2.472	2.713	2.945	3.170	3.386	3.594	3.794	3.986	4.170	4.345	4.513	4.672
78	0.590	0.902	1.206	1.502	1.789	2.068	2.338	2.601	2.855	3.100	3.337	3.566	3.787	3.999	4.203	4.398	4.585	4.764	4.935
80	0.620	0.948	1.267	1.577	1.879	2.172	2.456	2.733	3.000	3.259	3.509	3.751	3.984	4.209	4.425	4.633	4.832	5.022	5.204
82	0.652	0.995	1.329	1.654	1.971	2.278	2.577	2.868	3.149	3.422	3.686	3.941	4.187	4.425	4.653	4.873	5.085	5.287	5.481
84	0.684	1.043	1.392	1.733	2.065	2.387	2.701	3.006	3.302	3.588	3.866	4.135	4.395	4.645	4.887	5.120	5.344	5.559	5.765
86	0.717	1.092	1.457	1.814	2.161	2.499	2.828	3.147	3.458	3.759	4.051	4.334	4.607	4.872	5.127	5.373	5.609	5.837	6.055
88	0.751	1.142	1.524	1.896	2.259	2.613	2.957	3.292	3.617	3.933	4.240	4.537	4.825	5.103	5.372	5.631	5.881	6.122	6.353
90	0.785	1.193	1.592	1.981	2.360	2.729	3.089	3.440	3.780	4.112	4.433	4.745	5.047	5.340	5.623	5.896	6.160	6.414	6.658
92	0.820	1.245	1.661	2.067	2.462	2.848	3.224	3.591	3.947	4.294	4.630	4.957	5.274	5.582	5.879	6.167	6.444	6.712	6.970
94	0.856	1.299	1.732	2.154	2.567	2.970	3.362	3.745	4.117	4.480	4.832	5.174	5.507	5.829	6.141	6.443	6.735	7.017	7.289
96	0.892	1.353	1.804	2.244	2.674	3.094	3.503	3.902	4.291	4.670	5.038	5.396	5.744	6.082	6.409	6.726	7.033	7.329	7.615
98	0.930	1.409	1.877	2.335	2.783	3.220	3.647	4.063	4.468	4.864	5.248	5.623	5.986	6.339	6.682	7.015	7.336	7.648	7.948
100	0.967	1.465	1.952	2.428	2.894	3.349	3.793	4.226	4.649	5.061	5.463	5.853	6.233	6.603	6.961	7.309	7.646	7.973	8.289

Board Foot Volume Table for Estimating the Approximate Volume of Standing Hardwood Trees

(Based on Ontario Log Rule, Form Class 79)

dbhob (inch)	Merchantable Log Length in Feet: 8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	44	48	52	56	60	64
10	16	20	24	28	32	35	37	40	44	46	48	50	53	55	58	60	61	64	67	74	75	76	76
11	20	26	31	36	41	44	47	51	55	58	60	64	67	70	73	75	77	82	86	94	97	98	98
12	25	31	37	43	50	54	58	62	67	71	74	78	82	86	91	94	97	102	108	118	122	124	125
13	30	37	45	53	60	65	70	75	80	85	90	95	100	105	110	114	117	124	131	146	151	154	156
14	36	46	54	63	73	79	85	92	99	105	110	116	122	128	134	138	142	151	160	175	181	185	187
15	42	53	64	75	85	92	99	108	116	122	129	136	143	150	157	162	168	178	189	207	215	220	223
16	49	61	74	86	98	107	115	125	135	142	149	157	166	175	184	190	197	210	222	240	250	255	259
17	56	70	91	101	112	122	131	143	154	162	170	180	190	200	211	219	226	241	255	276	287	294	299
18	62	78	94	110	125	136	147	160	173	183	193	204	215	227	239	248	256	273	290	317	330	339	346
19	70	88	105	123	141	153	166	180	195	206	218	230	243	256	270	279	289	309	329	363	378	390	397
20	78	98	118	138	157	172	186	202	218	230	243	257	272	287	302	314	325	348	370	405	422	434	443
21	87	109	131	153	175	191	207	225	243	257	271	287	304	320	337	352	362	388	413	453	472	487	497
22	96	121	145	169	193	208	224	246	269	290	311	325	338	356	374	389	403	432	460	505	527	544	556
23	106	133	160	186	212	232	252	275	297	315	332	351	371	392	413	429	445	476	508	555	579	598	612
24	117	146	176	205	234	256	278	303	328	348	367	384	401	429	457	475	492	528	563	612	639	660	676
25	127	159	191	223	255	279	33	330	357	378	399	423	447	472	498	517	536	574	612	668	699	723	741
26	137	172	207	241	275	301	327	357	387	410	432	458	485	513	541	562	583	625	667	732	765	792	813
27	149	186	222	260	298	326	355	398	420	444	468	497	526	558	589	612	635	681	727	794	831	861	884
28	161	203	242	282	323	354	385	420	456	482	509	541	573	606	640	665	689	739	789	860	900	933	959
29	173	217	260	304	347	380	414	452	490	520	549	583	617	652	688	725	743	792	852	928	972	1007	1035
30	187	233	280	327	374	410	447	488	529	561	594	631	667	705	743	773	802	861	921	998	1046	1084	1115
31	200	250	300	350	400	439	478	523	567	601	635	674	714	756	799	830	862	926	990	1076	1128	1171	1205
32	214	267	320	374	428	470	513	560	608	645	683	720	768	813	858	893	928	998	1067	1158	1214	1261	1299
33	228	284	341	399	457	502	547	598	649	688	727	773	818	869	919	955	991	1064	1140	1238	1299	1350	1390
34	243	302	365	424	487	535	584	638	692	735	777	826	875	927	978	1018	1058	1139	1220	1322	1387	1441	1485
35	257	320	385	450	515	566	617	674	732	777	822	674	925	1030	1036	1079	1122	1210	1295	1409	1480	1539	1586
36	273	341	411	478	546	601	656	717	778	827	876	931	986	1045	1103	1149	1195	1286	1379	1500	1576	1639	1690
37	290	362	435	508	580	638	696	762	828	878	929	987	1045	1110	1174	1223	1272	1372	1469	1592	1673	1742	1797
38	306	381	454	533	612	674	736	806	875	929	983	1045	1108	1176	1244	1297	1350	1457	1561	1686	1774	1847	1908
39	323	402	485	565	646	708	771	847	923	982	1040	1106	1172	1241	1311	1367	1422	1533	1643	1785	1879	1958	2024
40	340	425	511	596	681	751	821	898	975	1038	1101	1170	1240	1313	1386	1444	1508	1628	1746	1877	1977	2062	2133

