Silvicultural Systems Handbook for British Columbia

March 2003

BRITISH COLUMBIA

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Ministry of Forests
Forest Practices Branch

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Acknowledgements

This handbook was initially compiled by Ken Zielke and Bryce Bancroft of Symmetree Consulting Group Ltd. from November 1998 to March 1999. Much of the work in this document is based on the *Silvicultural Systems: Decision-making and Prescription Development Reference Manual* – developed, under contract, for a five-day Ministry of Forests (MOF) Workshop by Ken Zielke, Bryce Bancroft and John Przeczek (Interior Reforestation Co.). John Przeczek provided many insights over the years and created many of the graphical diagrams in the harvesting section. The staff of Forest Engineering Research Institute of Canada, specifically Ray Kragg, Eric Philips and Doug Bennett, provided a considerable amount of information for the Harvesting Section. The manual was a work in progress for five years while being used for training courses during that time. Peter Bradford of Forest Practices Branch envisioned a more complete and formal reference document that would serve practitioners as a primary reference on silvicultural systems in British Columbia. Ken and Bryce were contracted, with FRBC funding, in 1998 to put a field handbook together and submitted their report to Forest Practices Branch contract co-ordinators Rob Bowden and Mel Scott in the spring of 1999.

Research results, as well as changes in legislation and policy from 1999 to 2001 caused a number of changes to that document. Ken and Bryce produced a CD. Greg Kockx, Ministry of Forests changed and updated the soils section. Stephen Mitchell, PhD, Faculty of Forestry, University of British Columbia updated the Windthrow Risk Assessment section. Colene Wood, of the British Columbia Ministry of Water, Land and Air Protection, added valuable input on environmental issues. Numerous MOF personnel, including all the forest regions reviewed and commented on the text. John Harkema of Forest Practices Branch reviewed and edited sections based on his field experience. John and Mel Scott, with assistance by Hal Reveley of Vancouver Forest Region, added the retention silvicultural system to this handbook. Susanne Barker and Paul Nystedt of the MOF Library corrected numerous citations and made format suggestions. Bill I'Anson edited the handbook in July, 2001. Peter Affleck of the Interior Lumber Manufacturers Association and Les Kiss from the Council of Forest Industry reviewed the draft.

In 2003, minor changes have been made, primarily as a result of changes to legislation. Lastly, it is important to acknowledge all the foresters, engineers, technicians and loggers across the province that have freely discussed their experiences and shared their successes and failures. Your contribution is invaluable to this evolving handbook.

Layout was done by TM Communications, in Victoria.

PART 1: GENERAL APPROACH OF THE HANDBOOK

1.1 Purpose

As partial cutting silvicultural systems are being used more often in British Columbia, many questions are beginning to emerge from practitioners, whose previous experience was mainly with even-aged clearcut systems. Some of these questions may be answered by consulting a range of references.

The intent of this handbook is to provide field forestry practitioners with a first reference for silvicultural systems prescription development and implementation in BC. The handbook catalogues background knowledge intended to clarify concepts related to partial cutting silvicultural systems. The handbook also brings together treatments and approaches that have worked in various parts of the province to highlight strengths and weaknesses of each.

The handbook also addresses the key questions and issues that emerge as partial cutting silvicultural systems are prescribed and implemented. While this handbook may not answer all questions, it will hopefully provide valuable guidance and direct practitioners to other references that can give additional detail on a range of subtopics.

The subject of silvicultural systems could conceptually include all aspects of forestry. However, this handbook focuses on those issues specific to partial cutting systems. Discussion of issues common to all silvicultural systems (including clearcutting), and the presentation of general forestry concepts not strictly related to partial cutting silvicultural systems, are minimized.

Corporate database systems handle record keeping.

Survey procedures are in the *Surveys Guidebook*.

1.2 How to Use this Handbook

This handbook is not intended as a textbook. It is structured to be most effective as a resource when you have specific questions on specific issues.

The Parts of the Handbook

The handbook is divided into parts that start with a one- to two-page overview.

Sections

Each part is divided into sections that begin with an introduction and a list of the key content items. Following the introduction is a table of contents for the section that details the subsections and the issues and questions addressed. This is a good place to start if you have a specific question that you would like to investigate.

Questions and Issues

Within each subsection, key questions or issues are highlighted with an answer or a suggested approach to address the question or issue.

Additional Reading

At the end of each subsection, the handbook includes a list of references that the reader may wish to consult. Also, throughout the text these references are identified so that the reader immediately knows where to go for more information.

Outline

PART 2: DEFINITIONS, CONCEPTS, AND PRINCIPLES

Part 2 provides an overview of silvicultural systems definitions, concepts, and principles to foster a better understanding of their potential uses and limitations.

2.1 Review of Silvicultural Systems Definitions

This section presents basic silvicultural systems options and clarifies terminology.

2.2 The Foundations of an Effective Silvicultural System

Silvical Considerations

This subsection reviews the silvical characteristics that must be considered for the various species suitable to a site.

Stand Dynamics

To assist in visualizing changing stand characteristics over time, this subsection presents the key considerations and processes for stand dynamics.

Partial Cutting and Genetics

Partial cutting can have a profound impact on genetic composition and diversity, especially when relying on natural regeneration. This subsection discusses the issues and considerations for genetics when using partial cutting silvicultural systems.

Section 2.1 Review of Silvicultural Systems Definitions

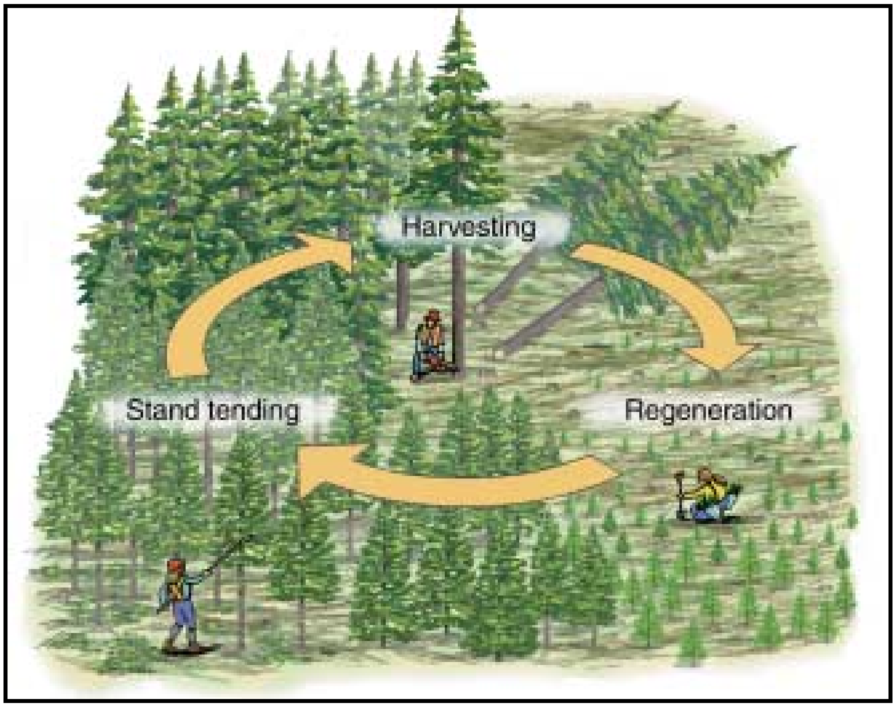

Figure 2.1-1

What is a silvicultural system? Is it only relevant when we are doing something other than clearcutting? Why not keep it simple and speak in terms of clearcutting or selective logging? Why do some seed tree systems and shelterwoods look the same?

In BC the careless use of silvicultural systems terminology created considerable confusion and frustration among practitioners. Yet these systems are the foundation of sustainable forestry at the stand level. Systems are complex integrated programs that are designed to facilitate a process. Silvicultural systems facilitate the process of forest management for predictable sustainable flows of desired goods and services at the stand level. These systems integrate all aspects of forest management over a long time to accomplish this task.

This section gives a brief overview of the range of silvicultural systems. The topic is complex and many good references already exist. Therefore, this section reviews the basic terms, and answers the most common questions regarding silvicultural systems definitions.

In this section we will…

- Review the basics: the definition of a silvicultural system and the difference between even-aged and uneven-aged management.
- Differentiate between clearcut, seed tree, shelterwood, and selection systems.
- Explore the numerous types of shelterwoods that are based on structural distribution of leave-trees, the timing of overstorey removal, and the species composition in the stand layers.
- Investigate the three approaches to structurally manage uneven-aged stands.
- Learn about less common silvicultural systems such as the coppice system, patch cutting, clearcuts "with reserves," and the retention silvicultural system.

Table of Contents

What Is a Silvicultural System?

A silvicultural system is a planned program of silvicultural treatments designed to achieve specific stand structure characteristics to meet site objectives during the whole life of a stand. This program of treatments integrates specific harvesting, regeneration, and stand tending methods to achieve a predictable yield of benefits from the stand over time. Naming the silvicultural system has been based on the principal method of regeneration and desired age structure.

Silvicultural systems on most sites have been designed to maximize the production of timber crops. Non-timber objectives, such as avalanche control and wildlife production, have been less common. Recently, ecological considerations and resource objectives have increased. A silvicultural system generally has the following basic goals:

- Provides for the availability of many forest resources (not just timber) through spatial and temporal distribution.
- Produces planned harvests of forest products over the long term.
- Accommodates biological/ecological and economic concerns to ensure sustainability of resources.
- Provides for regeneration and planned seral stage development.
- Effectively uses growing space and productivity to produce desired goods, services, and conditions.
- Meets the landscape- and stand-level goals and objectives of the landowner (including allowing for a variety of future management options).
- Considers and attempts to minimize risks from stand-damaging agents such as insects, disease, and windthrow.

Even-aged and Uneven-aged Stands

Even-aged stands generally have one age class, although two age classes can be found in some two-layered natural or managed stands. These stands generally have a well-developed canopy with a regular top at a uniform height.

Pure even-aged stands generally have a nearly bell-shaped diameter distribution. This means that most trees are in the average diameter class. However, diameter distributions should be viewed cautiously since diameter can be a poor criterion for age. The smallest trees in natural even-aged stands are generally spindly, with vigour suppressed by the overstorey.

Uneven-aged stands have three or more well-represented and well-defined age classes, differing in height, age, and diameter. Often these classes can be broadly defined as regeneration (perhaps regeneration and sapling), pole, and sawtimber (perhaps small and large sawtimber). In the classic managed form, where diameters are a good approximation for age, distribution of diameters will approach the classic inverted-J form. The objective of such an approach is to promote sustained regular harvests, with short intervals, at the stand level.

Uneven-aged stands have an uneven and highly broken or irregular canopy (often with many gaps). This broken canopy allows for greater light penetration and encourages deeper crowns and greater vertical structure in a stand.

Integrating "Reserves" within a Silvicultural System

Reserves are intended to satisfy management objectives, requiring that the stand be maintained for a long period. Reserves are forested patches or individual trees retained during harvesting, or other forestry operations, to provide habitat, scenic, biodiversity, or other values, for at least one rotation. Reserves are areas that are to be maintained for a long time, such as more than 100 years—think old trees as in the *Biodiversity Guidebook*. Any incidental seed or shelter to the regenerating stand and site that reserve trees supply is secondary to their purpose as reserve trees. Seed or shelterwood trees are not reserves, since they are removed as soon as a new crop is established. Where trees are not retained for the long term, they are not reserves. Areas that are deferred from harvest only until the adjacent area is greened up are not reserves, simply areas of deferred harvest.

Use of reserves can be compatible with any silvicultural system, under appropriate stand and site conditions. When reserves are combined with a silvicultural system, they are incorporated into the name of the system as in *clearcut with reserves*.

To protect the structural integrity of reserve patches, there will generally not be any harvest entries. However, in limited cases, harvest entries may be required to address safety concerns or a management objective such as forest health. Treatments can be done on reserves for non-timber objectives. The treatment may involve cutting trees. Where a harvest entry occurs, predetermined stocking standards must be met.

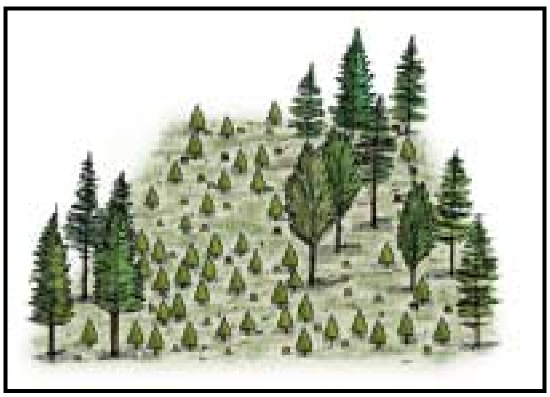

Figure 2.1-2

There are three types of reserves. Type is based on the objective for the reserve. The two primary types are riparian and wildlife. The third type is a catchall for recording other objectives and simply labelled "other."

1. **Riparian** –as described in the *Riparian Management Area Guidebook*. Typically objectives are to minimize or prevent impacts of forest and range uses on stream channel dynamics, aquatic ecosystems, and water quality of all streams, lakes, and wetlands.
2. **Wildlife** – wildlife tree management strategies can range from the retention of existing wildlife trees, as scattered individuals or in patches, to the creation of new wildlife trees. Many approaches can be applied within a single cutblock, though reserving patches is usually recommended as the priority approach. Wildlife tree requirements apply to the use of all silvicultural systems.

3. **Other** – a catchall for reserves that provide for objectives other than the first two categories.

Each type of reserve can be further described as a patch or as dispersed. A patch is a group of trees important enough to be mapped at the scale being used. Dispersed is the appropriate description when trees are being reserved individually or in groups too small to be mapped. Any reserve that is not a patch, is by definition dispersed.

Note: Reserve trees are greater than 12.5 cm dbh.

The Clearcut System

The clearcut system manages successive even-aged stands by cutting the entire stand of trees at planned intervals (the rotation) then regenerating and tending a new stand in place of the old.

The clearcut system is the most straightforward and easiest system to use, and has been applied around the world. While it has been successful for pure timber management, especially for valuable shade-intolerant species, concern over aesthetics, habitat impacts, and watershed impacts have prompted interest in alternate systems in many areas of BC.

A "clearcut" means a silvicultural system that

a. Removes the entire stand of trees in a single harvesting operation from a area that is:
   i. One hectare or greater; and
   ii. At least two tree heights in width, and

b. Is designed to manage the area as an even-aged stand

This definition of clearcut focuses on the size and width of openings. Kimmins (1992) defines clearcutting as harvesting all trees in a single cut from an area of forest large enough so that the "forest influence" is removed from the majority of the harvested area. Forest influence occurs along the edge or ecotone of an opening adjacent to a forest and is an intermediate mircoclimate between forest openings.

A "clearcut with reserves" means a variation of clearcutting in which trees are retained either uniformly or in small groups, for purposes other than for regeneration.

Patch Cut System

The patch cut system involves removal of all the trees, from an area **less than one hectare in size**. Each patch cut is managed as a **distinct even-aged unit**. If an area has several patch cuts, each opening is still managed as a distinct opening. Regeneration is obtained either by artificial or natural regeneration, or a combination of the two.

Many references will recognize this as a variant of the clearcut system. However, in BC the Ministry of Forests recognizes these very small openings, which have characteristics that are different than an average clearcut, as a separate system.

The Basis for the Patch Cut Definition

Smith (1986) recognized the patch cut system as a type of clearcut silvicultural system promoting natural regeneration in small openings.

All definitions of patch cuts include the concept of small openings that will be managed as individual stand units, unlike the openings created in the group selection or group shelterwood systems.

→ **See** "Additional Reading" (this section).

Retention System

The **retention system** sustains the major ecological conditions and processes characteristic of a forest by maintaining a level of stand structure, complexity, and diversity.

The retention system is a silvicultural system that is designed to:

a. retain individual trees or groups of trees to maintain structural diversity over the area of the cutblock for at least one rotation, and
b. leave more than half the total area of the cutblock within one tree-height from the base of a tree or group of trees, whether or not the tree or group of trees is inside the cutblock.

A harvested area is not a clearcut if the major ecological conditions and processes characteristic of a forested environment remain more or less intact (Kimminis, 1992). Forest influence extends from residual trees into a harvested area.

One tree height is used as an administrative way to get at the concept of influence. A retention silvicultural system is where the resulting stand/area has retained trees (aggregate, edge, patch, or single) distributed throughout the cutblock, such that if a person were to conduct a random sample (of 20 samples or more) of the area actively harvested, they would find that greater than 50% of the cutblock is within one tree height of retained trees (i.e., under the influence of retained trees).

The retention system is differentiated from the clearcut with reserves system by the distribution of leave trees and the influence of edge effect. The retention system requires individual trees or groups of trees to be distributed over the block, with edge effect influence covering at least 50% of the opening. The clearcut with reserves system is not bound by a 50% edge influence requirement, nor the distribution over the block.

The retention system requires retained trees to be left in various locations across the whole cutblock, not concentrated in a few areas. The trees can be left singly, in groups of various sizes, or some combination of the two. There can also be a range in the amount and pattern of the retention. Retention objectives are unique to the individual area or landscape unit, and can include, but are not limited to, biodiversity, wildlife habitat, or aesthetic values. These objectives must be clearly expressed in the operational plan for the area.

Regeneration can be accomplished by either natural or artificial methods. A description of the residual stand in the harvested area is required.

Forests are dynamic, and temporal change is a feature of functioning ecosystems. The element of time is a crucial consideration in planning ecosystem maintenance. The structure retained by the retention system will promote a more rapid return of ecosystem functions into the stand. Group retention has the additional advantage of providing refugia for many organisms. These areas can act as lifeboats, and allow organisms to repopulate adjacent areas once conditions become suitable again. With the retention system, the emphasis is on selecting what will be retained.

> *Unlike most silvicultural systems, which are named for the primary method of promoting regeneration, the name of the retention system reflects the importance placed on the structural elements of the pre-harvest stand that are retained after the area is harvested.*

Variable retention is an approach to forest planning and forest harvesting in which structural elements of the existing forest are retained throughout a harvested area for at least through to the next rotation to achieve specific management objectives. The approach utilizes a wide spectrum of retention with varying amounts, types and spatial patterns of living and dead trees. Variable retention uses all silvicultural systems, from single tree selection to clearcutting, including the retention silvicultural system, to achieve variable retention over a landscape.

The Vancouver Forest Region Circular Letter *Variable Retention—Defining for Use* (http://www.for.gov.bc.ca/vancouvr/van_r.htm) provides implementation information.

Seed Tree System

In a seed tree system the entire cutting unit is managed as it is with clearcut systems except that, for a designated time period, harvesting excludes those trees selected for the purpose of supplying seed. Trees are generally left just to supply seed for the next crop; therefore, the best phenotypes should be selected to try to encourage desirable genetic traits to meet specified management objectives.

In a classic seed tree system natural regeneration is used, although the seed trees may not be relied upon entirely and some planting may occur beneath seed trees, often at reduced stocking levels. It is useful to conduct a stocking survey after three years and use fill planting to fill in any gaps in stocking. Usually, the seed trees are removed in a “removal cut” once regeneration is established, although in practice this is not always the case.

Seed Tree System Variations

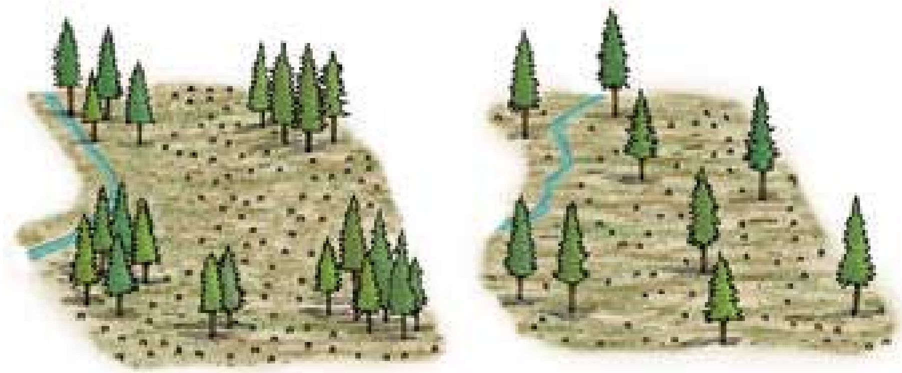

Figure 2.1-3

Uniform Seed Tree System

Seed trees are left more or less uniformly distributed throughout the block.

Group Seed Tree System

Group seed trees are left in small groups. These groups may be irregular or in strips. Seedfall distance and windthrow risk play a major role for their distribution on the block.

Combination

The uniform and group seed tree systems can be used in combination. When this is done the terminology is combined, as in "*uniform and group seed tree system.*"

Seed Tree System with Reserves

Reserves can be used with any system.

→ **See** "Reserves" in this section.

Shelterwood System

In a shelterwood system the old stand is removed in a series of cuttings to promote the establishment of a new even-aged stand under the shelter of the old one.

The primary intent of this system is to protect and shelter the developing regeneration. Generally, shelterwood systems aim at natural regeneration, although some planting may occur to diversify the species mix, bolster stocking and introduce improved seed. The central theme to shelterwoods is that the overstorey leave-trees are left on site to protect the regenerating understorey until the understorey no longer requires the protection. At some point the overstorey starts to inhibit development of the understorey trees through crown expansion and shading. This depends on the density of overstorey trees and the species being managed. The shelterwood trees are removed after the new trees no longer need their protection, so that the new tree can develop uninhibited.

Variations of Shelterwoods

Uniform Shelterwood

Leave trees are left for shelter, more or less uniformly distributed throughout the block.

Group Shelterwood

Patches are opened in the stand such that the surrounding edges of uncut timber shelter the new regeneration. The group size will be increased by one or more cuts until the entire block has had the overstorey removed. This gradual removal of the original overstorey occurs relatively quickly in successive harvesting entries within a normal regeneration period for an even-aged stand (10–25 years). The final groups to be harvested may require artificial regeneration.

Strip Shelterwood

Initial harvesting occurs in the stand as uniformly spaced linear strips. In future harvesting entries, strips are added beside the initial strips, progressively into the wind, until the entire block is harvested within a normal even-aged regeneration period (10–25 years). Harvesting in each strip may occur gradually and include a preparatory, regeneration, and removal cut, following in sequence. Strips may be oriented to use the side shade from adjacent timber, maximize sunlight penetration, or allow for visual screening from the uncut timbered matrix.

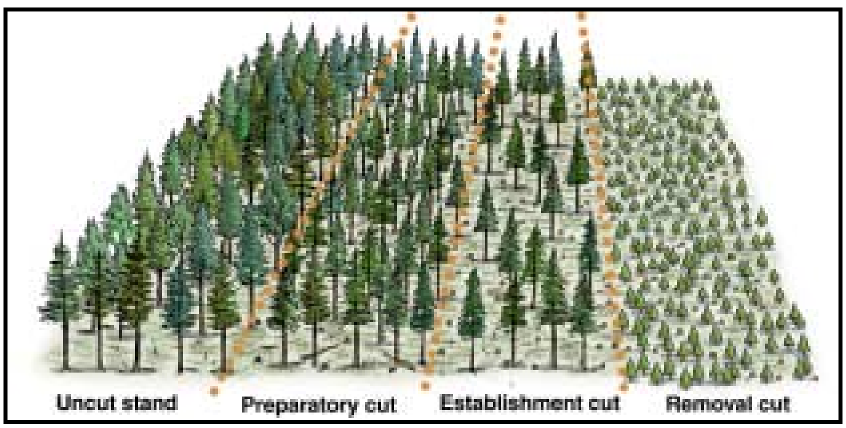

Figure 2.1-4

Irregular Shelterwood

Irregular shelterwoods differ from others based on timing of harvesting entries. There are longer periods between the initial establishment cut and the removal cut than for a traditional shelterwood (removal period generally exceeds 20% of the projected rotation).

Uniform, group, and strip shelterwoods can all be used in an irregular variant (e.g., *irregular group shelterwood*). This system may be the same as a *shelterwood with reserves* if the overstorey is retained for the entire rotation. The difference is that with an *irregular shelterwood* the seedbed is receptive to regeneration for a very long time. The intent is to continue to procure regeneration for much longer than the normal regeneration period. "*Irregular*" refers to the subsequent variation in tree heights in the new stand, which provides an age-class structure that is neither even- or uneven-aged. This variant is difficult to administer and approaches single tree and group selection.

Natural Shelterwood

The *natural shelterwood* often referred to as overstorey removal or release cutting, is a form of shelterwood where the overstorey is removed to create open growing conditions for a fully stocked suppressed understorey. This form of shelterwood has only a removal cut as a harvesting entry.

Nurse-tree Shelterwood

This form of shelterwood is similar to a natural shelterwood except the overstorey trees are of a different species from those in the understorey. The establishment cut would leave the overstorey nurse-trees, while the removal cut removes the overstorey nurse-trees.

This shelterwood approach follows natural successional patterns in stands such as those that include aspen and spruce, larch and redcedar (or hemlock), pine and spruce (and subalpine fir), alder and redcedar, and cottonwood and Sitka spruce (or redcedar). Often these stands are originally established after large disturbances that open the entire stand. Both species may establish at approximately the same time. The understorey species may build its presence more slowly under the established overstorey.

Nurse-tree shelterwoods may be started in cleared areas by planting. For example, at the Malcom Knapp UBC Research Forest, alder and western redcedar have been planted together for this purpose. Nurse-tree shelterwoods have been established through underplanting where the pioneer species is already established as a continuous canopy. In such cases, gaps in the canopy may be created by cutting or girdling to increase early survival and growth in the understorey. When long-lived species are managed as the pioneer overstorey, careful retention of a pioneer component through the rotation will ensure a regeneration potential for that component, helping to sustain the system, if that is desired.

Combinations

The following combinations of shelterwoods may commonly be applied:

- Group and strip – different combinations of group and strip are commonly used in Europe and elsewhere.
- Uniform and group – may be used when sheltering leave-trees are clumpy in distribution.
- Irregular with uniform, group, strip, or nurse-tree – as described previously.

Shelterwood System with Reserves

Reserves can be used with any variant of the shelterwood system (e.g., *strip shelterwood with reserves*). These may be a form of irregular shelterwood.

→ **See** “Reserves” in this section.

Selection System

Selection systems remove mature timber either as single scattered individuals or in small groups at relatively short intervals, repeated indefinitely, where an uneven-aged stand is maintained. Regeneration should occur throughout the life of the stand with pulses following harvest entries.

These systems depend on recruitment of trees into successive age classes over time and the predictable yield from merchantable age classes. Yield will be obtained by thinning clumps, by harvesting individual trees, or by harvesting whole groups of the oldest age class to create small openings scattered throughout the stand.

The selection system can be complex. Three variations of selection systems are used.

Variations of the Selection System

Single Tree Selection

Single tree selection removes individual trees and small clumps of trees of all size classes, more or less uniformly throughout the stand, to achieve or maintain a balanced, regulated, uneven-aged stand structure. It is easier to apply such a system to a stand that is naturally close to the uneven-aged condition. However, an even-aged stand can be converted to an uneven-aged stand for management under a single tree selection system, although numerous establishment cuttings must be made to bring the stand into a structure where the system can truly be applied.

Once the uneven-aged structure approximates the balanced condition, the single tree selection system generally manages a complex mixture of small even-aged clumps that are thinned over time. In theory these clumps should be able to yield at least one mature tree of the specified maximum diameter; however, in practice these clumps are often larger.

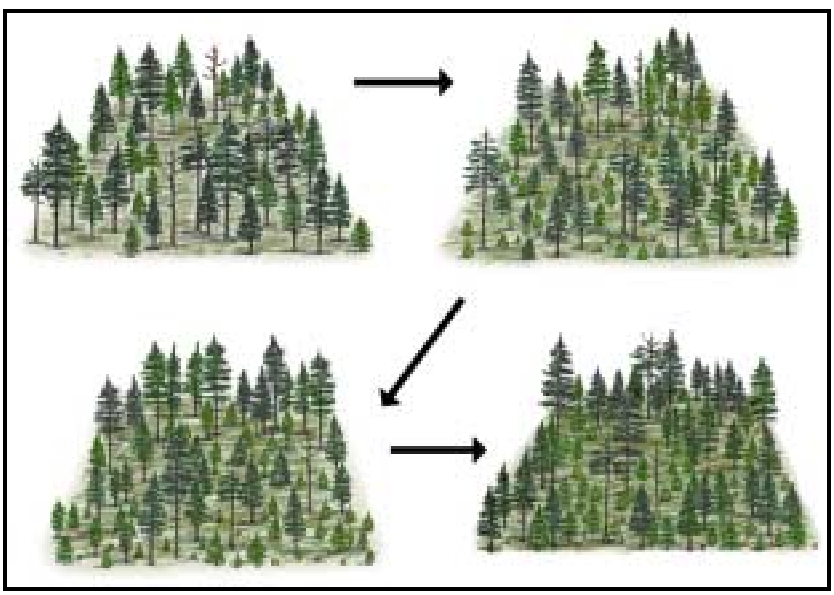

Figure 2.1-5

New regeneration develops in small, scattered openings created in small gaps. Since regeneration is always being recruited and larger mature trees are scattered, or in very small groups, these stands appear quite open, with many gaps. Since regeneration is always being recruited and immature age classes are intermixed in a balanced uneven-aged structure, the total stand basal area may be somewhat less than that of a fully stocked, mature, even-aged stand on a similar site.

Issue: *Single tree harvesting is not necessarily single tree selection.*

Single tree selection is a term that has been misunderstood and therefore abused in BC. It has been incorrectly applied to many stands where single trees were only harvested for salvage, highgrading, or general thinning. This has created considerable confusion around the term. Single tree selection manages a stand using regular, predictable sustained harvesting entries in perpetuity by managing towards a balanced (or close to balanced) uneven-aged structure, as described previously.

Single tree selection is much more complex than removing a few large trees from a stand. While highgrading should not be tolerated, one may legitimately harvest just a few large trees. Such a harvesting entry should be labelled an intermediate cut or thinning (e.g., *intermediate cut for salvage*).

Group Selection

Group selection systems also promote uneven-aged stands with clumps of even-aged trees well distributed throughout the cutting unit. Unlike single tree selection, however, these small even-aged groups are large enough that they can be tracked within the stand (see Figure 2.1-6).

Figure 2.1-6
A 0.25-ha first entry opening in a group selection system in the Engelmann Spruce Subalpine Fir (ESSF) zone.

The small gaps or openings are created on short intervals to develop a mosaic of at least three or more age classes throughout the stand (see Figure 2.1-7). The harvesting entries are light enough so that an uneven-aged structure develops, unlike a group shelterwood.

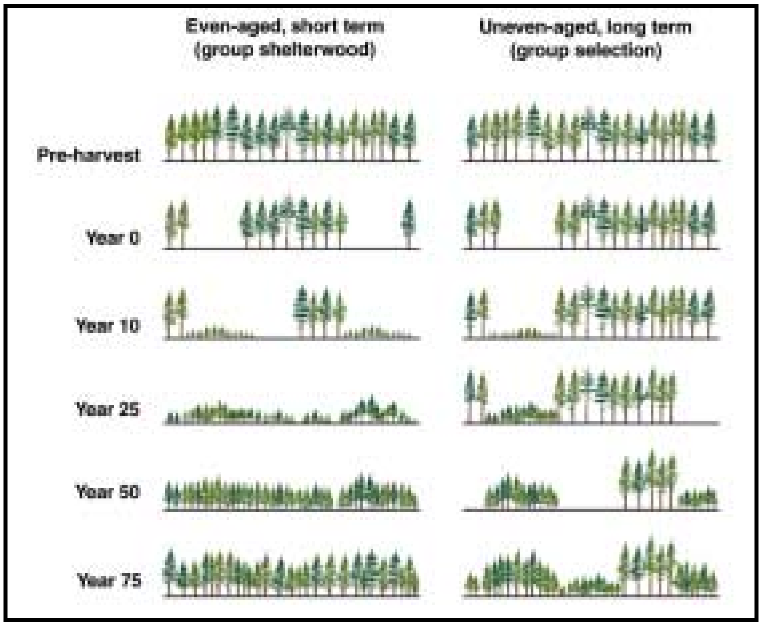

Figure 2.1-7

Groups may be uniformly staggered narrow linear strips (usually 15–50 m wide). Future harvesting strips are added at short regular intervals beside the initial strips, progressively into the wind (see Figure 2.1-8). Such an approach minimizes windthrow risk.

Harvesting intensity and timing between entries are planned to create an uneven-aged stand with linear clumps of age classes, thus meeting the definition of selection. This differs from its shelterwood counterpart by harvesting the entire area much more slowly over time through harvest entries that remove much less volume.

Figure 2.1-8
First entry strips in a four-pass strip selection system in the Interior Cedar Hemlock (ICH) zone. Future strips will progress down the ridge (to the right) into the wind.

Selection System with Reserves

Reserves can be used with any variant of the selection system (e.g., *group selection with reserves*).

The Coppice System

The coppice system is defined as an even-aged silvicultural system for which the main regeneration method is vegetative sprouting of either suckers (from the existing root systems of cut trees) or shoots (from cut stumps). In British Columbia, this system is limited to broadleaved (hardwood) species management. Due to the shade-intolerant nature of most of BC's broadleaf commercial tree species, opening sizes for the coppice system are generally larger than one hectare.

Variations of the Coppice System

Coppice with Reserves

Reserves can be used with the coppice system.

Additional Reading

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Section 2.2 The Foundations of an Effective Silvicultural System

Figure 2.2-1
Interior Douglas-fir ecosystem.

The primary mission of the Ministry of Forests is to manage and conserve the province's forest and range resources in a manner that balances economic, ecological, and social benefits for all British Columbians. The Ministry of Forests is guided by the ethics of sustainable use and good stewardship. The sustainable use ethic is to manage forest development to meet the current needs of British Columbians without prejudice to those of future generations. The stewardship ethic is to care for the health and sustain the beauty and natural functioning of the province's ecosystems by managing forests and rangelands to maintain natural diversity across the landscape. Planning and implementing the appropriate silvicultural system are a vital link in sustainable use and good stewardship.

A site plan or silviculture prescription (SP) must be consistent with the needs for the landscape in which the site is located.

The choice of silvicultural system is made with the goal of providing stand conditions consistent with the objectives stated for the larger area within which the specific site is situated.

→ **See** http://www.for.gov.bc.ca/hfp/pubs/silvsystems/Note5.pdf

→ **See** http://www.for.gov.bc.ca/hfp/planning/writing.htm

When planning or implementing any silvicultural system, the silvics of the tree species being managed must be considered. The intent of this section is to ensure leave-tree selection and choice of regenerating species match their silvical characteristics and ecological tolerances. Questions are asked to promote wise use of BC species in creating future forest structures. Along with this chapter, reading a copy of *The Distribution and Synopsis of Ecological and Silvical Characteristics of Tree Species of British Columbia's Forests* (Klinka et al. 1999) is strongly recommended.

In this section we will…

- Promote the linkage between objectives for the system with the tolerances and characteristics of the species.
- Provide a list of questions to address when
    a. leaving trees on site post-harvest, and
    b. managing regeneration beneath an overstorey.
- Remind practitioners of the dynamic nature of stand structural changes and stress the importance of building in additional harvest entries if needed to achieve desired conditions.
- Discuss issues about genetics and partial cutting.

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Silvical Considerations

Leave-trees

Some species are better adapted to being left on site after a partial harvest than others. Consider the following when choosing leave-trees:

Environmental Resistance of the Leave-trees

Windthrow – this is a complex phenomenon; see section 3.5 for further insights on leave-tree selection and options.

Susceptibility to mechanical damage – species with thin bark and non-resinous wood, such as the true firs (*Abies* spp.) and hemlock (*Tsuga* spp.), are more commonly wounded than thick bark species such as Douglas-fir. Season of harvest will affect the amount of damage. Harvesting during periods of spring sapflow will make even thick bark species susceptible to wounding. Wounding and gouging are two forms of mechanical damage. Wounds remove bark and possibly cambium, but do not penetrate the sapwood. Gouges penetrate the sapwood (BC Ministry of Forests 1997). These forms of mechanical damage create potential entry points for decay fungi and may degrade wood value. See the *Tree Wounding and Decay Guidebook* (BC Ministry of Forests 1997) for recommendations on managing and assessing decay fungi.

Susceptibility to fire – especially relevant where underburning is a desired option for site preparation. Again, bark thickness is a key element in rating the susceptibility of overstorey trees to the effects of underburning. Ponderosa pine, western larch, and older Douglas-fir are thick-barked species that will withstand some level of underburning. If lower branches remain on the overstorey trees, the fire may travel into the crowns causing mortality. In general, species with thin bark are not suited to underburns and therefore should not be left in areas where underburns are prescribed. An exception is when the individuals can be protected or are being left as future snags or wildlife trees.

Susceptibility to pests –a number of detailed references are available on species and their susceptibility to forest health agents or pests. The following references are a starting point and should be used to determine what, if any, potential agents should be considered before leaving trees on site.

- When applicable, see the *Guide to Site Indentification and Interpretation* for the appropriate region. Once a potential pest has been identified, additional information should be obtained on the pest and its relationship to the species before prescribing its retention.
- A good source for specific information on various pests is the Pest Leaflet series produced by the Canadian Forest Service (Pacific Forestry Centre, 506 Burnside Road, Victoria, BC V8Z 1M5). Additionally, a Web diagnostic tool for common tree diseases is available on the Internet at http://www.pfc.cfs.nrcan.gc.ca/health/td_web. This diagnostic tool describes the host, identification characteristics, damage, and means of entry, along with pictures and figures regarding the pest.

→ **See** also Zeglan (1997) for an overview of forest health agents and partial cutting.

→ **See** Klinka et al. (1999) and Bancroft and Zielke (1999) for more information regarding silvics of BC tree species.

Regeneration

Regeneration under a partial cutting system requires the assessment of a range of issues. Because different species have varying tolerances and resistance to environmental factors it is important to understand and attempt to quantify them. Klinka et al. (1999) in *The Distribution and Synopsis of Ecological and Silvical Characteristics of Tree Species of British Columbia's Forests* provide a synopsis of useful silvical characteristics, tolerances, and risk classes for all BC crop species. That will help the practitioner choose regeneration species to suit the structural objectives for the site.

