6.7 HEMLOCK

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Introduction

Eastern hemlock often grows on dry, shallow tills, interspersed with wet swamps; on north- and northwest-facing shallow rocky slopes; and on wet, sandy swamp borders. It is also found in coves and cool moist valleys. It grows in coniferous and mixed forest stands, and occurs on a wide range of soil textures including sands, loams, and clays, primarily in the moist to fresh moisture regimes. In coniferous stands, it is typically found on coarser, acidic soils. In Site Region 6E it occurs on shallow and deep soils; in Site Region 7E it is found on deep soils. It is more widespread in eastern Ontario. Typical associated species include white pine, eastern white cedar, red maple, and yellow birch.

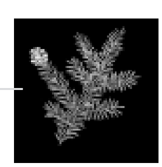
Eastern hemlock can form a dense canopy and together with its acidic litter, can restrict the growth of understory vegetation. Although it is the most shade-tolerant tree species in southern Ontario and can become established in as little as five per cent sunlight, it responds poorly to any significant canopy disturbance that allows other species such as sugar maple, beech, and red spruce to gain dominance. It also has a shallow root system that makes it sensitive to disturbance and drought, and no ability to resprout.

Hemlock has sensitive requirements for regeneration. It does best in shade, often germinating on rotten stumps, logs, or mounds that are warmer and moister than litter or mineral soil. Frequently it regenerates under white pine or sugar maple. However browsing deer often destroy regeneration. This species grows slowly and is very tolerant of competition. It may become part of a climax community on some north-facing upland sites as it easily survives under its own canopy. It can also become codominant in a hardwood stand.

Fresh-moist hemlock coniferous forest ecosite (FOC3)

This ecosite if usually found on sites with soil texture varying from sands to coarse and fine loams, with some finer silt and clay components. Soil moisture regime ranges from fresh (MR 2,3) to moist (MR4-6); drainage is classed as well (DR3) to imperfect (DR 5). It is generally found in cooler areas, such as middle to lower slopes with northern exposure, seepage areas, and bottomland topographic positions. Often the water table is high and the microtopography is complex.

The ELC describes one vegetation type for this ecosite. The fresh-moist hemlock coniferous forest type is typically found on coarser acidic soils. It occurs sporadically throughout Site Regions 6E and 7E but is most common in the northern parts of Site Region 6E.



Dominant Trees	hemlock dominated with white pine, balsam fir, and white cedar
Less Common Associates	sugar maple, green ash, and white birch
Common Shrubs	beaked hazelnut and maple leaf viburnum
Common Herbs and Ferns	wild sarsaparilla, Canada mayflower, foamflower, bluebead lily, starflower, goldthread; wood ferns; ferns species are often numerous
Soil Moisture Regime	moist (MR 4-6) to fresh (MR 2-3)
Soil Drainage	well-drained (DR 3) to imperfect (DR 5)
Equivalent Ecosite in Central Ontario	ES30 (Chambers *et al.* 1997)

Fresh-moist hemlock mixed forest ecosite (FOM6)

This forest ecosite is found on sands, loams, and sometimes clays. It is found on lower to mid-slope, and bottomland topographic positions, as well as in seepage areas.

There are two vegetation types associated with this ecosite. The fresh-moist sugar maple-hemlock mixed forest type is typically found on soils with a fresh moisture regime (MR 1-3). This forest type is common in Site Region 6E but in Site Region 7E, it is restricted to sites with cooler than normal microclimates. The fresh-moist hemlock-hardwood mixed forest type is typically found on soils with a moist soil moisture regime (MR 4-6). It is infrequently encountered in Site Region 6E, being most common in the northern part of this region. It is rare in Site Region 7E.