Appendix I—CONIFER TREE VOLUME TABLES

Cubic Metre Volume Table for Estimating the Approximate Total Merchantable Volume of Standing Red Pine Trees

(Stump Height at 15 cm and Top Diameter at 7.0 cm inside bark)

(Derived from "Metric Timber Tables for the Commercial Tree Species of Central and Eastern Canada", Honer, T.G., M.F. Ker and I.S. Alemdag, CFS Maritimes For. Res. Centre)

Formula: Merchantable Volume = Total Volume * (0.9672 + (-0.0393*X3) + (-1.0523*X3*X3)

Where X3 = (Top diameter*Top diameter/(dbhob*dbhob*((1-0.04365*0.151)^2)))*(1+Stump Height/total tree height)

dbhob							Total Tree Height (metres)										
(cm)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
2																	
4																	
6																	
8	0.001	0.003	0.005	0.006	0.008	0.009	0.011	0.012	0.013	0.015	0.016	0.017	0.019	0.020	0.021	0.022	0.024
10	0.005	0.011	0.016	0.021	0.026	0.031	0.036	0.040	0.045	0.049	0.054	0.058	0.062	0.066	0.070	0.074	0.078
12	0.009	0.019	0.028	0.036	0.045	0.053	0.061	0.069	0.077	0.085	0.092	0.100	0.107	0.114	0.120	0.127	0.133
14	0.014	0.027	0.040	0.053	0.066	0.078	0.090	0.101	0.113	0.124	0.134	0.145	0.155	0.165	0.175	0.185	0.194
16	0.018	0.037	0.054	0.072	0.088	0.105	0.121	0.137	0.152	0.167	0.181	0.196	0.209	0.223	0.236	0.249	0.262
18	0.024	0.047	0.070	0.092	0.114	0.135	0.156	0.176	0.195	0.215	0.233	0.252	0.270	0.287	0.304	0.321	0.338
20	0.030	0.059	0.087	0.115	0.142	0.168	0.194	0.219	0.244	0.268	0.291	0.314	0.336	0.358	0.379	0.400	0.421
22					0.173	0.205	0.236	0.267	0.297	0.326	0.354	0.382	0.409	0.436	0.462	0.487	0.512
24					0.207	0.245	0.282	0.319	0.354	0.389	0.423	0.457	0.489	0.521	0.552	0.582	0.612
26						0.288	0.332	0.375	0.417	0.458	0.498	0.537	0.575	0.613	0.649	0.685	0.720
28						0.335	0.386	0.436	0.485	0.532	0.579	0.624	0.669	0.712	0.755	0.796	0.837
30						0.385	0.444	0.501	0.557	0.612	0.665	0.718	0.769	0.819	0.867	0.915	0.962
32						0.438	0.505	0.571	0.634	0.697	0.758	0.817	0.875	0.932	0.988	1.042	1.096
34						0.495	0.571	0.645	0.717	0.787	0.856	0.923	0.989	1.053	1.116	1.178	1.238
36						0.556	0.640	0.723	0.804	0.883	0.960	1.036	1.109	1.182	1.252	1.321	1.389
38						0.619	0.714	0.806	0.896	0.984	1.070	1.154	1.237	1.317	1.396	1.473	1.548
40						0.686	0.791	0.894	0.993	1.091	1.186	1.280	1.371	1.460	1.547	1.632	1.716
42							0.873	0.985	1.096	1.203	1.308	1.411	1.512	1.610	1.706	1.800	1.892
44							0.958	1.082	1.203	1.321	1.436	1.549	1.660	1.767	1.873	1.976	2.077
46							1.047	1.183	1.315	1.444	1.570	1.694	1.814	1.932	2.047	2.160	2.271
48							1.140	1.288	1.432	1.573	1.710	1.844	1.976	2.104	2.230	2.353	2.473
50							1.238	1.398	1.554	1.707	1.856	2.002	2.144	2.283	2.420	2.553	2.684
52							1.339	1.512	1.681	1.846	2.007	2.165	2.319	2.470	2.617	2.762	2.903
54							1.444	1.631	1.813	1.991	2.165	2.335	2.501	2.664	2.823	2.979	3.131
56							1.553	1.754	1.950	2.141	2.329	2.511	2.690	2.865	3.036	3.204	3.367
58									2.092	2.297	2.498	2.694	2.886	3.074	3.257	3.437	3.612
60									2.239	2.459	2.673	2.884	3.089	3.290	3.486	3.678	3.866
62										2.625	2.855	3.079	3.298	3.513	3.722	3.928	4.128
64										2.798	3.042	3.281	3.515	3.743	3.967	4.185	4.399
66										2.975	3.235	3.490	3.738	3.981	4.219	4.451	4.679
68										3.159	3.435	3.704	3.968	4.226	4.478	4.725	4.967
70										3.347	3.640	3.926	4.205	4.479	4.746	5.008	5.263
72											3.851	4.153	4.449	4.738	5.021	5.298	5.569
74											4.068	4.387	4.700	5.005	5.304	5.597	5.883
76											4.291	4.628	4.957	5.280	5.595	5.903	6.205
78											4.520	4.875	5.222	5.561	5.893	6.218	6.536
80											4.755	5.128	5.493	5.850	6.200	6.541	6.876

Cubic Metre Volume Table for Estimating the Approximate Total Volume of Standing Red Pine Trees

(Stump and Top Included)

(Derived from "Metric Timber Tables for the Commercial Tree Species of Central and Eastern Canada", Honer, T.G., M.F. Ker and I.S. Alemdag, CFS Maritimes For. Res. Centre)

Formula: Volume = (0.0043891*dbhob*dbhob*(1-0.04365*0.151)**2/(0.710+(0.3048*355.623/tree height in metres))