The following factors should be considered before choosing the regeneration mix and method:

- Suitability of the leave-trees as parents – will regeneration from the leave-tree species be desirable? Will they provide adequate seed?
- Seedbed – is there a suitable seedbed present or must one be created?
- Microclimate – is it suitable for establishment and growth of the tree species being prescribed?
- Shade tolerance, specifically growth potential in varying overstorey densities.
- Ability to release – for species with a high potential for release (e.g., subalpine fir) expect 1–2 year delays in diameter response and longer for height growth response (3–5 years). For species that are shade intolerant, the ability to respond may not be applicable as the species is not adapted to survival in an understorey position (e.g., western larch).
- Productivity – potential will vary by site and elevation. Potential generally decreases with increasing elevation.
- Species susceptibility to frost can range from high (e.g., lodgepole pine, subalpine fir) to low in yellow-cedar that requires a snowpack for protection.
- Susceptibility to mechanical damage varies by species depending upon flexibility and branch orientation.
- Susceptibility to pests such as spruce budworm must be addressed when planning complex stand structures. See forest health references for additional information.

Important Questions for Designing a Silvicultural System

With these factors in mind here are some species-related questions when choosing a silvicultural system.

- What is the objective – protect species diversity, maintain genetic vigour, produce timber in the shortest time, create high quality snags, create the most volume in the least time? Higher level plans, if in place, provide direction to determine priorities for the management area. See Section 3.3 for additional details on higher level plan directions.

Once you have some forest-level direction you can ask site-specific questions, such as:

- What species do we want to manage on this site, and for what reason(s)?
- What species are best adapted to this site ecologically and are they here now?
- How many leave-tree candidates do we have?
- How many do we want – a few for seed trees, lots for shelter, a range of ages for uneven-aged management?
- Are they windfirm and will they remain windfirm after harvest?

- Which species/structures/areas in the block are windfirm, which are not?
- How are the potential leave-trees located over the area – patchy, uniformly? How will this affect my harvesting options? (See Section 5.2, "Harvesting Options and Considerations.")
- Are they healthy, will they remain healthy until the next entry?
- Are leave-trees susceptible to disease and insect attack? What factors might contribute to greater susceptibility (e.g., what level of logging damage would be considered acceptable)?
- Is natural regeneration appropriate?
- Do we need to use site preparation to promote natural regeneration? Mechanical site preparation is achievable for group harvesting. Spot treatment with herbicides is a potential site preparation tool. Even fire has been used in a few situations, particularly for ecosystem restoration.
- Do we need to control competing vegetation to obtain natural regeneration or promote survival of planted stock?
- Are the potential leave-trees good seed sources?
- Are adjacent trees good seed sources?
- How many species are we expecting to regenerate, do they grow well together?
- What species will likely out-compete the others, will this be a problem?
- Is some form of precommercial thinning likely needed to promote diameter growth (e.g., to promote timely recruitment of diameter classes in single tree selection)?
- How will the regeneration grow under the remaining canopy?
- When should we remove the leave-trees, if ever?
- Should we start over as the stand does not lend itself to meeting the objectives with the present structure?
- What steps need to be taken to allow the stand to meet objectives in this cut and subsequent cuts?

The best answers to the above questions come from understanding the characteristics and ecological tolerances of the species in the area. For silvics, use Klinka et al. (1999) to calibrate your base knowledge. Field cards (Bancroft and Zielke 1999) summarize silvical information as it pertains to partial cutting. These cards are available from the Ministry of Forests Web site at http://www.for.gov.bc.ca/hfp/pubs/silvsystems/Silvic.pdf.

It is necessary to understand the potential for significant vegetation competition. Consider using local knowledge or experts to help with your assessment. Where local knowledge is unavailable, the various ecological field guides (entitled: *A Field Guide to Site Identification and Interpretation for the _____ Forest Region*) can help identify brush-prone site series.

The establishment to free growing guidelines, available for each forest region, are a useful starting point for identifying ecologically adapted species. Remember that the guidelines rank species for even-aged management, with no overstorey competition. Where an overstorey is to be left, additional information on shade tolerance and ability to withstand overstorey removal must be included when choosing species and a regeneration strategy.

Stand Dynamics

Partial cutting can result in relatively simple dynamics, such as a uniform seed tree system where the seed trees provide seed and limited shade or competition. Alternatively, multi-species single tree selection prescriptions will result in complex dynamics of competition and possibly synergy amongst the various layers and species.

For successful long-term productivity, adequate regeneration and strong early growth do not necessarily equate to good long-term performance. A successful partial cutting prescription needs to be a well thought out plan distributing growing space between regeneration and the remaining older trees. To ensure continued regeneration growth, adequate light is required, which may require removal of the overstorey at some point (e.g., most shelterwoods).

When managing multi-species/multi-aged stands, it may be useful to model future outcomes using a stand model. At present a pilot version of PrognosisBC is available for site series in the southwestern Interior. This model can project a range of species and sizes over time. It has also been used in the Cariboo Forest Region to examine impacts of several partial cutting regimes on mule deer winter range, and in the Prince George Forest Region to assess yield impacts on selection management, using a local calibration.

Remember, larger trees will impact the growth of lower layers—plan for the dynamic growth of all layers in your prescriptions. If need be, suggest harvest entries, even if they are beyond the free growing window.

Use local examples wherever possible to help calibrate your expectations. Models need to have a "reality check." Use your local observations to check the results. If not what you expect, question your observations while looking for reasons within the model for the results.

Integrating Forage Production

Forage production is a concern for wildlife as well as cattle. Strategic placement of forage sites can be very important. Forage includes forbs, grasses, and shrubs. Forage production is highest under open canopies and is reduced as canopies close and leaf litter accumulates.

- Forbs are highest in nutritional value when actively growing. They do not cure well on the stem.
- Grasses are highest in protein when green and actively growing. The shade-intolerant grasses (e.g., fescues, needlegrasses, and wheatgrasses) retain reasonably high energy levels when cured on the stem. Shade-tolerant grasses such a pinegrass and wood reedgrass do not cure as well.
- Shrubs are highest in nutritional values when in leaf, but many shrubs retain relatively high protein levels in their new leaders after leaf-fall.
- In the ponderosa pine and dry-belt Douglas-fir zones, widely spaced stands generally have an understorey of bluebunch wheatgrass or rough fescue. Under a closed canopy, the less valuable pinegrass will replace these grass species.
- In boreal spruce and aspen systems, fireweed, marsh reedgrass, and peavine will increase in production following an opening in the forest canopy and will decline as the canopy closes.

Partial Cutting and Genetics

An issue often attributed to partial cutting is that of dysgenic selection. In many instances, past partial harvest took the best trees first, leaving less desirable trees to parent future stands. Hence the term “highgrading.” There is a general concern that other “non high-grading” partial cutting systems may also be dysgenic. The following discussion is taken largely from Howe (1989).

This section is not meant as an exhaustive treatise on forest genetics; instead it is meant to introduce the topic and to increase awareness of the potential genetic effects of partial cutting. Howe’s interpretation of the genetic literature is likely not unanimous amongst geneticists. It is recommended that local experts be consulted where leave-trees are to be used for natural regeneration. In some cases, partial or full use of artificial regeneration may be suggested.

A synopsis of the principles and effects of genetic change due to harvesting, as presented by Howe (1989), follow.

Principles of Genetics Related to Partial Cutting

Humans can modify the genetic constitution of forests by changing gene frequencies through mutation, migration, genetic drift, or selection. Timber harvesting can significantly alter the last three principles.

Mutation – occurs where there is an actual change in DNA or chromosomes (e.g., Downs syndrome in humans where there is an extra 21st chromosome). There is very little likelihood that partial harvests affect mutation rates.

Migration – is the movement of genes into or out of a population. Planting seedlings from populations outside of the area is a form of migration. In animal populations, Howe (1989) suggests migration of genes from adjacent areas is often beneficial especially for small populations. He implies this could also be true for forest trees, especially those chosen for specific genetic traits.

Genetic drift – changes in gene frequency due to chance. Howe (1989) gives the example of a small group of trees surviving a wildfire. As a result of chance, selection of alleles from these parent trees could result in significant shifts in the gene frequency of the offspring. The offspring therefore may exhibit a substantially different array of alleles from their parents. Different alleles result in different characteristics of inheritance. The use of leave-trees of all types can result in genetic drift.

Selection – is the change in gene frequencies as a result of differential reproduction. This can be both positive (eugenic) and negative (dysgenic). Where parents of positive attributes mate, the result can be that of genetic gain which is a combination of the heritablity of a factor and the selection differential. The result of the cross of parents with desirable attributes is an individual with a greater chance of having and passing on those traits to future generations.

Heritablity – is the ability for parents to pass on their genetic makeup to their progeny. The ability to pass on traits depends on the ratio of variation due to genes plus the variation due to the environment. The amount of heritablity will be small where variation due to the environment is large. Howe (1989) cites a range of sources to provide the following generalizations on heritablity:

- Strongly inheritable traits are specific gravity, disease susceptibility, and many insect susceptibilities.
- A moderately to strongly inheritable trait is form.
- **Moderately to weakly inheritable traits are diameter and height growth.**

Question: *What does this mean for partial cutting prescriptions?*

Often environmental influences can mask genetic differences. However, genetic gains can be made from the selection of superior phenotypes. Phenotypic selection is ineffective on stands that are not of uniform age or spacing, or on stands that grew up on sites of variable aspect, slope, and microsite. Howe (1989) indicates that age is likely the most important of the influences as trees established first will often never be surpassed by a neighbour. Uniformity of spacing also will affect the growth of individuals. Those disadvantaged through crowding may not grow to their potential.

In general, it is difficult to know for sure if you are leaving a genetically superior tree or one that just started earlier on a good microsite. This uncertainty should not dissuade you from leaving quality phenotypes (trees with good outward characteristics) as seed sources. Trees of poorer phenotypes appear to be more effective at achieving genetic loss than do good phenotypes at showing genetic gain. This may be due to earlier susceptibility to disease or insects (highly heritable traits). The data in the literature on this phenomenon is not extensive, yet observation of past practices seems to provide numerous examples in the field.

Genetic Advice by System (from Howe 1989)

Even-aged Systems

Shelterwoods

Leave the best phenotypes specifically for pest resistance. A small genetic gain could be expected if superior phenotypes of a strongly heritable trait are left (e.g., rust-resistant white pine). There will likely be no genetic gain for height or diameter by leaving superior phenotypes. To promote healthy long-lived regeneration, do not leave poor phenotypes for any traits (Dorman 1969, cited in Howe 1989).

Inbreeding is not expected to be a problem except for heavy-seeded species, thus planting is an option. Most BC conifers do not have heavy seeds. Most species have dispersal rates of 100 m plus.

Seed tree

Howe suggests that potential genetic gains from seed tree cutting will be greater than shelterwood cutting, as fewer trees of better phenotype can be left. Seed trees will likely be from separate families resulting in little inbreeding. However, Howe (1989) cautions that use of shelterwood or seed tree systems for more than one rotation could result in inbreeding over the longer term. Avoid leaving poor phenotypes as seed trees.

Commercial thinning

Howe (1989) indicates a potential to choose desirable phenotypes resulting in genetic gain. Poorer phenotypes should be removed. He recommends starting stands with higher than normal densities using more than one thinning to cut out undesirable traits.

Planting

Use the best seed available. Using planting stock from well-managed seed orchards will ensure you will have no inbred stock. Local provenances may or may not be the best for the site. Howe (1989) cites numerous authors that indicate that at times "non-local provenances are better than local provenances in every way." Planted stock is preferred in areas that have been formerly high graded.

Uneven-aged Management

Single tree selection

Uneven-aged management has a high potential for dysgenic selection. Howe (1989) offers the following opinions for appropriate selection cutting.

It can be done correctly only if:

1. You have narrow age classes;
2. You cut only the oldest from the age class, not the best phenotype from the younger age class; and
3. You thin out the poor phenotypes at each entry.

The implication is that one needs to know the age of each tree being cut. This is not going to be the case. To minimize genetic loss, age estimates based on bark and crown characteristics checked with some sampling should be carried out. While this approach may not always be foolproof, the approach should promote leaving the younger, well-adapted stems.

Another problem seen with single tree selection is the simplification of stands away from seral species. Climax species can coexist in even-aged seral stands, while seral species will often be excluded from uneven-aged stands.

Planting is seen as an option to supply good genetic stock. Reduced residual basal area (RBA) and use of group selection can be implemented if shade-tolerant species are desired. In areas where shade-intolerant species are the climax species, single tree selection works well (e.g., ponderosa pine in the Ponderosa Pine zone).

Diameter limit cutting

Diameter limit cutting is not to be confused with true selection. It will undoubtedly result in dysgenic selection. Maynard et al. (1987, cited in Howe 1989) state:

"In terms of genetic consequences, diameter limit cutting is like destroying the 1st, 2nd, and 3rd place finishers in every horse race and putting the last place finishers out to stud!"

Using single tree selection in diameter limit cut stands

To avoid natural regeneration from inferior parents, Steinhoff (1992) suggests supplemental planting of 10 to 50% of the stand area depending upon the severity of earlier harvests. Species mixes and genetic gain can be achieved by planting while natural regeneration will result in quality near the level found in the present stand.

In Sweden, the forestry owner decides which harvesting system to implement, clearcutting[1] or selective harvesting. However, selective cuttings are generally not permitted. The method of choice during the first half of the 20th century, selective cutting resulted in the harvesting of selected timber sizes that left open stands of low productivity (Westland Resource Group 1995).

Additional Reading

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1 Clearcutting in Sweden has two forms: 1) all trees are harvested; 2) seed or screen trees are left standing.

PART 3: PREPARING THE PRESCRIPTION

Part 3 addresses the components of a silviculture prescription or site plan (SP) for silvicultural systems involving partial cutting. Standards that meet management objectives must be identified for the site. The SP identifies and locates licensee forest management obligations at the stand level. However, a good prescription from a professional standpoint must go beyond standards and explicitly describe all aspects of the silvicultural system, with supporting data, which will guide its implementation. Much of this information will be kept on file (as "treatment regimes"), separate from the formal SP. In this part of the handbook we will separate prescriptive content, which should be in the formal SP, from that which should be on file to support a treatment regime. Only issues specific to partial cutting silvicultural systems are discussed.

3.1 Unit Designations within the Area Summary

This section addresses designating different areas under the plan including standards units.

3.2 Setting Soil Conservation Standards for Multiple Entry Systems

This section addresses issues dealing with layout of trails, harvesting numerous small openings, and other issues specific to partial cutting silvicultural systems.

3.3 Describing Current Stand Structure for Complex Prescriptions

A clear picture of current stand structure is useful to make decisions on partial cutting systems and to provide a rationale for your decisions. This section suggests some approaches.

3.4 Describing the Silvicultural System and Harvesting Parameters

This section gives advice on describing complex silvicultural systems and harvesting parameters both in the SP and on file so others can properly implement it.

3.5 Windthrow Risk Assessment

Windthrow is a major concern in partial cutting silvicultural systems. This section describes a method for risk assessment and suggestions for incorporating this information into a prescription.

3.6 Stocking Standards for the Range of Silvicultural Systems

Stocking standards can vary in a prescription when complex structures are left behind. This section offers some suggestions for the range of prescriptive situations.

3.7 Maps for Partial Cutting Prescriptions and Plans

This section provides some suggestions to make maps more useful with complex systems.

Section 3.1 Unit Designations within the Area Summary

Figure 3.1-1

Under BC law silviculture prescriptions or site plans identify obligations for specific standards unit designations within them. For the area under the SP, the prescription must describe areas from which timber is harvested and mappable features, including wildlife tree patches, riparian reserves, and leave tree areas. The prescriber must understand the implications of these obligations and match the unit designations appropriately within the prescription. Partial cutting silvicultural systems create complex stands that may present some confusion for designation of units within the area under the prescription.

This section helps produce an area summary within the SP that will work with the intent of the prescribed silvicultural system. Tips on standards unit designations and size of group and strip openings are also presented.

In this section we will…

- Determine how to administratively account for all potential unharvested area within the range of silvicultural systems.
- Investigate how to designate standards units for group and strip systems.
- Review questions regarding mapping of multiple harvest entries, and opening size in group and strip selection.
- Discuss how to achieve success through writing measurable, action-oriented statements—"mean what you say, say what you mean."

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Designation of Block Area

Issue: *How do we administratively account for the unharvested area in group and strip systems?*

This issue is most confusing for group and strip shelterwoods, and especially selection systems, since the interval between harvesting entries can exceed the life of an active SP. What this means is that harvesting in the "block" is scattered over many small openings or strips, interspersed with unharvested mature timber. The main question becomes "If the unharvested area is part of the block, what do we call it in the SP?"

In BC, the USA, and Europe, it is well established with existing group selection systems that the cutting unit (i.e., block) is designated as the entire area under management over the rotation, to which the group selection prescription applies.

Since the unharvested area is part of the block, it should be part of the *total area under prescription* (TAUP), but not part of the *net area to be reforested* (NAR). By placing it in the section that delineates *no planned reforestation* (NPR), under a heading entitled "*Other Unharvested Area*," the intent then becomes clearer.

Example:

Prescription Overview	A **group selection system** with a cutting cycle of 20 years and five age classes. Ground skidding will be used on a permanent trail network established in the first pass. Regeneration will be a combination of artificial and natural.

AREA OF NO PLANNED REFORESTATION (NPR) – (ha)									
Perm Access	Rock	Water	Swamp	Other NP	NC >4 ha	Reserves with no Modifications	Immature	Other Unharvested Area	Total NPR
4.4	1.2	0.5	0.5	0	0	13.5	10.0	95.9	126

NET AREA TO BE REFORESTED (NAR) including reserves with modifications – (ha)		
Stratum	Stratum Description	NAR (ha)
1	Mesic, very productive lower to mid slopes	16.0
2	Subhygric lower slopes with very compact fine-textured soils	8.0
	Total Net Area to be Reforested	24.0

Total Area Under Prescription (TAUP): 150.0

Designation of Standards Units

Standards Units

An area in which regeneration date, free growing date, stocking requirements, and soil conservation standards are the same is known as a standards unit. These units are areas that will be managed to a specified silvicultural system and to soil conservation and stocking standards. Stand management objectives and biogeoclimatic ecological classification (BEC) site series are significant factors leading to setting standards units.

Other factors may apply under site-specific circumstances. Although BEC site series influence stocking and soil conservation standards, there is not necessarily a direct overlap between BEC site series and standards units. For instance, some stocking standards apply to many BEC site series. In other cases, forest health factors may require the application of different stocking standards within one BEC site series.

Occasionally, areas are temporarily deferred from harvesting. Such areas are not reserves, but are left temporarily until the harvested portion is free growing. At that time another entry may be planned, requiring a new SP. Areas that are not reserves and are not harvested should be entered in the SP as “other” area in the Area of No Planned Reforestation.

For more detail on standards units, refer to the *Silviculture Prescription Guidebook*.

Issue: *For group and strip systems, how do we set standards units using numerous small openings or strips?*

For uniform shelterwoods, seed tree, and selection systems, or systems with uniform reserves, the entire area may be one standards unit. The issue of standards unit designation is straightforward, and really no different than for a clearcut system. Some variation may occur with these systems as the prescription varies with leave-tree densities or characteristics.

However, the issue is less clear with group and strip systems that have many very small openings. Standards units for group selection systems become the entire area and the area is treated as a mosaic. If the cut groups can be managed and tracked individually, consider labeling them as patch cuts.

Figure 3.1-2

Designate different standards units where standards or other considerations make it necessary to do so. Site series may be combined for efficiency. However, the most demanding or restrictive standards should apply to reflect the most productive or sensitive site series. For example, the higher stocking standards should apply and the most restrictive standards for soil conservation should be used. All standards should be biologically appropriate across lumped strata, including for example, minimum height and preferred and acceptable species in the stocking standards.

Many group selection systems already established in BC have large block sizes with 40 or more group openings per harvesting entry.

As future passes are harvested, the appropriate standards will be assigned to each standards unit. Areas may be broken into smaller units only for variations in features that are significant for management up to the free growing stage.

Some group selection research sites in the Cariboo Forest Region have group openings as small as 0.03 ha. Where group openings become so small that they cannot be adequately tracked over time, using classic uneven-aged management as in single tree selection systems may be more useful. However, if the initial stand is even-aged, even these very small openings may be more effectively managed by tracking them on a map and managing each pass as a collective even-aged standards unit for the first few entries. If the openings become difficult to track, it may be more effective to describe the area as single tree selection regulation.

Question: *Should all openings for all passes be shown on the SP map and indicated in the SP for group and strip systems?*

No! This would likely become a paper exercise that would have little value beyond the current entry. Many factors can influence where to locate openings in each pass, and not all of them may be known at present. It is best to only show the current harvesting entry on the SP map. Stand damage and market priorities may cause you to target certain parts of the stand in subsequent entries in ways you cannot predict now. When future entries occur, new or amended maps will be submitted that show both old and new groups.

The exercise of mapping out all harvesting entries and all openings in a block for group selection may be worthwhile as an informal planning tool. This may be practical when windthrow is an issue, or complex terrain make it challenging to plan access and all harvesting passes in the spirit of total chance. Such an informal plan should be kept on file for future reference as it helps with understanding the initial decision.

Question: *How large can group or strip openings be in a group or strip selection system?*

The definition of group selection has been stretched to the point that it is meaningless when prescriptions include openings with the characteristics of clearcuts. A group becomes a clearcut ecologically when most of the opening (greater than 50%) starts to have the same environmental regime as a large clearcut. Group or strip selection systems are recognized as having small openings of two tree lengths or less in width.

Additional Reading

British Columbia Ministry of Forests and BC Environment. 1999. Silviculture prescription guidebook. Victoria, BC. Forest Practices Code of British Columbia Guidebook.

Kimmins, J.P 1992. Balancing act – environmental issues in forestry. Univ. BC Press, Vancouver, BC.

Mathews, J.D. 1989. Silvicultural systems. Clarendon Press, Oxford, UK.

Smith, D.M. 1986. The practice of silviculture. John Wiley and Sons, New York, NY.

Section 3.2 Setting Soil Conservation Standards for Multiple Entry Systems

Figure 3.2-1

Guidelines for setting soil conservation standards and survey methodologies for assessment of compliance are well established in BC for both the coast and the interior. However, suggested allowable limits for permanent access and soil disturbance were set mostly based on benchmark studies and experiences on clearcuts with one harvesting entry. Potentially, when stands are entered several times over a normal rotation for harvesting, the cumulative impact can be greater than a clearcut with one entry. The end result will depend, of course, on equipment used and harvest layout. However, some concerns exist.

When traditional ground skidding is used over multiple entries, especially for uneven-aged management, the proportion of the area occupied by skid trails may be of concern. The allowable limits for soil disturbance that are specified in the prescription must facilitate all entries in the silvicultural system, while protecting the soil resource.

This section will review the critical issues and questions that generally arise while prescribing allowable limits for permanent access and soil disturbance.

In this section we will…

- Examine all sides to the question: Do multi-pass silvicultural systems threaten soil conservation?
- Review the prescription and layout tips that can keep permanent access within acceptable levels.
- Investigate the question of trail rehabilitation.
- Review the issue of excessive trails in a first-entry group selection.
- Examine how skid trails may impact site productivity and the implications for soil conservation designations.
- Investigate the main issues regarding the setting of limits for soil disturbance in silvicultural systems with small openings.

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Soil Conservation Standards and Multiple Entries

Question: *Do multiple entries with ground skidding threaten soil conservation objectives?*

Example of a silvicultural system with multiple entries: group, strip, or single tree selection; irregular shelterwoods; or any shelterwoods with preparatory cuts and/or several removal cuts.

This question is central to the issue of multi-pass systems and soil conservation. Generally, ground-based operations in these partial cut systems use a network of trails to skid or forward the wood to the landings. The density or spacing of these trails will depend on many factors including:

- slope and terrain
- tree height (or skidded log length)
- type of skidding or forwarding equipment
- falling methods (e.g., use of directional falling, manual, or fellerbunchers)
- skidding pattern (e.g., allow for dispersed skidding off trails)
- level of planning (e.g., designated trails).

With group selection systems, a total chance network of trails must be constructed in the first entry, while only a small portion of the area may actually be harvested. This high density of permanent skid trails per area harvested prompts concerns among forest managers about soil conservation.

→ **See** Sections 5.1 and 5.2 for more information on layout and harvesting.

This subsection is devoted to addressing:

1. maximum proportion of cutblock in permanent access
2. maximum allowable level of soil disturbance.

Permanent Access

It is accepted that the area occupied by permanent access structures should be minimized. Generally, the *Soil Conservation Guidebook* recommends no more than 7% of the total cutblock area should be occupied by these structures. These structures can include roads, landings, pits, and quarries, as well as permanent logging trails. These trails can be excavated or bladed trails or unbladed trails, that will be reused in subsequent entries and are designated as permanent in the SP.

Silvicultural systems that include multiple entries should avoid the need to develop an expensive road network and numerous landings by:

- Skidding longer distances on major skid trails between openings to minimize haulroads and landings.
- Carefully locating and designing landings and permanent skid trails, with minimum off-trail traffic, to create an efficient access network for all harvesting entries throughout the entire cutblock. These trails are usually unbladed, although occasionally small portions have to be excavated for topographic reasons. First-pass openings are dispersed along this network throughout the block to facilitate a good mix of age classes at the completion of a rotation of cutting cycles.

- Reusing the same landings and permanent skid trails in subsequent passes. Although some small trail extensions or spurs may be added in subsequent entries, these should provide only minimal additions to overall permanent access.

→ **See** Sections 5.1 and 5.2 for more information on layout and harvesting.

Figure 3.2-2

Since the skid trail network is permanent, to be reused in subsequent passes, the area occupied by these trails must be included in the calculation of permanent access structures (PAS) for the block. Where it is determined that PAS will occupy more than 7% of the cutblock area, the actual amount and supporting rationale should be available. Approval for exceeding 7% in these situations should be available if the skid trail network, roads, and other permanent access structures are well planned, well designed, and well located.

Question: *Why not designate skid trails as temporary access and rehabilitate them after harvesting?*

Because these permanent skid trails are built through unharvested standing timber, rehabilitation activities, which may further disturb and damage the root systems of these trees, **should be avoided**. Normal, temporary deactivation activities for permanent access trails should be performed (e.g., cross-ditching and grass-seeding). However, any deep ripping or excavation associated with rehabilitation, road building, or logging should be avoided or minimized to protect the root systems of leave-trees.

Rehabilitation is carried out to restore productivity to be able to grow a commercial crop of trees. If the re-entry period will not allow a commercial crop to grow on rehabilitated trails, then no rehabilitation is needed.

In Europe, where multi-pass silvicultural systems have been used for some time, a well-planned network of trails is seen as an essential part of permanent access with ground-based operations.

→ **See** Sections 5.1 and 5.2 for more information on layout and harvesting.

Soil Disturbance in the NAR

The *Soil Conservation Guidebook* recommends 5% allowable soil disturbance on the coast and 5 or 10% in the interior, depending on soil sensitivity. These guidelines apply for individual standards units within the block.

Generally, following good logging practices achieves the guidebook recommendations for soil disturbance. The main concern for partial cutting is when harvesting occurs on a series of small openings or strips. Standards for disturbance are normally specified by standards unit not by opening. Therefore, when the opening and SU are the same area, such as for group selection or strip selection it is important to ensure that the SP sets limits to be applied to any portion of the SU.

Regardless of the soil disturbance limits set for the areas, if excessive disturbance is obvious within an opening or strip, and potentially threatens resource management objectives, the district manager has the discretion to direct the person responsible to rehabilitate the area.

It is therefore recommended that a person does not create more disturbance than the limits set for the standards unit in any one of the group or strip openings. If layout or terrain conditions within a planned opening threaten achievement of the standards in that opening, you should plan for the increased disturbance upfront, along with a rationale for the variance from the recommended limits in using site-specific standards.

Additional Reading

Bennett, D.M. 1993. Partial cutting in a second-growth Douglas-fir stand in coastal British Columbia: productivity, costs, and soil impacts. For. Eng. Res. Inst. Can. Vancouver, BC. Wood Harvesting Tech. Note TN-199.

British Columbia Ministry of Forests and BC Environment. 1997. Soil rehabilitation guidebook. Victoria, BC. Forest Practices Code of British Columbia Guidebook.

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McDonald, T.P. and F. Seixas. 1997. Effect of slash on forwarder soil compaction. J. For. Eng. 8(2)15–26.

Section 3.3 Describing Current Stand Structure for Complex Prescriptions

Figure 3.3-1

Use of partial cutting silvicultural systems with complex stand structural goals requires detailed knowledge of the stand before harvesting. Standard cruising procedures are often insufficient to give the detail required for developing partial cutting prescriptions or defending them.

This section explains why more detailed pre-harvest stand information is necessary, what data to collect and how to collect, and compile the data.

In this section we will…

- Understand the purpose of current stand structure information.
- Determine why standard cruise data are insufficient for prescription development.
- Review methods of stand data collection.
- Investigate one approach for data collection and compilation.

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The Purpose of Current Stand Structure Information

To obtain a clear idea of potential management options for a stand over the long term, you must have a clear understanding of current stand conditions. Collect stand information to allow for the development of stand and stock tables. These data may be helpful in two ways:

1. to make decisions on residual basal area, leave-tree characteristics, and perhaps, the silvicultural system you should use
2. to justify your prescription to a supervisor, client, or regulatory official.

Question: *Why not just use cruise information for stand and stock tables?*

Usually, it is best to prepare the prescription and determine the silvicultural system and harvesting system before cruising. Often block boundaries have to be changed to suit the specific harvesting equipment chosen. Also, this avoids the expense of a cruise if the prescription is economically marginal under current markets.

Where a cruise has been completed ahead of time, the cruise stratification does not often fit with the SP stratification due to differing criteria.

Probably the strongest argument for collecting this information, aside from the cruise, is the fact that cruisers rarely collect information on leave-tree potential, beyond defect indicators. Vigour classes should be established on the site to fit each stand, and to facilitate leave-tree decisions. Usually vigour criteria will include a minimum percent live crown; perhaps crown shape, colour, and density criteria; and presence of forest health factors. Knowledge of stand vigour by species and diameter class is critical so that you have a clear idea of current stand condition and potential leave-trees. The cruise usually does not include such data (defect information is not sufficient), nor does it include stand structure data for trees below the merchantable limit.

Collecting Data in the Field

Data can be collected using fixed-radius plots or prism plots. Prism plots are preferred since they are much faster and easier. The basal area factor (BAF) size for the prism or the radius of the fixed-radius plots should be chosen to include 5–16 trees per plot (7–11 optimum). For fixed-radius plots the following plot sizes may be chosen:

Fixed-radius sample plot sizes

Area of plot	Radius of plot	Plot/ha factor
0.01 ha (100 m^2)	5.64 m	100
0.02 ha (200 m^2)	7.98 m	50
0.03 ha (300 m^2)	9.77 m	33.3
0.04 ha (400 m^2)	11.28 m	25
0.05 ha (500 m^2)	12.62 m	20
0.10 ha (1000 m^2)	17.84 m	10
0.20 (2000 m^2)	25.23 m	5

Stand Data to Collect

Use plot cards that allow for easy tally of the trees in each plot, by species, by diameter class, and by vigour category. Vigour categories should be defined at the start of data collection and should be based mostly on the characteristics of the crown—shape, colour, density, percent live crown, and forest health criteria. However, bole characteristics may also be important. Consider collecting data on scars, forest health indicators, and height/diameter ratio, since each may be important.

It is important that vigour categories are developed for each stand separately, since expression of vigour can be slightly different in each species. The primary interest here should be in the ability for the trees tallied to make acceptable leave-trees in the residual stand. Three categories may be useful for this: *Good* – the trees are highly desirable as leave-trees; *Fair* – the trees are acceptable as leave-trees, but not optimum; and *Poor* – the trees are unacceptable as leave-trees.

Figure 3.3-2 is an example of a plot card for stand table data collection. Note that there is room for sample tree data. Sample trees should be representative across diameter classes and species. Use good and fair trees as sample trees.

Example of a Plot Card for Stand Table Data Collection (using a combination of prism and fixed-radius plots)

BRITISH COLUMBIA

PRE-HARVEST SILVICULTURE PRESCRIPTION
STAND STRUCTURE AND
WINDTHROW ASSESSMENT CARD

LOCATION	OPENING	C.P.	BLOCK NO.	BAF	
EXAMINER	DATE YYYY - MM - DD	PLOT / STRATA		PLOT	3.99 5.64

DBH CLASS	SPECIES TALLY - SPH																		
																TOTAL			AVERAGE HEIGHT
	G	F	P	G	F	P	G	F	P	G	F	P	G	F	P	G	F	P	

SAMPLE TREE INFORMATION							
SPECIES	HEIGHT	DBH	AGE	C / C	L / C	10-YEAR	DAMAGE

COMMENTS

FS 39D HSP 96/7

Figure 3.3-2

Using a Prism and a Computer Spreadsheet for Rapid Data Collection and Compilation

A plot card such as the one in Figure 3.3-2 may be used with a prism to collect data relatively quickly. Diameter classes are recorded in the left column, and should correspond with those set in your computer spreadsheet. Five-centimetre diameter classes work well in variable stands, especially for multi-storied or uneven-aged stands. The following approach is recommended for sampling to fit with common merchantability splits and silviculture layers. The pole, sapling and regeneration layers (2, 3, and 4 respectively) are assessed with fixed-radius plots, while all layer 1 trees are assessed with prism plots. For most stands a fixed-radius plot of at least 5.64 m is recommended, except where regeneration is very dense (3.99 m may be used).

Note: To facilitate compilation of data, plot size needs to be consistent throughout the stand.

Recommended diameter classes and sampling approach

dbh class (use diameter class mid-points for speed)	Actual diameter class range	Silviculture layer	Sampling technique
0	0–1.3 m in ht.	Layer 4	Fixed-radius plots
5	1.3 m ht to 7.5 cm dbh	Layer 3	Fixed-radius plots
10	7.5–12.5 cm	Layer 2	Fixed-radius plots
15	12.5–17.5 cm	Layer 1	Prism plots
20	17.5–22.5 cm	Layer 1	Prism plots

The prism plot data can be recorded as a dot tally, using one card per plot or multiple plots on one card. If more than one plot is recorded on a card, plots must be in the same stratum and the stratum and number of plots must be recorded on the card.

→ **See** the MOF *Cruising Manual* available at http://www.for.gov.bc.ca/revenue/manuals/cruising/

The prism plot data can be compiled using a spreadsheet with your BAF and stand table conversion multipliers to produce stand tables with stems/ha, basal area/ha, and rough volume/ha by species, by diameter class, and by vigour class and stock tables. Of the numerous approaches for compilation, two are illustrated as follows. You may want to use one approach or the other, both together, or your own approach. The key is that the stand/stock tables are constructed to help you make decisions and/or give someone else a picture of what the stand is like.

Spreadsheet Data Entry Sheet

PRISM SWEEP SUMMARY SHEET OF "IN" TREES

BAF 4 **Regen. Plot Radius = 3.99 m**

 # PLOTS 3

STF for BAF=1																
DBH	DBH	SPH		Fdi			Se						TOTAL		Avg.	Cruise
Class	Range	Factor	G	F	P	G	F	P	G	F	P	G	F	P	Ht. (m)	Volume
layer 4	0.0–2.4	n/a	7	1	1							7	1	1		
layer 3	2.5–7.4	n/a	12			2						14				
layer 2	7.5–12.4	n/a														
15	12.5–17.4	56.6				2						2			18	
20	17.5–22.4	31.8			1									1	22	
25	22.5–27.4	20.4		1									1		27	
30	27.5–32.4	14.1	1									1			28	
35	32.5–37.4	10.4	1	1								1	1		28	
40	37.5–42.4	8.0	1									1			32	
45	42.5–47.4	6.3		2									2		32	
50	47.5–52.4	5.1	1									1			33	
55	52.5–57.4	4.2		1									1		34	
60	57.5–62.4	3.5														
65	62.5–67.4	3.0														
70	67.5–72.4	2.6														
75	72.5–77.4	2.3														
80	77.5–82.4	2.0														
85	82.5–87.4	1.8														
90	87.5–92.4	1.6														
95	92.5–97.4	1.4														
100	97.5–102.4	1.3														
TOTAL												6	5	1		

Spreadsheet Summary for Stems/ha

	SPECIES TALLY – SPH																
DBH		Fdi				Se											DBH
Class	G	F	P	TOT	G	F	P	TOT	G	F	P	TOT	G	F	P	TOT	Class
0	467	67	67	600									467	67	67	600	0
5	800			800	133			133					933			933	5
10																	10
15					151			151					151			151	15
20			42	42											42	42	20
25		27		27										27		27	25
30	19			19									19			19	30
35	14	14		28									14	14		28	35
40	11			11									11			11	40
45		17		17										17		17	45
50	7			7									7			7	50
55		6		6										6		6	55
60																	60
65																	65
70																	70
75																	75
80																	80
85																	85
90																	90
95																	95
100																	100
TOTAL	50	63	42	156	151			151					201	63	42	307	

Spreadsheet Summary for Basal Area/ha

	SPECIES TALLY – BA																
DBH		Fdi				Se								TOTAL			DBH
Class	G	F	P	TOT	G	F	P	TOT	G	F	P	TOT	G	F	P	TOT	Class
10																	10
15					2.7			2.7					2.7			2.7	15
20			1.3	1.3											1.3	1.3	20
25		1.3		1.3										1.3		1.3	25
30	1.3			1.3									1.3			1.3	30
35	1.3	1.3		2.7									1.3	1.3		2.7	35
40	1.3			1.3									1.3			1.3	40
45		2.7		2.7										2.7		2.7	45
50	1.3			1.3									1.3			1.3	50
55		1.3		1.3										1.3		1.3	55
60																	60
65																	65
70																	70
75																	75
80																	80
85																	85
90																	90
95																	95
100																	100
TOTAL	5.3	6.7	1.3	13.3	2.7			2.7					8.0	6.7	1.3	16.0	

Stand/Stock Table – One Summary, All Data

CURRENT STAND TABLE – 1996										
			Height (m)							
Species	Layer /CC	DBH class	Ave.	Range	Stems/ ha	BA (m^2/ha)	Age	%LC	10 yr increm. (mm)	Vigour and damage
Bl (Fdi)	3&4	–	0.8	0.2–2.0	1200	–	–	–	–	
Fdi (Sx, Pl)	1/Int	10–20	22	8–27	256	6.4	115	20	11	
Fdi (Pli)	1/Cod	25–40	31	28–35	481	39.1	115	20–25	12	10% – G; 40% – F (some damage – windsnap)
Fdi	1/Dom	45–70	40	39–43	96	19.9	115	30	13	60% – G; 30% – F (minor Tomentosus)
		TOTALS – Layer 1 only			832	65.4				

Stand table data as presented above can now be used to determine appropriate leave-tree mixes by species, diameter class, or other categories, as appropriate.

