Logging Methods

	Comments
Overview	• three general categories of logging methods are: full-tree logging, tree-length logging, and shortwood (cut-to-length) logging (see Section III) • in addition to the economics of harvest, selection of a logging method has particular impact on the following aspects of boreal mixedwood management: - protection of advance growth and residual trees - accumulation of slash - the number and distribution of cones left on site - disturbance of organic layers
Promotion of Conifer or Hardwood	N/A
CR Conditionally Recommended Practices	• careful logging practices are required to minimize logging damage; these include providing operator training for minimizing damage when working in partial harvest situations; pre-planning and harvest layout and selecting and marking skid trails to minimize site disturbance and protect residual trees and/or advance growth; requiring felling and skidding equipment to use the same trails; marking rub posts for use along skid trails and at tight corners; and using directional felling • require that logging only be permitted on frozen ground or with low-impact equipment when there is potential for rutting and compaction (see OMNR 1997c); potential for site damage is particularly high on saturated, fine textured and moist mineral soils
D Developmental Practices	N/A
NR Not Recommended Practices	• full-tree logging is not recommended for any harvest methods or thinning treatments that leave a partial overstorey or when protection of advance growth is required; in these cases, the risk of unacceptable levels of damage to residual stems will be high
Considerations for Implementation	• all logging methods may result in damage to residuals; 10 to 20% of stems damaged is not uncommon for full-tree logging (Pulkki 1996); cut-to-length may result in damage as low as 2% • as part of the silvicultural prescription, objectives relating to acceptable levels of harvesting damage should be determined • cut-to-length is the most suitable logging method for shelterwood and selection harvest methods, small patch harvesting, and thinning • in a two-stage harvesting operation, feller-bunchers working with grapple skidders caused minimal damage to residuals with operator-controlled felling direction and bunching location (Navratil *et al.* 1994); protection of understorey may increase with the use of feller bunchers and single-grip harvesters

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Logging Methods (cont.)

	Comments
Considerations for Implementation (cont.)	• careful logging practices include: - providing operator training for working in partial harvest situations - pre-planning harvest layout and selecting and marking skid trails to minimize site disturbance and protect residuals and/or advance growth - operating felling and skidding equipment on the same trails - delimbing stems before skidding - using "rub trees" along skid trails and at tight corners - where possible, avoiding harvest in spring when the opportunity for bark damage is greatest - using directional felling - using the main-line and winch (where applicable) to reduce the amount of travel of harvesting equipment • tree length and cut-to-length logging will result in higher slash loadings on site than will full tree logging: - increased shading of the forest floor from logging debris will reduce soil temperatures and, therefore, reduce the amount of aspen root suckering - increased slash loading will reduce the distribution and abundance of plantable spots and receptive seedbeds • windrowed slash from single-grip harvesters may result in uneven distribution of aspen suckers and a reduction of available seedbed
Opportunities	(based on Kenney and Towill 1999) • season of harvest must be considered in selecting a logging method to meet mixedwood objectives; for example, logging on frozen ground reduces the amount of site and soil disturbance • accumulations of slash, and the amount and distribution of plantable spots and receptive seedbeds, may be modified using appropriate site preparation treatments • some slash may benefit tree establishment by modifying the microclimate and providing some seed • full-tree logging is suitable for stands with smaller trees due to the multiple tree-handling ability of feller-bunchers
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Regeneration Type: Natural / Regeneration Method: Advance Growth	
	Comments
Overview	• advance growth is composed of tree species mid tolerant to tolerant of shade, such as white spruce, black spruce, and balsam fir (Weetman and Vyse 1990)
Promotion of Conifer	• advance conifer growth may be protected during harvesting operations to contribute conifer stocking to the developing stand
Promotion of Hardwood	• advance growth is not a viable technique for regenerating shade intolerant hardwoods
CR Conditionally Recommended Practices	• where most advance growth is large and near-merchantable (10 to 15 cm dbh), advance growth must be below a critical slenderness coefficient (SC) to lower the probability of wind throw and top breakage following overstorey removal (see Wind Damage, Section IV) • layer-origin black spruce is acceptable as potential advance growth only on moist mineral soils • careful logging practices for the protection of advance growth are required
D Developmental Practices	N/A
NR Not Recommended Practices	• full tree logging is not recommended when harvesting to protect advance growth
Considerations for Implementation	• white spruce advance growth is rarely abundant in Ontario (Groot *et al.* 2001) • black spruce advance growth is not abundant and is very variable within and between sites (Walsh and Wickware 1991, Arnup 1996a, b, c); on upland boreal mixedwood sites, black spruce advance growth is generally only sufficiently abundant to be considered as a supplementary, rather than the primary, source of regeneration (Walsh and Wickware 1991) • presence and abundance of seed origin black and white spruce advance growth is limited due to the lack of spruce seed source and sufficient quality and quantity of receptive seedbeds (Groot *et al.* 2001) • balsam fir advance growth is generally abundant, but longevity and growth is affected by spruce budworm population levels • advance growth should be evaluated to assess its ability to respond to release and to determine its acceptability as the new crop • ability of balsam fir and black spruce advance growth to respond to improved light conditions can be related to pre-harvest live crown ratio and the percentage of stem surface area wounded or damaged during harvest (Ruel and Doucet 1998, Ruel *et al.* 2000a) • survival and growth of advance regeneration following overerstorey removal is favoured on moist sites where partial canopy removal has occurred (Kneeshaw *et al.* 2002) • ability of advance growth to positively respond to changing light and other microclimatic conditions is delayed on dry sites following full canopy removal; survival and growth of balsam fir advance growth is particularly adversely affected by prolonged periods of drought • advance growth may not be a reliable source of regeneration on clearcuts where silviculture practices can result in damage and seedling mortality may increase from sudden exposure to full light conditions (Ferguson 1984, Ruel *et al.* 2000)