dbhob							Total Tree Height (metres)										
(cm)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
2	0.000	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004
4	0.001	0.002	0.004	0.005	0.006	0.007	0.008	0.009	0.010	0.011	0.012	0.013	0.014	0.015	0.016	0.017	0.018
6	0.003	0.006	0.008	0.011	0.014	0.016	0.018	0.021	0.023	0.025	0.028	0.030	0.032	0.034	0.036	0.038	0.040
8	0.005	0.010	0.015	0.019	0.024	0.028	0.033	0.037	0.041	0.045	0.049	0.053	0.057	0.061	0.064	0.068	0.071
10	0.008	0.016	0.023	0.030	0.038	0.044	0.051	0.058	0.064	0.071	0.077	0.083	0.089	0.095	0.100	0.106	0.111
12	0.011	0.022	0.033	0.044	0.054	0.064	0.074	0.083	0.093	0.102	0.111	0.119	0.128	0.136	0.144	0.152	0.160
14	0.015	0.031	0.045	0.060	0.074	0.087	0.100	0.113	0.126	0.138	0.151	0.162	0.174	0.185	0.196	0.207	0.218
16	0.020	0.040	0.059	0.078	0.096	0.114	0.131	0.148	0.165	0.181	0.197	0.212	0.227	0.242	0.256	0.271	0.284
18	0.026	0.050	0.075	0.098	0.122	0.144	0.166	0.188	0.208	0.229	0.249	0.269	0.288	0.306	0.325	0.343	0.360
20	0.032	0.062	0.092	0.122	0.150	0.178	0.205	0.231	0.257	0.283	0.307	0.332	0.355	0.378	0.401	0.423	0.444
22	0.038	0.075	0.112	0.147	0.182	0.215	0.248	0.280	0.311	0.342	0.372	0.401	0.430	0.458	0.485	0.512	0.538
24	0.045	0.090	0.133	0.175	0.216	0.256	0.295	0.333	0.371	0.407	0.443	0.477	0.511	0.545	0.577	0.609	0.640
26	0.053	0.105	0.156	0.205	0.254	0.301	0.346	0.391	0.435	0.478	0.519	0.560	0.600	0.639	0.677	0.715	0.751
28	0.062	0.122	0.181	0.238	0.294	0.349	0.402	0.454	0.504	0.554	0.602	0.650	0.696	0.741	0.786	0.829	0.871
30	0.071	0.140	0.208	0.273	0.338	0.400	0.461	0.521	0.579	0.636	0.692	0.746	0.799	0.851	0.902	0.951	1.000
32	0.081	0.159	0.236	0.311	0.384	0.455	0.525	0.593	0.659	0.724	0.787	0.849	0.909	0.968	1.026	1.083	1.138
34	0.091	0.180	0.267	0.351	0.434	0.514	0.592	0.669	0.744	0.817	0.888	0.958	1.026	1.093	1.158	1.222	1.285
36	0.102	0.202	0.299	0.394	0.486	0.576	0.664	0.750	0.834	0.916	0.996	1.074	1.151	1.225	1.298	1.370	1.440
38	0.114	0.225	0.333	0.439	0.542	0.642	0.740	0.836	0.929	1.020	1.110	1.197	1.282	1.365	1.447	1.527	1.605
40	0.126	0.249	0.369	0.486	0.600	0.711	0.820	0.926	1.029	1.131	1.229	1.326	1.420	1.513	1.603	1.691	1.778
42	0.139	0.275	0.407	0.536	0.662	0.784	0.904	1.021	1.135	1.246	1.355	1.462	1.566	1.668	1.767	1.865	1.960
44	0.153	0.302	0.447	0.588	0.726	0.861	0.992	1.120	1.246	1.368	1.488	1.604	1.719	1.830	1.940	2.047	2.151
46	0.167	0.330	0.488	0.643	0.794	0.941	1.084	1.225	1.361	1.495	1.626	1.754	1.879	2.001	2.120	2.237	2.351
48	0.182	0.359	0.532	0.700	0.864	1.024	1.181	1.333	1.482	1.628	1.770	1.909	2.045	2.178	2.308	2.436	2.560
50	0.197	0.389	0.577	0.759	0.938	1.111	1.281	1.447	1.609	1.767	1.921	2.072	2.219	2.364	2.505	2.643	2.778
52	0.213	0.421	0.624	0.821	1.014	1.202	1.386	1.565	1.740	1.911	2.078	2.241	2.401	2.557	2.709	2.859	3.005
54	0.230	0.454	0.673	0.886	1.094	1.296	1.494	1.688	1.876	2.061	2.241	2.417	2.589	2.757	2.922	3.083	3.240
56	0.247	0.488	0.723	0.953	1.176	1.394	1.607	1.815	2.018	2.216	2.410	2.599	2.784	2.965	3.142	3.315	3.485
58	0.265	0.524	0.776	1.022	1.262	1.496	1.724	1.947	2.164	2.377	2.585	2.788	2.986	3.181	3.370	3.556	3.738
60	0.284	0.561	0.830	1.094	1.350	1.600	1.845	2.083	2.316	2.544	2.766	2.984	3.196	3.404	3.607	3.806	4.000
62	0.303	0.599	0.887	1.168	1.442	1.709	1.970	2.225	2.473	2.716	2.954	3.186	3.413	3.634	3.851	4.064	4.271
64	0.323	0.638	0.945	1.244	1.536	1.821	2.099	2.370	2.635	2.894	3.147	3.395	3.636	3.873	4.104	4.330	4.551
66	0.344	0.678	1.005	1.323	1.634	1.937	2.232	2.521	2.803	3.078	3.347	3.610	3.867	4.119	4.364	4.605	4.840
68	0.365	0.720	1.067	1.405	1.734	2.056	2.370	2.676	2.975	3.267	3.553	3.832	4.105	4.372	4.633	4.888	5.138
70	0.387	0.763	1.130	1.488	1.838	2.178	2.511	2.836	3.153	3.462	3.765	4.061	4.350	4.633	4.909	5.180	5.445
72	0.409	0.807	1.196	1.575	1.944	2.305	2.657	3.000	3.335	3.663	3.983	4.296	4.602	4.901	5.194	5.480	5.760
74	0.432	0.853	1.263	1.663	2.054	2.435	2.806	3.169	3.523	3.870	4.208	4.538	4.861	5.177	5.487	5.789	6.085
76	0.456	0.900	1.332	1.755	2.166	2.568	2.960	3.343	3.716	4.082	4.438	4.787	5.128	5.461	5.787	6.106	6.418
78	0.480	0.948	1.404	1.848	2.282	2.705	3.118	3.521	3.915	4.299	4.675	5.042	5.401	5.752	6.096	6.432	6.760
80	0.505	0.997	1.476	1.944	2.400	2.845	3.280	3.704	4.118	4.522	4.918	5.304	5.682	6.051	6.412	6.766	7.112