Assessing Biological (Structural) "Control Points" in the Field

Any silvicultural system with leave-trees must work closely with the availability of suitable trees in the original stand. Group and strip selection and shelterwoods, group seed tree systems, and any clumped or grouped retention or reserve system have a non-uniform arrangement of leave trees.

At the reconnaissance or layout stages, document control points that influence the ultimate layout and design of the block from a harvesting and engineering standpoint. When partial cutting in a non-uniform fashion, unique structural features that may fit with the management objectives for the stand should also be documented as "control points." Document these control points on the field map with additional notes recorded as qualitative descriptions.

The "biological" or structural control points should be integrated with the other standard engineering control points to design the cutblock and choose the harvesting methods. To ensure success with this approach, field layout and silvicultural experience should be used together in the field.

→ **See** Section 5.1 "Marking Options and Procedures" for more information on this approach to layout.

Additional Reading

Luttermerding, H.A., D.A. Demarchi, E.C. Lea, D.V. Meidinger, and T. Vold. 1990. Describing ecosystems in the field. 2nd ed. BC Min. Environ. and BC Min. For., Victoria, BC. Environ. Man. 11.

Section 3.4 Describing the Silvicultural System and Harvesting Parameters

Figure 3.4-1

Good communication is necessary for proper implementation of plans. The silvicultural system and harvesting standards must be clearly described to ensure that proper communication occurs between all people connected to the prescription.

A rational silvicultural system for a specific site should accommodate the overall management objectives for the forest of which the site is a part. The system may need to be very complex when dealing with complex situations.

This section provides guidance for describing silvicultural systems and harvesting standards in the prescription. Some specific issues are explained and detailed examples given.

In this section we will…

- Review some basic tips for describing silvicultural systems.
- Review an example of a silvicultural system description for a complex stand.
- Review some basic tips for describing leave-tree characteristics.
- Examine several examples of leave-tree descriptions.
- Explore reasons for including leave-tree damage criteria in a prescription.
- Review examples of leave-tree damage criteria.
- Review other important harvesting standards that should be included in a prescription.

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Describing the Silvicultural System

Using consistent terminology will help communication between foresters now and in the future when someone new must pick up the site plan and conduct follow-up treatments. Here are several suggestions:

1. Use clear terminology. Where it is necessary to add modifying adjectives to better explain what is being done, make sure they are clear and define correctly what is intended. Do not abuse current terms by using them in the wrong context; this will only ensure confusion and not achieve objectives.

→ **See** Section 2.1 for more information on terms and definitions.

2. Do not be afraid to use silvicultural systems combinations, such as strip and group shelterwood, and uniform and group seed tree system. British Columbia's heterogeneous, unmanaged stand types will often require such flexible approaches. Provide diagrams and detailed descriptions in site plans where the system is complex and out of the norm. A diagram with detailed explanations, rather than just a two- or three-word label will help those who follow to understand the intent.

Question: *What if computerized tracking systems do not allow for entry of silvicultural systems combinations?*

3. If the computer program accepts only one silvicultural system per standard unit, use the code for the dominant system for that computer, but leave the combination description in the SP text or comment field for clarity.

Describing Complex Silvicultural Systems

Describe the planned system fully such that it is not misunderstood by anyone that has to follow it. Include a detailed description of the stand structural goals so that the indicators are clear. The silvicultural system may include diagrams if the system is complex.

→ **See** "Silvicultural System Detailed Description" on page 3.4–29.

Information Included in the SP

The name of the silvicultural system.

Example:

SILVICULTURAL SYSTEM:
GROUP SHELTERWOOD

Group selection systems

When using group selection systems include the range and approximate average size of the group openings:

Example:

SILVICULTURAL SYSTEM:
GROUP SELECTION: • Openings will range from 0.2 to 0.33 ha in size with an average opening size of about 0.26 ha.

Additional Information Suggested for Your Block File (Treatment Regime)

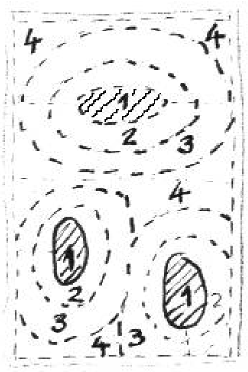
Include the rationale for the silvicultural system approach and a detailed description of how to implement it. Such a description will help those involved in the implementation and provide a clear rationale if the system is questioned in the future. Common topics in the choice of silvicultural system are visual quality, watershed management, green-up, and adjacency.

STAND STRUCTURE AND COMPOSITION GOALS:
Even-aged Fdi (Bl/Cw) stand, slowly replacing the current stand with small groups expanding with entries separated by 5–10 years. The resulting stand will be somewhat irregular in height for up to 50 years, allowing for gradual replacement of the stand. Visual screening of new openings will be provided first by mature timber, and then by older regeneration. Follow up with Silvicultural System Detailed Description (example follows).

SILVICULTURAL SYSTEM DETAILED DESCRIPTION:

PROGRESSIVE GROUP SHELTERWOOD:

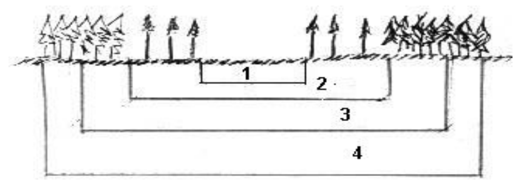
The stand will be brought under even-aged management within about a 20-year regeneration period through a system of progressively expanding group openings. Initial shelter is provided by the side shade cast by the timbered edge around the cleared openings, while normal shelterwood cuttings progress outward from these openings to gradually establish and release the new crop. The parameters that will govern this system here are as follows:



Conceptual diagram of the progressive group shelterwood as seen from above

- First, a system of winter trails will be pre-located to access the entire stand.
- The trail network will feed downhill into landings on either the upper or lower road.
- Locate initial openings to take advantage of windfirm exposed edges and to allow access to the surrounding edge via the pre-located trail network.
- Rough rectangular to elliptical-shaped openings will be cut across the hillslope.
- These openings will be 20–30 m across.
- The openings will be 25–60 m in length (roughly 0.05–0.20 ha).
- These openings are labelled as shaded zone 1 in the conceptual diagram.
- Slope, terrain, and the logistics of harvesting will determine the exact location and orientation of initial openings.
- Surrounding these openings will be a series of cutting zones labelled in the conceptual diagram as zones 1–4.
- Cutting zone 2 (about 1.0 to 1.5 tree lengths in width) will be harvested to reduce the basal area by approximately 40% to increase windfirmness and promote regeneration.
- Cutting zones 3 and 4 will see no harvesting, except perhaps some salvage cutting in the first pass (see below).

After initial harvest
year = 0



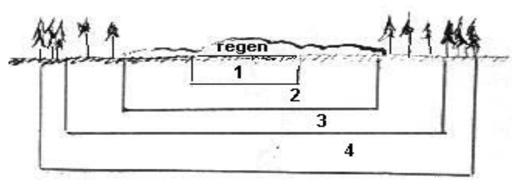
1 = 100% removal cut

2 = 30–40% prep/estab. cut (m^2/ha)

3 = 2–5% salvage cut

4 = salvage (5% max)

After the second cut
year = 5–8

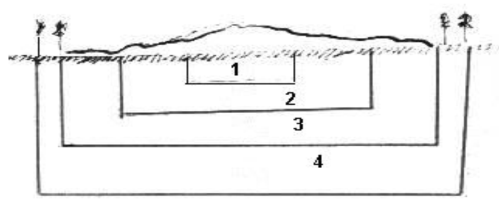


2 = 100% removal cut

3 = 30–40% prep/estab. cut

4 = salvage (5% max)

After the third cut
year = 10–16



3 = 100% removal cut

4 = 30–40% prep/estab. cut

- **A fourth entry** will then be planned for years 13–23 to remove the residual trees in zone 4.
- The time between entries may be lengthened before the next entry if deemed worthwhile for management or research, thus providing an ***irregular*** variation of the progressive group shelterwood. This will produce a structure something between even-aged and uneven-aged.

Some suggested details to be included in the file description of the silvicultural system include:

- A general description of the stand manipulations for the system to give a rough picture of the silvicultural system.
- For any system, removal or retention levels can be described with approximate re-entry time periods or intervals. The purpose of the harvesting entries should also be explained (e.g., preparatory cut, establishment cut, removal cut, salvage cut, intermediate harvest, or improvement cut).
- Ranges with minimums and maximums are essential for the harvesting that will be carried out to give some indication of the potential flexibility for time periods or number of openings, for example.
- For all strip and group systems (selection or shelterwood), a maximum width should be included in addition to the range of sizes. If they are relevant to the prescription, the shape, orientation, and relative position of the openings should also be included.

Harvesting Standards

Describing Leave-tree Characteristics

Information Included in the Site Plan

Standards units need to be specified in the SP. Ensure that the standards to be achieved are thought out prior to harvest. Leave-tree density and distribution for riparian management zones (RMZs) may be different and require a separate SU designation (see next heading, "Additional Information Suggested for Your Block File").

Clearcut with reserves example:

Description of Leave-tree Characteristics	
Purpose/Function of Leave-trees	• To act as a seed supply, provide for future wildlife trees, and retain some of the characteristics of the original old-growth stands. • These trees are to be long-term reserves. • Good quality trees are being left for future wildlife trees to maintain the genetic quality in the stand.
Species Preference	• The species order of preference is Fd, Pw, and Cw.

A shelterwood example:

Description of Leave-tree Characteristics	
Purpose/Function of Leave-trees	• To act as a seed supply and provide scattered shelter for developing regeneration. • These trees will be removed in 5–10 years once most of the regeneration is 50–100 cm tall.
Species Preference	• Douglas-fir.

Additional Information Suggested for Your Block File (Treatment Regime)

Provide clear guidance including indicating opportunities for flexibility. The purpose, preferred species, and general characteristics of leave-trees should be clear. Purpose and species preference should be repeated here for thoroughness. Density in stems/ha or residual basal area/ha should have a range to allow enough flexibility to meet other leave-tree criteria within the stand. Where leave-tree basal area is less than 5 m^2/ha it is recommended that a density range also be given (as in the seed tree example below).

Where another harvesting entry is to be performed, it may be included in this section as in the shelterwood example below, placed in the description of the silvicultural system, or both.

Clearcut with reserves example:

Description of Leave-tree Characteristics	
Purpose/Function of Leave-trees	• To act as a seed supply, provide for future wildlife trees, and retain some of the characteristics of the original old-growth stands. • These trees are to be long-term reserves. • Good quality trees are being left for future wildlife trees to maintain the genetic quality in the stand.
Species Preference	• The species order of preference is Fd, Pw, and Cw.
Density and Distribution	• 10–15/ha (3–6 m^2/ha) uniformly throughout.
Leave-tree Characteristics	• Dominant windfirm trees of good form, colour, and vigour. • The average leave-tree should be >50 cm in diameter and have a minimum of 40% live crown.

Another reserve tree option is to suggest leaving five groups of three to four trees with one dominant and two to three codominants per group per hectare. All intermediates and suppressed stems within 2 m of the group would be retained for additional structure and future snag (wildlife tree) recruitment.

A shelterwood example that differentiates by standards unit (SU):

Description of Leave-tree Characteristics	
Purpose/Function of Leave-trees	• To act as a seed supply, and provide scattered shelter for developing regeneration. • These trees will be removed in 5–10 years once most of the regeneration is 50–100 cm tall.
Species Preference	• Douglas-fir.
Density and Distribution	• Leave-trees will be left uniformly throughout SUs B, C, and D. • Residual basal area for the first entry is set at 10–18 m^2/ha to supply some scattered shelter for developing regeneration. The range allows for selection of the best, most windfirm trees, while providing relatively uniform shelter.
Leave-tree Characteristics	• Dominant windfirm trees of good form, colour, and vigour with no signs of disease. • The average leave-tree should be >40 cm in diameter (>50 cm is preferred) and have a minimum of 30% live crown.

Sound information at the prescription stage is necessary to determine the number of potential trees that you have to work with. This requires classifying trees for vigour, windfirmness, and their role as leave-trees.

→ **See** Section 3.3 for more information on describing current stand structure.

Leave-tree Damage Criteria

Additional Information Suggested for Your Block File (Treatment Regime)

Present a thorough harvesting plan to help minimize damage. As well, describe clearly what is acceptable and provide a removal strategy for stems above a threshold level. Often, the most damage to leave-trees occurs where pre-located skid trails are not followed or are laid out with excessive curves. The *Tree Wounding and Decay Guidebook* (BC Ministry of Forests 1996) offers a good overview of the effects of wounding and makes suggestions on maximum damage, taking into account the length of time trees are to be left on site.

The objective of all prescriptions is to minimize damage, unless trees are being damaged intentionally to create habitat. While the intent is to have no damage some minor damage is often unavoidable. Therefore limits of acceptable damage should be included on the standards for the area.

Damage criteria should include the following information:

- Acceptable percentage of damaged trees.
- List of what constitutes countable damage.
- Schedule for tree removal if damage levels are exceeded.

The damage criteria should relate to the length of time that the trees are to be on site and the difficulty of harvesting. For single tree selection, the percentage should be as low as reasonably possible, as the stems left on site could be left for extended periods.

→ **See** the *Tree Wounding and Decay Guidebook* (BC Ministry of Forests 1996) for suggested criteria categories.

An example of leave-tree damage criteria for a regeneration cut in a shelterwood:

Leave-tree Damage Criteria:
No more than 6% of layer 1 trees in any one hectare of the NAR; • With wounds >400 cm^2 or one-third the circumference of the stem. • With any wounds on a supporting root within 1 m of the stem. • With a gouge – a wound that penetrates (splintered) into the sapwood, or deeper.

Note: In blocks with small numbers of leave-trees per hectare, the minimum stratum size can be made as large as the entire standards unit to ensure fairness.

Issue: *The treatment regime on file should explain what will be done with damaged timber.*

Should damaged trees be removed at the time of harvest or left as future wildlife trees? The decision should be stated in the prescription. For example: All damaged trees will be removed in the next entry in 5–10 years.

Harvesting Entries

Information Included in the Site Plan

Part of the rationale for a site is to identify the opportunities for future harvesting entries within the current rotation, if timber has been left that is surplus to that required to meet management objectives. A tentative time for re-entry, and an indication of the amount of timber available, its location, and any special harvesting considerations should be included. This information will reduce confusion regarding the intent for timber retained within the block. A range of years should be given to allow for some flexibility to time entries for suitable markets and other factors. Also, any critical site factors that influence timing of harvesting operations must be outlined.

Examples:

Opportunities for Future Harvesting:
Approximately 6 ha are available in deferred areas for a second pass once green-up is achieved, an estimated 12–16 years from the initial harvesting entry. See map for location.
Critical Site Factors That Influence Timing of Harvesting Operations:
For harvesting operations, avoid the "bark-peeling" stage of growth (between April and June), when the bole is highly susceptible to damage.

Other Harvesting Information

Additional Information Suggested for Your Block File (Treatment Regime)

Any constraints to harvesting should be outlined in sufficient detail to ensure that they are considered and dealt with in engineering and harvesting activities. Several issues may arise about leave-trees.

The required configuration of leave-trees or patches may require that specific harvesting equipment, configurations, and techniques be used. For example, layout may require a drop-line carriage be used on a yarding crane for a portion of a block to ensure that leave-trees can be efficiently yarded around while staying within acceptable damage limits. Any comments arising from the stand reconnaissance and SP data collection stage that may help to guide layout and harvesting should be included on file. Comments regarding marking of leave-trees would also be appropriate here. Collaboration between foresters and engineers will be helpful.

→ **See** Part 5 for more information on layout, marking, and harvesting options.

Additional Reading

British Columbia Ministry of Forests. 1997. Tree wounding and decay guidebook. Victoria, BC. Forest Practices Code of British Columbia Guidebook.

British Columbia Ministry of Forests. 1999. Silviculture prescription guidebook. Victoria, BC. Forest Practices Code of British Columbia Guidebook.

Zeglan, S. 1997. Tree wounding and partial-cut harvesting – a literature review for British Columbia. BC Min. For., Vancouver, BC. Pest Manage. Rep. No. 14.

Section 3.5 Windthrow Risk Assessment

Figure 3.5-1

Risk of windthrow is a common concern in forest management. Windthrow has always been an important consideration when planning cutblock boundaries in many portions of BC. Partial cutting silvicultural systems raise even more concerns regarding windthrow due to the increased amount of edge relative to typical clearcuts.

The potential for windthrow must be considered before harvesting. A diagnostic framework can be used to assess the potential risk of various treatments based on initial stand, site, topographic, and prescription design factors. The consequences of windthrow for prescription objectives should be considered. If expected impacts are unacceptable, partial cutting prescriptions may have to be altered to reduce anticipated windthrow risk including prescribing crown modification treatments. In some cases, a partial cutting prescription may be virtually impossible without high levels of windthrow. It is best if this can be anticipated so that the alternative options can be considered before harvesting. Sometimes a high windthrow risk may be acceptable if salvage can easily be accommodated or if stand structural objectives include damage. Again, it is best if this is anticipated.

This section reviews an approach to windthrow risk assessment, discusses potential approaches to reduce risks, and makes suggestions for incorporating these assessments into SPs for complex silvicultural systems.

A windthrow self-study site is available at
http://www.for.gov.bc.ca/HFP/FORDEV/windthrow/index.htm

In this section we will…

- Review the basic conceptual framework behind an approach to windthrow risk assessment.
- Review a process for windthrow risk assessment and the corresponding Ministry of Forests field cards.
- Investigate the range of options for treatments to minimize windthrow risk.
- Learn how to report a windthrow risk assessment in a SP.

Table of Contents

A Conceptual Framework for Windthrow Risk Assessment

Forest managers have always been concerned about losses to windthrow. Some silvicultural systems, like strip selection, were designed to reduce such losses. In the 1960s the British began to investigate windthrow, seeking to predict and prevent windthrow losses in their uniform even-aged Sitka spruce plantations. This research culminated in 1977 in a quantitative windthrow risk prediction system that could identify the critical height at which windthrow will occur in a given stand.

The British model took 10 years to develop in relatively uniform terrain with one species and two management regimes. In BC we are faced with more than 20 tree species, highly complex and diverse terrain, and a multitude of potential management regimes. In the early 1990s increasing interest in partial cutting silvicultural systems in BC led to the development and evolution of a diagnostic framework for relative windthrow risk assessment (Mitchell 1998). The framework combines topographic exposure, soil, and stand features with treatment parameters to help categorize risk for a given situation. The framework is used with observations in areas previously harvested to provide a feedback loop that refines previous judgements.

The basic conceptual framework is as follows:

Windthrow Risk	=	Biophysical Hazard + Treatment Risk
Windthrow Impact	=	Windthrow Risk + Management Consequences

Windthrow Risk = The likelihood of damage from endemic winds. It is the combination of biophysical hazard and treatment risk.

Biophysical Hazard = The combination of the topographic, soils, and stand hazard components. It represents the intrinsic windloading and wind stability of trees on the site before treatment.

Treatment Risk = The way in which a particular treatment increases or decreases the windloading or wind resistance of trees—angle or shape of edges, or removal levels in thinnings.

Windthrow Impact = The consequence of wind damage. If wind damage conflicts with your management objectives, the impact is negative. Depending on your objectives, some damage may be acceptable.

Endemic Winds = Peak winds expected to recur every year or so in a given location; distinct from “catastrophic winds” which recur infrequently.

Steps in Assessing Windthrow Risk – A Process

Step One – Investigate Past Windthrow Patterns

- Review maps for evidence of past windthrow salvage in the landscape around your prospective cutblock. Look for patterns of recurrent strips of salvage.
- Interview people experienced with past logging and management in the area for clues on the direction of endemic winds, the frequency of peak winds, and past blowdown events.
- Review aerial photos looking for ragged edges or larger plumes of blowdown along boundaries of older clearcuts close to your prospective block.

Step Two – Conduct Initial Stand Reconnaissance and Preliminary Windthrow Evaluation

→ **See** Part 1 for more information on the general steps in prescribing and engineering a complex silvicultural system.

The first step in developing a complex partial cutting prescription should be the initial stand reconnaissance to explore harvesting, engineering, and silvicultural systems options. During the initial reconnaissance in your prospective block, observe and map the location and orientation of old and historic windthrow on the block. At this time some initial observations of ecological factors such as soils, slope, aspect, and stand structure and composition may already provide clues for windthrow risk if the prescriber is experienced. These clues should be factored into the development of the initial prescription, which will include:

- tentative block boundaries
- the tentative location of retention or reserve patches or groups
- the initial basal area retention or removal levels
- the types of leave-trees to be favoured.

Step Three – Calibrate Your Assessment

Windthrow assessment should be part of the formal data collection phase of the site planning. It should begin with a visit to an old clearcut boundary noted in step one. The boundary should exhibit a "high treatment risk" (e.g., downwind boundary at right angles to damaging winds) and have evidence of blowdown. The *Windthrow Field Assessment Card* (see step five) will have to be completed first for the calibration edge. Next, the predicted windthrow risk is compared with the windthrow experienced using the calibration card to adjust component hazard classes to the local situation. The Ministry of Forests now has a *Windthrow Field Card Calibration Page* (MoF field card FS712-3 HFP 98/05) for this purpose.

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Windthrow Field Card Calibration Page

Observed Damage

1. Complete Windthrow Field Card Assessment Pages A and B in a nearby 2–5 year old cutblock on a High Treatment Risk Boundary.
2. Record initial evaluation of windthrow from Assessment Card Page B.

Initial Evaluation (from Assessment Card Page B):

	Very High	High	Moderate	Low	None
Topographic Hazard	•	☐	☐	☐	•
Soil Hazard	•	☐	☐	☐	•
Stand Hazard	•	☐	☐	☐	•
Biophysical Hazard	☐	☐	☐	☐	•
Treatment Risk	•	☐	☐	☐	☐
Windthrow Risk	☐	☐	☐	☐	☐

Calibration of Windthrow Risk Classification

3. Record observed damage on calibration boundary.

Trees Damaged (%):			
First Tree Length	☐>70	☐10–70	☐<10
Second Tree Length	☐>70	☐10–70	☐<10
Third Tree Length	☐>70	☐10–70	☐<10
Describe Damage:	☐Extensive	☐Partial	☐Minimal ☐None

Characteristics of Downed Trees:			
Size (compared to mean tree)	☐Same	☐Smaller	☐Larger
Species Composition	☐Same	☐Different: (describe)_______________	
Rot (compared to average in stand)	☐Same	☐Less	☐ More

4. Look up the expected level of damage for your initial Windthrow Risk Class on Reference Page B, and compare with actual damage recorded above.

Diagnostic question: Is the level of damage observed along the calibration boundary consistent with that predicted for the estimated class of Windthrow Risk? (See top of Reference Page B)

If	Action
Yes, damage is consistent with expected level. ☐	Use the values for topographic, soils, and stand indicators to identify threshold values for high, moderate, and low hazard classes for each of the Exposure, Soils, and Stand Hazard components.
No, there is less damage. ☐	Consider which of the component hazards (Exposure, Soils, or Stand) might have been rated too highly. Reduce the rating and raise the hazard class thresholds accordingly.
No, there is more damage. ☐	Consider which of the component hazard (Exposure, Soils, or Stand) might have been rated too low. Increase the rating and decrease the hazard class thresholds accordingly.

5. Use the revised thresholds for classifying Soils, Topographic and Stand Hazards for nearby areas.

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Figure 3.5-2

Actual damage should reflect the damage listed for the following windthrow risk classes (from the *Windthrow Field Reference Card* – Page B):

Windthrow risk	Expected damage caused by endemic winds
None	No stand present to be damaged by winds.
Low	Little or no damage along recent cutblock edges.
Moderate	Partial damage along recent cutblock edges. Between 10 and 70% of trees are uprooted or snapped within the first tree length in from the edge.
High	Heavy damage along recent cutblock edges. More than 70% of trees within the first tree length damaged.
Very High	Very severe damage along recent cutblock edges. More than 70% of trees damaged in both the first and second tree lengths from the edge.

Step Four – Determine the Formal Assessment Requirements

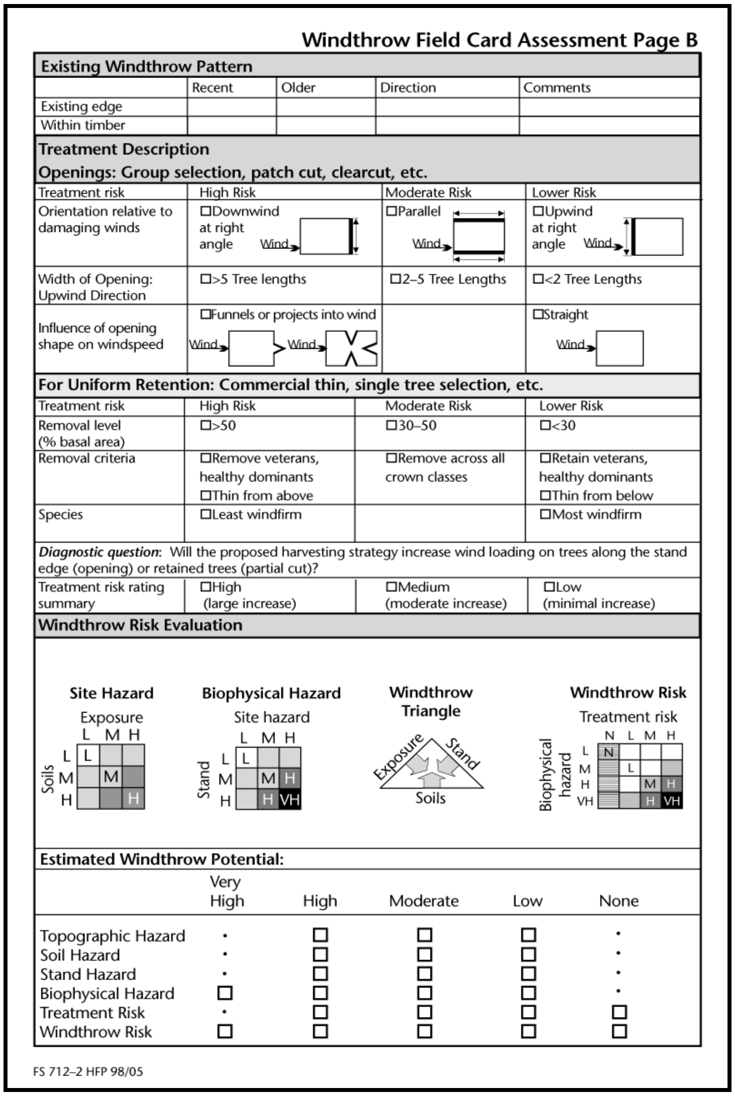
This step may have been done before the calibration, in the field during the initial reconnaissance, or in the office using the reconnaissance map. All exposed stand edges on the proposed cutblock that have the potential for windthrow are identified. These will include block boundary segments and exposed edges of retention or reserve patches. Also, homogeneous portions of the block where leave-trees will be dispersed should be individually assessed.

Step Five – Determine Windthrow Risk for Each Edge Segment and Partial Cut Stratum

→ **See** Mitchell (1998) in “Additional Reading” for more information on determining windthrow risk using this procedure.

Treatment Risk Assessment

Assess treatment risk first, using Page B of the *Windthrow Field Assessment Card* (FS 712-2 HFP 98/05). A separate section for openings and edges focuses on the size, shape, and orientation of openings. The section for uniform retention focuses on removal levels and leave-tree characteristics.



Windthrow Field Card Assessment Page B

Existing Windthrow Pattern				
	Recent	Older	Direction	Comments
Existing edge				
Within timber				

Treatment Description
Openings: Group selection, patch cut, clearcut, etc.

Treatment risk	High Risk	Moderate Risk	Lower Risk
Orientation relative to damaging winds	☐Downwind at right angle (Wind)	☐Parallel (Wind)	☐Upwind at right angle (Wind)
Width of Opening: Upwind Direction	☐>5 Tree lengths	☐2–5 Tree Lengths	☐<2 Tree Lengths
Influence of opening shape on windspeed	☐Funnels or projects into wind (Wind) (Wind)		☐Straight (Wind)

For Uniform Retention: Commercial thin, single tree selection, etc.

Treatment risk	High Risk	Moderate Risk	Lower Risk
Removal level (% basal area)	☐>50	☐30–50	☐<30
Removal criteria	☐Remove veterans, healthy dominants ☐Thin from above	☐Remove across all crown classes	☐Retain veterans, healthy dominants ☐Thin from below
Species	☐Least windfirm		☐Most windfirm

***Diagnostic question*:** Will the proposed harvesting strategy increase wind loading on trees along the stand edge (opening) or retained trees (partial cut)?

Treatment risk rating summary	☐High (large increase)	☐Medium (moderate increase)	☐Low (minimal increase)

Windthrow Risk Evaluation

Estimated Windthrow Potential:

	Very High	High	Moderate	Low	None
Topographic Hazard	•	☐	☐	☐	•
Soil Hazard	•	☐	☐	☐	•
Stand Hazard	•	☐	☐	☐	•
Biophysical Hazard	☐	☐	☐	☐	•
Treatment Risk	•	☐	☐	☐	☐
Windthrow Risk	☐	☐	☐	☐	☐

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Figure 3.5-3
Page B of the Windthrow Field Assessment Card.

The diagnostic question is the key

The diagnostic question at the bottom of the treatment assessment section is the most important part of this section. The preceding boxes simply ensure the prescriber considers each factor. The general risk categories for each factor (low, moderate, and high) are rough and should only be considered within the diagnostic question.

Diagnostic question for treatment risk

Will the proposed harvesting strategy increase windloading on trees along the stand edge (opening) or retained trees (partial cut)?

Biophysical Hazard Assessment

As the intrinsic stability of the stand on the site in question, the biophysical hazard is determined using the three key factors from the windthrow triangle: exposure, soils and the stand (Mitchell 1998). The entire page A of the *Windthrow Assessment Field Card* is devoted to helping the prescriber assess these factors.

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Windthrow Field Card Assessment Page A

Administrative				
Location	Opening	Block #	Examiner/Date	Segment/Portion

Topographic Exposure Description	High Hazard	Moderate Hazard	Low Hazard
Large-scale Topography	☐Coastal plain ☐Plateau ☐Rolling plateau ☐Major coastal inlet ☐Near large water body	☐Large valley ☐Hilly	☐Mountainous ☐Small coastal inlet ☐Far from large water body
Mid-scale Topography	☐Ridge ☐Saddle ☐Knoll ☐Shoulder	☐Flat ☐Side slope	☐Side valley
Topographic Position	☐Crest ☐Upper slope	☐Mid slope ☐Flat	☐Lower slope
Elevation (________m)	☐High	☐Middle	☐Low
Diagnostic question: Are wind speeds normal for the area, or do they vary due to the presence of a terrain obstacle or constriction?			
Topographic hazard rating	☐High (higher)	☐Moderate (normal)	☐Low (lower)

Soil Description	High Hazard	Moderate Hazard	Low Hazard
Parent material	☐Organic ☐Rock ☐Fine alluvial	☐Till ☐Moderate alluvial	☐Coarse alluvial ☐Colluvial
Texture	☐Fine	☐Medium/ ☐V.Coarse	☐Coarse
Coarse fragment %	☐>70	☐30–70	☐<30
Rooting depth (cm) and pattern	☐< 40 ☐Plate roots	☐40–80 ☐Flattened base	☐>80 ☐Rounded base
Impeding layer	☐Water table	☐Surface fractured rock	☐Deep fractured rock
Soil drainage	☐Poor	☐Moderate	☐Good
Diagnostic question: Is root anchorage restricted by an impeding layer, low strength soil, or poor drainage?			
Soil hazard rating	☐High (severely restricted)	☐Moderate (somewhat restricted)	☐Low (unrestricted)

Stand Description	High Hazard	Moderate Hazard	Low Hazard
Structure	☐Uniform	☐Two-layer ☐Uniform with vets	☐Multi-layer
Height (m)	☐>30	☐15–30	☐<15
Live crown Ratio	☐<30	☐30–70	☐>70
Height diameter ratio	☐>90	☐70–90	☐<70
Stand density	☐Dense	☐Moderate	☐Open
Root/stem rots	☐Significant	☐Some	☐Minor
Species			
Diagnostic question: Are the individual trees within the stand adapted to wind loads?			
Note: If damaged stems would lean back into canopy and be supported by their neighbours instead of working down through the canopy to the ground, then stand hazard is low for clearcut edges.			
Stand hazard rating	☐High (poorly adapted)	☐Moderate (somewhat adapted)	☐Low (well adapted)

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Figure 3.5-4
Page A of the Windthrow Field Assessment Card.

As in the assessment of treatment risk, the card is used to ensure that the prescriber considers all factors that could potentially influence biophysical hazard. DO NOT assume that the factors can be averaged across the high, moderate and low hazard categories. One factor may far outweigh the others and exert much more influence on the hazard rating. Consider the importance of each factor when answering the diagnostic questions for each hazard.

Diagnostic questions for biophysical hazard

Topographic Exposure Hazard – Are wind speeds normal for the area, or do they vary due to the presence of a terrain feature?

Soil Hazard – Is root anchorage restricted by an impeding layer, low strength soil, or poor drainage?

Stand Hazard – Are the individual trees within the stand adapted to wind loads?

The three hazard ratings are brought together to determine the overall biophysical hazard with two matrices found at the bottom of page B on the field assessment card.

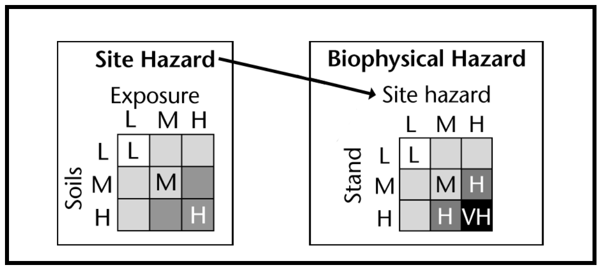

Figure 3.5-5

Using Treatment Risk and Biophysical Hazard to Determine Windthrow Risk

The treatment risk determination and the biophysical hazard rating are then brought together using the matrix at the bottom of page B on the field assessment card.

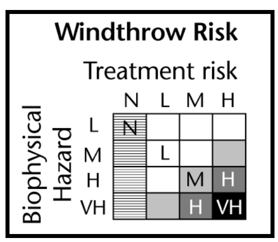

Figure 3.5-6

The expected damage caused by endemic winds for each windthrow risk class is summarized on the Windthrow Field Assessment Card, page B.

Step Six – Determine the Management Impact and Prescribe Treatments

Windthrow risk only defines the likelihood of windthrow occurring. The threat to management objectives from the resulting windthrow is the more important issue facing a forest manager. If management objectives are threatened by the level of windthrow predicted by the assessed windthrow risk class, the manager must consider either changing the prescription or developing a plan for salvage.

If the windthrow is to be accepted and salvage is the option chosen, a salvage plan should be developed as part of the prescription. For the salvage option to work, a clear opportunity for salvage without threatening management objectives or prescription standards must be available. This option should include access management plans.

Potential Treatments to Minimize Windthrow Risk

The Windthrow Field Card Prescription Page

The MoF *Windthrow Field Card* prescription page (FS712-3 HFP 98/05) allows the prescriber to describe the following for assessed edge segments and partial cut strata:

- key management objectives
- acceptable amounts of windthrow
- expected levels of windthrow
- recommended treatments.

Windthrow Field Card Prescription Page

Summary of Management Objectives and Acceptable Damage

Management Objectives for Outside Segment/Within Portion		
Environmental	**Recreation/Visual/ Property**	**Timber**
☐Riparian area ☐Terrain stability area ☐Gully ☐Wildlife tree patch ☐Wildlife corridor ☐______________	☐Recreation area ☐Visual reserve ☐Powerline ☐Structure ☐Road ☐Trail ☐Property ☐______________	☐Value ☐Bark beetle ☐__________
Acceptable amount of damage: ☐None ☐Up to ____% of stems	☐None ☐Up to ____% of stems	☐None ☐Up to ___% of stems

Expected Level of Damage

Windthrow risk:	☐High ☐Very High	☐Moderate	☐Low
Expected damage:	☐Extensive	☐Partial	☐None-Minimal
Is this expected level Acceptable?	☐Yes ☐No	☐Yes ☐No	☐Yes ☐No

Recommended Treatment Modifications

Recommended treatment	Comments:
General:	
☐No treatment	
☐Salvage if damage exceeds acceptable amount	
For clearcuts:	
☐Adjust boundary	
☐Feather	
☐Top	
☐Top-prune	
☐Feather and top/top-prune	
For partial cuts:	
☐Leave more trees	
☐Change leave tree criteria	
☐Other	

Comments:

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Figure 3.5-7

The Range of Treatment Options

If management objectives are significantly threatened by the expected windthrow given the windthrow risk determined, and salvage is not an option, a prescriptive solution must be found. Such a prescriptive solution may include:

- ***Altering the block boundary***—changing the block shape and boundary orientation can lower treatment risk. Relocating boundaries on deeper well-drained soils or in less susceptible stand types can lower biophysical hazard.
- ***Altering the silvicultural system*** to reduce partial cutting removal levels or change leave-tree choices (see below).
- ***Conducting windfirming treatments*** on exposed edges (see below).
- ***Prescribing regeneration or stand tending treatments*** aimed at reducing future windthrow susceptibility (see below).

Note: These choices are not mutually exclusive and can be combined if necessary.

FS 712-4 Windthrow Assessment Summary Card

The BC Ministry of Forests has produced a summary card (FS 712-4 HFP 00/03) which allows you to compile the results for up to six boundary segments or strata on one card. You can used cards FS 712-1 to 3 for reference and enter the component hazards, windthrow risk, expected damage, management issues and recommended action for each segment/strata directly on the summary card (Figure 3.5.8).

FS 712-4 page A

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Windthrow Assessment Summary Card Page A

Note: This card summarizes information from FS 712 -2 & 3. For description of assessment process and definitions refer to FS 712-1.