Dominant Trees	eastern hemlock, sugar maple, and yellow birch
Less Common Associates	red maple, white birch, beech, black ash, and eastern white cedar
Common Shrubs	riverbank grape, maple leaf viburnum, and beaked hazelnut
Common Herbs and Ferns	trillium, wild sarsaparilla, and red baneberry
Soil Moisture Regime	moist (MR 4-6) to very fresh (MR 3)
Soil Drainage	well-drained (DR 3) to very poorly drained (DR 7)
Equivalent Ecosite in Central Ontario	ES30, 28 (Chambers *et al.* 1997)

Changes since the presettlement era

The prevalence of eastern hemlock in northern hardwood forests, including those of southern Ontario, has likely declined since settlement (Frelich 1995). During the late 19th century, Europeans logged most areas where it was found. The bark was used extensively for the tanning industry (Elliott 1998) and the wood was used for framing, sheathing, sub-flooring, and crating (Quimby 1996). Regeneration of hemlock was often poor, probably due to its inability to compete with sugar maple and beech. In some areas, extensive cutovers resulted in an unsuitable microclimate for hemlock seedlings, leading to a further decline in the distribution of this species (Davis *et al.* 1996). More recently, heavy browsing by white-tailed deer have further limited the re-establishment of hemlock. Enclosure studies using fencing to eliminate deer browsing indicate that deer densities as low as six deer per square mile seriously inhibit the growth and regeneration of this species (Sauer 1998).

Some hemlock has persisted due largely to its longevity, ability to remain suppressed in the understory for years, and the market preference for hardwoods during the 1900s (Foster *et al.* 1992). Many of the seedlings and saplings that were released when the canopy old-growth trees were cut for tannin are now polewood or mature trees (Quimby 1996). In some areas its location on steep rocky slopes made economical removal difficult.

Choosing an appropriate silvicultural system

Selection of the most appropriate silvicultural system for the management of hemlock stands and/or clumps of hemlock within other stands depends on several factors:

- an understanding of the autecology of hemlock
- site potential or capability
- the current stand composition, structure, and condition
- wildlife habitat and other natural heritage values
- other considerations

These factors are briefly discussed in the following.

Autecology of hemlock

Some knowledge of the autecology of eastern hemlock can help to improve the likelihood of successful silvicultural management of forest types with a dominant component of this species. Important biological information for hemlock is listed below and additional information is provided in **Appendix B**.

Reproduction and early growth of hemlock (Anderson 1994*a*; Godman and Lancaster 1990; Collins 1990)

a) *Seeds and germination*
   - Seed crops occur every two to three years.
   - Cones mature in the fall and the seeds are dispersed by wind over the snow throughout the winter.
   - Viability of seed is low.

b) *Site factors*
   - Germination and early survival are best on cool moist sites, and favorable seedbeds include moist well-decomposed litter, rotted wood and moss mats. Mixed mineral soil and humus are the best substrate for survival and growth. Full sunlight and dark-colored mediums promote poor survival due to desiccation and/or heat stress.
   - In managed sites, seedbeds must be prepared for successful regeneration either through mixing organic material and mineral soil, or through prescribed fire to expose a partially decomposed layer. Without these conditions, most regeneration is limited to rotten logs, stumps and mounds that have a warmer surface and better moisture retention than the forest floor.

- Survival of hemlock seedlings is greater in habitats with shallower litter, more coniferous litter, and less woody debris**.** Hemlock seems unable to establish itself on hardwood litter, but can establish on the pit and mound topography found in moist hardwood stands. Windthrown root balls will eventually disintegrate into mounds of mineral soil ideal for hemlock germination.

c) *Early growth*
- Slow growing seedlings may be smothered by hardwood litter, particularly litter of sugar maple.
- Hemlock is extremely shade-tolerant and can become established in as little as five percent sunlight.
- Saplings growing in deep shade can be 2.5 cm DBH at 100-years-of-age
- While hemlock can survive in low levels of sunlight, it is also easily released from overhead competition.
- Hemlock establishment is associated with years of regular, adequate precipitation.