Cubic Metre Volume Table for Estimating the Approximate Total Merchantable Volume of Standing White Pine Trees

(Stump Height at 15 cm and Top Diameter at 7.0 cm inside bark)

(Derived from “Metric Timber Tables for the Commercial Tree Species of Central and Eastern Canada”, Honer, T.G., M.F. Ker and I.S. Alemdag, CFS Maritimes For. Res. Centre)

Formula: Merchantable Volume = Total Volume * (0.9735 + (-0.2348*X3) + (-0.7378*X3*X3)

Where X3 = (Top diameter*Top diameter/(dbhob*dbhob*((1-0.04365*0.184)^2)))*(1+Stump Height/total tree height)

dbhob	Total Tree Height (metres)																
(cm)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
2																	
4																	
6																	
8	0.001	0.003	0.005	0.007	0.009	0.010	0.012	0.013	0.015	0.016	0.018	0.019	0.021	0.022	0.023	0.025	0.026
10	0.005	0.010	0.015	0.020	0.025	0.030	0.034	0.039	0.043	0.047	0.052	0.056	0.060	0.064	0.068	0.071	0.075
12	0.009	0.018	0.026	0.035	0.043	0.051	0.058	0.066	0.074	0.081	0.088	0.095	0.102	0.108	0.115	0.121	0.128
14	0.013	0.026	0.038	0.051	0.062	0.074	0.085	0.097	0.108	0.118	0.129	0.139	0.149	0.158	0.168	0.177	0.186
16	0.018	0.035	0.052	0.069	0.085	0.100	0.116	0.131	0.146	0.160	0.174	0.188	0.201	0.215	0.228	0.240	0.253
18	0.023	0.045	0.067	0.089	0.109	0.130	0.150	0.169	0.188	0.207	0.225	0.243	0.260	0.277	0.294	0.310	0.326
20	0.029	0.057	0.084	0.111	0.137	0.162	0.187	0.212	0.236	0.259	0.282	0.304	0.326	0.347	0.368	0.388	0.408
22					0.167	0.198	0.229	0.259	0.288	0.316	0.344	0.371	0.398	0.424	0.449	0.474	0.499
24					0.200	0.238	0.274	0.310	0.344	0.379	0.412	0.444	0.476	0.507	0.538	0.568	0.597
26						0.280	0.323	0.365	0.406	0.446	0.486	0.524	0.562	0.598	0.634	0.670	0.704
28						0.326	0.376	0.425	0.473	0.519	0.565	0.610	0.653	0.696	0.738	0.779	0.819
30						0.375	0.433	0.489	0.544	0.598	0.650	0.702	0.752	0.801	0.850	0.897	0.943
32						0.428	0.494	0.558	0.620	0.682	0.742	0.800	0.858	0.914	0.969	1.023	1.075
34						0.484	0.558	0.631	0.701	0.771	0.839	0.905	0.970	1.033	1.095	1.156	1.216
36						0.543	0.627	0.708	0.788	0.865	0.941	1.016	1.089	1.160	1.230	1.298	1.365
38						0.606	0.699	0.790	0.878	0.965	1.050	1.133	1.214	1.294	1.372	1.448	1.523
40						0.672	0.775	0.876	0.974	1.071	1.165	1.257	1.347	1.435	1.522	1.606	1.689
42							0.855	0.966	1.075	1.181	1.285	1.387	1.486	1.584	1.679	1.772	1.864
44							0.939	1.061	1.181	1.297	1.411	1.523	1.632	1.739	1.844	1.946	2.047
46							1.027	1.161	1.291	1.419	1.544	1.666	1.785	1.902	2.016	2.128	2.238
48							1.119	1.265	1.407	1.546	1.682	1.815	1.945	2.072	2.197	2.319	2.438
50							1.215	1.373	1.527	1.678	1.825	1.970	2.111	2.249	2.385	2.517	2.647
52							1.315	1.485	1.652	1.815	1.975	2.131	2.284	2.434	2.580	2.724	2.864
54							1.418	1.602	1.782	1.959	2.131	2.299	2.464	2.626	2.784	2.938	3.090
56							1.526	1.724	1.917	2.107	2.292	2.473	2.651	2.824	2.994	3.161	3.324
58									2.057	2.261	2.460	2.654	2.844	3.031	3.213	3.392	3.567
60									2.202	2.420	2.633	2.841	3.045	3.244	3.439	3.630	3.818
62										2.585	2.812	3.034	3.252	3.465	3.673	3.877	4.077
64										2.755	2.997	3.234	3.466	3.693	3.915	4.132	4.346
66										2.930	3.188	3.440	3.686	3.928	4.164	4.396	4.622
68										3.111	3.384	3.652	3.914	4.170	4.421	4.667	4.907
70										3.297	3.587	3.870	4.148	4.420	4.686	4.946	5.201
72											3.795	4.095	4.389	4.677	4.958	5.233	5.503
74											4.010	4.327	4.637	4.941	5.238	5.529	5.814
76											4.230	4.564	4.891	5.212	5.525	5.833	6.133
78											4.456	4.808	5.153	5.490	5.821	6.144	6.461
80											4.688	5.058	5.421	5.776	6.124	6.464	6.797