Administrative			
Location	Opening	Block #	Examiner/Date

Cutblock Edge Segment or Partial Cut Stratum Summary

Segment/ Stratum	Exposure Hazard	Soil Hazard	Stand Hazard	Treatment Risk	Windthrow Risk	Expected Damage	Management Issues	Recommended Action
	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H ☐ VH	☐ None ☐ <10% 1 TL ☐ 10–70% 1 TL ☐ > 70% 1 TL ☐ > 70% 2 TL	☐ RMA ☐ Visual ☐ Terrain ☐ Gully ☐ WTP ☐ Timber ☐ _______	☐ None ☐ Salvage ☐ Feather ☐ Top/prune ☐ Revise Boundary ____________________ ☐ ______________

Segment/ Stratum	Exposure Hazard	Soil Hazard	Stand Hazard	Treatment Risk	Windthrow Risk	Expected Damage	Management Issues	Recommended Action
	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H ☐ VH	☐ None ☐ <10% 1 TL ☐ 10–70% 1 TL ☐ > 70% 1 TL ☐ > 70% 2 TL	☐ RMA ☐ Visual ☐ Terrain ☐ Gully ☐ WTP ☐ Timber ☐ _______	☐ None ☐ Salvage ☐ Feather ☐ Top/prune ☐ Revise Boundary ____________________ ☐ ______________

Segment/ Stratum	Exposure Hazard	Soil Hazard	Stand Hazard	Treatment Risk	Windthrow Risk	Expected Damage	Management Issues	Recommended Action
	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H ☐ VH	☐ None ☐ <10% 1 TL ☐ 10–70% 1 TL ☐ > 70% 1 TL ☐ > 70% 2 TL	☐ RMA ☐ Visual ☐ Terrain ☐ Gully ☐ WTP ☐ Timber ☐ _______	☐ None ☐ Salvage ☐ Feather ☐ Top/prune ☐ Revise Boundary ____________________ ☐ ______________

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Windthrow Assessment Summary Card Page B

Cutblock Edge Segment or Partial Cut Stratum Summary (continued)

Segment/ Stratum	Exposure Hazard	Soil Hazard	Stand Hazard	Treatment Risk	Windthrow Risk	Expected Damage	Management Issues	Recommended Action
	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H ☐ VH	☐ None ☐ <10% 1 TL ☐ 10–70% 1 TL ☐ > 70% 1 TL ☐ > 70% 2 TL	☐ RMA ☐ Visual ☐ Terrain ☐ Gully ☐ Structure ☐ WTP ☐ Road/Trail ☐ Timber ☐ _______	☐ None ☐ Salvage ☐ Feather ☐ Top/prune ☐ Revise Boundary ____________________ ☐ ________________

Segment/ Stratum	Exposure Hazard	Soil Hazard	Stand Hazard	Treatment Risk	Windthrow Risk	Expected Damage	Management Issues	Recommended Action
	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H ☐ VH	☐ None ☐ <10% 1 TL ☐ 10–70% 1 TL ☐ > 70% 1 TL ☐ > 70% 2 TL	☐ RMA ☐ Visual ☐ Terrain ☐ Gully ☐ Structure ☐ WTP ☐ Road/Trail ☐ Timber ☐ _______	☐ None ☐ Salvage ☐ Feather ☐ Top/prune ☐ Revise Boundary ____________________ ☐ ________________

Segment/ Stratum	Exposure Hazard	Soil Hazard	Stand Hazard	Treatment Risk	Windthrow Risk	Expected Damage	Management Issues	Recommended Action
	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H	☐ N ☐ L ☐ M ☐ H ☐ VH	☐ None ☐ <10% 1 TL ☐ 10–70% 1 TL ☐ > 70% 1 TL ☐ > 70% 2 TL	☐ RMA ☐ Visual ☐ Terrain ☐ Gully ☐ Structure ☐ WTP ☐ Road/Trail ☐ Timber ☐ _______	☐ None ☐ Salvage ☐ Feather ☐ Top/prune ☐ Revise Boundary ____________________ ☐ ________________

Comments:

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Figure 3.5.8

Considerations for Silvicultural Systems

There are four silvicultural systems considerations to reduce windthrow risk:

→ **See** Navratil (1995) for more information on wind damage and silvicultural systems.

1. *Choose narrow strips or group openings rather than uniform removal as a harvesting pattern*

Uniform leave-trees no longer have the damping effect of neighbouring tree crowns to reduce their crown sway. Opting for small groups or strips leaves much of the stand in an unharvested condition with mutual protection between trees intact. Exposed edges of openings or strips can be a problem, but this will depend on the location of the edges and the width of the strips or openings in the direction of the prevailing winds.

As the wind profile travels over a canopy it drops into large openings and may travel along the ground surface at similar speeds as above the canopy. When it encounters the exposed unharvested edge, the wind is forced up and over the edge, increasing in speed. This increased speed increases the windloading on the trees near the edge and may contribute to windthrow. Narrow openings, less than five tree lengths in width, reduce the penetration of the wind profile into the stand and the subsequent windloading on the exposed edges.

As opening and strip width are reduced to two tree lengths or less in width, windloading on exposed edges can be substantially reduced.

Increase group size to decrease edge-to-area ratio. This will mean fewer, larger groups and planning of group shape must consider wind direction.

→ **See** Novak et al. (1997) for more information on the impact of opening size on wind speeds.

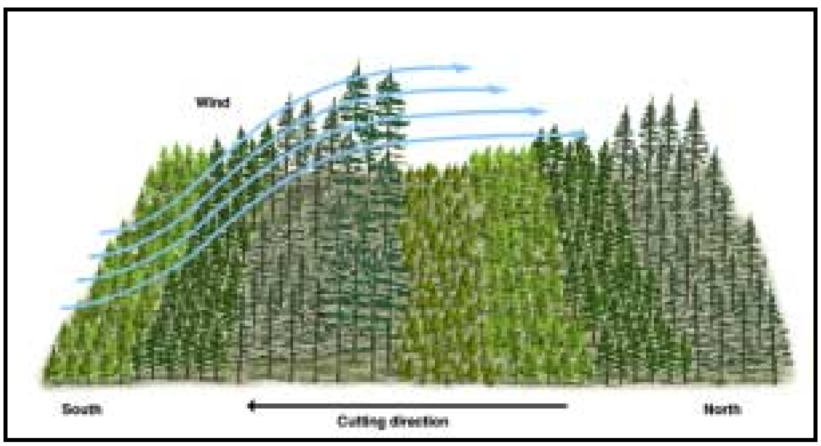

Figure 3.5-9

2. *Consider lighter, more frequent entries where group and strip systems are used*

Where group or strip systems are chosen, the re-entry periods and pattern of subsequent entries will be critical in prolonging the wind resistance of the stand. Group and strip selection will provide longer intervals between re-entry and may allow more time for exposed edge trees to expand crowns and improve taper, rooting, and windfirmness. The use of repeated entries allows vigorous trees to change allocation of resources from foliage and stem to the roots as they respond to increased movement from exposure to more wind. Each stand will have to be assessed individually to make this decision and the system chosen must meet other management objectives. Several variations of strip selection were originally designed in Europe to help deal with windthrow problems.

→ **See** Section 2.1 for more information on group and strip silvicultural systems.

3. Reduce removal levels in uniform retention systems

Where windthrow is a concern, shelterwoods or other systems with uniform leave-trees may require lower initial removal levels and more entries to gradually create appropriate conditions for regeneration. Restricting initial basal area removal levels to 30% or less can substantially reduce windthrow risk in uniform stands, since leave-trees are denser and offer greater crown damping. Silvicultural systems that include light harvesting with enough time between entries to allow leave-trees to expand crowns and increase taper can reduce losses to windthrow. Remember, however, that quality of leave-trees rather than quantity may be more important (see following point).

4. Choose leave-trees with windfirm characteristics

Where uniform retention is planned in a heterogeneous stand, choosing individuals that exhibit more windfirmness will greatly increase the windfirmness of the stand. Generally, large, mature dominant trees that have most of their crown above the stand canopy will have lower height-to-diameter ratio and more wind resistance. Since these trees likely developed while exposed to the wind, they are more windfirm than other crown classes when neighbouring trees are harvested.

Question: *Aren't larger trees more susceptible to windthrow in some situations?*

In some cases where root anchorage is severely restricted, such as sites with a high water table, larger dominants may become more susceptible to wind as they reach their critical height for windthrow.

Because wind force acts on a root system as a lever, trees with longer stems and larger crowns exert a greater turning moment or torque on their respective root systems. Every tree, therefore, has a critical height at which endemic winds are certain to force its root system out of the ground. However, in most instances on well-drained, deep soils, larger dominant trees can never reach the height required because of the resisting forces offered by deeply spreading root systems and strong, tapered stems. These trees maximize their height growth based on site growth potential and blow over only when subjected to catastrophic winds or a range of other damaging agents.

When root anchorage is severely restricted and stand densities are high, dominant trees may grow to a height that will induce the force required to uproot the restricted root system. In Britain researchers have been able to determine this height for various sites and management regimes and use height, rather than age, to determine rotation length on sites with a high windthrow risk.

In previously unmanaged stands in BC, we may find clues during the pre-harvest stand reconnaissance indicating where larger dominant trees are most susceptible to windthrow if:

- a significant number of the largest dominant trees have already been windthrown, and
- field examination indicates the cause to be a severely restricted root system (rather than root disease, butt rot, or other defects).

In this situation, dominant trees should not be favoured as leave-trees unless their height or crown area is reduced through crown modification treatments (see “Crown Modifications”).

Considerations for Windfirming Treatments on Stand Edges

Where stand edges must be exposed and windthrow impacts are a concern, several windfirming treatments can be used.

Edge Feathering

Feathering an edge opens up the windward edge and reduces the speed-up of the wind profile at that point. Feathering is generally a good option on edges with a windthrow risk of moderate or less. High-risk edges may be destabilized with feathering treatments, unless they are combined with crown modifications (see below).

Several options for feathering exist

Edge-profiling – In multi-storied stands, where smaller, windfirm trees can be left, removal of taller trees at the stand edge may help create a profile that gradually lifts the wind up and over the edge.

Edge-thinning – In uniform even-aged stands, the edge can be thinned by removing fewer windfirm trees, which are expected to blowdown. These trees are usually the less windfirm species and smaller codominants/intermediates that have lower live-crown ratios and higher height-to-diameter ratios.

Typically, feathering is best if confined to the first tree length into the stand from the edge. Removal levels within this zone should not exceed 30% of the total stand basal area. To be most successful at feathering it is best to observe which trees survive wind events on similar edges and retain these in subsequent feathering treatments. Partial salvage to retain naturally feathered edges.

Crown Modifications

Wind creates forces on tree root systems like a lever. If the force on the crown can be reduced, or lowered closer to the ground, the ultimate torque on the roots is reduced. While crown modifications are expensive, stumpage appraisal cost allowances are now available for such treatments in coastal BC. Still, crown modifications should be reserved for edges where management objectives are threatened and no other options exist.

Crown modification treatments include several approaches

Topping – Crowns are topped to remove the top one-third of the crown. This is usually accomplished with tree climbers at $30–100 per tree.

Top pruning – Branches on the top one-third of the tree are removed. Several helicopter-lifted mechanical devices can top prune for $30–50 per tree.

Tree-crown thinning – Tree climbers have been used to climb and thin individual crowns uniformly by 30–40% in riparian leave strips for costs of $14–30 per lineal metre when the strip is 10–15 m wide. These crews are certified in safe climbing procedures and use climbing ropes to transfer directly from crown to crown.

Crown modifications combined with feathering – High risk retention strips or patches may be feathered to remove the highly susceptible smaller trees, and the larger trees will receive a crown modification treatment as previously described.

→ **See** Kosicki et al. (1997) for more information on crown modification equipment and techniques.

Regeneration and Stand Tending Treatments

Most windfirming treatments focus on current harvested areas. However, in areas where management objectives may require partial cutting silvicultural systems, and windthrow is a concern, the regrowth and tending of the new stand should also be carefully considered. Species that are generally more windfirm should be preferred and/or stand tending treatments should be used to create a stand structure through the rotation that is suitably windfirm to fit with the silvicultural systems option.

The British stress the importance of site preparation and planting techniques to ensure that root systems have a balanced, strong architecture. Large well-spaced dominant trees can be produced through a combination of regeneration and stand tending treatments over time. Alternately, windfirm clumps or strips of trees can be created through carefully planned regeneration treatments and silvicultural systems that develop windfirm edges.

Results of the Windthrow Risk Assessment in the Prescription

Windthrow risk assessments for silviculture prescriptions must be completed to properly determine the risks associated with proposed silvicultural systems. The most practical time to complete such assessments is at the SP data collection stage. The detailed results of this assessment should be kept on the opening file to assist monitoring. The results should be addressed in planning and implementing a harvest.

If the windthrow risk assessment indicates a significant potential impact from the partial cutting prescription, this must be recognized and prescriptive measures should be included in the SP to ensure that impacts can be minimized.

Information to Be Included in the Silviculture Prescription

The prescription should identify measures to reduce windthrow risk where significant risk (and impacts) are identified.

Actions to reduce significant windthrow risk and associated impacts:
SU 2 and 3 will be clearcut to avoid extensive blowdown and difficult salvage in a moist-wet area (with the potential to cause excessive soil disturbance). The deciduous reserve trees may blow down eventually but will contribute to large woody debris that will become a rooting medium eventually for naturals. **SU 1 and 4** and the south end of the WTP—little salvaging is expected (risk is low). However, the stratum will be monitored and salvaged if required. RMZ in NE corner—extend the RMZ to 40 m in width and harvest most timber >25 cm dbh. In this moist-wet area, it is expected that the larger trees on such an exposed boundary would be most susceptible to windthrow. Harvesting in the RMZ is intended to remove these susceptible stems while buffering the impact of wind on the RRZ by profiling the edge and feathering to disperse wind loading. In front of the RMZ we will retain and protect as much non-merchantable Bl and Sx as possible to further enhance the profiling effect of the feathering in the RMZ.

Additional Information Suggested for Your Block File

Information from the windthrow risk assessment should not be lost, but remain on file for future reference.

Portion of SU	Biophysical hazard[a]	Treatment risk[b]	Windthrow risk[c]	Impacts
Southern edges of retained groups in SU 1	Moderate	Moderate	Low	Expect up to 5% of leave-trees to blow down
Dispersed dom. Cw in western and southern section of SU 1	Moderate–Low	Moderate	Moderate–Low	Expect 1–2% blowdown
Edge of NE corner (RRZ)	Moderate–High	High	High	Expect 70–90% blowdown in the extra buffer left next to the RRZ. The buffer will help prevent blowdown in the RRZ, maintaining gully and streambank stability, water quality, and habitat values.
South edges of retained groups in SU 2	Moderate	High	Moderate	Expect 30–40% blowdown up to one tree length into the groups. This level of blowdown is considered acceptable for maintaining the structural attributes left in the groups.
Comments				
• In SU 1, the windthrow risk and associated impacts assume that the dominant redcedar will be favoured where dispersed trees are required. Where no dominants exist, the tallest codominants will be chosen. In these well-drained soil types the larger, more dominant trees will be the most windfirm. If smaller leave-trees, especially Hw or Ba, are chosen, losses could be higher. Scattered past blowdown was noted in SU 2 and SU 3, indicating a greater susceptibility to wind than in SU 1. This is especially true for Hw that have established on mounds of organic matter with little soil shear strength.				

[a] **Biophysical hazard** – is the intrinsic stability of the stand in its pre-treatment condition.
[b] **Treatment risk** – is the way in which the prescribed treatment for harvesting and leave-trees will increase windloading on residual leave or edge trees.
[c] **Windthrow risk** – is the likelihood of damage from endemic peak winds. Endemic winds are strong winds that occur on a yearly cycle. Windthrow risk is a function of both biophysical hazard and treatment risk.

Additional Reading

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Section 3.6 Stocking Standards for the Range of Silvicultural Systems

Figure 3.6-1

The Province of British Columbia, or any landowner, needs standards to ensure levels of growing stock meet expectations to sustain yield over the long term. Partial cutting silvicultural systems introduce a level of complexity into stocking that must be carefully considered when setting standards in prescriptions.

This section will help a prescriber decide on the types of stocking standards to use in a prescription for any harvesting entry in a complex silvicultural system. The full range of approaches are presented for the various types of harvesting entries and stand structures.

In this section we will…

- Investigate the application of multi-storied stocking standards, beyond just single tree selection.
- Examine multi-storied standards for uneven-aged management including diameter distribution tables.
- Examine the requirements and rationale for standards that apply to intermediate harvests with no regeneration objectives.

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Stocking Standards: The Range of Approaches for Different Entries in Partial Cutting Silvicultural Systems

Stocking standards are well established for even-aged stands managed with clearcut systems. When partial cutting silvicultural systems are used that create stands with a significant portion of stocking in larger trees, different standards must be used. Generally, the following range of approaches is available.

Classic Even-aged Stocking Standards

- For stands that will be managed with small cleared openings or strips, such as group or strip shelterwoods or selection, and patch cuts.
- For stands that will be very open once regeneration is established and removal cuts are complete. Larger leave-trees are rare in these stands. Silvicultural systems used may include classic seed tree and shelterwood systems.

When applying classic even-aged stocking standards in group or strip selection, the challenge will be in stratification and survey design.

Even-aged Standards | **Multi-storied Standards** | **Standards for Intermediate Harvests**

Figure 3.6-2

Multi-storied Stocking Standards

- For stands that will be managed through time with a significant portion of the growing space always occupied by uniformly dispersed larger trees. These systems may include single tree selection, irregular shelterwoods, natural shelterwoods with larger trees in the understorey, or any system with a significant density of dispersed reserves or retention.

Standards for Intermediate Harvests with No Regeneration Objectives

- For commercial thinning, harvesting of poles, sanitation cutting, and improvement cutting where sufficient stocking is still retained to constitute a reasonably stocked stand and there is no intention of procuring regeneration.

Use of Multi-storied Stocking Standards

Issue: *Can multi-storied stocking standards be used for silvicultural systems other than single tree selection systems?*

The regional *Establishment to Free Growing Guidebooks* were updated for all forest regions in 2000 (http://www.for.gov.bc.ca/tasb/legsregs/fpc/FPCGUIDE/Guidetoc.htm). There is information for *Uneven-aged Stocking Standards – Single Tree Selection Only*. These standards can in fact be used as multi-storied stocking standards and applied to regenerated stands with the following characteristics.

- More than 6% crown closure in silviculture layer 1[1] and layer 2 trees combined, and
- A minimum of three layers present OR one of the following combinations:
  - Layer 1 and 4
  - Layer 2 and 4
  - Layer 1 and 3.

→ **See** the *Silviculture Surveys Guidebook* (1995) for information on multi-storied surveys in such stands.

Larger trees occupy more growing space than smaller trees, especially when they have large crowns. Stocking standards must allow for systems that include larger trees to avoid unnecessary and wasteful planting in understorey positions where additional stocking can never attain acceptable growth or vigour.

The silvicultural systems that create stands that require multi-storied stocking standards include:

- single tree selection
- irregular shelterwoods
- natural shelterwoods with larger layer 1 and 2 trees in the understorey
- any silvicultural system (even-aged or uneven-aged) with a significant density of dispersed reserves or retention to produce a stand as described previously.

The Establishment to Free Growing Guidebooks were developed when the use of partial cutting silvicultural systems was rapidly evolving in BC and the application of multi-storied stocking standards not fully understood. Any silvicultural system that establishes a new stand with a significant inclusion of larger layer 1 and 2 trees will require stocking standards that allow more growing space for those larger trees. Use the “Uneven-aged Stocking Standards” in the regional *Establishment to Free Growing Guidebooks* to help develop such standards.

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[1] Layer 1 = Mature layer (≥12.5 cm dbh), Layer 2 = Pole layer (7.5 cm to 12.5 cm dbh), Layer 3 = Sapling layer (1.3 m in height to 7.5 cm dbh), and Layer 4 = Regeneration layer (<1.3 m in height).

Question: *Why are multi-storied stocking standards and a target diameter distribution for single tree selection stands necessary?*

The target diameter distribution is a regulatory goal that is used for general guidance in marking and management, along with the q-quotient, the residual basal area goal, and the maximum diameter. These regulatory goals assist in creating a structure that yields an even flow over regular cutting cycles. In this regard these goals benefit the manager and the licensee.

→ **See** Part 4 for more information on regulation for single tree selection systems.

The multi-storied stocking standards ensure the Ministry of Forests that the stand is suitably stocked and free growing after the prescribed time periods. In this regard they become the legislated obligations for the licensee and are for the benefit of the Crown.

Stocking Standards for Intermediate Harvests with No Regeneration Objectives

For any intermediate harvest where there is no intention for establishing regeneration, standards will be needed to ensure that a sufficiently stocked stand remains. These intermediate harvests may include:

- commercial thinning
- harvesting of poles
- sanitation cutting
- improvement cutting.

For such intermediate harvesting entries the following stocking information is required in the prescription:

- the preferred and acceptable species of trees
- the stand structure and composition goals, including the planned residual basal area or density per hectare
- the species and function of any trees that will be left standing to satisfy non-timber resource objectives.

A survey to confirm the stocking information in the prescription will be completed in such stands no earlier than 12 months after harvest.

These "stocking requirements" are to ensure that an acceptably stocked stand still exists with no requirement to fill stocking gaps. A period of one year allows for potential windthrow and snow-breakage losses that could result from excessive thinning or poor leave-tree choices. These standards should appear in the prescription in a similar manner to the leave-tree characteristics described in the silvicultural system section.

General

A great range of potential stocking descriptions follow harvest, due to the great range of possible removal. Describing reforestation for clearcutting is routine. As components of a stand are not harvested and contribute to the post-harvest stand structure and condition, the standards are increasingly complex to describe and measure. When setting standards for stocking, when vertical structure is to be uniformly distributed, a general approach to take is to account for trees from the largest to the smallest. Describe the layer 1 trees, then layer 2, then layer 3, and finally layer 4. It is futile to prescribe a full regeneration layer if one knows that there will be lots of overtopping trees. However, it is necessary to have such a description for openings that "happen" in an area that is mostly having large trees left with uniform distribution. One must ensure that the standards can be adequately measured with a survey.

→ **See** Section 3.4 for more information on describing leave-trees for partial cutting.

Additional Reading

British Columbia Ministry of Forests. 1995. Silviculture surveys guidebook. For. Prac. Br., Victoria, BC. Forest Practices Code of British Columbia Guidebook.

British Columbia Ministry of Forests. Multi-storied surveys course workbook. For. Prac. Br., Victoria, BC.

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Section 3.7 Maps for Partial Cutting Prescriptions and Plans

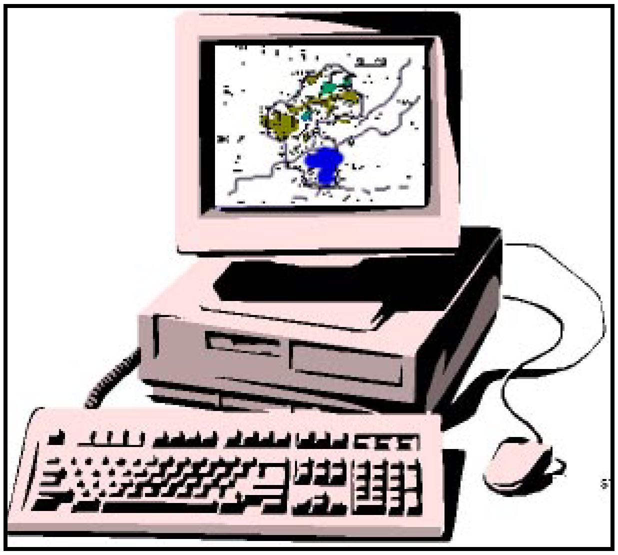

Figure 3.7-1

As with everything else regarding partial cutting silvicultural systems, mapping requirements are more complex than those for clearcutting. However, the approach or principles behind mapping are similar.

This section does not reiterate the general requirements for site plan maps. Rather this section highlights those criteria that are especially critical to partial cutting systems and answers common questions regarding mapping requirements for such systems.

In this section we will…

- Review the general approach that should be used to map partial cutting silvicultural systems.
- Examine the specific mapping requirements for harvesting or logging plans.
- Determine if specific silvicultural systems require specific mapping critieria.

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An Approach to Maps for Partial Cutting Silvicultural Systems

A map graphically represents key planning units and considerations. Its value is in providing clarity for the prescription by illustrating where activities will occur, the size of different treatments, and the context for all activities. A map for a partial cutting silvicultural system should use the same approach as for clearcutting—all information vital to ensuring the success of the prescription should be on maps at some point.

In addition to the elements required by legislation, the prescription map should give enough information so it is clear where activities and standards will apply.

It is necessary to guide loggers and others involved in the harvesting of the block. The prescription map should become the basis for the logging plan, which will also include harvesting details for the block, even though a logging plan is not a legal requirement. This ensures that harvesting will be completed in accordance with the prescription.

General Mapping Requirements for Harvesting Plans

During harvesting operations, logging plan maps are the key operational linkage to the management objectives and the success of the prescription. To ensure complete success, they must be combined with close on-site communication with the logging crew.

→ **See** Section 5.2 for more information on communication with logging crews.

Some suggested information that should be included in a thorough logging plan map include:

- The location of all harvesting boundaries. The boundaries of adjacent blocks and roads (actual or proposed) should also be included.
- Landing and designated trail locations, and other associated access structures.
- Corridor locations, shapes, and widths for yarding.
- Location of backspar, tailholds, and mid-span spar trees or potential trees (if the final decision is to be left up to the logging crew).
- Location of wildlife tree patches, riparian management areas, culturally modified trees, associated management reserves, and other sensitive areas. Directions to, or procedures for, finding special archeological sites, or culturally modified trees or other sensitive areas may be included in the margins of, or on the back of, the map.
- Location of dangerous trees previously noted on the ground.
- When dispersed leave-trees are being left, leave-tree characteristics included in the prescription can be provided as text in the margin on the map or on the back of the map. The approach for leave-tree selection should be clarified if the choice is left up to the faller. If the stand is previously marked, a description of the marking approach should be included.

→ **See** Section 3.4 for more information on leave-tree characteristics.

- All special harvesting requirements should be indicated on the map when a location is required. Otherwise, these requirements can be included in the margin or on the back of the map. These requirements may include:
  - seasonal considerations and ground-based shutdown criteria
  - general machine travel restrictions within the block
  - leave-tree damage standards
  - soil disturbance standards and specific concerns
  - special equipment requirements (e.g., protective devices for rub trees, or special protective collars for spar trees)
  - special road or trail construction and maintenance requirements
  - salvage and debris management information
  - direction for utilization of trees felled outside of the harvesting area (dangerous trees).

Question: *Should maps for systems with uniform (dispersed) leave-trees have any special requirements?*

Generally these areas will not have any special requirements apart from those previously mentioned. Areas with different silvicultural systems, retention levels, retention patterns, or criteria for leave-trees should be indicated on the site plan map. Where skid trails will be reused, they should be indicated on the map. Where individual leave-trees have unique or special characteristics, they may also have a special mark and be indicated on the map.

Question: *Should maps for systems with group reserves or retention have any special requirements?*

Where reserves are left in groups, show the location and size of those groups on the map so they can be adequately tracked over time. Any special requirements for logging in and around the groups should be indicated. Where groups are numerous and small, several approaches may be used:

GPS and estimate of length and width – During layout, use GPS to establish a location coordinate for a corner of the group. A cardinal coordinate (N, S, E, W) may be useful for simplicity. It is best to always use the same corner for consistency. Next, the length and width of the group is estimated or measured in metres. This information will be used as a rough estimate in the SP. It will allow for rough mapping of the groups in the office.

Airphotos – Where some groups are located such that they are easily discernible from air photos or maps, such as a dry rocky knoll, a more accurate area determination may be extracted directly from the photo or map.

Estimate only – If the two previous approaches cannot be used, it may be acceptable to estimate the size and shape of each group laid out on the ground. These estimates should be relatively accurate if you know the length and widths of retention patches. Rough mapping will be possible by tying into known coordinates from deflection or cruise lines.

Short-term deferred areas (may be harvested within the rotation) should be differentiated from reserves (retained for the entire rotation).

Question: *Should maps for systems with group or strip openings have any special requirements?*

Group and strip system (selection and shelterwoods) must show all openings or strips in the current harvesting entry on the maps for the prescription and logging. It is not necessary to show all openings for all passes on the map, especially when such a mapping exercise may involve hundreds of openings over three to five passes.

While it may be helpful to know where the future passes will occur sometimes for windthrow and other considerations, it will often be time consuming and the results will be fairly meaningless. This is because future entries may depend on salvage priorities and shifting management priorities. A conceptual map of the progression of passes may be useful, especially in strip shelterwoods and selection. Such a conceptual map should be included in the description of the silvicultural system. On the prescription and harvesting map it is usually best to show only the openings for the current harvesting, unless future passes are planned within the effective time frame of the current prescription.

→ **See** Section 3.4 for more information on conceptual maps.

Additional Reading

British Columbia Ministry of Forests. 2000. Silviculture prescription guidebook. Victoria, BC. Forest Practices Code of British Columbia Guidebook.

British Columbia Ministry of Forests. 1998. Planning and harvest layout for partial cutting workshop (participants workbook). http://www.for.gov.bc.ca/pscripts/hfd/efp/abstract.asp?doc=15&cat=3

Rutherford, D., A. Howard, K. Zielke, and B. Bancroft. 1999. Engineering for partial cutting silvicultural systems workshop – participant’s workbook. BC Min. For., For. Prac. Br., Victoria, BC.

PART 4: REGULATION FOR SINGLE TREE SELECTION

Uneven-aged management with single tree selection is a complex silvicultural system. For this reason, a separate part of this handbook is devoted to clarifying this silvicultural system.

Figure 4.1-1

Regulation for single tree selection differs from even-aged regulation in that it must address structural variability at the stand level.

Single tree selection can be looked at as a balancing act, at the stand level, between managing adequate space for new regeneration to establish and grow and the retention of sufficient growing stock to capture the productive capacity of the site.

An historical note…

> The history of single tree selection can be traced to the late 1800s and early 1900s. In the late 1880s, Henry Biolley, a follower of the French forester Adolphe Gurnand, formalized the management of the selection forest through an original system of silviculture and production principles in the forests of Swiss Jura region (Schütz 1997). As an indication of the difficulties of implementing this system, a recent Swiss inventory indicated only 8% of the forest area in Switzerland has fully irregular permanent structures. This fact attests to the challenge of creating the necessary prerequisite conditions for the system to function, specifically management of a stand

that "creates sufficient irregularity as well as a continuous recruitment from below" (Schütz 1997).

In 1898, the French forester de Liocourt observed the inverse J-shaped distribution for stems/ha by diameter class in uneven-aged stands (Fiedler 1995). To the present day, North American foresters have used the concept of the inverse-J distribution to help with uneven-aged regulation. The contemporary approach of managing to an inverse-J distribution drawing from work done in the United States over the past 20 to 30 years is discussed. Other regulatory approaches for consideration are also introduced.

In this section we will…

- Review the basic conceptual framework used for single tree selection regulation, specifically BDq.
- Present advantages and disadvantages of BDq.
- Provide implementation tips from a field practitioner.
- Comment on uneven-aged regulation and alternative approaches.

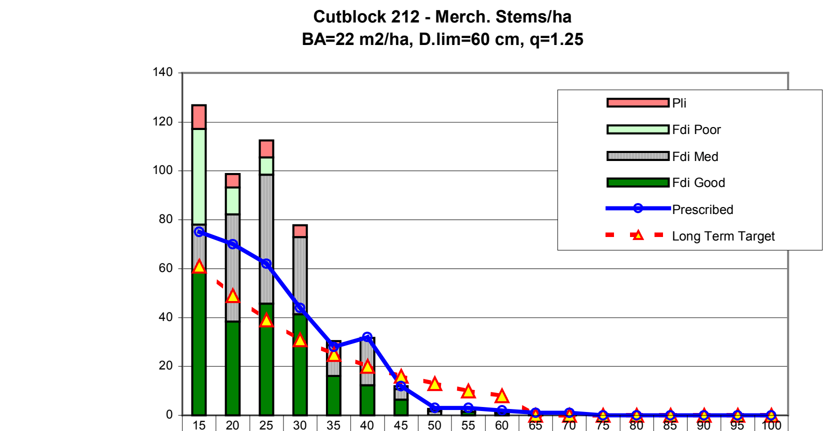
Table of Contents

Section 4.1 Introduction

Single tree selection provides continual forest cover at the stand level. The traditional North American approach for regulation of growing stock in uneven-aged stands has relied on a target diameter distribution described using the elements "BDq" (Daniel et al. 1979; Guldin 1991; Fiedler 1995). In this section the elements of BDq and how it can be used to regulate uneven-aged stands in BC are described.

Numerous authors have indicated the limitations of using the BDq approach (e.g., Smith 1986; Long 1995; O'Hara 1995). Limitations include the inability to manage inherent structural diversity at the stand level while accounting for timber flow regulation at the forest level. While there is a need to look further at those objectives, presently the use of BDq, with caveats, appears to be the most workable solution for managing uneven-aged stand structure in BC. Experimentation with other regulatory approaches should be explored. In the interim an understanding of BDq should help practitioners set realistic harvesting prescriptions for single tree selection at the stand level. Alternative methods of uneven-aged regulation are also introduced and references for additional reading and experimentation are provided.

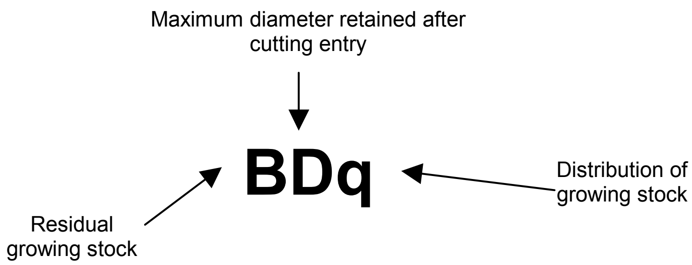
Section 4.2 Some Thoughts on the Application of BDq



	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Pli	10	5	7	5	2													
Fdi Poor	39	11	7				1	1										
Fdi Med	20	44	53	32	13	19	4	2	1	1		0						
Fdi Good	59	38	46	41	16	12	7	0	1	1	1	0	0	0	0	0	0	0
Prescribed	75	70	62	44	28	32	12	3	3	2	1	1						
Long Term Target	61	49	39	31	25	20	16	13	10	8	0	0						

Figure 4.2-1
(Provided by K. Day, UBC Alex Fraser Research Forest, May 2000)

BDq are three parameters that are used to create an inverse-J shaped diameter distribution. These parameters describe uneven-aged structure where more stems are found in the smaller diameter classes than in the larger classes. The implication is that, over time, smaller stems will grow and some will die, leaving fewer larger stems.



The terms BDq refer to the residual growing stock (B in basal area), the maximum diameter class retained after a cutting cycle (D in dbh), and the distribution of the growing stock among the various diameter classes (q) (Long 1995). The purpose of BDq is to set a target diameter distribution for the stand, from which to plan harvest strategies. The BDq approach, if strictly followed, would result in a "balanced uneven-aged" condition where equal space is allocated to each diameter class (Smith 1986). This balanced condition is set up to provide a sustained yield from each stand unit. In practice, a range of small openings are created with variations in area by diameter class.

This condition is one that can be approached but is almost never attained in practice; even approximations of the condition are difficult to maintain. In fact, single-minded efforts to mold stands into sustained-yield units often produce results that are illogical in the light of other considerations (Smith et al. 1997).

In BC, generally we do not have administrative units, outside of small private landholdings, that are set up to track or determine cutting or reservation of particular diameter classes at the forest level. Therefore, to approximate sustained yield at the forest level, a balanced or near balanced approach is recommended on a stand-by-stand basis in BC. Numerous other authors (Alexander and Edminster 1977; Marquis 1978; Fiedler et al. 1988; Guldin 1991; Becker 1995; and others) promote the balanced approach if used with an understanding of its limitations.

The following sections will discuss BDq and how to use it, then it will cover some of its limitations and ways to work with it.

Section 4.3 B of BDq—the Residual Basal Area (RBA or B)

The residual density is described as the residual basal area (RBA) that is to be left after harvest. It is measured in square metres per hectare (m^2/ha). Since the options range from what is found on site to total removal of the overstorey, guidance is required on what level to choose.

Figure 4.3-1
How to choose what to leave—is this enough or not?

General Considerations for Setting RBA in Your Stand

To create or maintain an uneven-aged structure, two opposing objectives need to be considered when choosing the RBA:

1. To maintain the RBA low enough to allow for regeneration and early growth of the new age class. A common error of past prescriptions was leaving too much basal area, resulting in regeneration left in a state of "suspended animation" or seriously reduced growth.
2. To retain sufficient trees on site to capture the full growth potential for the site. Taking too much creates holes in the stand, resulting in reduced volume production.

The Concept of B-level Stocking

A good initial guess of RBA can be drawn from even-aged thinning or shelterwood experience (or assessing your stand for small openings where regeneration is surviving but not growing really well).

> *A reasonable value to choose is the basal area that, if uniformly distributed, provides ecological conditions that would barely suppress regeneration establishment and growth. After harvest your stand will have a scattered distribution with gaps that will provide conditions suited to regeneration.* (Guldin 1991, p. 28).

Figure 4.3-2
Carefully controlled BA to promote growth in both overstorey and regeneration layers.

This value is often referred to as B-level stocking. Unfortunately, if it is set too high, regeneration establishment and growth are compromised. In some cases, carrying too much stocking results in poor vigour stems with greater susceptibility to insect and disease attack (Day 1997b). Additionally, closely grown trees with a high height-to-diameter ratio are at an increased risk to breakage due to snow and wind (Herman and Lavender 1990). If the RBA is set too low, stand growth will be reduced along with possible reductions in wood quality, thus losing potential volume and/or value and increasing the time between merchantable harvests.

Some Suggested RBAs

- 18.4 m^2/ha (80 ft^2/acre) for 25 cm and greater stands is suggested for central and southern Rocky Mountain spruce types (Alexander 1974; Myers 1974).
- Guldin (1991) chose approximately 41 m^2/ha (180 ft^2/acre) for a highly productive Sierra mixed conifer stand.
- Site potential will strongly affect the value chosen. Fiedler et al. (1988) suggest values ranging from 8 to 16 m^2/ha to meet site occupancy and regeneration objectives for single tree selection for dry interior forests in Montana (see table below).

Forest type	RBA (m^2/ha)	RBA (ft^2/acre)
Ponderosa pine	8	35
Dry Douglas-fir	8–10.3	35–45
Moist Douglas-fir	11.5–16	50–70
Grand fir	11.5 +	50–??

- Day (1997a), using radial increment data from 794 trees, calculated 17.5 m^2/ha as the B level for a Douglas-fir stand in the Interior Douglas-fir Dry Cool subzone in the Cariboo Forest Region.

Another tool that has been used to show B-level stocking is a Gingrich stocking chart. It relates basal area (y axis) with trees/ha (x axis) for trees of different diameter. A full stocking line (A) and a (B) level line are given. The B-level stocking is lower for smaller stems than for larger stems.