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Regeneration Type: Natural / Regeneration Method: Advance Growth (cont.)	
	Comments
Considerations for Implementation (cont.)	• harvesting can result in significant damage and reduction in densities of advance growth (Walsh and Wickware 1991), although 80% of pre-harvest stocking of black spruce advance growth can survive after winter harvesting with careful logging (Groot 1995) • damage to advance growth can be reduced during harvest through use of high flotation tires, winter logging and careful directional felling and skidding with spaced skid trails (Walsh and Wickware 1991) • when advance growth is small (e.g. 0.5 to 2.5 m in height), a minimum pre-harvest seedling density of 18,000 stems/ha would be required to achieve 40% stocking (based upon a 4 m^2 assessment plot) (Greene *et al.* 2001, 2002)
Opportunities	• black spruce advance growth densities ranging from 5000 to 15,000 stems/ha have been documented for some sites in northwestern Ontario, with the majority of advance growth less than 0.5 m in height (Buse and Farnworth 1995) • due to less than recommended pre-harvest black spruce advance growth stocking levels on most boreal mixedwood sites, some form of supplementary regeneration (e.g. fill-planting, or natural seeding where the opportunity exists) will likely be required • advance spruce that is a minimum of 2.5 to 3.5 m in height may be successfully released by overstorey removal (Johnson 1986, Yang 1989, Bell 1991); spruce of shorter stature can be susceptible to overtopping by regenerating hardwood trees and/or woody shrubs following overstorey removal
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<table>
<tr><th colspan="2">Regeneration Type: Natural / Regeneration Method: Seed</th></tr>
<tr><td></td><td>Comments</td></tr>
<tr><td>Overview</td><td>use of this treatment for the regeneration of white spruce, black spruce, and white birch on boreal mixedwood sites is developmental</td></tr>
<tr><td>Promotion of Conifer</td><td>clearcut with seed trees, clearcut with pre-harvest understorey site preparation, shelterwoods, and group selection harvests may be used to regenerate white and black spruce by natural seeding</td></tr>
<tr><td>Promotion of Hardwood</td><td>natural seeding may be used to promote white birch
birch regeneration is most successful on low competition sites (Peterson et al. 1997), and may be promoted under appropriate conditions on coarse and medium broad soil groups in Northwest ecoregions and on the coarse broad soil group in Northeast ecoregions</td></tr>
<tr><td>CR Conditionally Recommended Practices</td><td>N/A</td></tr>
<tr><td>D Developmental Practices</td><td>sufficient distribution of receptive seedbeds is critical; when preparing seedbeds prior to harvest, site preparation should result in 35% coverage of receptive seedbeds (refer to autecology tables in Section VII for appropriate seedbeds); site preparation should be timed with a seed year (Greene et al. 2002)
conifer seeding results must be closely monitored to identify vegetation management requirements, including protecting conifer seedlings from smothering by leaf litter
using pre-harvest site preparation, basal areas of white spruce seed trees required in the canopy to obtain various stocking levels have been proposed for Alberta boreal mixedwood sites, as follows (Greene et al. 2000, 2002):
<table>
<tr><td>Stocking Levels</td><td>Minimum 0 – 30%</td><td>Moderate (30 – 50%)</td><td>Full (100%)</td></tr>
<tr><td>Basal (BA) area of seed trees (m²/ha)</td><td>1</td><td>2</td><td>6.6</td></tr>
<tr><td>Density of seed trees (#trees > 40 cm dbh)</td><td>12</td><td>24</td><td>75</td></tr>
</table>
for additional recommendations on natural seeding, see Seed Tree (page 24), Shelterwood (page 28), and Selection (page 33) harvest methods fact sheets</td></tr>
<tr><td>NR Not Recommended Practices</td><td>aspen regeneration by seed is highly variable due to a short period of seed viability (Navratil 1991) and rigorous seedbed requirements (Brinkman and Roe 1975, Davidson et al. 1988)
potential for recruitment of white and black spruce from seed is low for aspen dominated, white birch dominated, aspen leading, and white birch leading mixedwoods
regeneration of balsam fir not a common management objective due to its susceptibility to eastern spruce budworm and stem and root rots (Groot et al. 2001)</td></tr>
</table>

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Regeneration Type: Natural / Regeneration Method: Seed (cont.)	
	Comments
Considerations for Implementation	• seed tree harvest should be delayed for a number of years to increase seeding success; seeding should be completed within four years of site preparation (Greene *et al.* 2000), because seedbed quality declines rapidly as vegetation colonizes the site and organic matter begins to accumulate; on boreal mixedwood sites, receptive seedbeds may quickly become covered with hardwood litter (OMNR 1997c)
Opportunities	• understorey scarification could be conducted prior to overstorey harvest to secure natural regeneration of spruce from seed; harvest of seed trees occurs after seed release
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Regeneration Type: Natural / Regeneration Method: Vegetative/Coppice	
	Comments
Overview	• vegetative reproduction may result in rapid development of hardwood species
Promotion of Conifer	N/A
Promotion of Hardwood	• after cutting parent trees, trembling aspen regenerates rapidly from root suckers and white birch regenerates from stump sprouts
CR Conditionally Recommended Practices	• require that there is sufficient distribution of white birch and/or aspen stems to meet hardwood compositional requirements for the desired future stand condition • require 100 to 120 aspen stems/ha (Davidson *et al.* 1988)(or ≥ 20% basal area of aspen) well distributed throughout the pre-harvest stand to provide for adequate vegetative reproduction of aspen to meet aspen dominated or aspen leading future stand conditions • to secure adequate aspen vegetative reproduction (and prevent site damage), harvesting may not occur when the ground is subject to compaction or rutting (a particular concern on fine and moist mineral soils) (Perala 1981, Bates *et al.*1993); winter logging can be used to reduce soil compaction and mechanical damage to root systems
D Developmental Practices	N/A
NR Not Recommended Practices	N/A
Considerations for Implementation	**Aspen** • the average area covered by individual trembling aspen clones in northwestern Ontario is 0.12 ha, but on occasion may exceed 2.0 ha (Kemperman 1977) • most aspen suckers are located within 5 m of the nearest bole, with dispersion declining rather abruptly within another 10 m (Greene *et al.* 1999) • most aspen suckers originate from roots 0.8 to 1.8 cm in diameter and within 8 cm of mineral soil surface • soil temperature is the most important environmental factor controlling sucker formation; aspen suckering is inhibited by root zone temperatures lower than 15 °C, and is optimal between approximately 20 and 30 °C (Maini and Horton 1966, Maini 1967) • heavy accumulations of slash and debris after harvest will discourage aspen suckering (Peterson and Peterson 1995) • forest floor organic layers > 15 cm will generally require site preparation to facilitate mineral soil exposure or mineral soil/organic layer mixing to ensure adequate warming of the rooting zone for aspen (Perala 1991a) • most suckers are produced in the first growing season following disturbance (Sandberg 1951); scarification after aspen suckering has commenced will result in reduced height growth of the replacement suckers (Weingartner 1980)