Cubic Metre Volume Table for Estimating the Approximate Total Volume of Standing White Pine Trees

(Stump and Top Included)

(Derived from "Metric Timber Tables for the Commercial Tree Species of Central and Eastern Canada", Honer, T.G., M.F. Ker and I.S. Alemdag, CFS Maritimes For. Res. Centre)

Formula: Volume = (0.0043891*dbhob*dbhob*(1-0.04365*0.184)**2/(0.691+(0.3048*363.676/tree height in metres))

dbhob							Total Tree Height (metres)										
(cm)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
2	0.000	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004
4	0.001	0.002	0.004	0.005	0.006	0.007	0.008	0.009	0.010	0.011	0.012	0.013	0.014	0.015	0.016	0.017	0.017
6	0.003	0.005	0.008	0.011	0.013	0.016	0.018	0.020	0.023	0.025	0.027	0.029	0.031	0.033	0.035	0.037	0.039
8	0.005	0.010	0.014	0.019	0.023	0.028	0.032	0.036	0.040	0.044	0.048	0.052	0.056	0.059	0.063	0.067	0.070
10	0.008	0.015	0.023	0.030	0.037	0.044	0.050	0.057	0.063	0.069	0.075	0.081	0.087	0.093	0.098	0.104	0.109
12	0.011	0.022	0.032	0.043	0.053	0.063	0.072	0.082	0.091	0.100	0.109	0.117	0.126	0.134	0.142	0.150	0.157
14	0.015	0.030	0.044	0.058	0.072	0.085	0.098	0.111	0.124	0.136	0.148	0.159	0.171	0.182	0.193	0.204	0.214
16	0.020	0.039	0.058	0.076	0.094	0.111	0.128	0.145	0.161	0.177	0.193	0.208	0.223	0.238	0.252	0.266	0.280
18	0.025	0.049	0.073	0.096	0.119	0.141	0.163	0.184	0.204	0.224	0.244	0.264	0.282	0.301	0.319	0.337	0.354
20	0.031	0.061	0.090	0.119	0.147	0.174	0.201	0.227	0.252	0.277	0.302	0.325	0.349	0.372	0.394	0.416	0.437
22	0.037	0.074	0.109	0.144	0.178	0.211	0.243	0.274	0.305	0.335	0.365	0.394	0.422	0.450	0.477	0.503	0.529
24	0.044	0.088	0.130	0.171	0.211	0.251	0.289	0.327	0.363	0.399	0.434	0.469	0.502	0.535	0.567	0.599	0.630
26	0.052	0.103	0.152	0.201	0.248	0.294	0.339	0.383	0.426	0.468	0.510	0.550	0.589	0.628	0.666	0.703	0.739
28	0.060	0.119	0.177	0.233	0.288	0.341	0.393	0.444	0.494	0.543	0.591	0.638	0.683	0.728	0.772	0.815	0.857
30	0.069	0.137	0.203	0.267	0.330	0.392	0.452	0.510	0.568	0.624	0.678	0.732	0.785	0.836	0.886	0.935	0.984
32	0.079	0.156	0.231	0.304	0.376	0.445	0.514	0.580	0.646	0.709	0.772	0.833	0.893	0.951	1.008	1.064	1.119
34	0.089	0.176	0.260	0.343	0.424	0.503	0.580	0.655	0.729	0.801	0.871	0.940	1.008	1.074	1.138	1.202	1.264
36	0.100	0.197	0.292	0.385	0.475	0.564	0.650	0.735	0.817	0.898	0.977	1.054	1.130	1.204	1.276	1.347	1.417