Using a Gingrich Chart to Determine B-level Stocking

What Are Gingrich Charts?[1]

The stocking charts Gingrich created are based on the premise that growing space is the dominant factor controlling the growth rate of an individual tree. There is a wide range of stand density (basal area [BA]/ha, stems/ha, or volume/ha) in which stand growth is at its maximum. Day (1997b) summarizes the differences between stocking and density. Density is a quantitative measure of site occupation such as BA/ha, stems/ha, or an expression of the number of trees and their size, such as stand density indices. Stocking, on the other hand, is a relative term that describes the adequacy of a given stand density in meeting management objectives.

The Gingrich charts guide stocking for timber production. The charts take into account growth requirements over a range of stand sizes. For example, a stand with a density of 25 m^2/ha of BA/ha may be classed as under- or overstocked for maximum timber production depending upon the size of the trees on site. It turns out the quadratic mean diameter (the diameter of tree of average basal area) of the stand affects stocking.

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1 Adapted from Ginrich [sic] (1967). Note that Ginrich is the incorrect spelling of his name used in his 1967 publication; all other references will use the correct spelling of his name.

Calculating QMD or Dq?

- $$Dq = \sqrt{\frac{\sum_{i=1}^{N} d_i^2}{N}}$$
- Dq is the quadratic mean diameter (qmd).
- $\sum_{i=1}^{N} d_i^2$ is the sum of all the measured diameters (dbh) **squared** (from a range of sample plots in the stratum).
- N = number of trees sampled to get the diameters—divide the sum of the squared diameters by N and then take the square root of it all to obtain the Dq.

For full stocking, a stand can carry more basal area with larger diameter stems than with smaller stems. Therefore, a stand of 25 m^2/ha of BA/ha may be stocked with an average stand diameter of 15 cm and be understocked if the average stand diameter is 40 cm.

Question: *Why does average diameter make a difference to desired stocking (RBA)?*

Doubling the diameter of a tree increases the basal area of that tree by four times but only increases the space the tree needs for full growth potential by about three times (Gingrich 1967). Therefore, as the stand quadratic mean diameter increases, the basal area of a stand must also increase to maintain the same level of stocking (e.g., from the chart below, Dq of 12 cm for the upper stocking limit before stem exclusion mortality is 20 m^2/ha compared with 30 m^2/ha for a Dq of 26 cm). The same trend holds for the lower stocking limit (B-level stocking).

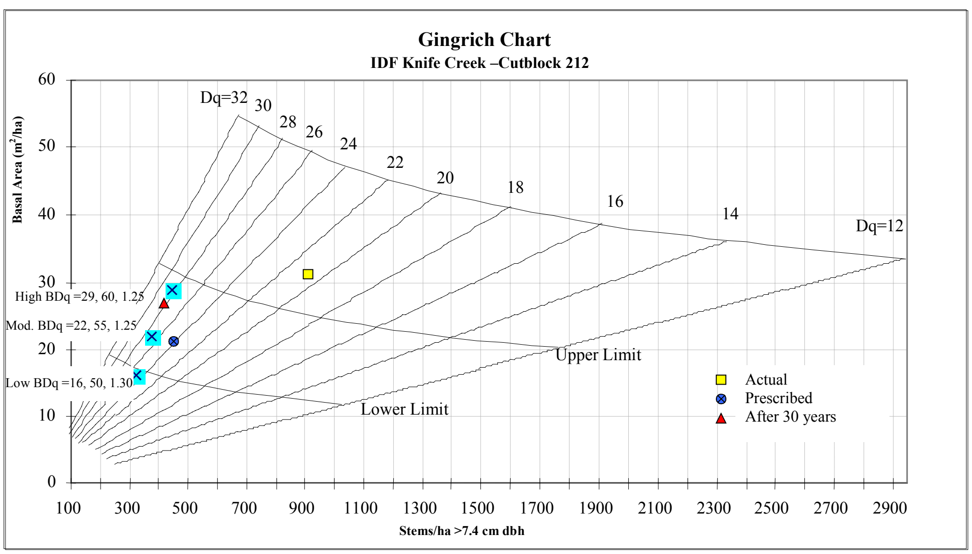

Figure 4.3-3
Example Gingrich chart from an IDF block in Knife Creek near Williams Lake (provided by Ken Day, UBC Research Forest, May 2000).

Balancing Use of Growing Space with Openings for Regeneration

As shown, a range of stem densities (and sizes) can capture site productivity. A range of stem densities maximizes this growth. If the stand goes below that density, growth potential is lost to open growing space; if the stand goes above it, the individual trees do not have sufficient growing space to reach their potential.

Figure 4.3-4
Open conditions are required for light-demanding species such as Py under Fd.

Gingrich came up with two formulas to address this issue: the first expresses the space taken by trees at a density that maximizes the growth and minimizes the individual space taken by each tree (dense conditions). The second determines the maximum amount of area a tree uses when open grown—he found the maximum area was independent of site quality or age. On good sites the trees took up the same space—they just grew faster and ended up larger.

Gingrich then calculated the ratio between the results of the two formulae and found that minimum stocking for full utilization of growing space was between 57 and 59% of the stocking for fully stocked stands. He found this relationship worked best with normally distributed even-aged stands, but was within 5% accuracy for uneven-aged stands.

The quadratic mean diameter of the stand is a useful stand parameter. Doubling the diameter increases the BA by a factor of four and the tree area requirement increases by about three. Hence the stocking charts must be sensitive to stems/ha, BA, and quadratic mean diameter. As quadratic mean diameter increases, fewer stems and more basal area are required to achieve B-level stocking—that point where you have the fewest number of stems (or BA) utilizing the site space to the maximum.

> **A rule of thumb…**
>
> *To take your stand down to the B-level stocking, remove approximately 40% of the BA of what is found on uncut mature sites. This level is set to maintain stand growth and promote regeneration, assuming the natural clumpiness will allow for space for adequate regeneration.*

So this is what B-level stocking means. Going below it, *which might be necessary to get good regeneration growth*, stand growing potential may be sacrificed. By remaining above it, the stand will maximize growth (and potentially restrict regeneration potential).

Question: *How is basal area measured?*

Basal area can be measured using prisms. Prisms come in a range of basal area factors (BAFs) from 1 to 15+ (metric). The surveyor establishes plot centre points throughout the area of interest. At each point, the surveyor sweeps the prism a full 360 degrees around the centre point to determine whether a tree is “in” or “out.” The total number of “in” trees divided by the number of plots times the basal area factor of the prism gives an estimate of the basal area per hectare of the stand.

→ **See** Section 3.3 for more information on data collection.

Density (stems/ha) from prism sweeps

To convert “in” trees from prism sweeps to stems/ha, the stems/ha conversion factor is used (where “d” is the diameter midpoint):

$$\text{Stems/ha conversion factor} = \frac{1}{0.001(d/2)2 \times \pi}$$

Using the following table, with the conversion factor already calculated for the respective diameter midpoints, stems/ha can be obtained from a prism sweep by simple multiplication:

$$\text{Stems/ha} = a \times b \times c$$

Where:

a = the stems/ha conversion factor for the diameter class

b = the basal area factor (BAF) of the prism used, and

c = the average number of “in” trees tallied per prism sweep in that diameter class.

Note: Basal area is measured with prism plots only for larger stems (merchantable stems >12.5 cm dbh). Smaller than this, use fixed-radius plots for layers 2, 3, and 4 stems. Often for single tree selection, larger, 0.01-ha plots (5.64 m radius) are used to account for variability in the smaller size classes.

Method to determine stems/ha from prism sweeps. STEMS/HA FACTOR BAF=1		a	b	c	d axbxc=
Diam. midpt	**Diam. range**	**Stems/ha factor**	**BAF**	**No in DC**	**Stems/ha**
10	7.5–12.4	127.30			
15	12.5–17.4	56.60			
20	17.5–22.4	31.80			
25	22.5–27.4	20.40			
30	27.5–32.4	14.10			
35	32.5–27.4	10.40			
40	37.5–42.4	8.00			
45	42.5–47.4	6.30			
50	47.5–52.4	5.10			
55	52.5–57.4	4.20			
60	57.5–62.4	3.50			
65	62.5–67.4	3.00			
70	67.5–72.4	2.60			
75	72.5–77.4	2.30			
80	77.5–82.4	2.00			
85	82.5–87.4	1.80			
90	87.5–92.4	1.60			
95	92.5–97.4	1.40			
100	97.5–102.4	1.30			
105	102.5–107.4	1.20			
110	107.5–112.4	1.10			
115	112.5–117.4	1.00			
120	117.5–122.4	0.88			
125	122.5–127.4	0.82			
130	127.5–132.4	0.75			
135	132.5–137.4	0.70			
140	137.5–142.4	0.65			

Stem/ha data will be used in prescription development when working towards the target distribution.

Section 4.4 D of BDq—Maximum Diameter to Be Retained

The maximum diameter to be retained (D) is used in creating the idealized or target stand structure. The intent of using a traditional, balanced, uneven-aged approach is to distribute different age classes within a stand so that over time, smaller diameter (younger stems) grow into larger diameter classes. The approach suggests that all stems above a predetermined maximum diameter (D) will be removed to allow space for new regeneration and growth in the smaller size classes.

The maximum diameter of the trees to leave is an important consideration when using the BDq approach. The maximum diameter you choose will imply that all stems above that size will be harvested at the next cutting cycle, unless otherwise prescribed. The maximum diameter is also used in determining the number of stems in each diameter class for the chosen basal area. With this in mind, how do we go about choosing this important attribute?

How to Choose the Maximum Diameter

The maximum diameter should be based on the objectives of the prescription along with the capabilities of the species and site. What follows are some considerations that may guide the selection of D: the potential diameter growth by species for the site, risk of death during the cutting cycle, aesthetics, seed production, habitat capability, economic maturity, or other objectives.

Choosing D—What Is Reasonable for the Site?

What is a reasonable diameter for a tree to grow on this site and how long will it take to become that large are questions that need to be answered. In general, better growing sites will produce larger trees faster allowing for the choice of a larger D. Fiedler (1995) suggests that instead of using the largest tree on site as your guide, observe where diameter growth noticeably slows or look for a common size less than the largest as a guide to an achievable diameter. Note the stands must not have been "highgraded" or cut with a diameter limit approach or you will under-represent the maximum diameter.

Day (1997a), managing an area for mule deer winter range in the Dry Douglas-fir forest (IDFdk) of the Cariboo Forest Region in BC, found diameter growth of Douglas-fir slowed between 50 and 60 cm dbh. He also found generally less than 10% of the BA or 10 trees/ha were above 60 cm. From these observations, a maximum diameter (D) of 60 cm was chosen for his prescription.

Choosing D—Assessing Growth Potential

It is also important to determine the time to achieve the diameter class chosen. One method is to simply age trees of the desired size. This method assumes the growing conditions (density) of the measured tree will be similar to that of a tree growing within the managed uneven-aged stand. In some cases, this may be true and give a reasonable approximation. However, because density will be controlled in the managed single tree selection stand, a different approach may be required.

A more realistic measure of potential growth may be to measure the radial growth over the best 20 or 30 years on a range of relatively competition-free trees and translate that into the time to reach the maximum diameter. While sustained diameter growth over the range of diameters is not seen as conventional wisdom, Becker (1995) presents data for ponderosa pine over a range of basal areas and maximum diameter combinations that show a relatively constant diameter increment. For this approach to work, relatively open conditions are needed to provide consistent growth.

For example:

- You measure, on average, 100 mm (10 cm) of diameter growth in 20 years (or 2.5 mm per year radial growth).
- Over four cutting cycles of 20 years each, you would have approximately 40 cm trees from the regeneration layer: six cutting cycles would produce 60 cm trees.
- The concerns are…*Is this realistic growth, and can the level of growth be maintained throughout the cutting cycle?* Local information, permanent growth samples in the managed stand, and research trials will help answer these types of questions.

Remember, D governs the largest trees to be left after harvest. It is important to question whether the trees will meet the other objectives set for the stand. Will they survive to the next cutting cycle? Will they provide adequate seed? Are they aesthetically pleasing?

Choosing D—Accounting for Risk

What does risk mean? In this context it is the risk that the trees of the maximum size retained post-harvest will die before the next cutting cycle and will not be available for harvest. The longer a tree is on site, the greater its risk of dying at the hands of insects, disease, or fire. The relative benefits of leaving a tree on site longer must be looked at with this in mind.

Risk becomes even more tangible when dealing with the stems you inherit. Many of the larger stems may already be older than a similar size stem in the managed stand. Depending upon the objectives for the stand, you may have to accept retaining some trees that have a higher risk and slower growth than optimal to maintain stand attributes and the desired uneven-aged structure.

Choosing D—Using Management Objectives as a Guide

Economic Maturity

Where maximizing timber returns drives management decisions, the concept of *economic maturity* may impact the choice of D. Economic maturity will depend on species, location, wood quality, discount rates chosen and site productivity. In BC, no tables link site productivity, rate of return, and tree size to maximize that return.

Trimble et al. 1974 (in Marquis 1978) present an economic assessment for oak showing that, as the rate of return increases, the maximum size (D) decreases. They found that better growing sites with a lower expected rate of return can use a larger maximum diameter. However, economic maturity cannot be exclusively relied upon for timber management. The economic rotation age may not be sufficient to allow for adequate seed production or provide the attributes desired for the uneven-aged stand.

Biodiversity and Aesthetics

Figure 4.4-1
Large diameter stems may be desired for wildlife, aesthetics, seed, or other reasons.

Large older trees are often *good* seed sources, supply structural diversity, and are seen as aesthetically pleasing. Larger size classes can provide habitat for organisms that need large branches, big boles, high perching sites, modified microclimates, future snag, and coarse woody debris. How large is large and is it feasible for a tree to grow to the desired size using the regulated BDq approach?

Here are some ideas. Choose a maximum size to meet the objectives for your stand (e.g., 1 m in diameter trees with large branches for perching). Determine if the stand has stems of that size. If so, bore them to determine how long it took to grow individuals of that size. From the data on site, determine if it is feasible to grow that size of stem within a traditional rotation length. To grow a tree to 1 m dbh may be infeasible objective within the rotation lengths set for the area.

An approach used in Montana (Becker 1995; Fiedler 1995) to retain a component of large trees (if they are already on site) is to manage them as reserves, lowering the value for B by the retained amount for the managed portion of the stand. To maintain a component of large trees over time, some individuals that reach the maximum D may need to be left uncut at each cutting cycle. These trees or areas need to be identified in the site prescription so that instructions can be provided to the loggers. Another option for using a large maximum D is exploring the feasibility of longer rotations.

Researchers at the University of California (Berkeley) Blodgett Research Forest, on the western slopes of the Sierra Nevada take a flexible approach to maximum diameter. In mixed sugar pine, ponderosa pine, incense cedar, and black oak, D is set to guide stand structure initially. However, trees exceeding D are only cut when the density around the larger trees is suitable, the regeneration they want from the trees is established, and a suitable successor for them is identified (Bob Heald, 1998, pers. comm.).

Some general considerations regarding D:

- A large D may be unattainable, risky for the present, or take a long time to obtain.
- A small D may end up leaving trees too small to regenerate the site naturally and may not provide the other attributes that promoted the use of single tree selection as the system of choice.
- A small D could result in "highgrading" if not carefully applied in stands being converted from even-aged to uneven-aged structure.

Section 4.5 q of BDq—Structural Regulation across Diameter Classes

The French forester Francois de Lallement first described the concept of q. He observed that a balanced or sustainable diameter distribution was characterized by a constant relationship among successively larger diameter classes—given the name "q" (Hann and Bare 1979, p. 5).

Diameter distribution—q—in a balanced uneven-aged system is defined as the ratio between the number of trees in successive diameter classes. When the number of trees is plotted over diameter class, you get the typical inverse J-shaped curve. A q of 1.3 describes a relationship whereby the number of trees in one diameter class is 1.3 x (the number of trees in the next larger diameter class).

The q factor is simply a multiplier that, when used with B and D, provides a balanced stand structure. To make q function, D must be described, B must be chosen, and the diameter classes to be presented must be identified. The closer q is to 1, the smaller the difference in numbers of stems between diameter classes (i.e., a "q" of 1 would have equal number of stems in all diameter classes).

Experiences with q

Becker (1995) and Fiedler (1995) suggest the use of low q values when managing for timber production. Becker (1995) recommends q values between 1.1 and 1.2 for operational diameter classes (such as 10 to 12 cm). Literature sources (Alexander and Edminster 1977; Marquis 1978) recommend a range of q values from 1.1 to 2 for 5-cm classes (1.4 to 4 for 10 cm classes). These values are seen as too high based on preliminary results from uneven-aged growth plots in Montana and southeast US (Fiedler 1995). Fiedler states that, while many of today's uneven-aged stands have a better fit with a high q, this is not necessarily suited to the stand due to decades of fire suppression.

Using low q values assumes little mortality. Once a stand using a low q is balanced, the stand will have few stems in the intermediate diameter classes that need to be harvested at each cutting cycle to maintain the balanced distribution. Stands managed under a high q value have high numbers of excess stems in the intermediate sizes that require harvesting to promote the balanced condition.

For low q management, where relatively few stems are needed to fill the commercial diameter classes, precommercial thinning (juvenile spacing) is often needed to fulfill the desired structure. This requires a threshold diameter for regulation. Marquis (1978) suggested selecting the lowest q that seems feasible in terms of markets and money available for thinning small trees.

Choosing q

The impact that q has on a prescription is as follows:

- A low q value equates to fewer total number of stems, with more of the growing space allocated to larger stems.
- A high q equates to more area allocated to smaller diameter stems.

Consider the advice of Fiedler (1995):

> Q is a tool to help you create a balanced uneven-aged stand. The diameter distribution created by choosing BDq must be viewed as a goal and not as something that must be slavishly adhered to. Instead the idealized stand structure should be looked at as something to move towards with a clear eye on the stand you are working with. In the long run the q chosen will influence the allocation of basal area. However, in most cases the first entry will only allow modest progress towards a balanced diameter distribution.

There is also no reason to stick dogmatically with a q factor for all size classes. A higher q could be chosen for precommercial size classes and a lower q for the commercial classes. This accounts for higher mortality in the smaller classes and promotes timely recruitment into the commercial size classes. Another option is to work towards a q for commercial size classes only and ensure numbers of recruits are adequate without using a q for sub-commercial sizes (minimum stocking of some sort). Do not carry too many small trees, or they will not have a timely entrance into the managed classes. This will translate into a shortage of stems in the larger diameter classes over time.

Creating a Target Stand Structure Using BD and q

Fiedler (1995) reviews the steps of translating chosen values of BDq into a target stand curve. To start, choose the maximum diameter of stem to leave, the diameter classes to be managed, the residual basal area (B), and the value of q.

Example of some BDq parameters:

Maximum diameter = 60 cm

Diameter class = 10 cm

Residual Basal Area = 25 m^2/ha

q factor = 1.2

To create the desired stand table takes two steps. The first step creates a hypothetical diameter distribution based on a single tree in the maximum diameter class. Each successively smaller diameter class has "q" times as many stems. This is repeated for all classes including the minimum class, in this case, a 10-cm diameter midpoint (7.5 to 12.5 cm dbh).

Step one in creating a target stand table using BDq

Diam. class midpt. (cm)	Stand structural goal q = 1.2, Max. diam. = 60 cm		
	T/HA	**BA/DC**	**BA/HA**
10	**2.5**	0.008	0.020
20	**2.1**	0.031	0.065
30	**1.7**	0.071	0.122
40	**1.4**	0.126	0.181
50	**1.2**	0.196	0.236
60	**1.0**	0.283	0.283
TOTAL	**16.5**	0.7147	0.9062

Additionally, the numbers of trees in each diameter class are multiplied by the basal area per tree for the mean tree diameter in that class. This value (BA/DC or basal area by diameter class) is then multiplied by the trees/ha (T/HA) to get the basal area/ha (BA/HA). The sum of the total basal area/ha is used to derive a multiplier that reflects a desired RBA. The sum of BA/HA (0.9062) is divided into the residual basal area (25) to produce a multiplier for the target stand table (25/0.9062 = 27.6). The numbers of stems/ha for the hypothetical structural goal are multiplied by the multiplier to obtain the planned stand structure.

Planned stand structure for a B of 25 m^2/ha, D of 60, and q of 1.2

Diam. class midpt. (cm)	**Stand structural goal q = 1.2, Max. diam. = 60 cm**			**Planned stand B = 25**	
	T/HA	**BA/DC**	**BA/HA**	**T/HA**	**BA/HA**
0	**3.6**			**99**	
5	**3.0**			**82**	
10	**2.5**	0.008	0.020	**69**	0.5
20	**2.1**	0.031	0.065	**57**	1.8
30	**1.7**	0.071	0.122	**48**	3.4
40	**1.4**	0.126	0.181	**40**	5.0
50	**1.2**	0.196	0.236	**33**	6.5
60	**1.0**	0.283	0.283	**28**	7.8
TOTAL	**16.5**	0.7147	0.9062	**455**	25.0

The balanced distribution created by the mathematical use of BDq can then be used as the standard from which the existing stand can be compared (Fiedler 1995). The trees above the target structure in each diameter class provide the harvest opportunity. In reality there will be some classes with more than the desired and some with less. The deficiencies can be filled with surplus trees from adjacent classes (Fiedler 1995). The table below shows a hypothetical stand with cut-and-leave values provided. The table describes the existing stand from a cruise compilation or reconnaissance data.

→ **See** Section 3.7 for additional information on reconnaissance data collection.

Example stand and cut characteristics

Diam. class midpt. (cm)	**Existing stand from cruise or recce data**		**Planned stand B = 25**			**Planned cut**		**Actual cut**		**Post-harvest stand**	
	T/HA	**BA/HA**	**T/HA**	**BA/HA**	**V/HA**	**T/HA**	**BA/HA**	**T/HA**	**BA/HA**	**T/HA**	**BA/HA**
10	**329**	3	**69**	1	5	260	2	280	2	**49**	0
20	**290**	9	**57**	2	17	233	7	230	7	**60**	2
30	**155**	11	**48**	3	36	107	8	110	8	**45**	3
40	**98**	12	**40**	5	53	58	7	48	6	**50**	6
50	**30**	6	**33**	7	74	-3	-1	0	0	**30**	6
60	**25**	7	**28**	8	91	-3	-1	0	0	**25**	7
TOTAL	**927**	48	**274**	25	276	653	23	620	23	**259**	25

The planned cut simply subtracts the planned stand from the existing stand. Note the negative numbers in the 50- and 60-cm classes. This occurs when there are insufficient stems in the stand to meet the planned stand structure. One way to address this is shown in the actual cut column where no trees were cut from the 50- and 60-cm classes. In reality there may be reason to remove some of the larger stems if they are diseased or damaged to make room for the rest of the growing stock. The last column provides a compilation of the stems left on site. For added usefulness, volume by diameter class can be easily added.

By using a spreadsheet, it is possible to modify BDq within realistic ranges to create a workable target structure. It is also easy to modify cutting specifications to determine the effects on the RBA. Once a comfort level has been reached for cut levels by diameter class, marking or cutting rules must be derived for the prescription. For the most part they should be kept simple and allow for some on-the-ground flexibility.

→ **See** Section 5.1 for information on translating prescribed cutting levels to a marking guide.

Remember that BDq is a tool to help shape the uneven-aged stand through time, allowing for new regeneration and continued growth and harvests. Many of the stands you will encounter will require two or more harvest entries to move towards the desired structure. Additionally, because of variability in growth, regeneration, and mortality, you will likely never achieve a balanced distribution; the key is to maintain stand vigour and structure. BDq is there to help.

Section 4.6 The Cutting Cycle: Planning for Harvesting on Regular Intervals

The cutting cycle is the number of years between harvest entries. Day (1997a) cites Davis and Johnson (1987) who suggest the cutting cycle is the cornerstone of the management prescription. In essence, the cutting cycle must be long enough to allow sufficient volume to accrue for an economical harvest and not too long to result in significant growth reduction within the understorey stems. Alexander and Edminster (1978) report that cutting cycles in western coniferous forests are often between 10 and 40 years.

To maximize site productivity, the cutting cycle should be timed to coincide with return of the stand to full stocking (a density at which mortality is about to set in). In actual practice, cutting cycles are often set in increments of 10 years for ease of record keeping.

Short Cutting Cycles

Frequent entries on a short cycle remove more of the natural mortality by removing the high-risk trees. With short cycles (8–10 years), relatively small volumes are removed per cycle, leaving a large amount of growing stock for the next cut (often higher than B-level stocking). Shorter intervals favour shade-tolerant species. In Europe, where single tree selection manages shade-tolerant species, the felling cycle is usually not more than 10 years and is often less. In France, it is between five and eight years; in Switzerland it is 6–10 years (Mathews 1991, p. 166).

Long Cutting Cycles

Longer cutting cycles (20–30 years) usually equate to higher volume removal per cut and create a more open stand allowing the management of shade-intolerant species (Mathews 1991). For unregulated coniferous stands being brought under regulation, a cutting cycle of 20 years has been used operationally in Montana (Becker 1995).

Choosing a Cutting Cycle

Day (1997a) used periodic annual growth data to help choose the cutting cycle for a single tree selection prescription for mule deer winter range management in central BC. His upper stocking limit was 32 m^2/ha with a B level of 18 m^2/ha. The periodic growth was calculated as 8.3 m^2/ha per decade. To grow the stand back to full stocking of 32 m^2/ha from 18 m^2/ha requires 14 m^2/ha of growth (32 - 18 = 14 m^2/ha). Using the periodic growth rate, it was determined to take approximately 17 years (14 m^2/ha /0.83 m^2/ha/yr) to reach the upper stocking limit. He then set the cutting cycle at 20 years to manage for several factors:

- The relatively long cutting cycle allows for some mortality not factored into the periodic increment. This allows for limited snag and coarse woody debris recruitment.
- Average diameter growth of 1.5 to 2.5 cm/decade is found in the area, thus a 20-year re-entry period allows more stems to pass into the subsequent diameter class between entries.
- A portion of basal area is reserved for larger stems.

Keep in mind that the longer the interval between cutting cycles, the greater the likelihood of crown closure. The resultant slowing of growth in the smaller diameter classes could influence the timing of stems moving into the merchantable classes.

Section 4.7 Structural Regulation—Considerations for Mixed Stands

Managing stands with more than one species adds complexity to single tree management. If left untreated these stands will tend towards dominance by late seral or climax tree species. This has been observed in many jurisdictions. Where seral species are preferred, Becker (1995) suggests this may not be as large an issue as once thought. Uneven-aged management requires relatively few trees/ha. Therefore, in areas with high overall densities where the desired species are well-distributed, density control can remove the unwanted species from the matrix leaving the desired species to occupy the site. This approach also requires cutting to a relatively low residual basal area to promote growth if the desired species are shade intolerant.

Where a mix of species are to be managed on a single site, some recognition of differential growth rates and spatial requirements are needed. Different species occupy varying amounts of space (e.g., Fd, Hw, and Bg have different maximum crown requirements). Paine and Hann (1982) suggest a range of densities to fully stock one hectare at maximum crown extension for a range of species and target diameters.

Minimum stems/ha to reach full stocking (Paine and Hann 1982)

dbh (cm)	Douglas-fir	Western hemlock	Grand fir
25	320	390	510
50	105	128	200
75	50	62	103

As well, different species have different shade tolerances. True firs are shade tolerant and can grow reasonably well under a canopy. Most pine species require open conditions for sustained growth. By leaving a relatively high residual basal area, you will shift the species mix towards tolerant species and may totally exclude regeneration of shade-intolerant seral species.

→ **See** Section 2.2 for additional information pertaining to silvics and stand dynamics.

Promoting the inclusion of shade-intolerant species may require moving towards a group selection system or reducing the basal area low enough to create open conditions. It may also require planting of intolerant species in appropriate microsites, depending upon the seed source.

Section 4.8 BDq at Work—On-the-ground Experience

BDq provides a goal from which to create a balanced uneven-aged structure. It should be used with flexibility. Spreadsheets allow easy "gaming" of reasonable options. In all cases use common sense in the field to choose leave trees. Remember also that regeneration success is vital to the success of uneven-aged regulation. This may require site preparation (e.g., underburning in some ecosystems), planting, and brushing as would be applied in traditional even-aged management. In many cases, the desired structure is not attainable from the starting structure within a single cutting cycle. Do not despair—here are some practical tips for implementation from those with experience.

Practical Implementation Tips

Rolan Becker manages uneven-aged ponderosa pine/Douglas-fir stands in northwestern Montana for the US Department of the Interior, Bureau of Indian Affairs. Some practical tips on implementation of single tree selection prescriptions include (from Becker 1995):

1. Not all prescriptive elements carry the same weight; consider the following priorities:
   - Site occupancy—select B with care and work towards achieving it on site.
   - q—if possible move towards the desired distribution. In doing so, maintain the existing structural diversity—this means keeping some of all of the size classes represented. When one or more classes are deficient, leave vigorous stems from adjacent classes as recruits. In some cases, leaving more larger trees is a better option to maintain stocking if the smaller size classes are of poor form and vigour. Use the vigour and health of the stand to help make those types of decisions.
   - Maximum size of the tree left after harvest—the residual basal area and the vigour of the remaining stand are more important than strict adherence to maximum size criteria or diameter distributions.
   - The key is to occupy the site with as vigorous and healthy crop trees of the desired species as possible.
2. Manage for broad diameter classes—use projected diameter growth for the cutting cycle as a basis for the classes.
3. When the objective is timber production, manage with relatively low q. He suggests q values of 1.1 to 1.2 for 10 to 12.5 cm diameter classes. When managing shade-tolerant species, higher q values can be used.
4. With extended cutting cycles (e.g., 20 years) and shade-intolerant species, manage at relatively low stand densities.
5. Leave a portion of the stand outside of the regulation. For example, where B is chosen as 20 m^2/ha, it is often useful to mange 18 m^2/ha for timber production and leave 2 m^2/ha in larger trees (above D) for visuals, genetic improvement, or biodiversity (i.e., left unmanaged and outside of the cut).
6. Don't mix group and single tree selection systems over the same area, as confusion over structures can emerge. In single tree selection it may be necessary to create small openings for regeneration; these are typically not the size of group selection openings. Remember the silvics of the species available and choose the silvicultural system accordingly.

7. Use trained and skilled people on the ground. Do not leave prescriptions to be managed by junior personnel, as the results can be disastrous.
8. When marking trees, mark-to-leave to focus on the future crop trees and residual stand structure. For faller selection, be sure there is good upfront training and monitoring to ensure the desired structure is being left.
9. Maintain a monitoring program for the harvesting operation. Be sure to minimize stem damage, and use directional falling and designated trails where possible.

→ **See** Section 5 for additional detail on harvesting tips.

Observed Advantages and Disadvantages of the BDq Approach

Carl Fiedler works with uneven-aged stands in northwestern Montana as a researcher at the University of Montana in Missoula. Some observed advantages and disadvantages of the BDq approach include (Fiedler 1995):

Potential advantages:

- It leaves the best quality trees on site, leaving a range of future options.
- It provides a flexible prescriptive framework. Varying BDq parameters within reasonable ranges provides significant flexibility for choosing suitable structures to meet management objectives.
- It sets a clear target for management. The documented stand structure sets a goal for the future providing a useful aid in creating a realistic prescription for the existing stand.
- It allows for evaluation at successive entries to determine the success on achieving the specified objectives. This allows for learning and fine tuning of future prescriptions.

Potential disadvantages:

- It is more complex than even-aged methods and possibly more complex than other uneven-aged approaches. It requires an informed prescriber to develop target structures that are ecologically realistic that will meet management objectives. It is somewhat difficult to apply since it requires evaluation of tree quality and spatial arrangement of future stand conditions.
- “It is based on the unfounded assumption that basal area is an unbiased measure of density” (see discussion on the Gingrich chart, this section).
- It does not fit into present growth and yield models easily. Tools for projecting BDq structures through time are not readily available.
- **It requires a long-term commitment, not necessarily a disadvantage unless the commitment is made and not maintained.**

Some Lessons from the Black Forest

Selection forests in the Black Forest are generally mixed-species forests composed of silver fir (*Abies alba*), Norway spruce (*Picea abies*), and small amounts of beech (*Fagus sylvatica*). Observations from the selection forest or "Plenterwald" provide the following (Spathel et al. 1997):

- Prerequisites for selection forests are stable sites, shade-tolerant species especially when young, good accessibility, skilled managers and forest workers, controlled game populations, and continuous management.
- In the Plenterwald, natural regeneration occurs spontaneously—trees in selection forests have reduced growth in their youth and accelerated growth rates once released.
- Frequent cuttings are needed to maintain the forest structure and promote good growing conditions for all size classes.

Section 4.9 Concluding Comments on Regulation for Single Tree Selection

Diameter distribution regulation using BDq is a tool to promote regulated yields from the cutting area. This may or may not be the most appropriate method for a particular stand.

Ideal uneven-aged management (according to Smith 1986) would have equal space for all age classes, from germinants through to rotation-aged veterans. This is not a likely situation.

For the most part we are going to be working with irregular-aged stands with a range of age classes. It may take two or more cutting cycles to create a stand that approaches a "balanced" condition.

Smith (1986) suggests that unless sustained yield of the stand is an objective, the management of any stand can be done using a selection method without diameter regulation. He promotes this approach when diameter and volume are managed over the forest rather than the stand. The problem in BC is to track each individual stand in terms of its ability to provide future volume and new regeneration. The approach of non-regulated single tree selection requires a clear forest-wide picture of potential growth and production, not available in BC at this time.

O'Hara and Valappil (1995) and O'Hara (1996, 1999) present an alternative approach to regulating selection systems. They recommend the use of leaf area index by cohort to manage stocking. This research has created a multi-aged stocking assessment model (MASAM), a model that allows creation of target stand conditions with two to five cohorts. This approach does not require a balanced diameter distribution. O'Hara (1995) describes three examples for ponderosa pine types in Montana.

Another approach to regulate stocking in uneven-aged stands is through the use of a stand density index. Long (1995) provides a methodology using stand density index (SDI) to assess and control growing stock for classic uneven-aged structures and for two-storied shelterwoods with reserves. The maximum SDI for a species is the maximum size and density at the point of self-thinning.

For more information regarding the application of BDq, Fiedler (1995)[2] and Becker (1995) offer good overviews of regulation and opportunities for use. Day (1997a, 1997b) presents a thorough overview of BDq as it relates to a Cariboo stand prescription. His papers give a thoughtful view of present limitations and innovative solutions in creating an uneven-aged prescription using BDq.

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2 The entire proceedings are useful reading for anyone wishing to pursue single tree selection management. They are available as MFCES Miscellaneous Publication No. 56. August 1995 for a fee from Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Missoula, MT, 59812. Email requests care of Carolyn Durgin chd@forestry.umt.edu.

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PART 5: IMPLEMENTATION ISSUES AND CONSIDERATIONS

Part 5 provides an overview of the operational implementation issues and considerations that may be encountered and suggests who should successfully address them.

5.1 Marking Options and Procedures

This section compares the various approaches to marking.

5.2 Harvesting Equipment and Layout Considerations

This section reviews the range of common harvesting equipment and systems available for partial cutting, their advantages and limitations, and layout steps.

Section 5.1 Marking Options and Procedures

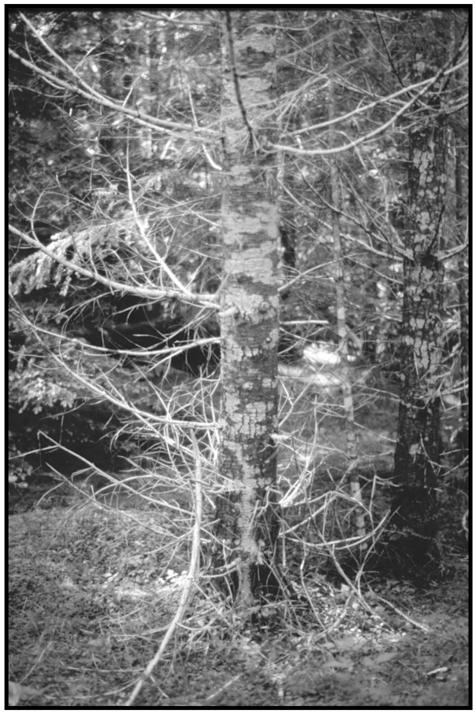

Figure 5.1-1

Numerous approaches have been developed to transfer the stand structural goals from a site plan to the ground. Many foresters would consider the marking of the stand for partial cutting to be one of the most powerful and rewarding experiences in transferring a plan to the stand. Others would suggest that training loggers to make these decisions is not just appropriate, but rewarding as well.

This section reviews all of the potential marking options, decisions, and considerations to ensure a smooth transition from a plan to the harvesting operation.

In this section we will…

- Compare the various approaches to marking.
- Review the procedures for marking dispersed leave-trees.
- Examine the potential complexities of marking rules associated with single tree selection, and several approaches to marking with these rules.
- Investigate ways to differentiate between trees marked for different purposes.
- Examine the decisions used to locate and mark leave-tree groups or clumps.
- Review some considerations for marking group and strip openings for harvest.
- Review considerations for properly transferring prescription elements to marking.
- Review considerations and rationale for substituting marked trees during logging.

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Transferring Information from the Plan to the Field

The site plan must provide enough information to guide the marking. Marking rules should be developed directly from the plan. The plan must have enough information so that markers can choose the right trees. Basal area stocking is frequently a better parameter for prescriptions than density, as it is based on growing space occupancy and does not assume all the trees will be exactly the same. However, a prism will be required. A range of basal area is best to allow for human error and stand diversity.

→ **See** Section 3.4 for more information on developing leave-tree parameters in site plans.

A good prescription becomes worthless if information is not accurately transferred to the marker and/or the faller. For example, where the intent is to leave all the Lw and Fd along with marked stems of other species, if the faller is not aware of the Lw and Fd objective, the Fd and Lw will be removed. Stand-level objectives will have been severely compromised.

Dispersed Leave-trees

Mark or Use Faller's Choice?

To determine this ask:

- How important is the choice of the leave-trees for the achievement of your objectives?
- Do the fallers understand and care enough about your objectives to make the right choices?
- Do the markers know enough about falling to recognize safety or operational problems?

Faller Selection

Faller selection may be used where the fallers are accustomed to working to a prescription. For example, a section of one area could be marked-to-leave (or cut) to train loggers initially. The remainder of the block would then be logged using logger selection (with no marking). The fallers should work with a prism if basal area is their objective and fully understand the objectives of the plan.

Faller Marking

A variation in faller selection that has been used is *faller marking*. Under such an operation, the faller marks a logical falling section using the leave-tree specifications developed for the stand, and then falls that section. He then proceeds in the same manner through the whole block, or his portion of the block. The faller may use low-quality white paint, putting only several dots on his leave-trees. This paint will start fading and falling off after several months and will be much less noticeable than blue or brighter-coloured paint. Since he just marked it, the faller usually has no problem picking up his marked leave-trees.