<u>Reaction to competition</u> (Anderson 1994*a*; Godman and Lancaster 1990)

a) Hemlock is the most shade-tolerant of all species because:
- The needles of its crown are concentrated on the ends of the branches and need only 2 % of full sunlight to live.
- Light saturation levels in mono-layered crown species such as hemlock show a rapid rise in photosynthesis from 2- 15 % of full sunlight; multi-layered crowns do not respond to these low light levels.
- Hemlock has a high root/shoot ratio. It is capable of high rates of root biomass production, even at low light levels. For example, it is 10 times more efficient than jack pine.

b) Hemlock is well adapted to respond to release from competition (i.e., increased light levels). The degree of response is related to the active crown size. Trees with live crown ratios greater than 50 % respond quickly; those with less than 30 % respond much more slowly. Individuals are capable of surviving suppression for up to 400 years, and dramatic growth releases (up to 8.8 mm/yr) have been recorded in some older trees (Abrams and Orwig 1996). However, excessive release can damage hemlock, reducing growth rates or causing mortality through windthrow.

c) Hemlock is adapted to cool environments such as north-facing slopes and sheltered valleys where it may be able to compete better. Net photosynthesis of hemlock is optimal between 14 and 19 ^{O}C.

d) Hemlock is sensitive to disturbance and does not compete as well with other shade-tolerant species such as sugar maple and beech. These other species are adapted to disturbance since they have less vigorous requirements for establishment, the ability to resprout, deeper root systems (sugar maple and beech), and are not as palatable to deer and other herbivores.

<u>Factors limiting growth and development</u> (Anderson 1994*a*; Godman and Lancaster 1990)

- Hemlock seeds are susceptible to mold damage, and damping off fungi, and root rots kill many seedlings. Several rusts affect the foliage and cone production.
- Few insects cause damage of economic importance; one exception is the hemlock borer that attacks weakened trees. Spruce budworm can defoliate hemlock if all of the balsam fir in the area have already been utilized. The hemlock looper causes foliage damage by eating part of the needle that then dies back. The hemlock wooly adelgid is increasingly infesting hemlock in the United States. Symptoms include poor crown condition and sharply reduced terminal branch growth (Souto *et al.* 1996**)**.
- White-tailed deer readily browse hemlock, often eliminating patches of regeneration. Snowshoe hare and eastern cottontail frequently browse hemlock, and mice, voles, squirrels, and other rodents eat the seeds. Porcupines sometimes remove the bark at the top of larger trees, causing serious wounds and/or topkill. Sapsuckers are associated with ring shake problems in some areas.
- Hemlock seedlings and saplings are vulnerable to fire, however the thick bark of older trees allows them to resist light fire damage. Burns are often beneficial in re-establishing hemlock on a site.
- Heavy cutting in a stand predisposes hemlock to windthrow.
- Light cutting may promote radial stress cracks and ring shake in older trees, severely reducing their value for timber.

Site potential or capability

Landowners and managers must determine whether the prevailing site conditions and growth rates permit the production of timber products. If not, the stand is better left alone to provide other values such as wildlife habitat.

Current stand composition, structure, and condition

Silvicultural options vary for even-aged and uneven-aged stands. Managers must determine stand composition and structure, and current age-classes and condition of the stand, using a site/stand assessment. Past management and natural influences affect current stand condition and structure, as well as the quantity of advanced regeneration. Landowners and managers must also know what species are desired in the stand after harvest operations.

Wildlife habitat and other natural heritage values

Hemlock stands often support numerous wildlife habitats, as well as rare species and other important forest values. **Section 4.4** and **Table 4.4.1** briefly discuss many significant wildlife habitats that managers and landowners should be aware of when considering silvicultural management.

Hemlock stands are considered essential for white-tailed deer in winter. These trees intercept snow well and moderate the local microclimate. With less snow on the ground, deer can move about more easily and they stay warmer than they do in more open habitats. However, deer numbers will have a significant impact on any plan to regenerate hemlock and this factor must be taken into account (Anderson 1994*a*). In contrast, sugar maple often resprouts fast enough to compensate for repeated browsing (Davis *et al.* 1996) and beech is relatively unpalatable (Runkle 1985).

Hemlock stands provide important winter cover for numerous other species such as ruffed grouse, wild turkey, and small mammals. Large trees provide roosts for wild turkeys and some raptors during winter, especially if they are close to foraging areas. In some parts of southern Ontario, hemlock stands and stands in which hemlock forms a dominant component have significant natural heritage value because they are an uncommon or even rare forest cover type. Therefore in these areas, management activities should not lead to an overall decrease in their area or representation within the larger region.