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Regeneration Type: Natural / Regeneration Method: Vegetative/Coppice (cont.)	
	Comments
Considerations for Implementation (cont.)	• vigorous aspen sucker production can be encouraged by complete removal of the overstorey to eliminate apical dominance and promote soil warming (Horton and Maini 1964, H.W. Anderson *et al.* 2001); however, minimum canopy openings 20 to 25 m in diameter may also support aspen (Paré and Bergeron 1995, Carlson and Groot 1997, Kneeshaw and Bergeron 1998, Cumming *et al.* 2000, Kelly *et al.* 2001) • harvesting aspen in the dormant season results in maximum aspen suckering during the next growing season since carbohydrate reserves are at their highest during dormancy (Schier and Zasada 1973); however, after two or three years, stem density is the same on summer-logged as on winter-logged sites (Bella and DeFranceschi 1972, Perala 1981a, Bates *et al.* 1993) • stand age does not affect the ability of aspen to sucker, provided that the stand is not subject to break-up or decay (Steneker 1976, Zasada *et al.* 1992, Lavertu *et al.* 1994, Frelich and Reich 1995); overmature stands may have inadequate suckering ability due to shrinking root systems or thick forest humus layers which prevent sucker production due to low soil temperatures (Perala 1991) **Birch** • birch sprouting undergoes an approximately linear decline with age, and may be effectively limited after parent trees reach 70 years of age (Zasada *et al.* 1992) • sprouting in white birch is encouraged by cutting stumps low to the ground (< 30 cm) and in the spring; the most vigorous sprouts are produced from small to medium sized stems (Perala 1974a)
Opportunities	• vegetative regeneration of trembling aspen and white birch can provide for rapid stand establishment, often at a low cost (usually just the cost of logging) • vegetative reproduction of white birch from stump sprouts may result in several stems which will require pre-commercial thinning in order to yield a suitable stem free of defect and sweep
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Regeneration Type: Artificial/ Regeneration Method: Pre-harvest Underplant	
	Comments
Overview	• generally involves planting of conifers prior to harvest
Promotion of Conifer	• underplanting is typically done 20 to 40 years prior to overstorey harvest, creating a distinct two-tiered stand structure • underplanting promotes a future conifer dominated or conifer leading stand condition
Promotion of Hardwood	N/A
CR Conditionally Recommended Practices	N/A
D Developmental Practices	• adequate light levels in the regeneration zone is key for success of this treatment; > 25% of full sunlight is required (and must be maintained) at seedling or sapling height (Greene *et al.* 2002), with shading by both the overstorey tree canopy and understorey vegetation being taken into account • maintaining > 25% of full sunlight is necessary for good survival and eventual response to release of understorey shade tolerant conifers (Greene *et al.* 2002) • there are indications that light transmission levels through mature aspen stands under certain conditions in eastern Canada may be less than in western Canada where underplanting has been implemented (Greene *et al.* 2002, and refer to summary of light levels by jurisdiction in Table 2 of Section IV) - although data are sparse, light levels measured thus far beneath mature closed canopy aspen stands in Ontario appear to be marginal to insufficient for underplanting in the absence of partial canopy removal (see Table 2, Section IV) - information is lacking on light conditions beneath mature closed canopies of white birch in Ontario; but information from other jurisdictions suggests light conditions may be insufficient for underplanting in the absence of partial canopy removal (see Table 2, Section IV) • in British Columbia, adequate light levels for underplanting have been met in 40 to 60 year-old aspen dominated or aspen leading boreal mixedwood stands with less than 1,200 stems/ha (35 m^2/ha) (Delong *et al.* 2000) • underplanting may be carried out in conjunction with a shelterwood harvest (partial canopy removal) where overstorey trees are left • juvenile aspen stands that are to be underplanted may be spaced to appropriate densities to allow for adequate light transmission (Coopersmith and Hall 1999, Lieffers *et al.* 2002, Comeau *et al.* submitted) • light transmission levels may be greatly reduced under intact juvenile aspen stands; the lowest period of light transmission in developing aspen stands appears to occur between the ages of 15 and 25 years and may reach levels as low as 4% of full sunlight (Pinno *et al.* 2001, Lieffers *et al.* 2002) • at least 50% canopy cover should be maintained to reduce competition from understorey non-crop vegetation (Greene *et al.* 2000) • understorey site preparation or cleaning may be required for control of non-crop vegetation, particularly where competition from beaked hazel, mountain maple, or Canada blue-joint grass is anticipated

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Regeneration Type: Artificial/ Regeneration Method: Pre-harvest Underplant (cont.)	
	Comments
D Development Practices (cont.)	• spacing of seedlings when underplanting can be fixed or random, but seedlings should be at least 1 m from live dominant hardwood stems (Delong *et al.* 2000) • planting should be scheduled for early spring when moisture is highest and prior to bud break of overstorey hardwoods (Green *et al.* 2000) • careful logging practices should be used when harvesting the overstorey
NR Not Recommended Practices	• full tree logging is not recommended when attempting to protect underplanted seedlings
Considerations for Implementation	• snowshoe hares can cause heavy browse damage to underplanted seedlings, especially if seedlings are nutrient loaded; to minimize hare damage: - underplanting should ideally occur after peaks in hare populations and on sites that do not offer suitable habitat - underplant in the interior of large, contiguous mature aspen stands • access trails should be left unplanted if tending or other treatments will require repeat entries to the stand • two-stage harvesting of merchantable hardwood overerstorey can be initiated when underplanted conifers are large enough to withstand post-harvest competition and mechanical damage
Opportunities	• potential for underplanting conifers in intact hardwood dominated or hardwood leading boreal mixedwood stands has been demonstrated in various jurisdictions, given suitable light conditions (Kabzems and Lousier 1992, Dyck 1994, Tanner *et al.* 1996, Comeau *et al.* 1998, 1999, MacDonald 2000, Stewart *et al.* 2000, Delong et al. 2000, Sherman *et al.* (submitted) a, b) • underplanting conifers in conifer leading or conifer dominated boreal mixedwood stands may also be an option (Man and Lieffers 1999, Lieffers *et al.* 1999), so long as light requirements are met • underplanting may also be carried out in conjunction with a shelterwood harvest; stands could be spaced to create light levels suitable for underplanting • underplanting can emulate natural succession by accelerating natural stand development from a hardwood condition to softwood dominated or softwood leading condition
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Regeneration Type: Artificial / Regeneration Method: Post-harvest Plant	
	Comments
Overview	• with appropriate vegetation management, this is a reliable technique for introducing conifer to a mixedwood stand
Promotion of Conifer	• post-harvest planting may be used to establish the coniferous component of mixedwood stands; this is a reliable method for achieving conifer dominated or conifer leading stand conditions • tending is generally required to maintain the survival and growth of conifers on boreal mixedwood sites
Promotion of Hardwood	N/A
CR Conditionally Recommended Practices	• planting must be monitored and appropriate vegetation management techniques applied to protect conifer regeneration while maintaining the hardwood component of the mixedwood stand
D Developmental Practices	N/A
NR Not Recommended Practices	• when aspen dominated and birch dominated future stand conditions are the objective, post-harvest planting is not recommended since broadcast tending methods (damaging to the hardwood component) would be required (clusterplant is the conditionally recommended regeneration method in these situations)
Considerations for Implementation	• future stand composition will depend on tree species planted, tending, ingress, and the presence of advance growth • site type, site preparation method, stock types and the type of planting tool can influence the number and distribution of suitable planting spots (McLain and Willcocks 1988) • current site preparation practices to promote black and white spruce on conventional clearcut boreal mixedwood sites usually involve post-harvest organic matter removal through some form of mechanical site preparation combined with chemical site preparation for vegetation control (Sutherland and Foreman 2000)
Opportunities	• area based (fill) planting can be used to supplement natural regeneration from seed or advance growth
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Regeneration Type: Artificial / Regeneration Method: Clusterplant	
	Comments
Overview	• this method is used to introduce the conifer component of a mixedwood stand
Promotion of Conifer	• future stand composition can be manipulated by varying the percentage of the area occupied by the conifer planting • planting densities for clusters and the inter-cluster spacing must be consistent with future stand objectives (e.g. planting densities should be greater to achieve a conifer leading future stand condition than to achieve an aspen leading stand condition)
Promotion of Hardwood	• an even-aged hardwood condition is promoted in the intervening spaces between the clusters of planted conifers, usually following conventional clearcutting or uniform shelterwood harvests (BCMoF 2000)
CR Conditionally Recommended Practices	• clusters must be monitoring and vegetation management techniques applied to keep conifer regeneration free of overtopping and lateral competition; a competition-free zone should be maintained around each cluster
D Developmental Practices	N/A
NR Not Recommended Practices	• this technique is not recommended when a conifer dominated future stand condition is the objective (post-harvest planting throughout the stand (not just clusters) is conditionally recommended to meet objectives in these circumstances)
Considerations for Implementation	• clusters have been established using white spruce trees spaced 1 to 1.4 m apart; other species may be considered for cluster planting if environmental conditions are suitable for their survival and growth • future stand yields will be influenced by initial number of trees per cluster, inter-tree spacing, and associated individual tree growth response (Terlesk and McConchie 1988)
Opportunities	• this method can be used to create patchy mixtures of conifer and hardwoods
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Regeneration Type: Artificial / Regeneration Method: Direct Seed	
	Comments
Overview	• involves the manual or mechanical sowing of seed • successful direct seeding depends on proper site selection, adequate site preparation, and good seed distribution
Promotion of Conifer	• direct seeding may be used to establish spruce, but results are unreliable in boreal mixedwood conditions
Promotion of Hardwood	• direct seeding may be used to promote white birch • birch regeneration is most successful on low competition sites (Peterson *et al.* 1997), and may be promoted under appropriate conditions on coarse and medium broad soil groups in Northwest ecoregions and on the coarse broad soil group in Northeast ecoregions
CR Conditionally Recommended Practices	• precision seeding of spruce is conditionally recommended in spruce dominated mixedwoods for the establishment of a softwood dominated or softwood leading condition; assessments are to begin within two years of seeding to determine seeding success and evaluate and schedule vegetation management requirements
D Developmental Practices	• white birch direct seeding on coarse or medium soil groups in Northwest ecoregions, and on the coarse soil group in Northeast ecoregions, is a developmental practice • recommendations for white birch direct seeding (Perala and Alm 1990): - precision seeding (rather than broadcast seeding) is preferred - seeding should be on scarified seed spots; best germination occurs on shaded mineral soil seedbeds (Peterson *et al.* 1997) - seed may be sown in fall or spring; seeding may be more successful if the seedbed is allowed to stabilize before sowing - seed may be protected with shelter cones to improve germination • shading improves establishment of birch from seed; once birch is established, light availability should be increased to improved seedling growth (Peterson *et al.* 1997)
NR Not Recommended Practices	• white spruce and black spruce direct seeding on upland boreal mixedwood sites is not recommended; aerial seeding of white spruce has been attempted in other jurisdictions but found to be unreliable (Waldron 1974); seedbed requirements for successful black spruce establishment are very precise and aerial seeding is also unreliable; precision seeding improves opportunities for matching seed to a receptive seedbed, but intense competition and smothering of seedlings with hardwood litter on mixedwood sites contribute to the poor success of this treatment