This marking system has the advantage of separating the two tasks, marking and falling, so that the faller can first concentrate on choosing the best leave-trees when he is marking, and then concentrate on falling. The faller may better be able to examine tree crowns from a distance while marking rather than trying to make critical choices at the base of each tree, with saw in hand.

When to Choose Mark-to-Leave

- When more basal area is removed than left.
- When leaving the best phenotypes is critical.
- Advantage: Puts the focus for markers on the residual stand thereby protecting long-term interests.

When to Choose Mark-to-Cut

- When less basal area will be cut than is left.
- Advantage: Quick, cut stems are often easy to choose (e.g., small, poor form, defective).
- Limitation: Tough for marker to visualize the residual stand.

Procedures for Marking Dispersed Leave-trees

Note: The block boundary and trails should be laid out and marked before marking the stand.

Markers Should Try to Think Like a Faller

Remember that a faller's first concern going into an area is to make the area safe for himself, whether it is a clearcut or a partial cut. This means the faller must address any hazards first.

The faller's second concern is to make the area safe for yarding or skidding crews. If trees are brushed up, or damaged, they may need to be taken out, especially if a large branch is hung up or another hazard is present. Fallers try to fall timber into an open area to avoid brushing crowns. This is straightforward in clearcutting, but becomes more of a challenge in partial cutting, especially in heterogeneous stands, when timber is tall. It helps if the marker can think about what will be harvested, as well as what will be left, and try to ensure that the faller has a place to fall each tree.

When the timber is clumpy and the crowns are interlocked, fallers may have difficulty just leaving a few trees in a clump—this is especially true with mixed-species stands. Sometimes it is easier to leave all or most of the clump and alternate by removing a clump. Trees with large, wide crowns are often difficult to fall without damaging many other smaller trees. Consider leaving such trees unless there is an obvious path for it to be felled into.

→ **See** Section 5.2 for more information on falling procedures in partial cuts.

General Marking Procedures

1. Marking should be done systematically over the entire area and with constant pace to give full, consistent coverage.
2. A crew of two or three should follow each other in staggered strips, communicating to provide feedback on top conditions of trees chosen.
3. Marking should focus on the objectives of the stand and the tree characteristics specified in the prescription.
4. Marks should be placed at eye level, using painted dots around the tree, unless the block is to be winter-logged, in which case marking should be as high as possible. See section on marking trees for different purposes. Often a line from the base of the tree up the stem through the maximum stump height is used, since it marks both the stump and the butt-log of a marked tree that is harvested. Such a mark should be placed in the crotch of two roots so it cannot be rubbed off during skidding.
5. A periodic prism sweep should be done to check residual basal area being left. If the basal area of trees to be cut or left in different diameter classes is important, as in single tree selection, these trees can be tallied for each prism sweep by a third person for a two-person marking crew.
6. When marking to leave, mark lighter near main skid trails and corridors to allow for removal of damaged stems.
7. Generally, a crew of two is sufficient for marking. However, a tallyperson is needed to record marked stems for the following reasons:
   - To gain a total cruise on all marked stems. This is useful for a mark-to-cut approach where you want accurate numbers on the volume to be harvested.
   - To mark across diameter classes according to marking rules, set to implement a prescription for proper single tree selection.

Marking for Single Tree Selection

After a prescription is developed to regulate or manage densities across all diameter classes, a set of “marking rules” must be designed to ensure that the structural design can be transferred to the ground. Usually, targets for residual basal area in the range of diameter classes are refined to just three or four marking rules in broad diameter classes.

Example of marking rules for single tree selection (mark-to-cut)

Marking category	Rule
Wildlife trees (>70 cm dbh)	Leave all (there are only 2–5 scattered through the block)
Large sawtimber (50–70 cm dbh)	Mark 50% – mark 1/leave 1
Medium sawtimber (30–50 cm dbh)	Mark 1 in 3 trees (distribution is clumpy so remove one-third of the basal area in this diameter class in each clump)
Small sawtimber (15–30 cm dbh)	Mark 2 for every 3 (mark 2/leave 1)
Other criteria for all categories	Mark trees to cut first that show defect, disease, or lack of vigour (small crown, high ht:dia. ratio)

A total marking tally may be kept of marked and leave-trees for single tree selection to ensure the right proportion of each is taken or left. This tally must be rationalized over a discrete area to balance cut/leave patterns.

Some European countries try to balance the marking rules across individual subunits within the stand as small as one hectare. They do this by marking 100 × 100 m gridline boundaries through the stand and then flagging each tree to identify it by the marking category or diameter class. Once they have tallied each marked tree within a one hectare subunit, they may revisit that subunit to adjust the marking to come closer to the target. It is hard to imagine such a degree of sophistication and intensity for marking. However, if you had a uniform, near-balanced, uneven-aged structure and your goal was well-regulated, highly predictable, sustainable yields at the stand level, such an approach may be useful. In BC, we would generally opt for a more extensive approach to fit with more heterogeneous stand types, rationalizing yield at the forest, rather than the stand, level.

→ **See** Section 4.1 for more information on regulation of uneven-aged stands with single tree selection.

Some prescribers have simplified marking rules so that markers may key in on one diameter category (e.g., large sawtimber) and mark one-third of the stems for removal. The other rules for the other categories would then relate to the first. For example, in the medium sawtimber category, they may mark two trees for every tree marked in the large sawtimber category. With this approach, only a tally of cut trees is needed. Additional prism sweeps to ensure that the total residual basal area meets the range in the prescription would also be needed.

At the University of California (Berkeley) Blodgett Research Forest (Bob Heald, 1998, pers. comm.), the distribution of current stand structures is analyzed through quick survey after structural regulation targets for single tree selection are set. A "step-point transect" survey is used to determine the distribution of different combinations of stand structure across the stand. In this way, the prescriber can design simple marking approaches for each unique situation. These marking rules may include simple spacing rules in clumps of immature trees, or special decision criteria for larger trees.

Marking for single tree selection will require much more experience and knowledge of the stand structural and management goals since numerous structural objectives can be implicit for each major diameter class.

Identifying, Designing, and Marking Leave-groups and Clumps

Leave-groups and clumps should be planned logically to fit with the management objectives and all harvesting and engineering considerations. A protocol to approach such marking is as follows:

1. Be very clear about management and structural objectives: "What are we hoping to provide from the leave-trees?"
2. During the engineering field assessment stage, identify engineering, economic, and stand structural control points.
   - If the groups or clumps are to have specific structural characteristics, you will want to combine these with standard control points for engineering and economics. Often a blind-lead for deflection may also have the structural characteristics needed for a leave-clump and will reduce costs per cubic metre if it can be left.
3. Because of their importance biologically and the inherent safety concerns, consider using snags to form the heart or centre of groups or clumps when logistically possible.
4. Map the location of the possible control points.
5. When locating the structural controls on the map, make notes on the values that each area can contribute.
6. Assess for windthrow hazard; rank sites based on their likelihood of remaining standing.
7. Assess the clumps and groups for forest health issues such as mistletoe. Recommend options.
8. Determine the area identified and compare it against the desired retention value.
9. If less than the desired amount use the spatial guidelines and engineering chance to identify candidate areas, field check, and locate on the ground.
10. In all cases, choose retention patches that make the most sense to leave: those with desired structural attributes, those that fit with the engineering plan and chosen harvesting equipment, and those that meet the management objectives.
11. Mark leave-groups and patches using a distinct colour, or have special tape created for retention patches to differentiate from outside boundaries.
12. Ensure all hazard trees have been identified and either have a sufficient buffer around them or are marked and identified for the faller.

Note that marking is just a final phase in the proper planning of these leave-clumps or groups.

Marking Groups and Strip Openings for Harvest

The layout of groups and strips must fit with the standard design of the silvicultural system and the objectives for the system. Generally, the block must be approached as a total chance unit and similar considerations will be necessary for choosing groups and strips to cut as in choosing groups and strips to leave (see previous).

→ **See** Section 2.1 for more information on the design of group and strip systems.

Since in group or strips you may have many small openings in any one harvesting entry, number each opening on your map and ensure that an identifying number can also be found on the ground to correspond with the map. This number should be placed consistently in each opening using materials that will allow for identification over the long term. This will speed up future silviculture operations and survey work as workers will have to spend less time trying to determine where they are.

The protocol for marking the boundary of each small opening should be similar to marking block boundaries, ensuring that loggers are aware of where to stop cutting (see the next section). An alternative that has been tried in some strip selection helicopter blocks is to give fallers a central reference line and allow them to create an opening of a specified width from that line. For example, the strips could be one tree length on both sides of the line, or two tree lengths on one side or the other. This allows some flexibility for fallers to deal with diverse conditions in very difficult terrain.

Marking Trees for Different Purposes

Stems can be marked for boundaries, as trees to leave or as trees to cut within a setting. To avoid confusion, a suggested approach follows.

Boundary Marking

Boundary marking refers to marking of block boundaries or internal groups (e.g., reserves, wildlife tree patches). A protocol for boundary marking is found within the *Boundary Marking Guidebook* (BC Ministry of Forests September 1995). For painted rather than blazed boundaries, it recommends the use of two horizontal **blue** stripes at least 15 cm apart, approximately 1.5 m from ground level, facing the cutting area. Trees should be marked at 5-m intervals. An additional mark is to be placed as close to the ground as possible on the downhill side of the tree.

→ **See** the *Boundary Marking Guidebook* at *http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/bound/boundtoc.htm* for more information regarding a boundary marking protocol.

Mark-to-Leave

Because blue paint is recommended for boundary trees that are left unharvested, blue is a logical choice for leave-trees within the setting. However, another pattern is needed to avoid confusion with boundary trees. The use of dots around the circumference is recommended and should not be confused with the double line for boundary trees and allow for easy recognition by the faller. When in a visually sensitive area, dots could be kept away from the viewing angle to keep a natural look for the stand. The use of a vertical basal line is needed to determine if trees were substituted. The basal mark should be in a bark furrow or indentation to avoid removal by logging abrasion. It should extend through the stump height zone to provide a mark both on the log and stump if the tree is removed.

Mark-to-Cut

To avoid confusion with mark-to-leave and boundary marks, the use of a colour other than blue is recommended. The chosen colour should be based on how long it will last and how well it can be seen by fallers. Red has been used with some success; orange has had less success as it degrades quickly in sunlight. Be sure to use a colour with strong contrast to the bark and communicate clearly to the contractor the intent of the mark (i.e., the trees are marked-to-cut). The use of a single horizontal band around the circumference along with the vertical basal mark should provide an easy to distinguish pattern in contrast to the blue leave-tree dots and blue double horizontal marks of the boundary trees. The more consistency, the fewer mistakes will be made at the harvest stage.

Question: *What is the best way to handle mistakes in marking?*

When a mistake in marking is made the easiest solution is to paint over the mark with black paint. For trees that have been erroneously marked to cut, DO NOT cross out your marks and write huge instructions on the tree. Such graffiti contributes little to the aesthetics of the block and can result in confusion.

Substituting Trees for Marked Trees during Falling

Remember that a faller who is used to clearcutting finds his sense of accomplishment by being able to look back at the wood he has laid on the ground. This focus must be balanced in partial cuts by some pride in what is left behind. A clear explanation of the objectives and rationale behind the whole prescription will be useful to foster this attitude in fallers and all members of the logging crew.

Regardless of the communication upfront, considerable flexibility must be built into logging contracts and prescriptions to allow fallers the ability to substitute leave-trees with similar characteristics when a marked leave-tree presents an unacceptable falling situation. This is especially important when:

- The faller feels it is unsafe to fall the marked tree.
- A considerable portion of the stand is to be left uniformly throughout the area and the pre-harvest stand structure is dense and heterogeneous.
- Inexperienced marking crews who cannot appreciate the degree of difficulty involved in falling on a given site are used.
- Marking crews cannot adequately see the tops of leave-trees because of a very dense canopy. If the faller is made aware of the desirable leave-tree characteristics, he may be able to substitute better trees where mistakes have been made. Remember that the faller will have a better opportunity to see tops as the stand is opened up. This is particularly useful if you are trying to leave some snag-recruitment trees, nest trees, or other wildlife trees.

Latitude allowed between the ideal or actual marking and the realistic or actual falling is important and should be decided upfront. At the prescription stage, it is often useful to get some input from fallers or contractors. The flexibility allowed fallers must be understood by all parties involved in the project, so that the final product meets the expectations of all.

In most previously unmanaged stands, particularly in old-growth stands, fallers should be allowed to interpret marking as a guideline for what is to be done, with lots of latitude to make substitutions where difficulties arise. In managed stands, which may be more open and/or more uniform, stricter marking criteria may be more feasible.

Additional Reading

British Columbia Ministry of Forests. 1995. Boundary marking guidebook. Victoria, BC. Forest Practices Code of British Columbia Guidebook.

Section 5.2 Harvesting Equipment and Layout Considerations

Figure 5.2-1

We can develop complex partial cutting prescriptions, but is it practical to harvest them? Clearcutting was favoured in the past because it was cheaper and easier. Many of the skills necessary for safe, efficient, and successful partial cutting were not widely known or practiced. Slowly these skills are being developed with tried and tested equipment, and many new types of equipment and techniques are emerging to effectively deal with the current partial cutting challenges.

It is critical that a prescriber be aware of the range of equipment and methodologies available to implement a prescription. It is also critical that layout and supervision be applied effectively, without having to learn everything from your own mistakes.

This section gives prescription writers a background knowledge on the range of harvesting systems and how these can be applied in the range of partial cutting applications. Direction is also provided for cutblock layout with many tips included that have been gleaned from many experienced sources. The most effective and efficient applications of equipment in various situations are also suggested.

Note: This document will focus on partial cutting and harvesting equipment.

→ **See** *Harvesting Systems and Equipment in British Columbia* (1999) (http://www.for.gov.bc.ca/hfd/pubs/Docs/Sil/Sil468.htm) for a more detailed discussion on harvesting equipment options in BC.

The equipment names or brands listed in this section do not imply a sole endorsement of the product. They are listed to provide a reference or illustration of the harvesting method.

In this section we will…

- Review the range of common harvesting equipment and systems available for partial cutting.
- Examine the advantages and limitations of equipment under different partial cutting conditions.
- Review layout steps and considerations for the range of harvesting systems.
- Investigate common tips to avoid problems in operations.

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Choice of Harvesting System for Partial Cutting

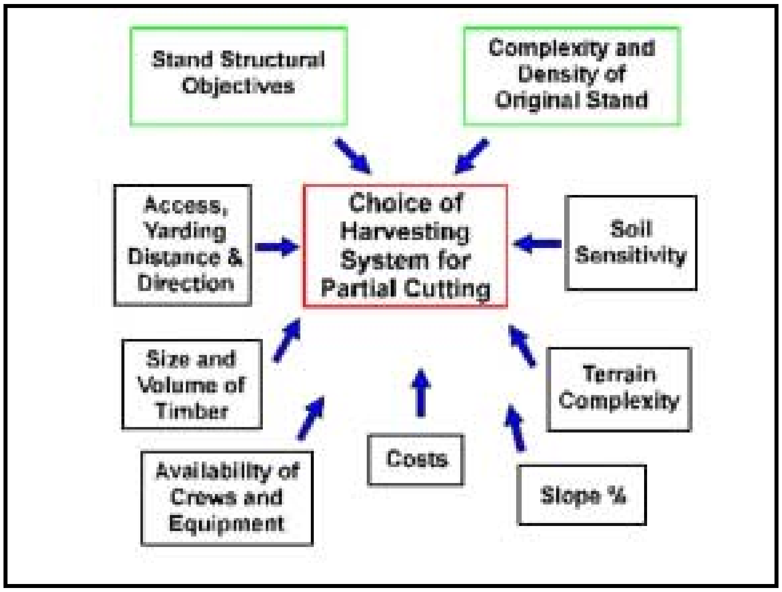


Figure 5.2-2

The choice of harvesting system, even when clearcutting, has always been influenced by:

- size and volume of timber to be harvested
- availability of equipment and crews
- access opportunities/yarding distance and direction (up or downhill)
- complexity of terrain
- slope
- soil sensitivity
- cost
- legal requirements.

Partial cutting adds more complexity to the harvesting system decision by adding the following considerations:

- Stand structural objectives (e.g., leave-tree characteristics and distributions at each harvesting entry, requirements to protect regeneration).
- Complexity and density of original stand structure (because it is within this stand that you will have to operate—at least initially).

This section reviews the various types of equipment used for partial cutting by detailing their specific application to partial cutting and some considerations for their use.

Overview of Common Harvesting Systems

Ground-based Systems

Harvesting system	Original stand structure	Desired stand structure	Suitable terrain types	Suitable slope (%)	Soil conservation comments	Skidding/ Forwarding distance	Skidding/ Forwarding trail arrangement	Other considerations
1. Handfall/ Ground skidding	**All structures** – including old growth. Depends on size and type of machine for skidding.	**All structures** – when a line skidding winch is used.	Even to rolling.	<40% (downhill) Over 40% may be possible – must fit with machine specs.	Designated trails should be pre-located. Machines must avoid wet ground. Machines must stay on designated trails.	<400 m is reported as best. Up to or >600 m may reduce roads and landings.	Flexible. Spacing is usually 30–40 m.	Best if timber felled to lead. Random/dispersed skidding has some limitations. Uphill skidding is limited. Considerable skill and care may be required to minimize dispersed leave-tree damage.
2. Feller-buncher/ Ground skidding	**Up to medium-sized timber.**[a] <50 cm dsh.[b] <35 m tall.	**Uniform/Dispersed** – only if leave-trees widely spaced or numerous wide corridors are acceptable. **Group/Strip removal/Retention** – well suited.	Even to rolling. Limited on broken ground.	<35% (downhill). <50% with a self-levelling undercarriage (but will be limited by method of forwarding).	Must avoid wet ground totally with machine tracks (unless rubber mats or puncheon used). Avoid broken ground.	See # 1.	Flexible. Must be wide enough for excavator to operate properly.	High purchase price. Readily available. Often used with grapple skidders/ crawlers to forward efficiently.
3. Processor (single grip)/ Forwarder combo	**Small- to medium-sized timber.** <45 cm dsh. Up to 25 m in height (25–35 m can be done but you lose control of falling).	**All structures**	Even (to gently rolling).	<30% (downhill).	High density of forwarder roads. Slash mat may reduce compaction. Compaction/ruts generally minor on secondary trails. Forwarding with excavators or other equipment may reduce disturbance.	1000+ m.	Flexible. Spacing is 15–20 m for secondary trails which are usually low impact. Higher impact main trails are few and farther apart.	Very high purchase price. Very high training requirement. Harvester/forwarder combos availablility. Felling processing head can be fitted to excavators. Self-levelling undercarriage may allow for steeper slopes.

[a] Small timber: <30 cm dbh; Medium timber: 30–60 cm dbh; Large timber: >60 cm dbh.
[b] dsh – diameter at stump height.

Harvesting system	Original stand structure	Desired stand structure	Suitable terrain types	Suitable slope (%)	Soil conservation comments	Skidding/ Forwarding distance	Skidding/ Forwarding trail arrangement	Other considerations
4. Excavator forwarding	**All structures** – including old growth. Depends on size of machine.	**All structures** in second growth or small- to medium-sized timber. **Open uniform/ dispersed** structures are difficult in high volume old-growth stands (leave-tree damage).	Even to rolling.	<35%	Can use rubber mats or self-constructed corduroy or puncheon to operate on wet ground.	<200 m. <150 m in old growth.	Flexible. Up to 15–20 m wide.	Narrow main skid trails used when bunched timber is forwarded by a grapple skidder. May be used with a grapple yarder. Wide trails may be needed to move the required volumes in old growth.
5. Horse logging	**Small- to medium-sized timber only.** <60 cm dbh.	**All structures** Especially well suited for light removal in with dense dispersed leave-trees.	Even to gently rolling.	Gentle (downhill) <30%. Light snow cover helps. Can handle short steep pitches (even over 50%).	Generally even main horse trails have low impacts. Total displacement usually is 1% or less.	200–300 m is possible. Generally best at or close to 100 m.	Flexible – generally noticeable trails are very widely spaced.	With very low production at less than one load/day, this system is generally reserved for special circumstances, like high residual densities, sensitive soils, or removal cuts where regen is to be protected. Often used with a machine for forwarding along main trails.

Cable and Aerial Systems

Harvesting system	Original stand structure	Desired stand structure	Suitable terrain types	Suitable slope (%)	Soil conservation comments	Yarding distance	Yarding corridor arrangement	Other considerations
Standing skyline – small tower with SP[c] carriage	**Small- to medium-sized timber.** Most stand types in the Interior (except largest timber). Commercial thin – coastal second growth.	**All structures**	Slope only limited by felling and bucking logis-tics and safety concerns. Uphill yarding is best – road location is key.	≥60%.	Few concerns with adequate deflection.	200–300 m. Some models are capable of 300+ m. Lateral yarding[d] of 20–30 m is possible.	Parallel corridors.	8–12 m towers (Mini-Alp, Skylead C40, Koller K501, etc). Must have deflection – backspar or mid-span spars can help. Full suspension (or close to it) may be possible. 2–4 guylines – set-up and road changes are quick.
Standing skyline – medium-sized tower with SP carriage	**Medium- to large-sized timber.** Limited on larger timber by size of lines.	**All structures**	Slope only limited by felling and bucking logis-tics and safety concerns. Uphill yarding is best – road location is a consideration.	≥60%.	Few concerns with adequate deflection.	200–300 m. Some models are capable of 300+ m. Lateral yarding of 30–40 m is possible.	Parallel corridors.	14–22 m towers (Madill 071, 171 or 172 size) or equivalent-sized swing yarders when rigged as a standing skyline). Must have deflection – backspar or mid-span spars can help. Full suspension or close to it may be possible. 4–6 guylines – set-up and road changes are still relatively quick.
Standing skyline – large tower with SP carriage	**All structures –** including large coastal old growth.	**All structures**	Slope only limited by felling and bucking logis-tics and safety concerns. Uphill yarding is best – road location is key.	≥60%.	Few concerns with adequate deflection.	Can long-line up to 1500 m or more. Can laterally yard up to 80 m, but 30–50 m is preferred.	Radiating corridors due to large landing size required and set-up time (6–8 guylines).	27–30 m towers. Must have deflection – backspar or mid-span spars can help. Full suspension possible. 6–8 guylines and large landings required; set-up and road changes are slow.

[c] SP = slackpulling carriage – which allows for lateral yarding but also assists in paying out mainline or dropline slack, assisting ground crews in lateral outhauls.

[d] Lateral yarding will also be determined by the specific type of carriage. It may be influenced by the weight of the line and deflection – especially with simple dropline carriages (commonly used with running skylines).

Harvesting system	Original stand structure	Desired stand structure	Suitable terrain types	Suitable slope (%)	Soil conservation comments	Yarding distance	Yarding corridor arrangement	Other considerations
Wyssen skyline	**All structures –** including large coastal old growth.	**All structures**	Slope only limited by felling and bucking logis-tics and safety concerns. Well suited for downhill yarding – requires a road at the bottom. Yarding distance allows lots of flexibility.	60%+.	Virtually none – generally use full suspension. Landings can be fairly small (generally on the road).	Up to 2000 m or more. Can laterally yard up to 110 m.	Parallel.	Often yards with full suspension. Must have deflection – backspar or mid-span spars can help. Must rig a headspar. Often used with intermediate spars. Yarder sits at top of block and lowers load. Yarder moves and corridor changes are very slow (use helicopter or yarder's own winch).
Yarding crane with grapple	**All structures –** including large coastal old growth, depending on yarder size.	**Very open dispersed trees and clumps or cleared strips and groups,** when used on its own. **All structures** when used with other equipment to forward to corridors.	More complex terrain may allow set-ups along a road to angle.	Likely <45%. Depends on other equip.	Few concerns with adequate deflection. Roadside logging – very small landings required.	200–300 m. No lateral yarding. Limited to forwarding bunches brought to a main corridor.	Parallel.	Yarding cranes (or swing yarders). Limited generally to partial suspension. Usually other equipment used to forward to corridors. Good control over logs and good inhaul speed with interlocked mainline/ haulback drums on swing yarders. Readily available (especially on coast).
Yarding crane with running skyline and SP carriage	**All structures –** including large coastal old growth, depending on yarder size and safety issues.	**All structures**	Slope only limited by felling and bucking safety and logistics. Uphill yarding is best – road location is a consideration	60%+. Limited to <30% if down-hill yarding.	Few concerns with adequate deflection. Roadside logging – very small landings required.	200–300 m. Lateral yarding of up to 30 m.	Parallel.	Yarding cranes (or swing yarders). Limited generally to partial suspension. Good control over the carriage and logs, and good inhaul speed with interlocked mainline/haulback drums on swing yarders. Lots of potential where adequate roading is available.

Harvesting system	Original stand structure	Desired stand structure	Suitable terrain types	Suitable slope (%)	Soil conservation comments	Yarding distance	Yarding corridor arrangement	Other considerations
Helicopter yarding	**All structures –** including large coastal old growth, depending on helicopter size.	**All structures** Must have openings in canopy large enough to spot hooktender and pull trees safely out of the stand.	Virtually no limits. Slope only limited by felling and bucking logistics and safety concerns.	Anywhere roads are limited.	Very little. May require large landings outside block.	Optimum within 1000 m horizontal and 300 m vertical.	None required.	Safety is an issue – should work closely with WCB. Overhead hazards must be dealt with. Small openings easier than high densities of dispersed leave-trees. Falling as critical as in skyline to keep total costs down. A wide range of helicopters with lift capacity ranging from 3500 to 20 000 lbs. Can be very expensive, but very fast production. Lots of logistics to keep the project running smoothly. Limited by weather (fog, high winds, etc.).

Handfalling Considerations for Partial Cutting

General Falling Considerations for Partial Cutting

Trees with Wide Crowns

- Wider crowns may lead to more hang-ups if uniform distribution of leave-trees is desired.
- Wider crowns, even where they are not interlocked, may present problems when falling to lead. They may easily deflect off other leave-trees and land in a position that is awkward for yarding.

Marking and Falling in Limb-tied Clumps

- If a stand is marked, markers should be wary of strict spacing criteria since it may be difficult to remove one tree out of a group.
- If marking or falling a small clump, it may be best to remove or leave either the entire clump, or portions on either side of the clump (falling into open spaces provided).

→ **See** Section 5.1 for more information on marking.

Dangerous Trees and Safety

→ **See** *Occupational Health and Safety Regulation* (Workers' Compensation Board 1998) and *Managing Dangerous Trees* video (BC Ministry of Forests 1998) for more information regarding dangerous trees.

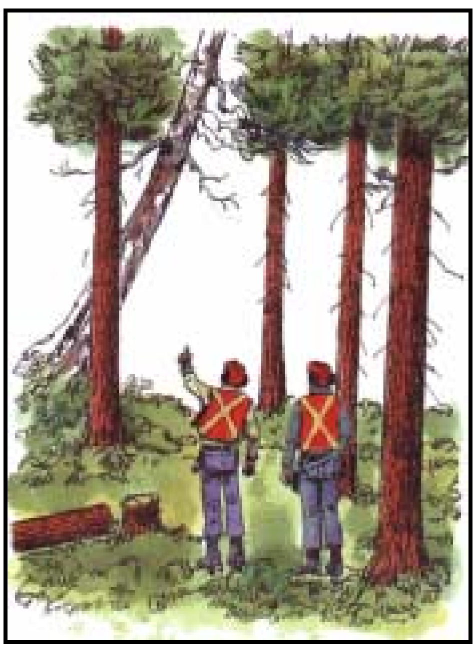


Figure 5.2-3

A dangerous tree is “any tree that is hazardous to workers because of location or lean, physical damage, overhead hazards, deterioration of the limbs, stem or root system, or a combination of these.” Some concerns that impact falling in partial cutting operations are:

- If work in a forestry operation will expose a worker to a dangerous tree, the tree must be removed.
- Trees that will interfere with rig-up or the movement of lines and equipment, or that could be pushed or pulled into the work area must be removed.
- Saplings over 6 m (20 ft) tall, in an area where cable logging is being done, must be removed before yarding begins.
  - If it is not practicable to comply with the subsection above, such as during partial cutting operations, alternative work methods or procedures that minimize the risk to workers may be used. The work must be directed by a supervisor who has, as far as practicable, controlled the danger to any worker.
- Any dangerous tree, regardless of height, located within an active hand falling or cable logging operation must not interfere with safe falling or yarding practices; if it does interfere, it must be removed.
- Falling, bucking, or limbing activities must not be undertaken in an area made hazardous by a leaning dangerous tree, or a dangerous tree that has been brushed by a felled tree, until the dangerous tree has been felled.

Until now, a great deal of emphasis for overhead falling hazards was placed on dead trees or snags. In the past, a maximum size of snag was applied as guidance over what could be left and what must be felled. Now the focus has shifted onto what is dangerous. Each snag and dead-topped tree will be judged on its own merits using criteria set for wildlife/danger tree assessment. This means that some snags over 5 m may be acceptable, and some even less than 3 m could be deemed dangerous depending on the equipment and workers on the ground. If a tree is deemed dangerous by either a faller or a danger-tree assessor, it will have to be dealt with—either felled, or buffered with no-work zones so it is no longer a hazard.

Note: Ensure that the latest WCB regulations are being followed.

Question: *How do high numbers of dangerous trees impact the choice of silvicultural system?*

If numerous dangerous trees occur throughout the block, a uniform distribution of leave-trees increases the difficulty and hazard associated with falling these trees. Grouped leave-trees or group removal is advantageous for reserving snags on site and reducing falling hazards if many snags are scattered throughout. When either the silvicultural system or the harvesting system makes dealing with dangerous trees difficult on a block, work closely with WCB and the fallers during the planning stage to ensure the safety of all those concerned.

Falling in Large Old-growth Timber

General Considerations

- Often there is no consistent lean to the timber. It may be extremely difficult to get the trees to go where you want. This also makes it very difficult to open a face in small openings as in group selection or patch cuts. Wedges will only work up to a point and jacking can be done for a few very large trees, but it gets expensive if it must be done too often.
- There are highly variable sizes of wood. On the coast, trees can be as large as 1 to 2 m at the butt. These trees require lots of work to fall them simply to minimize breakage, let alone to get them in a particular lead to a trail.
- These stands will have more snags to fall beforehand to produce a safe working area for the faller.
- Where you are trying to leave a range of sizes, with some smaller stems (intermediate size classes), clumps of these trees close to larger leave-trees are probably good candidates. Scattered uniformly distributed smaller individuals will have a high potential for damage where larger trees all around them must come out.

Safety Issues

Old-growth stands usually mean more limb hang-ups and broken tops. While individual trees may not themselves be deemed dangerous, if fallers are asked to fall among many leave-trees, the potential for brushing of timber dramatically increases. From a safety perspective, excessive brushing of timber must be avoided to minimize the potential of limb hang-ups or breakage of tops.

→ **See** *The Partial Cutting Safety Handbook* (BC Ministry of Forests 1997) for more information on safe felling techniques.

With small patch cuts or group selection, it may become physically impossible to have two fallers working in one patch. WCB requires the use of the buddy system for fallers to check on each other periodically. One person working alone in an opening is unacceptable, unless other arrangements can be made to have someone nearby checking on them. You therefore need either someone sitting by roadside keeping an eye on the faller, or some other means of communication. A suggested approach is to use hand-held radios, and have fallers using a buddy system—within easy access of other fallers in adjacent openings.

Some fallers may put speakers inside their earmuffs if they have a problem hearing the radio over the saw. One person in the crew takes responsibility for three to four others. Every faller calls in each time they stop to refuel or file the saw, and the person responsible for the crew will monitor these call-ins to check on any abnormal delays. Check with your local WCB representative for more information.

Summary: Advantages and Disadvantages of Handfalling for Partial Cutting

Relative to mechanical falling, handfalling has some advantages and disadvantages for partial cutting.

Advantages

- The main advantage is that handfallers are more mobile and can access timber that would be difficult or impossible to reach with mechanical methods.
- Handfallers have a better opportunity to examine and assess each tree for the characteristics desired for potential leave-trees (better than an operator in the cab of a machine).

Disadvantages

- Handfallers are exposed to a much greater risk of injury from overhead hazards. The greatest concern is “brushing of timber”—breaking limbs and tops in the process. Each tree felled in a dispersed leave-tree pattern requires the same thought process and considerations that a faller makes when he opens up a face—generally considered one of the most dangerous falling phases. Handfalling safety concerns increase with the size and age of the timber. Large old growth can be difficult to fall if high densities of dispersed leave-trees must be left.
- Handfallers have less control over where they put the timber than with mechanical falling. Falling “out of lead,” or with an inappropriate orientation for the extraction route or method, can substantially increase the costs of skidding or yarding.

Conventional Ground Skidding

Figure 5.2-4
Skidding in shelterwood.

General Considerations

Ground skidding is most feasible on slopes up to 40%. This depends on:

- terrain (benches or ridges?)
- snowpack
- allowable skid road sidecut
- equipment size.

Skid roads are generally required where side slopes exceed 30% unless you are going straight downhill, which may be allowed by WCB, depending on the manufacturer'specifications. Soils must have good bearing strength or climatic conditions must include a period of frozen soils or compressible snow greater than 1 m deep.

Remember the basics:

- Operations may be suspended during periods of heavy or prolonged rain.
- Skidding should be favorable as much as possible.
- Location of the primary road network is critical.

Ground Skidding Patterns—Dispersed/“Random”

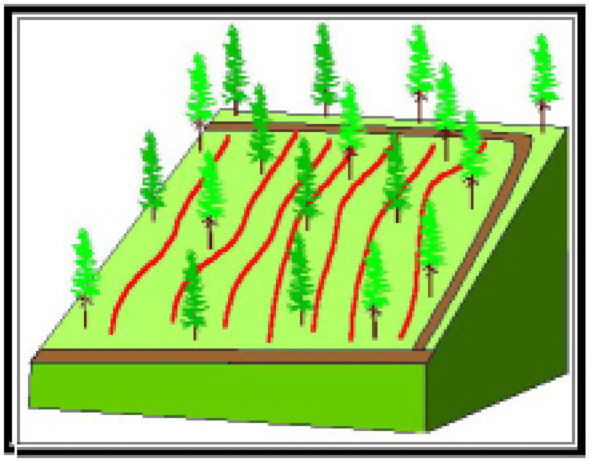


Figure 5.2-5

Advantages

- Possibly less deep disturbance, but this depends on soil and number of passes over the same ground. Topping (tree length) at stump may help since you will skid on branches, although this may require site preparation.
- On steep slopes, dispersed skidding downhill with one main go-back trail may create less soil disturbance than designated trails.

Limitations

- Random skidding has a greater potential to disturb root systems and damage more leave-trees than with designated trails (especially dense, uniformly distributed, shallowly rooted leave-trees).
- May create some compaction over an extensive area (increased bulk density and decreased large pore size). Consider moisture, texture, coarse fragments, and organic matter content of the soil.
- Remember that most studies indicate that significant compaction can occur on most mineral soils even after only two passes (unless dry, frozen, or covered with snow).

Random skidding can only be used when:

- Removal cutting will be done with understorey seedlings well protected by snowpack.
- No removal cutting is planned in the future and windthrow is not a concern (otherwise you may have to build trail to minimize regeneration damage during future entries, and this may be easier when you can see the ground).

Appropriate Types of Leave-tree Patterns

Uniformly distributed leave-trees

- With gentle ground and open, widely spaced leave-trees.
- A grapple skidder works very well in these situations.

Grouped leave-trees and group removal

- In all slope/terrain situations where other factors (e.g., soil) are not limiting because it is easier to miss the leave-groups with the equipment.

Soil Conservation Considerations

Dispersed patterns could increase or decrease potentially detrimental disturbance concerns depending on factors such as soil, coarse fragment content, and parent material. If skidding can be done on a compressible snowpack or a significant slash layer, soil compaction can be minimized. Processing, or partially processing (i.e., topping, limbing) the log on the trails may help to minimize soil disturbance.

Ground Skidding Patterns—Designated Trails

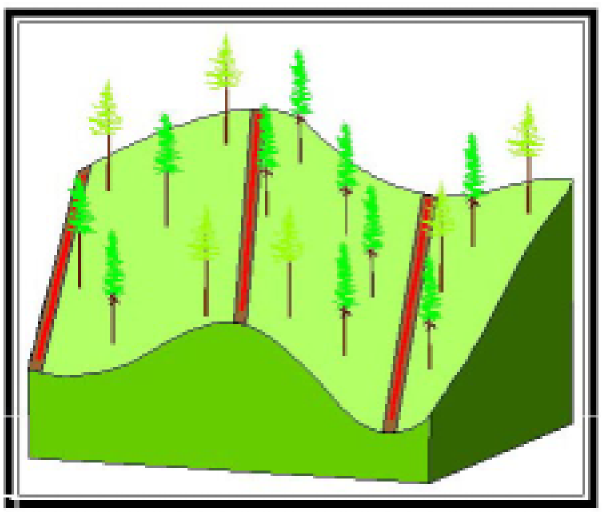


Figure 5.2-6

Advantages

- May allow for less overall soil disturbance, if disturbance is concentrated only on permanent trails that will be used for all subsequent entries.
- Depend on spacing and density of trails.
- Allows for protection of understorey seedlings from machine damage during removal cuttings (skidding damage is still possible).

Limitations

- Detrimental disturbance from skid trails (unless skidding can be accomplished on snowpack). These trails are often considered permanent when multiple entries are used. Also, rehabilitation options may be limited where tilling or ripping is restricted to protect leave-tree root systems.
- Even if this harvesting disturbance falls within provincial guidelines, it will limit future disturbance from mechanical site preparation.

→ **See** *Soil Conservation Guidebook* (BC Ministry of Forests 1995) for more information regarding soil disturbance and mechanical site preparation.

Designated trails should be included as part of the permanent access network in the prescription if future access for a harvesting entry is required in a relatively short time frame.

→ **See** Section 3.2 for more information on setting soil conservation standards.

- Generally, there is a greater requirement to pull winchline, slowing production.
- Grapple skidders will require some method for getting wood to the skidder on the trail.

Considerations to Minimize Damage from Designated Trails

General Considerations to Minimize Damage to Regeneration

1. If possible, conduct removal cuttings on snowpack.
   - To protect soil and regeneration.
   - Preferably later in the season when the snow has set up a bit.
2. Conduct removal cuttings while understorey is <1 m tall.
   - Taller regeneration tends to have more damage (snow or no snow).
   - Seedlings survive best because they have established root systems, well-developed crowns, and flexible stems that can withstand considerable abuse.
   - If regeneration is >1 m tall and the snowpack cannot provide protection, log in the summer/autumn rather than the winter when frozen stems are brittle and break easily. Generally, greater damage will still be incurred.