38	0.111	0.220	0.325	0.429	0.530	0.628	0.724	0.819	0.911	1.000	1.088	1.175	1.259	1.341	1.422	1.501	1.578
40	0.123	0.243	0.361	0.475	0.587	0.696	0.803	0.907	1.009	1.109	1.206	1.301	1.395	1.486	1.576	1.663	1.749
42	0.136	0.268	0.398	0.524	0.647	0.767	0.885	1.000	1.112	1.222	1.330	1.435	1.538	1.638	1.737	1.834	1.928
44	0.149	0.294	0.436	0.575	0.710	0.842	0.971	1.097	1.221	1.341	1.459	1.575	1.688	1.798	1.906	2.012	2.116
46	0.163	0.322	0.477	0.628	0.776	0.920	1.062	1.199	1.334	1.466	1.595	1.721	1.845	1.965	2.084	2.199	2.313
48	0.177	0.350	0.519	0.684	0.845	1.002	1.156	1.306	1.453	1.596	1.737	1.874	2.008	2.140	2.269	2.395	2.518
50	0.192	0.380	0.563	0.742	0.917	1.088	1.254	1.417	1.576	1.732	1.884	2.033	2.179	2.322	2.462	2.599	2.733
52	0.208	0.411	0.609	0.803	0.992	1.176	1.357	1.533	1.705	1.873	2.038	2.199	2.357	2.512	2.663	2.811	2.956
54	0.224	0.443	0.657	0.866	1.069	1.268	1.463	1.653	1.839	2.020	2.198	2.372	2.542	2.708	2.871	3.031	3.187
56	0.241	0.477	0.707	0.931	1.150	1.364	1.573	1.778	1.977	2.173	2.364	2.551	2.734	2.913	3.088	3.260	3.428
58	0.259	0.512	0.758	0.999	1.234	1.463	1.688	1.907	2.121	2.331	2.536	2.736	2.932	3.125	3.313	3.497	3.677
60	0.277	0.547	0.811	1.069	1.320	1.566	1.806	2.041	2.270	2.494	2.714	2.928	3.138	3.344	3.545	3.742	3.935
62	0.296	0.585	0.866	1.141	1.410	1.672	1.928	2.179	2.424	2.663	2.898	3.127	3.351	3.570	3.785	3.996	4.202
64	0.315	0.623	0.923	1.216	1.502	1.782	2.055	2.322	2.583	2.838	3.088	3.332	3.571	3.804	4.033	4.258	4.477
66	0.335	0.662	0.982	1.293	1.598	1.895	2.185	2.469	2.747	3.018	3.284	3.543	3.797	4.046	4.289	4.528	4.761
68	0.356	0.703	1.042	1.373	1.696	2.011	2.320	2.621	2.916	3.204	3.486	3.761	4.031	4.295	4.553	4.806	5.054
70	0.377	0.745	1.104	1.455	1.797	2.132	2.458	2.778	3.090	3.395	3.694	3.986	4.271	4.551	4.825	5.093	5.356
72	0.399	0.788	1.168	1.539	1.901	2.255	2.601	2.939	3.269	3.592	3.908	4.217	4.519	4.815	5.105	5.388	5.666
74	0.421	0.833	1.234	1.626	2.008	2.382	2.747	3.104	3.453	3.794	4.128	4.454	4.774	5.086	5.392	5.692	5.985
76	0.445	0.878	1.302	1.715	2.118	2.513	2.898	3.274	3.642	4.002	4.354	4.698	5.035	5.365	5.688	6.004	6.313
78	0.468	0.925	1.371	1.806	2.231	2.647	3.052	3.449	3.836	4.215	4.586	4.949	5.304	5.651	5.991	6.324	6.650
80	0.493	0.973	1.442	1.900	2.347	2.784	3.211	3.628	4.036	4.434	4.824	5.206	5.579	5.944	6.302	6.652	6.995