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Regeneration Type: Artificial / Regeneration Method: Direct Seed (cont.)

	Comments
Considerations for Implementation	• direct seeding is less reliable than natural seeding because seed application, and subsequent germination and establishment, must be completed under the conditions of one growing season • delays between seedbed creation and seeding may result in loss of receptive seedbeds as a result of covering by hardwood litter • seeding must be followed by early vegetation management to control herbaceous and graminoid vegetation (Bell *et al.* 1992) • continuous furrow scarification is the preferred site preparation method for spot seeding of upland sites because it promotes ingress of naturals, facilitates microsite selection, and contributes to higher worker productivity (Adams *et al.* 2001) • precision seeding of black spruce: - results in more efficient use of seed than broadcast application (Dominy and Wood 1986, Adams 1995) - provides better control of seedling density and spacing than broadcast seeding (van Damme *et al.* 1988, Corbett 1992) - must be conducted in the spring; the suggested rate is 15 seeds per seed spot (Adams *et al.* 2001) • boreal mixedwood ecosites 25 (Northwest Region) and 5f and 5m (Northeast Region) are suggested as “best bets” for successful seeding of black spruce (Adams *et al.* 2001)
Opportunities	N/A
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Site Preparation: Manual/Motor-Manual

	Comments
Overview	• this method involves manually preparing sites (e.g. using hand-held equipment) before or after harvest • manual techniques include boot screefing, mattocks, and grub hoes for preparing planting sites, and axes, brush hooks, shears, and machetes for removing woody shrubs • motor-manual techniques include motor-driven scarifiers attached to brushsaws for preparing planting sites and brushsaws and chainsaws for removing woody shrubs • manual and motor-manual techniques maximize protection of advance growth, minimize damage to residual stems, and minimize unwanted disturbance of the organic layers and the soil seed bank
Promotion of Conifer	• conifer planting or seeding spots may be prepared by manual or motor-manual means • techniques used to remove competing brush and hardwood stems prior to regeneration are similar to manual cleaning treatments
Promotion of Hardwood	• manual and motor-manual techniques provide an opportunity for protecting hardwood crop trees while preparing the site for additional regeneration treatments
CR Conditionally Recommended Practices	• this method is only recommended for reducing the litter layer or removing slash to prepare planting spots or receptive seedbeds for precision seeding; if extensive brush competition occurs on a boreal mixedwood site, this method alone will not result in successful seeding or planting
D Developmental Practices	N/A
NR Not Recommended Practices	• these techniques are not recommended when regenerating by natural seeding since the required seedbed conditions (distribution and abundance) are better obtained using mechanical site preparation techniques • these techniques are not recommended when promoting the regeneration of hardwoods by vegetative means; hardwood generation is vigorous and competitive
Considerations for Implementation	• boot screefing is most often used where the forest humus layer is < 5 to 10 cm in thickness • site conditions, including the type and abundance of ground vegetation, determine the efficacy of brushsaw-mounted scarifiers; see Cormier (1989) and Maxwell (1989) for an evaluation of several motor-manual scarification devices
Opportunities	• manual and motor-manual techniques may be combined with chemical treatments; cut hardwood stems may be treated with liquid herbicide applied with an applicator attached to a brush cutter; when combining these treatments with chemical application refer to product labels for information on herbicide efficacy, species sensitivity, and recommended timing of application • manual trampling or binding of mountain maple appears to be an effective technique for controlling its re-growth, since trampling does not promote re-sprouting from basal sprouts (Aubin and Messier 1999, Kneeshaw *et al.* 1999) • these techniques may be appropriate for use in partial harvest situations to undertake "spot" treatments and to minimize damage to residual stems or protect advance growth
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Site Preparation: Mechanical and Chemi-Mechanical

	Comments
Overview	• mechanical site preparation implements may create screefed, inverted, mounded, trenched, or mixed soil profiles • herbicides may be applied in conjunction with mechanical site preparation (chemi-mechanical) to delay re-establishment of competitive species • in addition to general considerations used in planning mechanical site preparation (e.g. desired microsite, terrain and slope limitations, rockiness and stoniness), certain factors have particular emphasis in boreal mixedwood management: - the amount and distribution of logging debris and stumps - the frequency and size of residual stems in partial canopy removal systems - the protection of advance growth - the amount of brush cover (see Considerations for Implementation) • for a thorough review of mechanical site preparation treatments in Ontario, see Sutherland and Foreman (1995) and Ryans and Sutherland (2001)
Promotion of Conifer	• mechanical site preparation is generally required to provide sufficient well-distributed seedbeds when regenerating white spruce or black spruce by seed (OMNR 1997) • site preparation is also generally required before planting conifers on productive boreal mixedwood sites • chemicals may be applied in bands when site preparing areas for conifer establishment, which allows flexibility when protecting advance growth or desirable hardwoods
Promotion of Hardwood	• mechanical site preparation is almost always required to provide sufficient well-distributed seedbeds when regenerating white birch by seed (Perala and Alm 1990, Peterson *et al.* 1997) • site preparation (scarification) may also be used to redistribute logging debris and improve conditions for aspen suckering; however, if applied after suckering, scarification will result in a reduction in the dominant height of aspen (Weingartner 1980) • chemicals must be selectively applied if the hardwood component is to be protected
CR Conditionally Recommended Practices	• the following conditions must be met when using mechanical or chemi-mechanical site preparation for natural regeneration of white spruce (Zasada 1972): - site preparation must be completed no later than mid-August during a good to excellent seed year - site preparation must provide for an average of 5 to 10% mineral soil exposure well distributed over 55 to 65% of the harvest area - site preparation must result in scarified patches that are a minimum of 1 to 1.5 m in the smallest dimension • mechanical site preparation to stimulate vegetative reproduction of aspen must be applied prior to suckering following harvest (Weingartner 1980) • appropriate manoeuvrable equipment must be used when site preparing in the vicinity of residual stems or advance growth that is to be protected