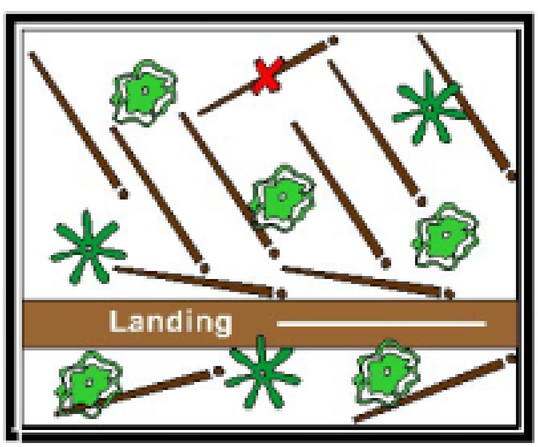


Figure 5.2-7

Considerations for Minimizing Damage to Both Leave-trees and Regeneration

1. Fall to lead.
   - "Falling to lead" in a herringbone pattern is the optimum for harvesting. The faller will cut the trails first so he has something to aim at while attempting to fall to lead. The trees will be felled in line with the direction that they will be skidded. The faller MUST know the lean of the timber and it MUST be favourable or considerable work will be required by the faller. The faller may need to use wedges or a jack and more time and effort to properly fall to lead. Logs can generally be either butt- or top-skidded and the faller will make his decision based on lean and location between trails.

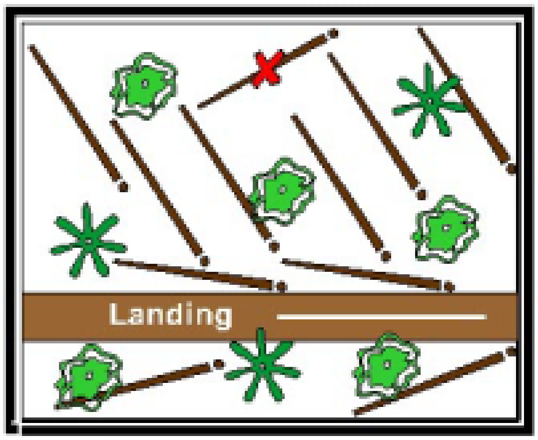


Figure 5.2-8

2. Maximize skid trail spacing by pulling winchline.
   - The average amount of line that a person can physically handle with a common winch allows for 30–40 m spacing on gentle terrain. This spacing can be increased with more specialized winches that improve the ease with which line can be pulled from the winch.
   - Proper landing location is critical!

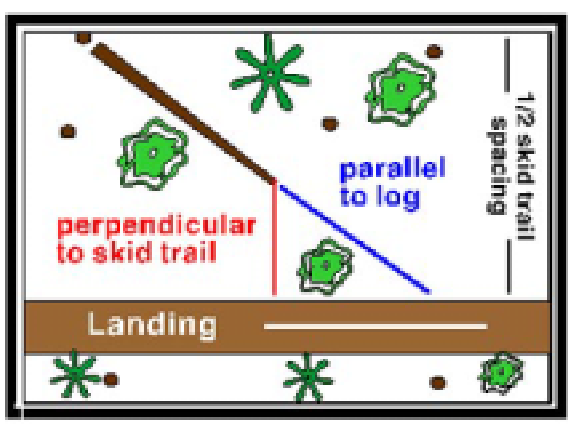


Figure 5.2-9

3. Keep trails as straight as possible.
   - Minimize hang-ups on rub trees/stumps.
   - Minimize excessive damage on leave-trees.

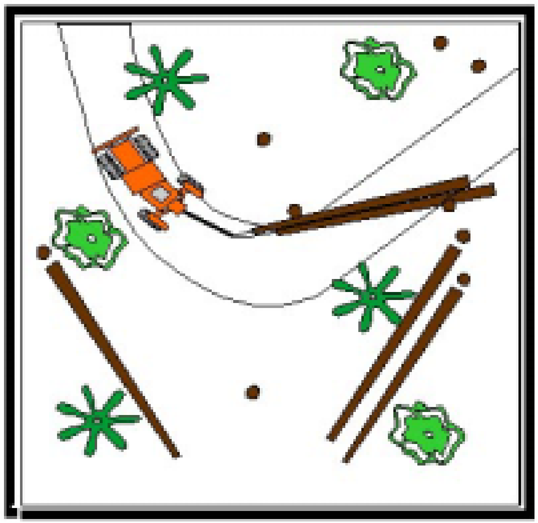


Figure 5.2-10

4. Protect scattered vulnerable leave-trees with barriers
   - Strategically located rub trees or rub stumps (high stumps). Make sure that you have a rub tree or rub stump use and removal strategy in place BEFORE the loggers get going. Rub trees should be only rubbed by a turn of logs, not jarred so that they become unstable or that tops and branches are dislodged. In some instances, WCB prefers rub stumps for safety; however, the waste and residue concerns should be discussed upfront.
   - A section of culvert (corrugated plastic is best) or large plastic commercial food drums cut in half can be custom designed with quick-release fasteners in back.
   - A turn of logs, slash, stumps, or other logging debris.

→ **See** *Partial Cutting Safety Handbook* (BC Ministry of Forests 1997) for more information on layout and safety.

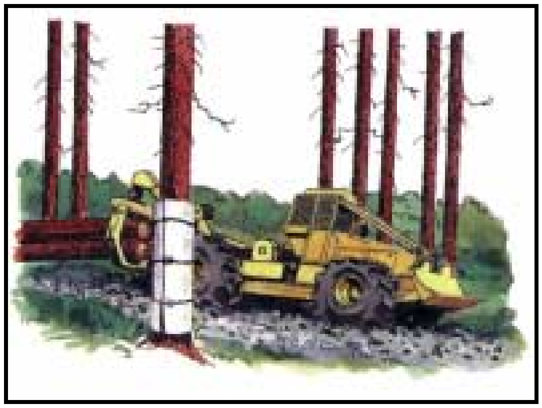


Figure 5.2-11

5. Position the skidding machine to pull line straight to the log.
   - Winching from the side will cause machine instability and cause the logs to swing, possibly damaging more regeneration.
6. Branch trails should enter the main trail at 35 degrees (optimum).
   - Greater angles will result in greater damage to regeneration in the inside of the turn when long logs are skidded around corners during removal cuttings.
7. Stagger branch intersections along main trail. Use high "rubbing stumps" on inside corners.
   - Assists in straightening the load and helps avoid swinging the logs over the regeneration in removal cuttings.
8. Consider stage felling or hot logging.
   - With stage felling, only a portion of the overstorey is felled, bucked, and skidded at one time. Fallers then return to the same area to put another "stage" on the ground.
   - Stage or hot logging usually results in less damage to understorey regeneration during removal cutting. Overstorey trees can be used as rub trees and then removed at the end of the removal cut.
   - Most observations of stage falling suggest that a first stage removal of about 40% of the timber marked for removal will normally open up enough area to allow the rest of the marked timber to be removed.
   - Hot logging involves one faller working with one or two skidding machines to move progressively through the unit.
   - It is generally easier for fallers in partial cutting systems to have the material removed as it accumulates, although it may slow falling and increase costs as fallers wait for a stage to be skidded.

Special Considerations for Group Selection

Figure 5.2-12

1. Design, lay out, and construct entire forwarding road network to access the entire unit over time, as with other partial cutting systems.
   - These will be permanent trails since they will be used in future passes.
   - There is no need to have a haul road to each opening; instead locate landings strategically in several groups and long-skid between groups to central landings.
   - The landings can also be used in future passes.
   - There should not be more area lost to trails and landings than with a clearcut.
   - You should consider where the future openings will be located, since logging chance and windthrow, for example, will become factors. However, it is not practical to plan on paper all openings and all passes initially in larger blocks, since you may have over 100 small openings. In small group selection units a total chance (all groups) paper plan may be useful.

→ **See** Section 3.7 for more information on paper plans and mapping for group selection.

2. Avoid round-shaped openings.
   - Unless mechanical harvesters are used, it is tough to fall-to-lead since fallers cannot develop a "face."
   - Better to use rectangular or teardrop-shaped openings (with tapered end at the exit).
   - Need to consider the location of future entry openings.

Horse Logging

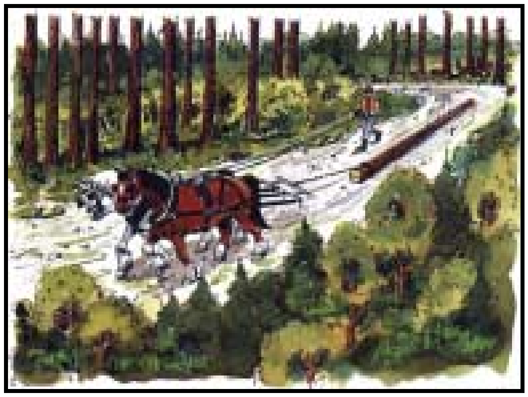


Figure 5.2-13

General Considerations

1. Usually skid log length to meet load restrictions.
   - This will depend on the grade, skidding surface (friction), and the size and number of horses used.
   - Will have to lop and scatter slash to keep it manageable for the animals.
2. Must have favourable grade.
   - Must be careful to avoid areas too steep such that logs slide into animals while skidding.
   - Generally, the maximum continuous slope of horse trails is 25–30%. Beyond this it may become tough for the horses to climb back up the hill empty. Short pitches even over 40% may be acceptable.
3. Light snow cover is preferred, but it is tricky to get the right conditions.
   - Snow has less friction; however, logging will only work on gentle slopes.
   - Snow cover must be light – excessive snow will slow and eventually shut down the operation.
4. Maximum skidding distance is on average about 100 m.
   - May use horses to skid to main trails and a machine (grapple skidder, or small tractor) to forward to landings from there.
5. Best to use an existing road (to avoid added costs).
6. Avoid the following areas.
   - Very heavy understorey.
   - High volume of dead and downed wood.

- Dense lower branches (as on Cw). Horses can sustain eye injuries slowing production.
- Situations where higher production is required (horse production is limited to 20–25 m^3/day).

Mechanical Falling—Fellerbunchers

Figure 5.2-14

Advantages of Fellerbunchers

1. ***Fast***—better production in falling.
2. ***Safe*** (worker is protected by cab). When combined with a grapple skidder, only two workers are onsite (away from landing) and both rarely touch the logs.
3. ***More control over falling.***
   - May cause less damage to leave-trees since the buncher can direct stems. This depends on the size of the tree. Occasional diameters over 50 cm dsh can be felled, but require several cuts. Tall timber can be problematic for smaller bunchers to directionally fell.
   - Has been used to create potential wildlife "stub trees" up to 5 m tall for cavity-nesting birds. These trees are limited for nesting and often used more by woodpeckers for foraging. Stub trees may play a dual role as a rub stump.

Limitations of Fellerbunchers

1. Stem size.
   - Most machines have a maximum size of 40–50 cm dsh for single-cut falling.
2. Accessible ground.
   - Machine must come very close to each tree cut (3–5 m).
   - Windfalls, boulders, "rough ground" make operating more difficult, if not impossible.
   - Wet depressions, gullies, and compactible soils must be avoided.
   - Excessive slopes can limit access.
     - 25–30% is the limit for normal bunchers.
     - Up to 40% for self-levelling fellerbunchers. Extra caution will be needed to ensure stability at 40–50% (not recommended over 50%). Steep-slope fellerbunchers may also be limited by the ability of the skidder or forwarder to negotiate the terrain.

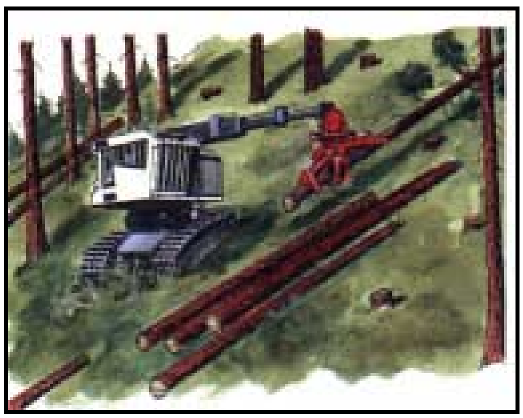


Figure 5.2-15

3. Requirement for wide-movement corridors.
   - These machines need room to swing a load of harvested trees so that they can be placed on the ground for skidding. This may require 6–8 m cleared radius from the machine centre.

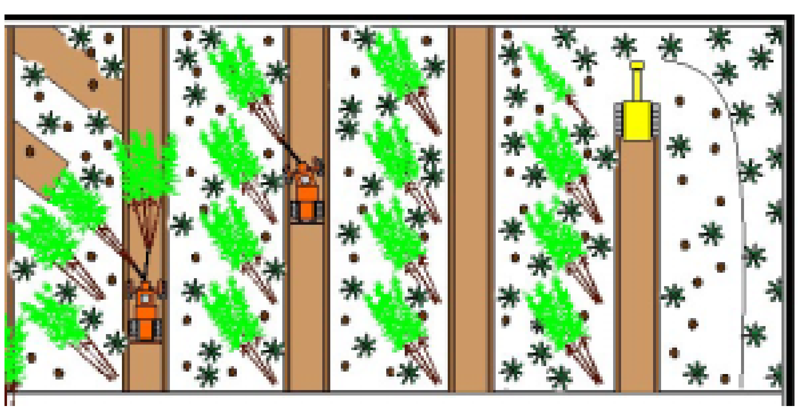


Figure 5.2-16

- Smaller excavators may require less clearance. Also, some machines are built with the boom extending from the back out over the cab to give a better centre of gravity, slimmer profile, and a lower requirement for clearance around the machine.

4. Limited reach from movement corridors.
   - Depending on the machine, up to 6 m.
     - Movement corridors must be close together (6–10 m), or the machine must leave the corridor, drive to the timber to be felled, and then back up to the corridor to place the timber on the ground for skidding.
5. Limited visibility for upper portions of tree.
   - Compared with handfalling. Premarking may be an option, but is rarely done due to cost, especially in small timber with marginal economics.

Appropriate Types of Leave-tree Patterns

1. Uniformly distributed leave-trees.
   - Limited applications:
     - Entire block must be accessible for machine movement.
     - May be suitable only for the initial entry. For future removal cuttings, this machine may impact too much of the area and damage too much regeneration.
2. Grouped leave-trees or group removal.
   - Well suited:
     - As long as it can operate in clearings between timber.
     - May be used for removal cuttings if machine can operate on protective snow cover.

Excavator Forwarding

With excavator forwarding, felled (and usually bucked) timber is forwarded to a roadside landing area through the use of an excavator-type machine. The machine works through a cutblock systematically to efficiently move the wood cumulatively from the back of the block to the roadside or a trail.

Requirements

- A swivel grapple attachment for grasping and moving logs.
- A heel or knuckle is often attached to the boom to facilitate easier handling and loading of logs. Clambuckets have been used, with the advantage of being versatile enough for ditch clearing and other maintenance activities.
- In old-growth timber on the coast, they use large machines capable of reaching 13–14+ m (e.g., Thunderbird 1146 and Cypress 182-C). In smaller second-growth stands, a medium-sized excavator may be used.
- Ground clearance is a concern. The amount required will depend on the types of stands you work in and stump height. Large coastal machines operating in old growth may have over 80-cm clearance. Fallers should be aware of the clearance of the machines—they may have to recut the stumps to facilitate forwarding.

- Floatation—the amount needed depends on the type of ground you are operating on. You can get longer and wider tracks. Other options include using puncheon (from logging debris), or mats that are especially suitable if on wet or sensitive ground.
- WCB requires roll-over protective structure (ROPS) *and* falling object protective structure (FOPS). A high profile cab may be used for a better view.

Patterns for Excavator Forwarding

Two basic patterns are used for excavator forwarding. Numerous variations on these two themes are possible to deal with specific terrain and stand conditions.

Serpentine (Typical Hoe Chucking)

The machine starts by moving to the back of the block by creating a pathway of wood towards the inside of the block. Once at the back of the block, they move along the inside of the block boundary, taking the wood in front and piling it to the inside of the machine (toward the roadside landing area). Once this has been done along a strip the entire length of the back boundary, the machine pivots around the end of the resulting log deck to its inside edge and begins the serpentine motion.

Figure 5.2-17

Now the machine moves along a new strip on the inside of the existing linear log deck, first decking felled-and-bucked in front of it to the inside of the machine, and then moving the wood previously decked on the outside of the machine to the inside deck. In this manner, the machine works back and forth through the opening in a serpentine pattern, eventually resulting in one very large linear deck at roadside.

Best applications

- Good for openings—group selection, patch cuts, larger openings around groups of leave-trees.
- More difficult where uniform leave-trees or numerous clumps are required.

The Up and Down Method

With this method, the hoe works up and down parallel pathways that run perpendicular from the roadside landing area. The machine first works up the pathway, decking material to either side to actually create the pathway. When the machine hits the back of the block, it turns around and returns down the cleared path sequentially moving decks closer to the roadside landing area. The action is one where the wood is moved laterally on one side of the machine, rather than being moved from one side of the machine to the other, as in the serpentine method.

Hoe sliding

A variation of this method, called "hoe sliding," is used in tight, uniform distributions of leave-trees, such as commercial thinning areas or uniform shelterwoods. Also, in such leave-tree patterns, the excavator uses the up and down/sliding technique to move the wood a relatively short distance to a main skidding or forwarding corridor first. From here it may be skidded or yarded directly to a landing, or it may also be excavator-forwarded along the corridor using the up and down/sliding technique. Generally, the forwarding/skidding method used on the corridors depends on the size of the wood.

Figure 5.2-18

Advantages

- The basic equipment is readily available since many are in current use as loaders. A refit for excavator forwarding is relatively easy and inexpensive.
- This method has a lower environmental impact than skidding, since the number of passes on a given trail is minimal at one to two passes. Also, the machine can travel over slash which reduces compaction even further. In wet areas, slash or logs may even be placed in front of the machine as puncheon to facilitate travel and minimize soil damage.
- On suitable terrain, this option may be cheaper than all other methods. Forest Engineering Research Institute of Canada (FERIC) studies show hoe forwarding in clearcuts on suitable terrain on the coast can be the least-cost harvesting option.
- May actually reduce the amount of area in main skid trails if used in tandem with a secondary forwarding machine (like a grapple skidder). The excavator will forward to

main trails, which may be 60–80 m apart. The drawback is that more area will be impacted by the hoe between the skid trails, although this can be reduced as described previously with an adequate slash mat.

Limitations

- Skidding distance when using excavators alone is generally limited in clearcuts to 200 m maximum (often less). A rule of thumb is six tree lengths. Beyond this distance the volume in the cumulative decks becomes too much to handle.
- May need more roading (over the landscape) due to limitations on skidding distance if a secondary forwarder is not used in tandem with the hoe (see previous "Advantages").
- Continuous slopes over 30% are limiting (excluding short pitches that may be dealt with by working from the bottom and the top.)
- The machine travels over much of the block impacting a large area. Impacts can be minimized through proper use of puncheon, rubber mats, and slash in general. Proper applications generally have low impact.
- Open, uniform leave-tree patterns may sustain more damage to leave-trees in high-volume stands (this is especially true with the serpentine method). Much more wood must be moved, thereby providing more opportunities to damage leave-trees. Excavator forwarding in open leave-tree patterns will likely have more success protecting leave-trees in second growth than in high-volume, old-growth stands.

General Considerations

Old Growth

- Size of wood is not a big problem—large coastal old growth can be forwarded but you must use a large machine.
- In uniform leave-tree patterns, if the hoe is on site during falling (perhaps forwarding a portion of the block already felled), the faller may be able to periodically call in the hoe to clean out yarding corridors to minimize breakage within the corridors.
- It may be easier to deal with wetter ground in old growth than in second growth since there will be lots of broken material or old coarse woody debris that can be used to build puncheon (pile in front on the machine to move forward on and minimize ground impact).

Patch Cuts and Group Selection Openings

- This method is well suited to forwarding small openings.
- As in clearcuts, these small units are generally felled before excavator forwarding. Supersnorkel loaders may even be used on the coast to yard the last 50 m to roadside.

Dense Uniform Leave-trees

These conditions occur in shelterwoods, commercial thinning, and dispersed retention, for example.

In old growth

- Logs must be bucked and the hoe must move off the forwarding corridors or trails to forward the wood. It is usually difficult to fall to lead due to differential lean on timber and the large size of timber, which contributes to excessive leave-tree damage if forwarded tree length.

- Major forwarding corridors must be planned and logged to allow for rapid forwarding. These do not necessarily have to be straight for excavator forwarding. They must, however, be wide enough for the machine to operate with the accumulating volumes.
- The excavator uses hoe-sliding along and between corridors to forward wood to the major corridors.
- Even where deflection is possible, it is likely not feasible to use a grapple yarder in old growth to yard pre-bunched wood because of the tremendous volumes. It is not possible to pre-bunch and yard at the same time, due to the safety issues involved with having excavators working closely to a cable machine.

In second growth

- Excavator forwarding is a preferred method on suitable ground on the coast. Falling can be done in a herringbone fashion to corridors. The hoe can move off very widely spaced trails to slide wood out to the main forwarding corridors.
- A grapple skidder (or a grapple crawler—perhaps an arch/grapple KMC, for example) in the corridors can be useful to increase productivity while forwarding to the roadside or landing. Also, with the grapple the forwarding corridors will be narrow and become essentially major skid trails. Grapple yarders may also be used where deflection is suitable, cumulative corridor volume is not excessive, and visibility allows the operator to move all of the volume.
- Several small excavators have been modified to also operate with a small tower and winch attached to the boom. When used with hoe-forwarding in partial cutting applications the collapsible tower allows access to more area between trails, with less impact. These excavators are relatively low cost ($100,000 to $150,000 purchase price with modifications) and can produce up to 50 m^3/day.

Mechanical Cut-to-Length Harvesting (Felling/Processing) and Forwarding

Description

This system is frequently referred to as either the *harvester-forwarder system*, the *cut-to-length logging method (CTL),* or *shortwood harvesting*. The system is ground-based, with a harvester and a forwarder operating in tandem to fell, delimb, buck, and transport merchantable wood to the roadside or landing.

Individual trees are felled, delimbed, and bucked by the tracked or rubber-tired harvester using a boom-mounted, single-grip harvesting head. An on-board computer may be able to store up to 80 or more log specifications, which allows the harvester to custom buck to a series of log grades, including a range of sawlog, pulplog, and even post and rail grades by species. The computer makes bucking decisions while the cutting/processing head measures the tree dimensions.

Tree limbs removed during processing are placed to the front of the machine, and may, if there is a sufficient volume, be used to form a mat that distributes the weight of the harvester and forwarder over a larger area and reduces contact between the machine tires and soil surface.

Figure 5.2-19

The forwarder follows behind the harvester on this slash mat, staying on designated trails. The forwarder has a self-loading arrangement, which allows it to pick up piles of logs processed and pre-bunched by the harvester. The rotating seat on the forwarder eliminates a turn-around requirement as the operator can rotate the seat after unloading its bunk to easily drive backwards along trails to the processed timber. Once the bunks are full again, the seat is rotated to its normal position for forwarding. The forwarder moves the logs, fully supported by hauling bunks, to a landing or roadside area where the wood can be loaded directly onto logging trucks by the forwarder.

Requirements

- Able to fell and process in confined spaces.
- A boom with attachments that can fell trees 5–10 m away from the machine.
- Soil disturbance is a concern; therefore operators and planners need to know the limitations of their machines.
- WCB requires roll-over protective structures (ROPs) and falling object protective structures (FOPs). A high profile cab may be used for better operator visibility.
- Work on slopes <30%.

Single-grip Harvesters Versus Double-grip

Single-grip harvesters are very manoeuverable while cutting in tight, crop tree configurations.

The single-grip harvester cuts, delimbs, and bucks the tree all through the same harvesting head located at the end of the boom. In tight stands of leave-trees this is an advantage, since the horizontal processing is not restricted by the location of a second processing head. The single-grip harvester can manipulate the cut stem around standing timber while processing the tree horizontally to minimize damage to crop trees.

Single-grip harvesters generally employ a telescoping slide boom that is easily maneuvered around tightly spaced trees, further reducing the potential damage to leave-trees.

Double-grip harvesters use a cutting head at the end of an excavator-type boom to grip and cut the tree at the base. While still in the grip of the cutting head, the stem is then turned horizontal to the ground to feed it into a second processing unit attached to the back of the harvester. The tree is gripped a second time by the processor, which delimbs and bucks the tree to computer-coded specifications.

The Harvesting Head Is the Key

The felling and processing head used on a single-grip harvester can be transferred to the boom of an excavator-type machine. While such a tracked machine may not have the manoeuverability of a harvester with a telescoping boom, larger excavators can handle larger trees when equipped with larger cutting heads. Forwarding can be accomplished with a second excavator, a larger grapple skidder, or a log forwarder, depending on the log lengths produced.

General Advantages of CTL Logging

1. **Lower cost per cubic metre** relative to other harvesting systems on favourable ground and stand conditions.
   - This is due to faster, fully mechanized equipment; very low labour requirements; fewer pieces of equipment to transport the wood from stump to dump; and computerized bucking decisions, which reduce operator decisions and waste.
2. **Possibly fewer soil impacts** compared with ground skidding on suitable sites.
   - Since the load is carried rather than skidded, no gouging of forest soils occurs between the tracks of the forwarding vehicle.
   - If enough volume of slash is processed, both the harvester and forwarder can travel on a slash mat created by processing. Also, the forwarder can carry up to half a standard highway truckload of wood at one time, significantly reducing the number of trips needed on one trail. The load is evenly distributed over all tires on the forwarder and adding a set of metal tire tracks can reduce ground pressure further.
   - Most of the nutrient pool tied up in the standing timber is left on site in the processed limbs and tops scattered evenly throughout the block.
3. **Very low damage to crop trees** can be expected.
   - This benefit is true even in high-density commercial thinning operations when compared with all other ground-based systems on comparable stands and sites.
   - Increased control of trees and logs during in-woods processing and primary transport to the landing contributes to low crop tree damage. Also, all trees are bucked at the stump to reduce piece size and to buck out defects.
4. **Higher quality logs.**
   - Computerized bucking and delimbing improve log quality.
   - Forwarding eliminates the problem of gravel, soil, and other debris becoming embedded in logs—a situation common in skidding operations. This reduces milling problems associated with such debris.

Limitations of CTL Logging

1. Low availability of equipment.
   - The technology is highly specialized and relatively new to BC. Also, most of these machines are made in Europe, although supplier representatives can be found throughout BC.

2. Requires gentle terrain.
   - The system requires slopes less than 40% with the ability to go up to 50% for short pitches. Some harvesters with self-levelling undercarriages, such as the Timbco® and Timberjack®, suggest operability up to 55%. However, the operability of the forwarder and the ability to hold the delimbed logs on the hillside still limit the system.
   - Broken and undulating terrain may significantly reduce productivity.
3. The system is restricted to relatively small timber (small- to medium-sized interior timber or coastal second growth).
   - Most felling heads cannot accommodate a stump diameter greater than 65 cm and the harvester best handles trees <25 m in height. The average diameter for best production is estimated at 20–30 cm. Larger cutting and processing heads may be fitted to excavators.
   - While forwarders with larger bunks have been used to forward logs up to 7 m in length, the most efficient piece size is 5 m. Different forwarding equipment may be used with the harvester/processor.
4. New operators may require extensive training.
   - Equipment is very complex, however, many equipment suppliers will provide training.
5. May be limited for production of some quality grades.
   - Roller teeth damage veneer stock but most harvester heads have rubber feed rollers.

Cable Yarding

Terms—A Quick Reference

Highlead Cable

A simple cable layout, that allows only partial suspension of logs and no lateral yarding. It is not useful for partial cutting, except when leaving isolated patches of timber or strips protruding from the backline.

Skyline Cable

Logs are yarded toward the landing by a carriage that is suspended and supported by a separate skyline.

True skylines

The carriage moves on a separate skyline attached to the yarding tower and a backspar.

1. Live skylines

The skyline is not a tight skyline and therefore it is raised and lowered during yarding.

Shotgun system on a live skyline – A very simple yarding system with only two lines—a mainline used as a slack skyline and a haulback used as a mainline. For the primary outhaul, the yarder uses gravity to get the carriage downhill to the next turn.

Slackline system – Similar to the shotgun except a third drum is added to the yarder for a true haulback line. This system has three yarding lines and winch-drums: skyline drum, mainline drum, and haulback drum. A fourth drum has the strawline needed for rig-up.

2. Standing skylines

The skyline is tight and static in that it is anchored at both ends and cannot be raised or lowered during the yarding cycle. The standing skyline can be operated as a two-line gravity system or with a haulback line.

Running skylines

Not a true skyline although it functions as one. The haulback line actually serves as the skyline with the carriage running on it while it is moving.

Slackpulling Carriage

This carriage provides lateral yarding capabilities.

All operate by pulling a segment of the mainline or a separate slackpulling line through the carriage, or by activating a drum inside the carriage, which lowers or releases a dropline or skidding line to which the chokers are attached.

Balloon Cable

While useful to yard long distances up to 1500 m with full suspension in clearcuts, these systems are often inappropriate for partial cutting because imprecise maneuvering and positioning of the balloon reduces control of the cables.

→ **See** MacDonald (1999) for more information on the full range of cable options in BC.

General Requirements for Cable Systems

1. Good for steep slopes >40%.
2. Lines must be free to operate.
   - Both for yarding lines and tower guylines (anchors).
   - No interference from leave-trees.
   - Guylines for the yarder must be free from overhead hazards.
3. Must have deflection.
   - Generally, the more the better.
   - Must have suitable anchor holds. Although usually not a problem on the initial entry, problems may occur on second pass, if pre-planning is insufficient.

Skyline Yarding—General Requirements for Partial Cutting

1. Good lift
   - In general, the higher the carriage, the greater the vertical lift exerted during the inhaul stage, and the greater the degree of control over the gravitational forces on the log.
   - "Good lift" will depend on the terrain, leave-tree density, and leave-tree distribution.
2. Good lateral yarding capabilities.
   - Logs are yarded across slope to a primary yarding corridor, where they are hauled straight into the landing.

Question: *What if you can't yard laterally?*

Grapple yarders are a good example of a yarder without lateral yarding capabilities. While limited in its application to partial cutting, retention of widely scattered clumps, groups, and individual trees is possible.

→ **See** "Running Skylines" in this section for more information on grapple yarders.

Types of Skyline Systems and Their Specific Application in Partial Cutting

Live Skyline Systems

Shotgun with a live skyline

Shotgun systems are simple gravity-fed "live" skylines. The mainline is used as a "slack skyline" for the carriage to ride on. The haulback is attached to the front of the carriage and used as a mainline, bringing the carriage into the landing during the primary inhaul. The shotgun carriage is simple and generally does not permit lateral yarding.

Slackline systems

A slackline system adds a third yarding drum to a simple shotgun system to include a true haulback line, allowing for outhaul on more gently sloping terrain or cross slopes. Also, a slackline system can be used for downhill yarding. A slackline system is more versatile than the shotgun; however, it is more complex to rig.

Advantages of live skyline systems

- These are relatively simple skylines may be more easily rigged than standing skylines.
- Lateral yarding may be possible on slackline systems.

Disadvantages of live skyline systems

- Less control over corridor width and leave-tree damage than a standing skyline or running skyline. For this reason they are not often used in partial cutting.
- Generally run with only partial suspension, except under rare circumstances where deflection is ideal.
- Other limitations tend to be related to the type of yarder used (see equipment for true skylines).

Standing Skyline Systems

Standing skylines, sometime called "tight skylines," differ from running skylines in that they cannot be raised or lowered during the yarding cycle; the carriage moves on a separate skyline that is anchored at both ends and cannot move. Standing skylines may use gravity for the outhaul when yarding uphill, reducing rig-up time, or a haulback can be included if the yarder has sufficient winch drums.

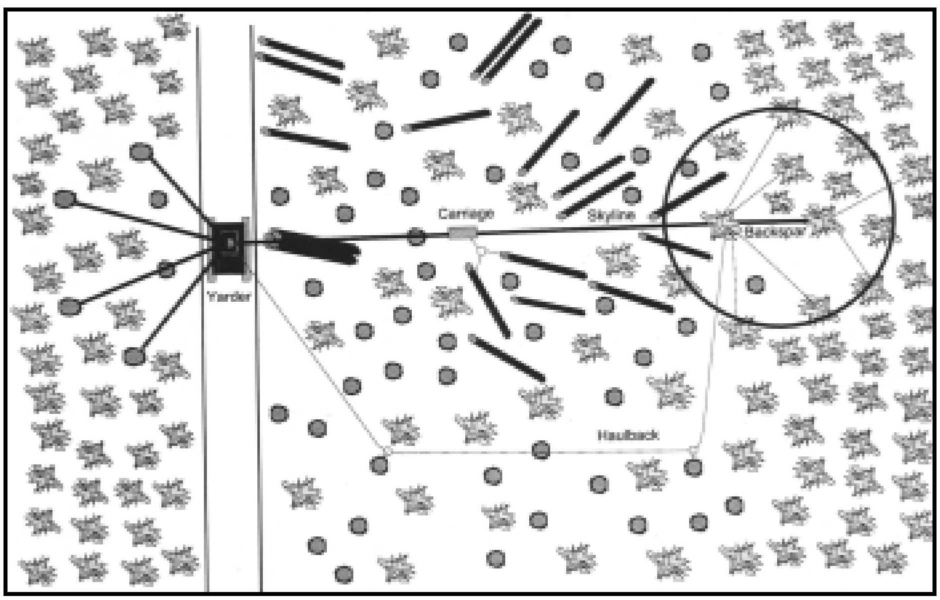


Figure 5.2-20
A typical standing skyline set-up with a haulback line.

Advantages of standing skylines

- Corridor width is more easily managed with closer to full suspension possible in partial cutting.
- The load path of the skyline remains the same for each cycle, which may help to ensure log clearance and minimize damage to leave-trees.
- Long span skylines (up to 1500 m) can be rigged in various configurations with spars at both ends, one end or not at all, depending on landing location, deflection, and anchoring opportunities.

- Intermediate or mid-span supports offer greater flexibility in yarding distances and possible set-ups in difficult terrain.

Limitations of standing skylines

- Generally more difficult to set up or change corridors than live skylines or running skylines. A tension check on the skyline may be necessary to ensure it will not be overloaded. Payload and deflection analysis is critical and may require special training.
- Other limitations tend to be related to the type of yarder used (see equipment for true skylines). Depending on the yarder, suitable tailholds and anchors can be difficult to find.

→ **See** *Cable Yarding Systems Handbook* (Workers' Compensation Board 1999) for more information on skyline tension calculations.

Types of equipment for standing skylines

Figure 5.2-21

Small towers

Small yarders (with towers 8–12 m), like the Skylead C40, the Koller K501, the Owren 400, the URUS II 600, and the Igland-Jones Mini-Alp, are operated as a live skyline or a gravity-fed, standing skyline by tightening the skyline from the tower. However, as in other standing skyline systems, a more sophisticated slackpulling carriage must be used to get the “skiddingline” or “tongline” to the ground rigging crew, and to precisely clamp the carriage on the skyline at the point of the lateral inhaul.

Small towers can be used on the coast to commercially thin second-growth stands or in the interior to commercially thin and conduct shelterwood or seed tree cuts. These small towers use parallel corridors, while yarding to roadside. Turns are often ground skidded to a central landing after they are decked and unhooked below the yarder, to avoid excessive disturbance along the road edge. Where terrain is very steep below the yarder, several types of "log brakes" may be installed. The local WCB officer must deem the brake "stable." Therefore, check with WCB before using a log brake.

Medium-sized towers

Medium-sized yarders (with towers 14–21 m) like the Madill 071, or the larger Madill 171, can be used to yard mature coastal second-growth timber in a live or standing skyline configuration. As in the smaller towers, these medium-sized towers are quite mobile and relatively easy to set up with three to six guylines. They can also be used to yard parallel corridors, decking the wood below the yarder at the roadside, as with the smaller yarders.

Large towers

As previously mentioned, large yarders (with towers 27–30 m tall) can be used in coastal old-growth or large second-growth timber using a live or standing skyline configuration. These towers are more difficult to set up, requiring six to eight guylines. Also, these towers require a large open landing area to deck logs and accommodate guylines free of hazards.

Unlike the smaller towers, these large towers are restricted to radiating corridor patterns from a major landing. Combined with the large landing to accommodate the yarder, the corridors create a significant opening where they converge. Also, when yarding cross-slope, full suspension is generally desired to avoid excessive leave-tree damage and/or a great deal of effort to protect leave-trees.

The Wyssen yarding winch and cableway system

This long-distance cableway system is operated as a standing skyline. It was developed in Switzerland, and usually consists of a sled yarder, a dropline carriage, and a mainline. The skyline is pre-tensioned with a set of tensioning clamps to the end of its lower anchor. Normally, a headspar, intermediate supports, and perhaps a backspar are used for proper deflection.

The yarder is on skids and can winch itself under its own power through standing timber to the top of the block, on slopes as steep as 100%. In the Greater Vancouver Watershed, the Wyssen has been flown to the top of blocks using a helicopter. The yarder is usually placed to the side of the headspar, with a minimum distance from the mainline lead block. Sometimes the yarder may be as far as 50 m away from the headspar.

Once positioned at the top of the yarding corridor, the yarder uses a strawline to string the skyline from a separate powered drum at the bottom of the block, up through the rigging and the headspar. The yarder is also used to install the carriage.

Although uphill yarding is possible, the Wyssen is generally operated as a gravity system for downhill yarding with the yarder at the top of the block and the landing at the bottom. The yarder and its snubbing line are used to lower the turn to the landing and then to bring the carriage back up the skyline. An air retarder, with a backup friction brake, controls the rate of descent. Usually, the skyline is rigged across a bottom road to land logs on the road.

Advantages of the Wyssen over large towers

- The Wyssen allows for effective yarding, both downhill and uphill, on steep rough terrain, with minimal leave-tree damage using a skyline that can be rigged over more than 1500 m slope distance. Rigging long distances has the environmental advantages of reduced road building.
- The Wyssen has a lower purchase price than most large towers. Time requirements for rigging and corridor changes increase costs. However, partial cutting may be possible in large timber and difficult terrain at \$30 to \$60/m^3. While this sounds excessive, the Wyssen may still compare well with helicopter systems in similar terrain.
- The Wyssen yarder comes in various sizes and can be used in coastal old growth where it is usually limited only by the stress on the skylines and anchors. Therefore, payload analysis is recommended.
- Often full suspension can be achieved. The location of the headspar and back spar anchors is very flexible. Either or both may even be in standing timber. Also, this system is often used in a multi-span configuration with intermediate supports. The drawback here is that considerable time and skill are required to rig this system effectively and safely.
- The system is used for parallel corridors, perpendicular to the contours, thus avoiding the problems associated with radiating corridors. Lateral yarding is accomplished up to 100 m either side of the corridor. The Wyssen will winch itself to successive corridors during corridor changes. However, this system is limited in that these changes are slow and may take as long as five days to accomplish.