Other considerations

At least two other considerations, landowner objectives and available resources (e.g., financial, human, time), will also influence the choice of the silvicultural system for management of hemlock stands.

The maintenance of aesthetic appeal of the stand as a landowner objective may preclude the use of the shelterwood silvicultural system and suggest a selection system. The type of wildlife habitat desired by a landowner will also determine which silvicultural system is used.

Managing hemlock stands

In general, managers should encourage the retention of hemlock, due to its reduced abundance and regeneration as compared to it historical presence. Depending on landowner objectives, hemlock could be re-introduced to areas where it was mostly eliminated through harvesting and has not recovered. It could be established in pockets by encouraging natural seeding or by planting seedlings. Refer to the ecosite descriptions for typical site conditions on which hemlock will thrive.

Hemlock is found in both even-aged and uneven-aged stands. It can be found in almost pure stands, or can be a minor component of hardwood stands. Typical even-aged associations tend to have white pine or sugar maple in the canopy, with hemlock in the understory to mid-canopy, and all trees are of similar age. These stands with stratified canopies can have better growth rates than pure hardwood stands, or pure hemlock stands. The stratified canopy appears to boost production as measured by basal area and biomass yield (Kelty 1989). Even-aged stands of pure hemlock are unusual, although stands of similar-sized trees do occur (Anderson *et. al* 1990).

Both even- and uneven-aged management systems can be successfully used to manage hemlock, but the even-aged system has had more success (Godman and Lancaster 1990).

However, clearcutting is not recommended as is it has been shown to result in the virtual elimination of hemlock from the overstory of stands after 46 years (Hix and Barnes (1984) as cited in Anderson 1994*a*). Without fire disturbance, hemlock will not regenerate naturally following clearcutting.

Managing even-aged stands of hemlock

Hemlock is part of the Tolerant Hardwood Working Group (THWG), and a considerable amount of silvicultural research has been done on it and its associates. A recommended treatment key has been developed for the THWG (Anderson *et al.* 1990) and it is presented in simplified format, focusing on hemlock and its associates (**Table 6.7.1**).

The term "overstory has potential for future development" is defined as an overstory comprised of stems that will improve in log quality and maintain growth and tree vigor over time. Stands with the majority of canopy trees exhibiting dieback at the top of the crown, excessive stem damage from previous logging activities, or overmature canopies of short-lived species such as aspen or white birch do not have potential for future development. Small proportions of trees in the overstory with little potential for future development are acceptable, as these stems can be removed through improvement cutting.

The decision key shown in **Table 6.7.1** was developed to help to select the most appropriate silvicultural options for a specific stand. Decisions are based on size of hemlock stems and its canopy position and stocking. Improvement cuttings should be light and remove no more than one-third of the stand's basal area (Eyre and Zillgitt 1953). Follow the numbered decision points to reach a management option (in italics) that best describes the site and stand conditions. Then read the accompanying description for further details on the management option.

1. Hemlock size in the stand

Management options in this decision key are based on the average diameter of hemlock in the stand. It is assumed that hemlock is either one of the dominant trees in the stand or is at least the dominant species in the understory.

2. Overstory presence and growth of seedling- or sapling-size hemlock

If seedling and sapling stands of hemlock do not have an overstory, the recommended management is to allow them to grow until the average diameter of dominant hemlock in the canopy is at least 9 cm in diameter. At this point the stand should be re-assessed.

3. Stocking of overstory with seedling- and sapling-size hemlock

If the seedling- and sapling-sized hemlock understory has an overstory, management is based on the density or stocking of the overstory.

Overstories with a density less then 9 m^2/ha of trees 24 cm DBH or larger are open enough to permit good hemlock growth in the understory. In this case, the silvicultural prescription is to wait and allow the dominant hemlock in the understory to reach a minimum size of 9 cm DBH and then re-assess the stand.

Table 6.7.1: Decision key for managing even-aged hemlock stands (adapted from Anderson 1994*a*).