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Site Preparation: Mechanical and Chemi-Mechanical (cont.)	
	Comments
CR Conditionally Recommended Practices (cont.)	• mineral soil exposure must be minimized on clays to reduce the incidence of baking and/or frost heaving, and to prevent increased competition from non-crop vegetation on a mixed mineral/ organic site • chemi-mechanical site preparation treatments must be compatible with the hardwood objective for the desired future stand condition; these treatments have the potential to damage white birch or trembling aspen crop trees • must refer to product labels for information on herbicide efficacy, species sensitivity, and recommended timing of application when using any method that incorporates the use of chemicals
D Developmental Practices	• pre-harvest site preparation (used in preparation for planting or seeding) is a developmental treatment • pre-harvest site preparation using blades has been done previously on boreal mixedwood sites in Ontario for the creation of white spruce seedbeds; the results are inconclusive given that this also disturb the underlying aspen root mat, stimulating the production of suckers which quickly occupy the available growing space • spot screefing treatments are currently being applied throughout western Canada in partial harvest and understorey situations in boreal mixedwood conditions using small excavators and skid-steer loader prime movers (Sidders 2001) • exposure of mineral soil while ensuring the removal of herbaceous and graminoid non-crop vegetation is essential to the satisfactory natural regeneration of white spruce (Packee 1990)
NR Not Recommended Practices	• site preparation on saturated, fine-textured soils is not recommended; site preparation should not be conducted under any conditions that result in soil compaction or rutting
Considerations for Implementation	**Heavy Slash** • high volumes of post-harvest downed woody debris have occurred in mixedwood stands (Sutherland and Foreman 1995), generally as a result of poor utilization or high levels of cull • the mechanical equipment best suited for heavy slash conditions are plows, brush blades, or rakes (Coates and Haeussler 1987) • powered disc trenchers and patch scarifiers have produced mixed results in heavy slash; however, plows may be attached to the front of the prime mover to improve results (Coates and Haeussler 1987) **Stumps** • winter logging operations tend to create high stumps; stumps from white birch clumps may also create significant obstacles to the operation of the prime mover and the site preparation equipment (Ryans 1989) • site preparation implements pulled by a skidder are generally preferable when stumps are high or frequent; skidders have a higher clearance than tractors and their articulated steering allows them to "duck walk" off obstacles (Ryans 1989) **Residual Stems and Advance Growth** • ability to avoid residual trees and advance growth is dependent on prime mover manoeuvrability and length of prime mover/implement combination (Ryans 1989)

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Site Preparation: Mechanical and Chemi-Mechanical (cont.).	
	Comments
Considerations for Implementation (cont.)	• for similar sized machines, skidders generally have a shorter turning radius than tractors due to their articulated steering; skidders also have the ability to reduce "off tracking", a situation where the rear of the machine doesn't cover the same path as the front (Ryans 1989); both factors would favour protection of residuals and advance growth by increasing manoeuvrability and reducing the percentage of the area traversed by equipment **Brush Cover and Other Factors** • heavy brush cover (especially green brush) may impede the effectiveness of site preparation equipment in creating desired microsites and may reduce treatment coverage and machine productivity • for a review of the impact of various soil profiles created by different site preparation implements on crop and non-crop vegetation, see McMinn and Hedin (1990), Sutherland and Foreman (1995), and Ryans and Sutherland (2001) • on productive sites, non-crop vegetation may quickly be established on raised berms; sides of berms are prone to drying out (Bell *et al.* 1992) • on fine-textured soils, minimal mineral soil exposure is desirable due to the risk of seedling mortality from frost heaving or drying out (Walstad and Kuch 1987, Sutherland and Foreman 1995); mixing may be a better option (McMinn and Hedin 1990) • mixing may encourage resprouting of competing vegetation (Sutherland and Foreman 1995); leaching of nutrients from the site may be reduced by spot mixing (McMinn and Hedin 1990) • for evaluations of specific mechanical site preparation implements in dealing with these and other conditions, refer to Smith (1979), Coates and Haeussler (1988), and Ryans and Sutherland (2001)
Opportunities	• this type of site preparation may be carried out either before or after harvest • site preparation with a shear blade has been effective for the establishment of planted white spruce on conventional clearcuts in Ontario (Sutton and Weldon 1995) • planting white spruce on inverted mineral mounds has been successful in British Columbia; seedlings demonstrate the same long-term mechanical stability as seedlings planted without site preparation (Heineman *et al.* 1999). • planting white spruce on mounds with thick mineral soil caps, particularly where screefing occurs before mounding, may greatly reduce the negative impacts of Canada blue-joint grass on white spruce establishment (Landhäusser and Lieffers 1999) • blading with small bulldozers has been effective for the establishment of underplanted white spruce in partially harvested mixedwoods in Ontario (Wedeles *et al.* 1995) and Alberta (Man and Lieffers 1999, Stewart *et al.* 2000) • mixing with a mixing head has been used to successfully establish underplanted white spruce in boreal mixedwood shelterwood cuttings in Alberta (Man and Leiffers 1999); this treatment is being investigated for use in shelterwood, patch cut, and clearcuts in Ontario (Sutherland 1996) • when herbicide is being applied as part of the site preparation treatment, it may be sprayed as a liquid (e.g. using a scarifier-sprayer) between or directly into scarified patches, or distributed as a granular formulation (e.g. using a centrifugal-type device) over patches or trenches (Desrochers and Dunnigan 1991)
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Site Preparation: Chemical	
	Comments
Overview	• chemical site preparation involves broadcast aerial applications or broadcast or selective ground-based applications of herbicides prior to the regeneration treatment for the purpose of controlling competing vegetation (Campbell *et al.* 2001)
Promotion of Conifer	• for black and white spruce, chemical site preparation (before planting) can be more effective in controlling competing non-crop species than chemical cleaning one year after planting (Wood and von Althen 1993); where chemical site preparation is used, crop trees are not injured by direct contact with herbicide and do not have to endure competition during the first growing season following outplanting
Promotion of Hardwood	• where chemicals are applied, intolerant hardwood regeneration will be discouraged
CR Conditionally Recommended Practices	• require appropriate manoeuvrable equipment when conducting ground-based chemical site preparation to ensure protection of desired residual stems or advance growth • chemical site preparation treatments must be compatible with the hardwood objective for the desired future stand condition; if not properly implemented, chemical site preparation may damage white birch or aspen crop trees • must refer to product labels for information on efficacy, species sensitivity, and recommended timing and methods of application when using herbicides
D Developmental Practices	• pre-harvest chemical site preparation is a developmental treatment; the ability to conduct the treatment effectively without detrimental impact on crop trees must be determined
NR Not Recommended Practices	• chemical site preparation does not provide the receptive seedbed conditions required for seeding success • chemical site preparation on saturated, fine-textured soils using ground-based equipment is not recommended; site preparation should not be conducted under any conditions that result in soil compaction or rutting • chemical site preparation is not recommended for the promotion of white birch or trembling aspen regeneration due to the susceptiblity of these species to damage or mortality from herbicides
Considerations for Implementation	• herbicides commonly used in the boreal mixedwood forests of Ontario are glyphosate, hexazinone, triclopyr, and simazine; the susceptibility of crop trees and target species to these herbicides is reviewed by McLaughlan *et al.* (1996); suggested application times for glyphosate and hexazinone are outlined by Carruthers and Towill (1987) • 2,4-D is discouraged for chemical site preparation on upland boreal mixedwood sites due to the promotion of hardwood re-sprouting and re-suckering from affected stems (Carruthers and Towill 1987) • chemical site preparation using glyphosate should be scheduled two years after logging or mechanical site preparation to ensure effective control of those species that reproduce vegetatively, from wind-borne seed, or from the soil seedbank • ground application equipment such as the cluster nozzle sprayers and mist blowers may be used to apply herbicides