Radio-controlled motor-driven self-contained yarding carriage (no yarder)

This carriage is used with a standing skyline, but no yarder (no mainline or haulback line). The carriage contains its own winch and dropline cable. The carriage propels itself along the skyline using the internal winch motor. TDL Gauthier Inc. has a system that uses two highly mobile excavator spars at either end of the skyline. The system is simple to operate and set up. However, it requires an established road network, and is normally only used for yarding downhill. Also, wear from the carriage may require relatively frequent skyline replacement.

Figure 5.2-22

Yarding Cranes with Running Skylines

Yarding cranes with running skylines are quite common due to their versatility. They can operate both uphill and downhill. They are highly mobile and can be used in smaller scattered settings. They can be used with a grapple as well as a slackpulling carriage. This system is "live" in that the lines that suspend the carriage are raised and lowered during the yarding phase. It can be used with a grapple (referred to as "grapple yarding") or a carriage with chokers and/or a dropline/skidding line.

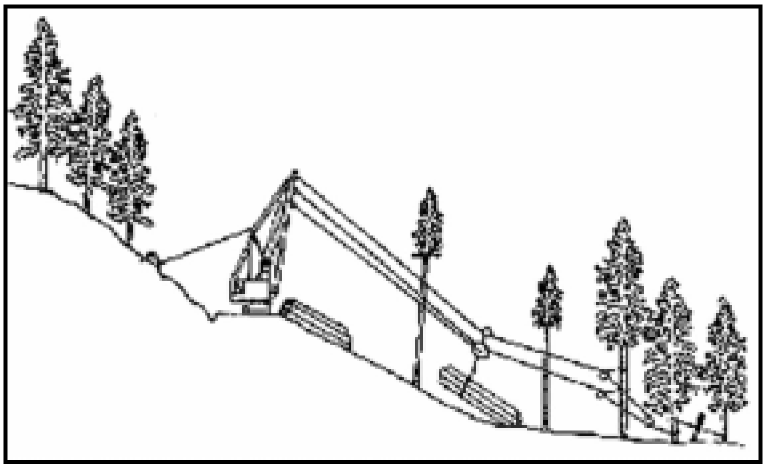


Figure 5.2-23

During yarding, the carriage rides the haulback line, with one end of the haulback attached at the rear of the carriage. The mainline is attached to the front of the carriage where a segment of the mainline or a separate slackpulling line is pulled through the carriage, or activates a drum that lowers a dropline. In a running skyline, the lift is provided from all of the lines, by tightening the haulback line during the inhaul. Running skylines therefore raise and lower the carriage during the yarding cycle, as in live skyline systems.

Question: *Can grapple yarders be used for partial cutting?*

Grapple yarders are yarding cranes with a grapple instead of a carriage. By themselves they are limited in partial cutting applications. However, they can be used with an experienced operator in conjunction with widely spaced clumps, groups, or individual leave-trees. Clumps or groups must be strategically placed so that the yarder can log the area behind them from several angles. Operators usually find it easier to yard around scattered leave-trees that are at least several tree lengths away from the yarder, rather than closer in. Being highly mobile, the yarder is easily moved at roadside. Individual trees can be left by breaking the strawline and flipping it to the other side of the tree. Additional time for such rigging work should be minimal.

Grapple yarders may be more effectively reconfigured for partial cutting in uniform leave-tree configurations by removing the grapple and using the grapple's closing line as a dropline for chokers. However, this may not be as effective or efficient as a slackpulling carriage, especially on steeper slopes.

Running skylines with old yarding cranes will have a difficult time partial cutting with a dropline carriage. They may not have the interlocked winch drums and the operator would have to hold the carriage in place manually, rather than simply applying both haulback and mainline drum brakes, as in the newer interlocked machines.

Question: *Can yarding cranes be used as a standing skyline?*

This will depend on the type and model of yarder. They will require another winchline drum for the skyline and the necessary guylines to support the crane loaded with a tensioned skyline. The Washington 78SL swing yarder was designed as a slackline machine that could be field-converted to a running skyline. Canadian Forest Products Ltd., Mainland Logging Division, has used this machine as a standing skyline with intermediate supports. Its original design as a slackline system allows for this. Most yarding cranes cannot be operated in this manner without modifications.

Advantages of yarding cranes with running skylines

- They are readily available where grapple yarding is popular, such as coastal areas, having widespread use in clearcut operations.
- Yarding cranes can swing wood easily to roadside at the side of the yarder, reducing concerns regarding the stability of decked wood below the yarder when yarding uphill. The yarder will, however, need space to swing—corridors that flare out at the landing are recommended.
- These machines require a minimum number of guylines (only two to four) and are relatively easy to set up. They are well suited to parallel corridors that require a relatively quick set up for each yarding corridor.
- Since the payload in a running skyline is supported by several lines, the cables only need to be about half the strength of an equivalent standing skyline (7/8 inch diameter lines are roughly equivalent to a 1-1/4 inch standing skyline).
- Safety—running skyline yarders can limit the tension in the haulback line to a safe value, which allows them to control tension in the suspended lines and adjust the deflection to the weight of the load. In contrast, line tension is uncontrollable in a standing skyline system. If a standing skyline is rigged with excessive initial tension, relatively light loads can cause a skyline failure.

Limitations of running skylines

- Corridor width is more difficult to manage than with a standing skyline.
- The system is limited mostly to partial suspension of logs.
- More limited than standing skylines in terms of slope and terrain requirements, particularly when yarding downhill. This generally restricts yarding distance to 250–300 m, although some can yard over 600 m.
- Intermediate supports cannot be used.

Skyline Yarding—Considerations for Improving Deflection

Figure 5.2-24

1. Use a larger tower.
   - A range of types of yarders are available, from small, gravity-fed yarders with 9 m towers to coastal swing-boom yarders with 15–17 m cranes, or large 27–30 m coastal towers.
   - As the tower gets larger the number of guylines increases, landing size increases, and the mobility of the yarder decreases.
2. Rig the skyline across a draw on a slope facing the yarding area.
3. Rig a backspar or “lift tree” (generally necessary).
   - On continuous slopes, only a “lift tree” can help achieve deflection with a single-span system.
4. Rig an intermediate support (multi-span system).

Figure 5.2-25
An intermediate support jack.

- A jack (hanger device) is hung from a suitable mid-span spar tree using one of three approaches:
  - From a single guyline running from a single spar tree across the corridor to an anchor. This is the simplest configuration to rig. The supporting guyline and jack can be raised with the skyline.
  - From a single spar tree, which is encouraged to lean over the yarding corridor using a number of guyline supports in conjunction with a careful undercut and backcut.

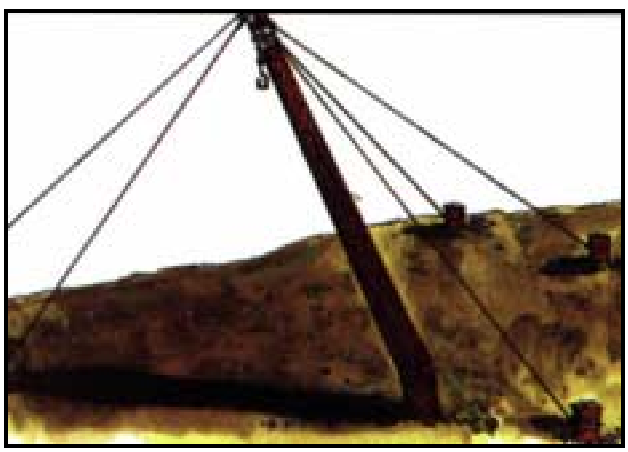


Figure 5.2-26

  - From a line connecting two supported spar trees. This double-tree support must be engineered to ensure the load is imposed equally on both spar trees.

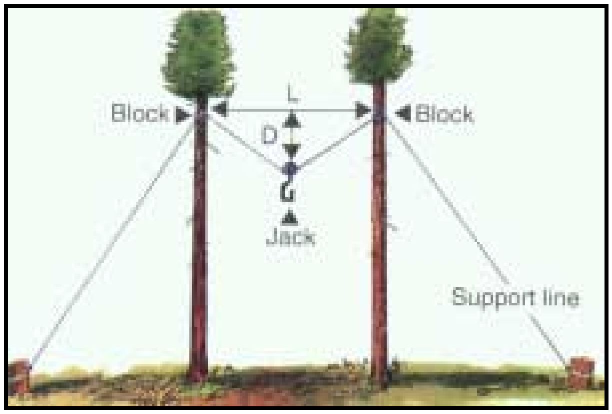


Figure 5.2-27

- The carriage must have open-sided sheaves to pass intermediate support jacks.
- Intermediate supports are used with a standing skyline configuration.

Guylines and tie-backs for both mid-span spars and intermediate supports must meet specific WCB requirements for angles from the ground (generally less than 45–50 degrees) and angles off-centre (generally less than 8 degrees). These requirements must be checked with the regulations, along with other rigging requirements for proper anchors and number and layout of guylines.

→ **See** *Occupational Health and Safety Regulation* (Workers' Compensation Board 1998) and the *Cable Yarding Systems Handbook* (Workers' Compensation Board 1999) for more information on proper skyline rigging.

Skyline Planning and Layout for Partial Cutting

A key element for cost-effectiveness and operational feasibility in partial cutting skyline harvesting systems is proper advanced planning and layout. The time required for planning and layout in a partial cut may be four to seven times the normal clearcut planning and layout. While it may seem significant at the time, extra costs for planning and layout may actually save logging costs down the road.

Planning and Layout Protocol for Skyline Corridors

The protocol to layout skyline corridors is generally as follows:

1. Initial stand recces, contour maps, digital terrain models—such as PLANS (USFS – Pacific Northwest) will help initially:
   - determine potential deflection problems, sensitive sites, and other control points
   - determine appropriate landing locations at roadside.
2. Determine the optimum spacing of parallel corridors to meet economic, engineering, and silvicultural objectives (see other considerations that follow).
3. Rough in preliminary corridor locations on a field map.
4. Walk the back boundary to choose potential backspars and/or tailholds at the back end of preliminary corridors. You should establish criteria for acceptable spar trees in advance (see considerations that follow).

5. Run deflection lines back to potential landing locations to roughly draw profiles in the field. Conduct a rough loadpath and deflection analysis. If deflection is inadequate, you must decide on either altering the landing location, altering the corridor placement, raising the tailblock in the backspar, or including a mid-span spar. You may also alter corridor placement at this stage if the corridor removes too many desirable leave-trees. Once you are satisfied with corridor placement, mark it roughly with ribbon.
6. If mid-span spars are necessary, choose potential spar trees and mark them with ribbon.
7. Walk these locations with the contractor, rigging slinger, and/or hooktender before logging. Incorporate their ideas into the layout.
8. Make any necessary adjustments to layout.

Specific terrain requirements will be necessary to get optimal landing locations and corridor placements for successful partial cutting. Careful deflection analysis will be necessary. Computer programs are available that will assist in deflection analysis. PLANS (USFS, PNW Research Station product) uses digital terrain modelling data files to analyze radiating or parallel corridors for skyline yarding from designated landings. PLANS allows the user to modify variables such as payload weight, height, and location of backspar, tailhold and yarding boundaries. The program also allows the user to visually analyze the block from user-selected viewpoints. For most applications rough field calculations of deflection should suffice.

Layout Considerations

Keep corridors narrow in dispersed leave-trees

Corridors of 3–5 m in width are possible. However, there is usually no need to have corridors width less than the minimum inter-tree spacing of the leave-trees, unless they will be used for more than two entries.

Narrow corridor widths will be especially important when the corridors are used in subsequent removal cuttings to minimize damage to regeneration.

Where corridors will be used for multiple entries and the width is narrow, it is easier to accept the loss of this growing space since roots and crowns will eventually use most of it as regeneration develops and grows from the side.

Lay out corridors perpendicular to contours where it is safe to do so

Perpendicular corridors reduce the potential for logs to swing downhill and damage or get hung up in leave-trees on the downhill side of the corridor. Perpendicular corridors therefore make yarding more efficient and productive.

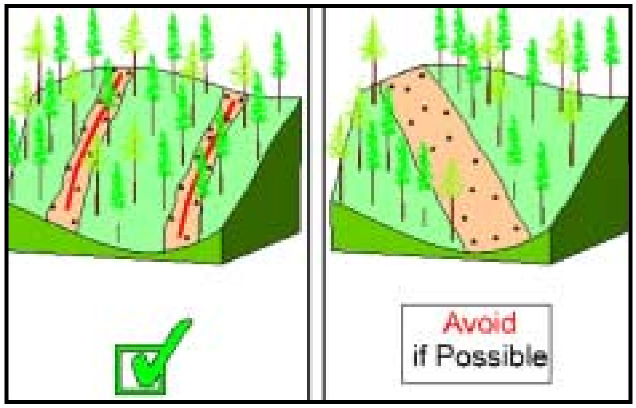


Figure 5.2-28

For steep uphill yarding – there may be safety concerns for the rigging crew with perpendicular corridors on runaway-prone ground. This is especially true where the corridor runs up a ridge. It becomes very difficult for the rigging crew to get in the clear, safe from potential landing runaways. In such situations, a plan must be developed and followed to get work crews in the clear before any yarding and/or loading takes place, or the corridors must be engineered angled slightly across, rather than straight down the slope.

Avoid downhill yarding where possible

Downhill yarding reduces control over logs. The Wyssen cableway system normally yards downhill in any terrain with great success. However, the lateral inhaul is usually pulled at an uphill angle and then the load is lowered, fully suspended, providing the full advantages of a standing skyline.

Every experienced partial cutting crew will generally prefer uphill over downhill yarding. In some cases, however, road location will eliminate uphill yarding as an option.

Another advantage to uphill yarding is that often the larger trees in a setting are found at the bottom of the block on more productive sites. Steep settings that must be downhill yarded frequently offer small trees as backspars and tailholds.

Avoid converging skyline corridors where possible

Converging skyline corridors, such as those used with large 30 m towers, disturb soils over a considerable area and create large openings close to the landing. Where only several corridors converge due to subtle terrain and layout requirements, the impact will be less.

If the corridors are used again for future removal cuts, it could be more difficult to protect regeneration.

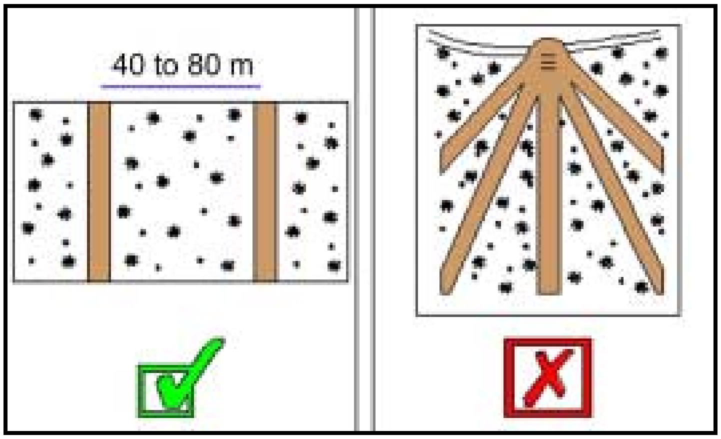


Figure 5.2-29

Lay out corridors parallel to one another, yarding to roadside

This does not need to be perfect, as corridor layout must conform to the local terrain. However, parallel corridors are more efficient for planning and execution than fan-shaped or radial patterns (unless large towers are used).

Question: *What about landing logs roadside securely with narrow corridors running straight downhill?*

If needed, you can forward the turns deposited at roadside to a central landing for loading. This will reduce the landing area in the unit. A log loader will be required to work continuously with the yarding machine to clear the logs from the log landing area.

WCB regulations require that the logs be landed in a stable manner such that the landing operator can undo the choker without the log being restrained from sliding downslope by a loading machine. This can be accomplished on a road width with the use of a swing yarder or a secured brow log across the mouth of the corridor.

→ **See** the *Partial Cutting Safety Handbook* (BC Ministry of Forests 1997) for more information on safe corridor layout.

Spacing suggestions for parallel corridors

Corridors should be spaced 40–80 m+, depending upon the silvicultural system, leave-tree density, and the equipment, especially the carriage. If rigging crews have to pull lots of mainline through the carriage unassisted, corridor spacing will dramatically decline.

Generally, if your corridors are spaced as wide apart as feasible for the ground crew, you will have less leave-tree damage and lower costs, due to the reduction in yarder moves. If a logging contractor suggests that he must have more corridors to make money, he is probably making his corridors too wide!

Spacing should decrease with slope and in more complex terrain, since it is more difficult to maneuver without damaging leave-trees. In such terrain the spacing will also be highly variable.

Corridors do not need to be evenly spaced. They must allow for lateral yarding to reach all of the wood from either side and proper deflection to minimize soil disturbance.

If possible, avoid placing corridors in gullies or portions of gullies since it is difficult for the ground crew to pull line laterally up the side of the gully.

→ **See** Howard and Temesgen (1997) for more information on optimum corridor spacing.

Select potential spar trees based on criteria you have established for the stand

WCB requires that spars have adequate strength.

The following general rules of thumb are sometimes used:

- Use the strongest, deepest-rooting species on site.
- Choose larger, windfirm dominant trees.
- Check roots to ensure rooting is deep and secure.
- Avoid trees with defect or rot that may provide a point of weakness.
- Use trees that are approximately the same size as the largest trees to be yarded.
- The point where the spar is rigged is no smaller than roughly 15 times the diameter of the skyline. The tree should therefore be large enough to give adequate lift at that point.

Identify potential spar trees (and anchors) for subsequent passes

If the same yarding corridors will be used for multiple entries, identify future spars and anchor/guy trees for the next pass.

Anchors/guy stumps for the spars (and maybe the yarder) can be a problem in subsequent passes. You may have to use mechanical holds or deadman anchors, for example.

Plan a general pattern of removal for group and strip systems

A herringbone-shaped opening toward the corridor may be suitable for group removal on moderately sloped terrain, where the faller can angle the timber a bit uphill toward the corridor.

Elongated openings that run across the corridor have advantages for falling and yarding on steep terrain where fallers cannot angle the tree uphill.

Consider that falling will be complicated in future passes with immature groups. You can easily remove wood at fairly low cost in the first pass, but you must consider what you are setting yourself up for in the subsequent passes. Think ahead!

When possible, do not schedule a group for harvest immediately above an immature group that developed since the last harvest because it is tough to protect the regenerating stand from falling material.

Minimizing Damage to Dispersed Leave-trees and Regeneration with Skyline Yarding

For cable yarding a uniform distribution of leave-trees on gentle to moderate terrain, leave-tree damage including basal and stem scarring, and broken tops are difficult to avoid. Steeper and more broken and difficult terrain could increase damage to leave-trees, although this may be minimized with good falling and experienced crews. Select uphill yarding, as downhill yarding makes control of the turn more difficult and often leads to more damage. Procedures to keep damage within a reasonable range follow.

The first step in damage reduction is to consider all factors that may impact damage. These include the species and age of leave-trees, the season of operation, the time before the next harvesting entry, and the type of harvesting equipment chosen.

→ **See** the *Tree Wounding and Decay Guidebook* for more information on general damage considerations.

Planning Residual Densities

Plan residual densities of leave-trees by considering factors that may reduce them. In addition to wind losses, the impact of the corridors and losses to falling and yarding should be considered.

Plan to leave additional leave-trees along corridors as rub trees to protect designated leave-trees (see following).

Minimize Lateral Excursion of Skyline during Lateral Yarding

The key here is to minimize the disturbance created by the skyline. You can shorten the span but that will generally lead to more roading for the same harvested area.

You can use "rub trees"

- These must be planned carefully and designated as rub trees.
- If damaged, they should be felled and yarded at the end of operations.
- They may be protected with protective mechanisms as with ground skidding.
- The lines can "rub" the trees, but should not jar them or put enough of a load on them to destabilize them or knock branches out of the crown.

Note: Removal of rub trees over several entries will progressively widen the corridor. You may not be able to avoid this.

- BE CAREFUL not to leave rub trees where skyline rubs them too high—this is unsafe.
  - May break tip of tree (hazard for rigging crew).
  - May flip over the top of the tree and come down the wrong side, causing hang-ups during the yarding cycle.

You can use intermediate supports (multi-span)

- Limits lateral excursion while giving great vertical lift, better deflection, and payload capacity. It also increases the ability to access more area with fewer roads.

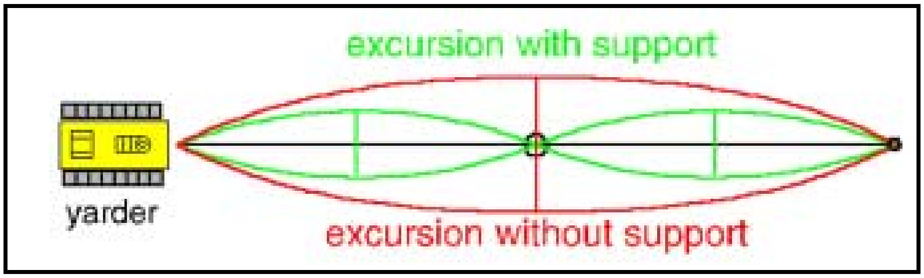


Figure 5.2-30

The carriage is important

- A motorized carriage capable of pulling slack in the mainline and paying out the skidding line will reduce excursion of lines.
- Also, the carriage should be capable of maintaining a fixed position on the skyline during the lateral inhaul so that it will not creep up the skyline toward the yarder when tension increases in the skidding line as logs are pulled in from the side. There are several approaches to maintaining carriage position, depending on the type of rigging set-up (running skyline or standing skyline).

→ **See** Studier (1993) for more information on carriages.

Good Falling Is Critical

Fall "in-lead"

- Falling is critical to the success of the yarding operation. Falling "in-lead" in a herringbone arrangement toward the corridors (at an angle of 30–45 degrees) greatly improves yarding efficiency and success and reduces leave-tree damage.
- This will likely be impossible in heterogeneous old-growth timber where wood must be felled into openings.
- The steeper the ground, the more parallel to the slope the faller will have to place the wood. However, consistent parallel falling will help reduce rigging time and will minimize the potential for multiple carriage placements and re-rigging on a turn.

Fall in a well thought-out sequence

- First, take out the necessary trees around the yarder to make yarding safe.
- Next, the corridor may be cleared to give something for the faller to aim for when it is possible to fall-to-lead.

Think ahead to the yarding phase

- Some contractors have the fallers rig for a day to appreciate how falling can help the rigging crew. Often fallers leap-frog corridors, always moving two corridors over after one is finished. This allows the yarder to work while fallers work at a safe distance away. Also, it often means that less timber accumulates in the middle zone between corridors, which could reduce breakage and facilitate yarding.

Log processing will help reduce leave-tree damage

- Bucking to shorter lengths generally allows for better lift and control of the turn. Also, processing logs to a higher standard in the bush by limbing all sides of the log, rather than just three, and pre-bunching may reduce leave-tree damage, while increasing yarder efficiency and streamlining landing operations. Such labour-intensive approaches to falling are more common in Europe where the fallers use specialized hand tools (falling iron and log hooks) to assist them in their work.
- Limbs and tops can reduce soil disturbance from yarding, but may inhibit regeneration in the corridors.

→ **See** McNeel and Dodd (1997) for more information on processing to reduce damage.

If falling and yarding must be done concurrently, consider the following

- Fallers must be at least two tree lengths away from yarding crews and rigging lines. This may require falling and rigging crews to be working two corridors apart depending on the height of the timber and the distance between corridors. If this is the case, the progression of falling and yarding from one corridor to another should be carefully planned before logging begins to maximize efficiency and avoid yarder down time.

→ **See** Hedin (1994) for more information on concurrent falling.

Proper Lateral Yarding and Corridor Yarding

Separate the primary inhaul from the lateral inhaul

- This separation helps to reduce damage to leave-trees or regeneration. The logs should be skidded laterally into the carriage as far as possible before the carriage is moved to the landing.
- The primary inhaul may be conducted with the lateral inhaul occasionally with experienced operators to avoid regeneration or leave-trees. However, this cannot be accomplished with a self-clamping carriage since the turn of logs must come close to the carriage to release the clamp such that the haulback can be used at the same time.

Lateral yarding requires patience

This phase should alway be slower. Many crews have a signal to the yarding engineer to pull the slackpulling line very slowly, usually to coax trees out of falling jackpots, or gently around leave-trees. The place for speed in the primary inhaul is up the corridors.

Downhill Yarding and Partial Cutting

Question: *What if I must yard downhill?*

Skyline systems vary in complexity and capability. Some can yard uphill only, or downhill only, while others can do both. Downhill yarding saves the cost of building additional roads, but generally requires added rigging time. Also, most yarding crews find downhill yarding more difficult for partial cutting due to the lack of log control, especially during the lateral yarding phase.

1. Consider a running skyline with slackpulling carriage if:
   - Slope is mostly less than 30%.
   - One-end log suspension will meet soil conservation objectives.
   - Maximum yarding distance is <250 m.

   Running skyline yarders (swing-boom yarding cranes) are generally about 50–60 feet (15–18 m) high. The restricted height and live skyline limit most operations to partial suspension. These machines generally operate downhill off haulroads where cutbanks are 1.5 m or less and the slope into the cutbank is 15% or less.

   Running skylines allow for downhill yarding in shelterwood and seed tree establishment cuts. However, removal and intermediate cuts will usually damage regeneration (removal cuts) or leave-trees (intermediate cuts). Since the skyline height above the ground is limited due to short spar height, damage usually occurs during lateral yarding and turning of the logs downhill into the corridors, because the logs are not fully suspended.

2. Consider a standing skyline with slackpulling carriage if:
   - Slope is generally greater than 30%.
   - Full log suspension is needed to meet soil conservation objectives.
   - Maximum yarding distance is >250 m.

   With the potential capability to use full suspension (or close to it) during the primary inhaul phase, the standing skyline gives the opportunity to adequately protect regeneration (during removal cuts) and leave-trees (during intermediate cuts) while downhill yarding. Lateral yarding should be conducted with the carriage uphill from the turn to be laterally yarded. Also, the carriage should be high enough to allow for full suspension while the log is turned downhill into the corridor, otherwise excessive damage will occur.

   To provide full suspension while yarding downhill, especially over long spans or multi-spans, large towers in large coastal timber may be limited for partial cutting—they will require radiating corridors, making yarding perpendicular to contours difficult. A system such as the Wyssen standing skyline may be more appropriate due to its flexibility for locating the skyline and anchors and its ability to yard parallel corridors in these situations.

→ **See** Binkley and Starnes (1988) for more information on downhill yarding.

Helicopter Logging

Advantages

High production rates (500–1500 m^3/shift).

Helicopters can work on terrain and slopes that are inaccessible by road.

- 50–100% slope for coastal partial cuts.
- Having no roads eliminates the associated development costs.

Helicopters may allow for logging in areas previously outside of the operability limits.

- Allow for increased allowable cut in some areas?
- BE CAREFUL HERE—you cannot simply expect to use this treatment to cream sensitive sites that you can never regenerate. The harvesting still must be part of a silvicultural system with a long-term plan for regeneration and stand structure.

Helicopters may damage fewer trees in removal cuts.

- With helicopter yarding, logs are typically lifted vertically from their resting position and therefore some authors suggest a reduction in seedling damage by as much as 50% over skyline systems.

Helicopters may allow for production efficiencies in some operations.

- This depends on factors such as the size of wood, yarding distances, and size of helicopter.

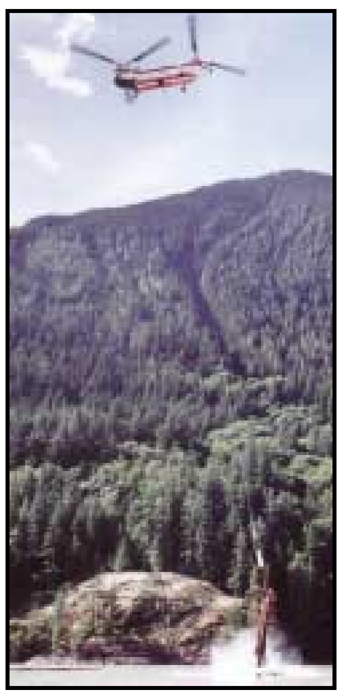


Figure 5.2-31

Operational Considerations

They have a limited range for maximum economic efficiency (1000 m horizontal distance and 300 m vertical distance is optimum).

May be expensive.

Logs have to be bucked for weight to match the helicopter load capacity.

You must have experienced fallers with a keen attitude as this is difficult, and can be frustrating work. Positive attitude is critical for all those involved.

Consider the noise that the operation will cause—some helicopters like the Bell 214 are extremely loud, while others like the Kaman Kmax are relatively quiet.

You must deal with overhead hazards:

Figure 5.2-32

- Work closely with WCB. Generally, they will require pre-felling of all snags in block and those within one tree length outside of block.
- Fallers must deal with snags at falling stage anyway (for safety of faller), but brushed-up trees, which are left with broken branches in their crown, may be an issue at the yarding stage.
- Trees inherently unstable—unable to deal with the force of the rotorwash—create another overhead hazard. The impact of the rotorwash is startling—large dominant trees will be whipping back and forth while the hooktender is setting the turn.
- Dealing with overhead hazards is left up to the hooktender. Uniform leave-tree patterns are not out of the question, even in coastal old growth. However, if the hooktender does not feel comfortable with a particular tree (e.g., hemlock growing out of a stump or on a rock, a forked tree that will split), he will call in fallers.
- You can somewhat reduce impact of rotorwash by using a longer tagline or dropline from the helicopter. However, it becomes more difficult to spot the hook in the hooktender's hands with a longer dropline. Depth perception becomes poorer and the hook has much more lateral movement, taking longer to catch up to the helicopter as it stops over the

next turn—all of this slows down the cycle time. Also, sometimes a long dropline has to be used to compensate for a very steep slope and tall trees.

- Dropline length is a sum of the dominant tree height plus the necessary 15 m clearance between tree crowns and helicopter. Dropline length may vary in partial cuts between 60 and 100 m for large helicopters on the coast. However, pilots prefer to stay within less than 75 m for better control, faster cycling, and safety.
- At the prescription stage, you must think about overhead hazards for falling and yarding. Walk your stand with a representative from the heli-logging firm and WCB to get some advice if you suspect overhead hazards will be an issue. Do this before the final prescription is developed to help avoid amendments later. You may opt for certain leave-tree or marking patterns that make dealing with these hazards easier.

→ **See** *Safe Work Practices for Helicopter Operations in the Forest Industry* (Workers' Compensation Board 1998) and the *Partial Cutting Safety Handbook* (BC Ministry of Forests 1997) for more information on safety.

Layout Considerations

Helicopter yarding offers a number of advantages over cable systems, since it is much more flexible in its ability to deal with a greater range of terrain. However, helicopter yarding is much more production/cost sensitive and it requires more careful and precise planning to make it efficient, safe, and successful.

The helicopter pilot must be able to see the hooktender on the ground to lower the hook to him, even though they are in radio contact. This means that you must make sufficient openings in the crown for this visibility.

Sufficient openings may be created with uniform leave-tree patterns depending on the original stand structure and the amount of basal area removed. You may find that clusters of trees must be removed to provide sufficient vents for removal of timber.

A grapple can be used with small openings, strips, or leave-tree group patterns. This will reduce the number of ground crew at risk from overhead hazards and boost production (reducing costs).

A computer tool is available to develop an aerial simulation of your stand after falling. FORSEE is produced through a cooperative effort by the Aerial Forest Management Foundation, USDA Forest Service, Pacific Northwest Research Station, and Good Wind Software. In addition to being useful for silviculturists and other resource specialists to visualize crown distributions after harvesting, this tool allows logging engineers to evaluate the potential for damage to the residual stand component as a result of logging activities and the overall safety of aerial logging with helicopters.

You will need up to four crews setting chokers to maximize efficiency, so you must have a substantial area laid out and volume developed.

Ideally, a clearcut or two nearby could be scheduled for logging at the same time to avoid helicopter down time since ground crews may have trouble keeping up. They must cover lots of ground for a given volume. As the helicopter works the larger opening, the ground crews can set the next round of turns in the partial cut. Plan out the yarding sequence so that the chokers are always in the clear and clean up as they go.

You will require a drop zone/landing nearby, ideally within 1 km and 300 m downhill from the harvesting area. With the larger helicopters production is high so a large area will be required for processing and decking.

Expect more time spent planning. Expect to spend at least twice the planning and layout time compared to clearcut heli-logging.

Walk the entire area to check layout with the fallers and bull-bucker (and contractor) before harvest.

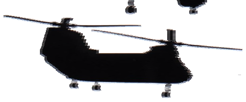
The payload capacity of the helicopter must be considered. It may restrict what can be done in terms of leave-tree patterns.

- Large helicopters like the Sikorsky S64 are rated for payload based on what they can deadlift. If rated for 20,000 lbs, they can lift this straight up out of the stand.
- Medium-lift helicopters cannot deadlift their rated capacity—it may only be two-thirds of that. They are using their forward momentum to develop some of their lift capacity. This is important if your stand requires you to deadlift straight up. A larger helicopter may be more economical with a tremendous advantage on the volume per turn.
- Group openings may allow you to use smaller machines while they swing the wood out away from the slope.

You must also have enough wood to make this equipment feasible. Larger economies of scale exist, especially for the larger helicopters.

Helicopter yarding is more sensitive to weather than cable yarding. Winds and landing locations need to be considered. Fog, low cloud, and wind speeds above 50 km/hr usually suspend helicopter operations. Very warm weather, particularly at high elevations, may reduce lift as air becomes less dense.

Some Common Logging Helicopters

Helicopter model		Lift capacity (lbs)	Other models with similar lift
	Sikorsky S64	20 000–25 000	Chinook (28 000 lbs)
	Boeing Vertol 107	10 000	Hughes 500D (11 000–12 000 lbs)
	Sikorsky S61	10 000	Aero-Speciale Puma (10 000 lbs)
	Kaman Kmax	6000	Sikorsky S58 (5000 lbs)
	Bell 214	7700	

Source: Workers' Compensation Board *Safe work practices for helicopter operations in the forest industry*, page 62.

Heli-falling in Standing Timber

Weyerhaeuser is experimenting on Vancouver Island with an approach to falling individual valuable trees that will allow helicopters to snap them right off a stump in a vertical position. Such an approach must be correctly applied to be safe; however, trees can be logged with virtually no damage to the trees themselves or the rest of the stand.

Partial Cutting Applications for Helicopters

Uniformly Distributed Leave-trees

Fairly well suited with the following limitations:

- Slower, less efficient...less logs to choose from to gather load.
- Possibly more dangerous due to more potential overhead hazards.
- The more complex the terrain, the less feasible this may become.
- As density increases, so do yarding times and costs.
- Tougher to spot the hooktender.
- More care is required to lower the hook through standing timber.
- Hang-ups are more common.
- Tougher to achieve optimum turn weights.

Grouped Leave-trees or Group Removal

Well suited in the following situations:

- Openings of a minimum of two tree lengths wide are best.
- Especially well suited for grapple-helicopter operations.
- Can have one crew choking in three to four small openings at once.
- May have to opt for these stand structures as the only safe and feasible options on very steep and complex terrain.
- Openings must fit the terrain and you should match the dimensions to the height of the timber (at least one tree length in width).
- Long rectangular openings that run parallel to the contours are easier to fall and yard.

Careful planning and data collection can all be wasted if you do not choose the right operator for the job. Also, it is extremely important that the operator understands and shares your objectives, and that you understand the challenges faced by the operator.

The Logging Crew

Figure 5.2-33

Considerations

1. Match the crew to the prescription

A fully mechanized high-volume production operator may not be the best choice for some complex partial cutting systems.

Where you can, work closely with reliable local operators to make sure that they can adjust their equipment profile with future investments to fit the harvesting situations that will be available.

2. Communicate thoroughly and clearly to the crew

Walk the block before harvest, pointing out all of the important considerations. Give them an excellent detailed map. Some operators can interpret ecosystem maps and use them to make operational decisions.

Discuss with them the tasks and precautions you are proposing during a pre-work conference at the site. Consider their ideas and concerns—these people are professionals too!

The cutblock should be walked with the contractor/crew before the layout and the contract clauses are finalized. Corridor or skid trail changes, falling difficulties, and other yarding or skidding problems can be discussed and solved before work begins.

Close supervision is essential. You should spend every day on site until you are sure that the loggers understand what they are to do in various situations (e.g., how to deal with leave-tree substitution, avoid leave-tree damage).

3. Ensure that the logger's objectives match your objectives

Some of the skills required for partial cutting may be relatively new to the crew. Considerable time will be required for a crew new to partial cutting to acquire these skills and be proficient. For example, cable yarding with standing skylines, backspar trees, and intermediate supports, as well as lateral yarding, will require more advanced skills.

For the success of the prescription and safety of the crew, it is absolutely necessary to have a crew that is specially suited to partial cutting. Such a crew will have the following characteristics:

- Motivated and interested in developing new skills.
- Less concerned about production and willing to spend the extra time thinking about leave-trees choices, safe falling decisions to facilitate yarding, yarding hook-ups, and re-hooks to minimize leave-tree damage.
- Well seasoned, so that they have the experience to deal with the complex situations they will face.
- Well organized, supervised with good communication and team spirit between all crew members at all times. Remember, stress levels will be high, particularly if this is a first experience with partial cutting and therefore, the crew must work very well together. Where company crews are used, a strong working relationship must exist between loggers and management staff to facilitate the communication and environment necessary for a successful, safe operation.

Compensate them for additional care and work. For a contract logger to cover additional costs and make a decent profit, they can either be paid more per cubic metre, or they can produce more cubic metres in less time. Obviously, compensation encourages a careful approach with less emphasis on production.

4. Be sensitive to workers' safety issues

Safety must not be compromised. Make sure your prescription considers this.

You must demonstrate to your crews that you are not prepared to compromise their safety.

Innovative approaches to partial cutting silvicultural systems that are unsafe will benefit no one, and will ultimately stall attempts to change forest practices.

Expect some down time due to wind hazards since it is hazardous for crews to work under standing trees that may have broken branches caught in tree crowns.

Discuss safety with the crew before and during the project. Work closely with WCB, especially in operations where new approaches are being tried.

→ **See** the *Partial Cutting Safety Handbook* (BC Ministry of Forests 1997) for more information on general safety issues.

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