Text Description	Decision Factor	Continue to Point No.
1.	Hemlock size is: Seedling and sapling (0-9 cm DBH)………………………………………………. Polewood (9-24 cm DBH)………………………………………………………… Sawlog (> 24 cm DBH)……………………………………..………………….	 2 7 9
2.	Is an overstory present? No: *wait until average understory dominant reaches polewood size* Yes: ……..………………..………………………………………………………….	 3
3.	Stocking of stems >24 cm DBH in the overstory is: < 9 m^2/ha: *wait until average understory dominant reaches polewood size* > 9 m^2/ha …………………………………………………………………………	 4
4.	Overstory has potential for future development? Yes …………………………………………………………………………….. No ………………………………………………………………………………	 5 6
5.	Stocking of overstory stems >24 cm DBH is: > 24 m^2/ha: *reduce stocking by one-third through improvement cutting* > 16 m^2/ha: *reduce stocking to 16*m^2*/ha by improvement cutting* between 9 to 16 m^2/ha: *apply light improvement cutting only where necessary*	
6.	Stocking of overstory stems > 24 cm DBH is: > 24 m^2/ha: *reduce basal area by one-third through improvement cutting* > 16 m^2/ha: *reduce to 16* m^2*/ha through improvement cutting* between 9 to 16 m^2/ha: *do nothing now, review when stocking > 16* m^2*/ha.*	
7.	Is an overstory present in polewood hemlock stand? No: a*pply crop-tree release and thinning* Yes: ………..…………………………………………………………………….	 8
8.	Does the overstory have potential for future development? Yes: a*pply crop-tree release and thinning to polewood and improvement cutting in the overstory* No: r*emove overstory and apply crop-tree release via thinning to polewood stems*	
9.	Do the sawlog hemlock stems have potential for future development? Yes: a*pply selection system* No: ……………………………………………………………………………….	 10
10	Regeneration in the understory of the sawlog hemlock canopy is: not satisfactory: *regenerate hemlock with the uniform shelterwood system* satisfactory*:*………………………………………………………………………….	 11
11.	Allow understory to grow. If overstory stocking of hemlock stems > 24 cm DBH is: > 24 m^2/ha: *reduce basal area by one-third* > 16 m^2/ha: *reduce to 16* m^2*/ha.* < 16 m^2/ha: *do nothing, review if stocking becomes > 16* m^2*/ha*	

4. and 5. Stocking and vigor potential of overstory

Overstories with a density between 9 and 16 m^2/ha of trees 24 cm DBH or larger may need a light improvement cutting to increase tree quality of residual stems and permit more light to reach hemlock seedlings/saplings in the understory. No improvement cutting is recommended if there is little potential for future development of the overstory (i.e., stems will not improve in log quality and maintain growth and tree vigor over time).

A light improvement cut should focus on removing trees:

- with dieback in the upper crown and/or dead tops
- with V-forks in the lower bole
- that are excessively crooked
- with stem wounds that are not healing, particularly those with ground contact
- of undesirable species.

See **Section 5.3** for more detail on tree health, vigor, and risk. By removing inferior trees, overall stand quality increases and the best trees remain to increase in diameter and value.

Overstories with a density greater than 16 m^2/ha of trees 24 cm DBH or larger should have an improvement cut applied to reduce basal area to 16 m^2/ha. However in stands with a dense hemlock overstory (i.e., > 24 m^2/ha of trees 24 cm in DBH), improvement cuts should not reduce the basal area by more than one-third.

6. and 7. Polewood stands

Management options in polewood hemlock stands are determined by whether there is an overstory and whether the overstory has any potential for future development.

Polewood stands without an overstory

In stands with no overstory the recommended prescription is to apply a crop-tree release and thinning. To apply a crop-tree release, the best 100 crop trees per acre (247 per ha) should be chosen. Crop trees should have the following characteristics:

- A healthy, wide and deep crown; trees with live crown ratios greater than 50 % respond quickly, those with less than 30 % respond much more slowly (Anderson 1994).
- No open stem wounds, V-forks, or old dead tops with new leaders; also avoid trees with broken/dead limbs, seams, and injuries in the butt log, because these deformities are associated with rot, decay, and shake (Perkey *et al*. 1993).
- Suppressed understory trees are good crop tree candidates with hemlock. The older hemlocks are when released, the more they seem to respond. Suppressed trees seem to have fewer problems with butt rot and shake (Perkey *et al*. 1993).