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Site Preparation: Chemical (cont.)	
	Comments
Considerations for Implementation (cont.)	**Access** • access and operability are not limiting factors to aerial application of herbicides for site preparation **Heavy Slash** • effective site preparation may be obtained using only herbicides, when the density of slash and logging residue from the previous harvest is light and is well distributed across the site, or woody non-crop vegetation is sparse enough to permit natural or artificial regeneration to be secured at a reasonable cost (Sutton 1985) **Stumps** • winter logging operations tend to create high stumps; stumps from white birch clumps may also create significant obstacles to the operation of the prime mover and ground chemical site preparation equipment (Ryans 1989) **Residual Stems and Advance Growth** • ground-based chemical site preparation is usually limited to situations where vegetation is less than 2 m in height to ensure satisfactory efficacy (Bell *et al.* 1992) **Non-crop Competing Species** • efficacy of chemical site preparation is significantly affected by the susceptibility of the target non-crop, competing vegetation (McMinn and Hedin 1990) and the timing of application • woody species which reproduce from the soil seedbank may be promoted by chemical site preparation, which exposes the duff layer to full sunlight and precipitation (Mallik *et al.* 1996) • chemical site preparation may leave a residue of standing dead or dying vegetation, which may impede planting or seeding and may also shelter animal pests and allow them to proliferate
Opportunities	• chemical site preparation may leave the forest floor essentially undisturbed, and, therefore, conditions are less favourable for the germination of windborne seeds and seeds in the soil seedbank (Bell 1991); soil disturbance is minimized and inherent site productivity is maintained (Walstad and Kuch 1987) • chemical site preparation may be used to control current non-crop vegetation and/or future non-crop vegetation predicted to arise through vegetative reproduction or from seed (Campbell *et al.* 2001) • chemical site preparation is useful in unstocked or understocked portions of plantations, or in natural stands where the application of prescribed burning or mechanical site preparation would cause unacceptable damage to residual overerstorey stems, advance growth, or previously established regeneration (Boyd 1982, Sutton 1985)
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Site Preparation: Prescribed Burning	
	Comments
Overview	• prescribed burning (fire) may be used to prepare seedbeds or planting spots for conifers, to reduce slash and organic layers, to stimulate hardwood regeneration, or to control competing vegetation (Wiltshire and Archibald 1998)
Promotion of Conifer	• post-harvest prescribed burning may be as effective or more effective than post-harvest mechanical site preparation in improving conditions for conifer establishment and growth (McRae 1985a, Arnup 1989, Ballard and Hawkes 1989, Wiltshire and Archibald 1998) • late summer burns are advised for preparing boreal mixedwood sites for conifer regeneration; late summer applications generally result in deeper burns which reduce the vegetative reproduction of hardwoods and shrubs, and decrease the soil seed bank of other competitive species (Wiltshire and Archibald 1998) • high severity prescribed burns may damage aspen root systems (Perala 1974b) and reduce the vigour of aspen suckers (Rowe 1953)
Promotion of Hardwood	• medium severity prescribed fires are suitable for regenerating aspen, especially when carried out immediately following harvest and prior to initial root suckering (Peterson and Peterson 1995) • light severity burns may not remove enough slash, ground vegetation, and organic matter to promote adequate aspen suckering (Horton and Hopkins 1963) • light or moderate burns will encourage white birch regeneration by stimulating root collar sprouting and by preparing receptive seedbeds for the light, wind-dispersed seed of this species
CR Conditionally Recommended Practices	• requires careful consideration of fire weather indices under which prescribed burning is to be conducted on boreal mixedwood sites; indices must be sufficient for fire spread and to meet fuel consumption objectives • requires careful planning using the *Prescribed Burn Planning Manual* (OMNR 1997a)
D Developmental Practices	N/A
NR Not Recommended Practices	• the application of fire prior to harvest to prepare planting or seeding spots is a not recommended practice due to the potential damage to crop trees, loss of value, and increased risks • prescribed burning is a not recommended practice when promoting advance regeneration
Considerations for Implementation	• guidelines have been developed to predict fuel consumption and estimate fire behaviour in the mixedwood fuel complex (McRae 1980, McRae 1985b) • post-harvest prescribed burns have often been conducted on boreal mixedwood sites under fire weather indices that are too low to meet objectives of fire spread and fuel consumption (McRae 1985b) • fire prescriptions that have a fuel consumption objective that may be achieved using lower fire weather indices will increase the burn window and decrease fire control efforts (Wiltshire and Archibald 1998) • prescribed burns scheduled for early spring will permit adequate fire spread and behaviour under lower indices, since it is more difficult for the fire to spread after leaf flush (McRae 1985b, Wiltshire and Archibald 1998)

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Site Preparation: Prescribed Burning (cont.)	
	Comments
Considerations for Implementation (cont.)	• prescribed burning as a site preparation treatment for seeding should be timed with good seed years • prescribed burning may only control competing vegetation temporarily (Methven and Murray 1974, Jeglum and Kennington 1993) • prescribed burning may be a cost-effective site preparation tool (Wiltshire and Archibald 1998)
Opportunities	• mixedwood forests are dependent upon periodic fire to maintain their health, productivity, and diversity; the use of prescribed burning reintroduces fire as a natural component of the ecosystem (Wiltshire and Archibald 1998) • prescribed burning is the best site preparation method for removing heavy accumulations of logging slash, and for reducing wild fire hazard • fire will eliminate balsam fir advance growth (McRae 1985a, Arnup 1989) • medium severity burns are considered optimal for the removal of slash, humus, brush, residual trees, and for the promotion of aspen suckering (Horton and Hopkins 1965) • chemical pretreatments may be used to cure fuels prior to prescribed burning, thereby improving fire spread (Wiltshire and Archibald 1998) • various tools have been developed to assist with the planning of prescribed burning (Wearn *et al.* 1982, Stocks *et al.* 1990, McCarthy *et al.* 1994, McRae 1996b).
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Tending/Cleaning Method: Manual and Motor-Manual