Appendix J—MEASUREMENT CONVERSIONS

Some Useful Metric and Imperial Conversions			
Length			
1 cm	= 0.3937 inch	1 inch	= 2.54 cm
1 m	= 3.28084 feet	1 foot	= 0.3048 m
1 km	= 0.621371 miles	1 mile	= 1.60934 km
1 metric chain (20 m)	= 65.6168 feet	1 chain (66 feet)	= 20.1168 m
Area			
1 cm^2	= 0.155 in^2	1 in^2	= 6.4516 cm^2
1 m^2	= 10.7639 ft^2	1 ft^2	= 0.0929 m^2
1 ha	= 2.47105 ac	1 ac	= 0.4046856 ha
1 km^2	= 0.386102 $mile^2$	1 $mile^2$	= 2.58999 km^2
Volume or Capacity			
(solid) 1 m^3	= 35.3147 ft^3	1 ft^3	= 0.0283168 m^3
(solid) 1 m^3	= 227 fbm	1 cord	= 3.62456 m^3
(solid) 1 m^3	= 0.353147 cunit	1 cunit	= 2.83168 m^3 (solid)
(solid) 1 m^3	= 0.41 cord	1 cunit	= 4.3 m^3 (stacked)
(stacked) 1 m^3	= 150 fbm	1 fbm	= 0.0024 m^3 (solid)
(stacked) 1 m^3	= 0.235 cunit	1000 fbm	= 2.4 m^3 (processed)
(stacked) 1 m^3	= 0.275896 cord	1000 fbm	= 4.4 m^3 (unprocessed)
1 L	= 0.2199691 imp gal	1 imp gal	= 4.54609 L
1 L	= 0.26417 US gal	1 US gal	= 3.7854 L
Mass or Weight			
1 g	= 0.035274 oz	1 oz	= 28.3495 g
1 kg	= 2.20462 lb	1 lb	= 0.453592 kg
1 tonne	= 1.10231 tons	1 ton	= 0.907185 tonnes
Map Scales			
1:10,000		1 cm = 100 m	1 in = 833.3 ft
1:15,840		1 cm = 158.4 m	1 in = 1,320 ft
1:20,000		1 cm = 200 m	1 in = 1,666.6 ft
1:25,000		1 cm = 250 m	1 in = 2,083.3 ft
1:50,000		1 cm = 500 m	1 in = 4,166.6 ft
Other Useful Ratios or Conventions			
1 m^2/ha	= 4.356 ft^2/ac	1 ft^2/ac	= 0.23 m^2/ha
(solid) 1 m^3/ha	= 14.29 ft^3/ac	1 ft^3/ac	= 0.07 m^3/ha
(stacked) 1 m^3/ha	= 0.112 cords/ac	1 cord/ac	= 8.956 m^3/ha (stack)
Metric Tree Breast Height is 1.3 metres		Imperial Tree Breast Height is 4.5 feet	
Sources: Metric conversion, Forest Management Institute, Canadian Forest Service, 1972 Tables of Conversion Factors, Weights and Measures, J.A.M. Gaboury Ontario Ministry of Natural Resources Publications. Metric Practice Guide, 1975, Ontario Interministerial Committee on National Standards and Specifications (Metric Committee).			