These crop trees are then subsequently released on a maximum of two sides of the crown. Trees whose crowns touch (or are very near to) the crop-tree crown are removed on two sides of the crop tree. Excessive release (i.e., four sides of the crown) can result in reduced growth or mortality and contributes to windthrow (Godman and Lancaster 1990).

Polewood stands with overstory

In polewood stands with an overstory with potential for future development, the recommended management prescription is to apply crop-tree release to the polewood and light improvement cutting to the overstory. Overstories with no potential for future development should be removed. Crop-tree release is then applied to the remaining polewood stand.

7. and 8. Sawlog stands

Management options for sawlog stands are determined by the quality of the stand, and whether or not there is any hemlock regeneration.

Overstory with no potential for further development

Sawlog stands with little potential for further development are at the rotation age and should be regenerated. If there is no satisfactory regeneration in the stand, the stand should be regenerated using a three-cut uniform shelterwood system. Three-cut shelterwoods are ideal because they compensate for slow hemlock seedling development by shading out other species.

The first cut is the preparatory cut and it is made in a good seed year. It reduces the canopy closure to about 80 %. Removal of hardwoods is favored and logging is carried out in the summer months to encourage scarification (i.e., exposure of mineral soil). Additional scarification may be required to provide adequate seedbed conditions (Anderson 1994*a*).

After the preparatory cut seedlings will establish themselves. At this point, the success of hemlock establishment should be evaluated carefully. Excessive hardwood competition may have to be controlled (Perkey *et al.*1993), and hemlocks may have to be artificially seeded or planted if the seed crop has failed. If planting is required, seedlings should be obtained from a seed zone as close as possible to that of the planting site (**Figure 4.1.4**).

The second cut occurs once the regeneration is well established, generally 10 years after the preparatory cut. Regeneration should be at least 30 cm in height and marking should leave a residual canopy closure of 50 percent. Logging should be carried out in the winter to protect the regeneration (Anderson 1994*a*).

The third or removal cut is done when the regeneration is at least 1.5 meters tall and preferably 3 meters tall. This will occur at least 10 years after the second cut. This height is required to ensure successful release of the regeneration (Anderson 1994*a*).

Common associates in hemlock stands such as white pine, white cedar, sugar maple, and yellow birch will also regenerate successfully under the uniform shelterwood system (**Sections 6.5, 6.6, and 6.1,** respectively). The landowner should determine the desired proportion of each species in the regenerated stand. The amount of each species that regenerates can be controlled in part by the number of each species left as seed trees.

If there is adequate regeneration present under an overstory with no potential for future development, management focuses on reducing the overstory density and allowing the regeneration to grow. If overstory density is greater than 16 m^2/ha of 24+ cm DBH trees, density should be reduced to 16 m^2/ha through improvement cutting. If density is less than 16 m^2/ha, do nothing and re-assess the situation once the regeneration has reached polewood size.

Overstory has potential for future development

The selection system is applied to stands with an overstory with the potential for future development. Both the single-tree and group selection systems can be used to regenerate hemlock and to convert even-aged stands to uneven-aged ones. The single-tree selection system will also successfully regenerate sugar maple; group selection will successfully regenerate yellow birch, white pine and white cedar.

The selection system should be applied to even-aged stands once the rotation age is reached thereby converting stands to uneven-aged management over time. It is difficult to define a rotation age for hemlock as even small trees could have been suppressed for years. Rotation age for hemlock stands might best be considered to be the time when log quality begins to deteriorate on a site. In the northeastern United States, rotation age in hemlock is commonly reached when the average hemlock diameter is 40 to 45 cm (Perkey *et al.* 1993). Landowners in southern Ontario who are interested in managing stands for old-growth characteristics should consider leaving hemlock stems to grow much larger. The selection system can be used to remove material that has begun to decline, promoting growth of healthy canopy trees and regeneration.