	Comments
Overview	• permits a directed and "crop tree centred" approach to release individual crop trees
Promotion of Conifer	• conifer crop trees growing in mixtures may be released from unwanted competition while protecting hardwood crop trees
Promotion of Hardwood	• hardwood crop trees may be released by this method where the broadcast application of herbicides would otherwise damage or kill the hardwood component of the desired future stand condition
CR Conditionally Recommended Practices	N/A
D Developmental Practices	N/A
NR Not Recommended Practices	N/A
Considerations for Implementation	• volume growth and survival of conifers consistently increases after competition is controlled (Wagner *et al.* 1999) and in direct proportion to the degree and duration of control achieved • a key consideration of this approach is that there are sufficient stems of the desired species to meet post-treatment compositional objectives and maintain site occupancy • cutting techniques are not effective in controlling the density and abundance of herbaceous and graminoid species • sprouting in white birch, mountain maple, pin cherry, and beaked hazel can be minimized by cutting very low to the ground (< 10 cm) (Harrington 1984, Hart and Comeau 1993, Jobidon 1997) • mountain maple will re-sprout forming clumps after cutting and temporary increases in stem density are common (Harvey *et al.* 1998) • manual or motor-manual cleaning to remove trembling aspen should be undertaken in mid-summer when carbohydrate stores for sucker and sprout production are at their lowest (Bell et al. 1999) • manual or motor-manual cleaning to remove aspen should target cutting immediately below the live crown or at a height of 50 to 75 cm to reduce the potential for re-suckering or the development of shoots from dormant buds in the lower portion of the stem (Bell *et al.* 1999) • tools and techniques which result in jagged cuts produce fewer and less vigourous sprouts than the clear cut of a brush saw (Bell *et al.* 1997) • manual girdling is effective for releasing conifer crop trees from dense overstorey canopies of hardwoods • manual and motor-manual cutting are also effective for controlling the density of unwanted conifer stems (e.g. unwanted balsam fir) • cutting non-crop vegetation may do little to reduce competition for moisture and nutrients, and may even increase it (Hibbard 1991), even though growing space and light availability may be improved; combined chemi-mechanical control should be considered where competition for moisture, nutrients, and growing space is of concern
Opportunities	• manual trampling or binding of mountain maple appears to be an effective technique for controlling its re-growth since trampling does not promote basal re-sprouting (Aubin and Messier 1999, Kneeshaw *et al.* 1999)
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Tending/Cleaning Method: Chemical (Direct and Broadcast)	
	Comments
Overview	• involves the application of chemicals to release conifer regeneration • chemicals may be applied in a broadcast application (aerially or on the ground) or in a selective application (i.e. band or spot application)
Promotion of Conifer	• herbicides are typically used to release conifer regeneration from surrounding non-crop vegetation • chemical cleaning is used to promote the conifer component of a developing mixedwood stand, which is generally difficult to establish
Promotion of Hardwood	• selective applications may be used to protect hardwood crop trees while releasing conifers
CR Conditionally Recommended Practices	• chemical cleaning must be compatible with the hardwood objective of the mixedwood stand; if not properly implemented (e.g. selective application), chemical treatments may damage desired white birch or aspen regeneration • must refer to product labels for information on herbicide efficacy, species sensitivity, and recommended timing of application when using any method that incorporates the use of chemicals; herbicides vary in their efficacy and ability to control different species of competing vegetation • chemical cleaning with ground-based equipment is not recommended on saturated, fine-textured soils; ground-based equipment should not be used under any conditions that result in soil compaction or rutting
D Developmental Practices	• chemical cleaning prior to harvest is a developmental practice
NR Not Recommended Practices	• chemical cleaning is not recommended for the promotion of white birch or trembling aspen regeneration due to the susceptibility of these species to herbicides and the high potential for damage or mortality
Considerations for Implementation	• volume growth and survival of conifers consistently increases after competition is controlled (Wagner *et al.* 1999) and in direct proportion to the degree and duration of control achieved; early chemical cleaning following establishment of the conifer component is considered biologically cost-effective (Lautenschlager and Sullivan 2002) **Broadcast Applications** • aerial or ground broadcast application of glyphosate at the stand initiation stage to release planted white and black spruce is effective at controlling the abundance and dominance of woody shrubs and herbaceous species on boreal mixedwood sites (Reynolds *et al.* 1997), while maintaining much of the stand-level plant species diversity (Biring and Hays-Byl 2001, Bell and Newmaster 1998, Lautenschlager and Sullivan 2002) • broadcast application of glyphosate is effective at controlling *Calamagrostis canadensis* on boreal mixedwood sites in northern Ontario (Bell *et al.* 2000) • ground application technology such as cluster nozzle sprayers and mist blowers can be used to apply herbicides for the release of conifer beneath a partial canopy without damaging or killing hardwood stems in the overstorey (Desrochers and Dunnigan 1991)