Appendix K—RAPTOR NEST REPORTING FORM

Ontario raptor and heron stick nest reporting form (Pg. 1)

Date (mm/dd/yyyy): ______________________ Mgmt Unit: ______________

Reported by: ______________________ Verified by: ______________

UTM: ______________ (☐ NAD27 OR ☐ NAD83) Accuracy: ______________

Location (e.g., block #, nearest lake): ______________________

Species: ______________________ # nests: ______________

Status*: ☐ active—currently being used ☐ active—used previous season ☐ inactive

Evidence used to determine status (**check off all appropriate boxes**):

Any one of the following suggests that a nest is active*:

- Bird on nest or bird flies off nest
- Bird perched in nest tree or adjacent tree
- One or more eggs in nest
- One or more chicks in nest
- One or more chicks perched in nest tree or adjacent tree
- Bird delivering food to nest
- Down feathers on nest
- Abundant fresh (green) decoration on nest
- Abundant old (brown) decoration on nest
- Lots of whitewash on nest or near base of nest tree
- Eggs shells near base of nest tree

Two or more of the following suggest a nest is active*:

- Bird behaving aggressively in vicinity of nest
- Small amount (1 or 2 sprigs) of fresh (green) or old (brown) decoration on nest
- One down feather on nest
- Prey remains (butcher block) in vicinity of nest
- A few splotches of whitewash on nest or near base of nest tree
- One or more molted feathers near base of nest tree
- Nest in good repair (e.g., new material added to nest)

***Evidence of breeding activity observed during the nesting searson (Feb./Mar. through July/Aug. depending on species) suggests nest is currently being used (i.e., occupied)(exception: old decoration alone suggests nest was used the previous nesting season). Evidence of breeding activity observed outside the nesting season suggests nest was used the previous nesting season.**

Characteristics of nesting habitat:

Habitat type: • forest • wetland • other ______________

Forest type: • hardwood-dominated • conifer-dominated • mixed conifer & hdwd

Forest age: • recent cutover ($\leq$ 10 yrs) • immature • mature or older

Location: • within 50 m of forest edge • forest interior

Ontario raptor and heron stick nest reporting form (Pg. 2)

Characteristics of next and nest tree:

Tree species: Approx. dbh (cm):

Tree condition: ☐ living ☐ dead ☐ living with dead top

Location in tree:
- ☐ base of live crown
- ☐ well within live crown
- ☐ top of tree

Diameter (width) of nest:
- ☐ less than 75 cm
- ☐ 75 to 150 cm
- ☐ more than 150 cm

Depth of nest:
- ☐ Shallow (less than half as deep as wide)
- ☐ Deep (more than half as deep as wide)

Diameter of sticks:
- ☐ Mostly pencil-sized and smaller
- ☐ Mostly pencil-sized and bigger
- ☐ Mostly cigar-sized and bigger

Type of nest
- ☐ Loosely built
- ☐ Solid and shaggy (some very log sticks)
- ☐ Solid but not shaggy (no very log sticks)

Condition: ☐ Good ☐ Fair ☐ Poor (falling apart)

Type of decoration: ☐ None ☐ Grass ☐ Hair ☐ Conifer ☐ Hardwood leaves

Have you attached: close-up photo showing details of next construction
distant photo showing nest tree and surrounding habitat

Prescription/Notes

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