To implement the single-tree selection system on a site, use the following guidelines from Anderson (1994*a*):

- The first cut should leave a residual basal area of 23 m^2/ha, but not reduce the stand's basal area by more than one-third.
- Harvesting should be done in snow-free periods to encourage scarification.
- A salvage cut may be needed five years after the first cut to salvage any mortality.
- A 10-year cutting cycle should be used leaving a residual stocking level of 18 m^2/ha in subsequent cuts.

Little hemlock regeneration may become established between harvests because of the lack of scarification (Kittredge and Ashton 1990).

Group selection could also be used to regenerate hemlock using the following guidelines from Anderson (1994*a*). See **Section 6.1** for more information on group selection.

- Maximum size of openings should be one-half tree height. Small openings limit light and competition from intolerant species, and limit drying of seedbeds.
- Openings must be scarified to expose suitable seedbeds (Godman and Lancaster 1990).

The selection system is more suited to stands being managed for wildlife habitat as well as timber. With the selection system, two to three hemlock can be left in clumps to provide cover for white-tailed deer, and to provide a more permanent conifer cover for a range of wildlife. The selection system also allows a forest manager to leave old hemlock supercanopy trees, some of which may range in age from 200- to 500-years-old. Old-growth features are also best preserved under the selection system (see the subsection on managing hemlock for old-growth features in the following).

Stocking guides for managing even-aged hemlock stands

A stocking guide is available to assist in managing even-aged hemlock stands (**Appendix E**). The ideal stocking level recommended for a stand depends on the proportion of hemlock in the stand. Mixed stands with little hemlock are maintained at lower stocking levels than stands with greater than 50 % hemlock. A stocking guide shows forest managers how a stand is occupying the area available to it, and how much the stand can be thinned without wasting growing space. For example, if the average basal area in a stand is 25 m^2/ha in a stand with 75 % hemlock, the average stocking level is around 850 trees/ha. If a stand had 1000 trees/ha, 150 trees/ha could be removed evenly throughout the stand to maximize growing space available to each residual tree. In general, average stand diameter should be 20 cm at this stage of stand growth.

Managing uneven-aged stands of hemlock

Uneven-aged stands can either be managed as uneven-aged stands or converted to even-aged stands. Typical situations where conversion to even-aged management may be appropriate include:

- quality of canopy hemlock trees is declining through dieback, insects, physical damage, or suppression
- there has been a significant increase in the proportion of undesirable species in the stand and/or decline of hemlock proportion in the stand
- there is significant browsing pressure. The best solution to limit browse damage may be to promote abundant regeneration over wide areas (Schaffer 1996). Even-aged systems produce abundant regeneration over large areas; uneven-aged systems produce small amounts of browse, and it is sometimes concentrated in smaller areas.

To manage an uneven-aged stand, use the single-tree and group selection guidelines provided previously in the ‘Overstory has potential for future development’ subsection.

To convert an uneven-aged stand to even-aged management, use the decision key provided in the previous section. When deciding on hemlock size (i.e., sapling, polewood, or sawlog), choose the dominant size class in the stand. For example if there are one or two scattered hemlock canopy trees and abundant polewoods, use the polewood section of the decision key.

Managing hemlock stands for old-growth features

Hemlock is a very long-lived tree and as such can be an important component of old-growth ecosystems. The record age for hemlock is 988 years (Godman and Lancaster 1990) and many stands of mature hemlock are quite old (e.g., 200 to 250 years). Hemlock is the longest living forest tree in Ontario (Stabb 1996), and only white cedar survives as long on the Niagara Escarpment. Two options exist for older stands: leave the stand alone or manage it for old-growth features by harvesting some wood products while preserving valuable features for wildlife and conservation. The former option is probably more appropriate for landowners who are less interested in timber production and more interested in wildlife, forest recreation, and appreciation of the aesthetics of older woodlands.

Desirable old-growth features in any stand include:

- large trees or old trees
- trees with few branches to canopy (clear bole)
- many layers in canopy
- large canopy gaps
- uprooted trees
- large dead or broken trees
- logs and woody debris
- tree species diversity
- hummocks from pits and mounds of fallen trees and root tip-ups
- undisturbed soil and woody debris with associated greater water retention

Many of these features can be restored to managed woodlots, enhancing wildlife habitat and biodiversity. The group selection system can be used to create canopy openings. A range of canopy opening sizes will encourage the regeneration of several different species. For example, gaps 6 to 10 m in diameter will promote regeneration of shade-tolerant species such as sugar maple or hemlock. Gaps 10 to 50 m in diameter will favor mid-tolerant species such as the oaks and white pine, while openings larger than 50 m in diameter will favor intolerant species such as aspen, tulip tree, and white birch (**Table 6.1.10**). However, large openings are not recommended in small or fragmented stands. Canopy gaps should be spaced 50 m apart and at least 30 m from the edge of the stand to avoid creating additional edge habitat and minimize forest fragmentation and invasion by undesirable species, especially exotics.

Pit and mound topography can be restored by allowing declining and dead trees to fall naturally. Once on the ground, these trees will provide habitat for a variety of species. To restore old-growth features, 10 fallen logs, preferably ones that are at least 2 m long and 60 cm in diameter, should be left in every hectare of forest. By allowing twigs and branches to decompose naturally on the forest floor, organic material can be enhanced. Ground vegetation can be better protected and encouraged by logging in winter when snow provides some protective cover.

Hemlock logs can persist for extended periods of time on the forest floor and it can take up to 200 years for them to lose their structural integrity and become partially incorporated into the soil. In old-growth hemlock forest in Wisconsin, stands greater than 350-years-old accumulated over 65 m^3/ha of logs, distributed across all decay classes (Tyrrell and Crow 1994).

Studies in the Lake States (Goodburn and Lorimer 1998) found that the amounts of downed woody debris in managed stands were much lower than in old-growth stands; volume of fallen wood greater than 10 cm in diameter was significantly lower in a selection stand (60 m^3/ha) and even-aged stands (25 m^3/ha) than in old-growth stands (99 m^3/ha). The large amount of downed woody debris often found in old-growth stands may not develop in managed forests, but landowners can try to conserve as much of this material as possible.

Cavity trees and snags can be preserved to promote old-growth features in a woodlot. Six living cavity trees and a minimum of four small snags less than 50 cm DBH and one large snag greater than 50 cm DBH should be left per hectare (OMNR 1998*b*). Snags can be created through girdling unmerchantable trees during thinning or regenerating operations. Studies in the Lake States discovered that the density of snags greater than 30 cm DBH in northern hardwood selection stands averaged 12 per hectare, approximately double that found in even-aged northern hardwoods, but only 54 % of the level in old-growth northern hardwoods. Highest densities of snags larger than 30 cm in diameter occurred in old-growth hemlock-hardwood stands, averaging more than 40 snags per hectare. Cavity tree density in selection stands averaged 11 trees per hectare, 65 % of the mean number in old-growth stands (Goodburn and Lorimer 1998). In many forests managed for old-growth features, these high snag and cavities numbers may not be achievable, but landowners should aim to retain as many as possible.

Mast trees can be promoted to provide food for wildlife. Hard mast species such as oak, beech, butternut, and hickory are preferred, but soft mast species such as cherries and mountain ash also supply important forage. Seven mast trees should be promoted per hectare (Naylor 1999).

Supercanopy trees are trees such as white or red pine that rise above the rest of the canopy and provide landmarks for birds and nesting, roosting, or escape cover habitat. At least one cluster of pines, hemlocks, or spruces should be left in every three to four hectares with three to four trees per cluster. Studies in central Ontario have found that stands disturbed by fire usually have up to 50 pine or hemlock canopy trees per hectare that survive to become supercanopy trees in new stands. The average density of supercanopy trees was found to be 16 pine or hemlock trees per hectare in Temagami (OMNR 1998*b*). Supercanopy trees near wetlands and along shorelines of water bodies provide habitat for eagles and ospreys. It is recommended that three supercanopy trees be left within 400 m of bald eagle and osprey nests, and that one supercanopy tree be left per 650 m of shoreline in nesting areas (OMNR 1998*b*).