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Tending/Cleaning Method: Chemical (Direct and Broadcast) (cont.)	
	Comments
Considerations for Implementation (cont.)	**Selective Applications** • ground application of herbicides to selectively control competing vegetation may be the most desirable method of chemical cleaning in developing hardwood leading, conifer leading, or conifer dominated mixedwood stands (Bell *et al.* 1996) **Band Application** - band application of herbicides (also called "green striping") at the stand initiation stage to remove overtopping and lateral non-crop vegetation surrounding conifers can be used to favour a hardwood leading or softwood leading mixture; green striping can be carried out with broadcast aerial spraying or using backpack sprayers or "reel and hose" technology **Spot Application** - chemical cleaning involving the spot application of herbicides permits a highly selective, crop tree centred approach to managing competition within and between species - backpack sprayers can be used to apply herbicide directly onto the foliage of competing woody and/or herbaceous vegetation, or onto the surface of freshly cut stumps surrounding planted seedlings; the latter is highly effective at eliminating large woody stems - backpack sprayers and spotgun applicators can be used to apply triclopyr herbicide to the basal bark of small diameter (< 15 cm) woody stems to prevent vegetative reproduction (basal sprouting and root suckering) - cut stump application of herbicides can also be accomplished using a brushsaw/cleaning saw with a herbicide applicator; the applicator applies herbicide to the lower side of the brush saw blade as it cuts the target stem - woody stems can also be targeted using the "hack and squirt" method where several cuts are made in the bark with an axe or knife followed by the application of herbicide to the exposed cambial layer – selective injection of herbicides is effective for releasing conifer crop trees from dense hardwood overstories
Opportunities	
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Tending/Cleaning Method: Supplemental Regeneration	
	Comments
Overview	• supplemental regeneration refers to the application of one or more silvicultural treatments at the stand initiation stage to establish trees in areas of inadequate stocking to meet compositional objectives • for example, portions of an aspen dominated stand at initiation could be site prepared and planted with conifers to meet the compositional requirements of an aspen leading condition • when supplemental regeneration treatments are being applied, coding conventions (i.e. R, CR, NR, D, and X) apply as described for each of the treatments that have been selected to comprise the silvicultural treatment package
Promotion of Conifer	• see applicable fact sheets
Promotion of Hardwood	• see applicable fact sheets
CR Conditionally Recommended Practices	• see applicable fact sheets • implementation of treatments should not result in the loss of the spruce component of the stand
D Developmental Practices	• see applicable fact sheets • some compositional objectives may not be achievable from the current stand condition while maintaining site occupancy
NR Not Recommended Practices	• see applicable fact sheets • this is not a recommended practice when site occupancy will not be maintained to achieve compositional objectives; or, when treatment is not required to meet objectives (i.e. same stand condition)
Considerations for Implementation	• see applicable fact sheets
Opportunities	• see applicable fact sheets
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Tending/Cleaning Method: Reinitiate	
	Comments
Overview	• reinitiate involves the application of any combination of appropriate silvicultural treatments throughout a stand at the initiation stage when the composition or condition of the stand is deemed not acceptable • reinitiate is one management option; it is considered a "retreatment" as described in the *Silvicultural Effectiveness Monitoring Manual for Ontario* (OMNR 2001c) • when reinitiating the stand, the designations (i.e. R, CR, NR, D, and X) apply as described for each of the treatments that have been selected to comprise the silviculture treatment package
Promotion of Conifer	• see applicable fact sheets
Promotion of Hardwood	• see applicable fact sheets
CR Conditionally Recommended Practices	• see applicable fact sheets
D Developmental Practices	• see applicable fact sheets
NR Not Recommended Practices	• see applicable fact sheets
Considerations for Implementation	• see applicable fact sheets
Opportunities	• see applicable fact sheets
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Tending/Intermediate Stand Treatment: Compositional Treatment	
	Comments
Overview	• the primary objective of a compositional treatment is to change stand composition type through removal of sufficient overstorey stems (e.g. a compositional treatment could be applied to change an aspen leading mixture to a softwood leading mixture by removing some aspen stems) • this treatment may be conducted in young stands (similar to juvenile spacing or pre-commercial thinning) or older stands at the stem exclusion stage where merchantable volume may be removed (similar to commercial thinning)
Promotion of Conifer or Hardwood	• various proportions of hardwoods and/or undesirable conifers may be removed to achieve compositional objectives
CR Conditionally Recommended Practices	• when a compositional treatment is used to create a hardwood leading mixture, stocking of desirable conifers must be sufficient to ensure that site occupancy is recovered • a compositional treatment in a softwood leading or softwood dominated condition is only permitted if the spruce component of the stand is not being targeted for removal; only unwanted conifer species may be removed (e.g. balsam fir) and sufficient conifer stems must remain to provide for rapid recovery of site occupancy • compositional treatments are not permitted if, to achieve a compositional objective, an unacceptable reduction in site occupancy will occur (e.g. excessive numbers of trees are removed requiring an extended period to recover site occupancy)
D Developmental Practices	N/A
NR Not Recommended Practices	• this treatment will result in insufficient conifers in the residual stand to recover site occupancy
Considerations for Implementation	• the impact of this treatment on future stand development and site utilization is the key focus • compositional treatments should be monitored to ensure that there is not an excessive removal of stems which would result in underutilization of the site for an extended period - size of trees to be killed or removed, the impact of the treatment on the remaining stems, and the promotion of undesirable competition should be considered in selecting a method of conducting a compositional treatment - methods for conducting a compositional treatment may include cutting, girdling, or chemical treatments (see Liberation Treatment, page 67, for a description of these methods)
Opportunities	• this treatment may mimic natural successional trends by removing shade intolerant tree species to favour more shade tolerant tree species • undesirable shade tolerant conifers (e.g. balsam fir) may also be targeted for removal
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Tending/Intermediate Stand Treatment: Juvenile Spacing and Pre-commercial Thinning	
	Comments
Overview	• juvenile spacing occurs when the stand is still in the stand initiation stage (i.e. prior to crown closure) • pre-commercial thinning (PCT) applies after the stand has reached crown closure and entered the stem exclusion stage • the objectives of both treatments may be similar
Promotion of Conifer	• spacing or thinning of spruce is generally not required on naturally established upland sites, which are seldom overstocked to spruce
Promotion of Hardwood	• spacing or thinning of aspen and birch is a questionable silvicultural expenditure when fibre production is the goal because aspen and birch self-thin effectively (Peterson and Peterson 1995, Peterson *et al.* 1997). • spacing or thinning of aspen and white birch stands may be justified to improve the yield of large diameter trees or to increase crop tree value, but should be considered only for the best sites; for example, when vegetative reproduction of white birch from stump sprouts results in several stems (coppice clumps), spacing or thinning may be required to yield a suitable stem free of defect and sweep
CR Conditionally Recommended Practices	• spacing or thinning of aspen is generally not required if fibre production is the goal (Peterson and Peterson 1992), because aspen self-thins very effectively (OMNR 1997c); they may be required to increase product value, or to reduce the time the stand will take to become merchantable
D Developmental Practices	**White Birch** • little experience with pre-commercial thinning white birch in Ontario • pre-commercial thinning may potentially have negative effects such as the delay of natural pruning, growth of large lower branches, increased taper of crop trees, and decreased total biomass yield; there are also questions about the economics of pre-commercial thinning (Peterson *et al.* 1997) • suggestions for pre-commercial thinning in pure, single-storied birch stands (Peterson *et al.* 1997, Towill 2000): - target density for high quality birch stems (13 cm dbh) is 1,000 to 1,500 stems/ha - begin thinning at age 10 to 15 years or when the stand is 4 to 6 m in height, once dominance is well established - retain the straightest, fastest-growing, and healthiest stems - thin coppice clumps to one or two stems per clump - retain the best-formed, most widely spaced, low-origin (i.e. originating at ground level or no more than 15 cm above ground level), dominant or codominant sprouts with U-type connections between companion sprouts; V-type sprout connections should be treated as a single unit, either leaving or cutting both - retain sprouts on the uphill side of the stump on slopes

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Tending/Intermediate Stand Treatment: Juvenile Spacing and Pre-commercial Thinning (cont.)	
	Comments
NR Not Recommended Practices	• spacing or thinning black spruce and white spruce that has been naturally established on upland sites (in softwood dominated or softwood leading composition types) is rarely required since stands are seldom overstocked
Considerations for Implementation	• both juvenile spacing and pre-commercial thinning retain the original species composition of the overstorey **Aspen** • pre-commercial thin during the dormant season to reduce the risk of damage to residual stems (Jones and Shepard 1985); wounds can provide entry points for decay (Perala 1978) • thinning by motor-manual and mechanical methods tends to be effective (OMNR 1997c, St Amour 2000, David *et al.* 2001) • if thinning is uniform throughout the stand (i.e. where a motor-manual method is used), remove the smaller trees and leave the larger trees of greatest vigour (i.e. thinning from below) to focus on the growth potential of the best trees in the stand • for mechanical strip thinning, leave strips should not exceed 2 m in width and cut strips should not exceed 4 m (Steneker 1976); this suggestion assumes no additional manual thinning in the leave strips • alternatively, mechanical strip thinning has been done leaving wider (5.6 m) untreated strips between cleared strips; motor-manual techniques were then used to select crop trees in the leave strips (St Amour 2000) • to promote aspen dominated stands: - initiate thinning after expression of dominance begins, which is generally from 7 to 10 years or at 5 cm dbh (Perala 1991b), but may be expressed later on cool soils in northern Ontario (Rice *et al.* 2001) - space or thin to approximately 2.5 m (1600 stems/ha) (Steneker 1976) • Hypoxylon canker incidence is thought to be greater in thinned aspen stands (Day and Strong 1959, Anderson 1964, Anderson and Anderson 1968, Copony and Barnes 1974, Brunck and Manion 1980, Ostry *et al.* 1988); however, Pitt *et al.* (2001) did not observe any relationship between stand density and Hypoxylon incidence in young, thinned aspen stands throughout northern Ontario
Opportunities	
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Tending/Intermediate Stand Treatment: Liberation Treatment	
	Comments
Overview	• liberation treatment is the release of young stands, not past the sapling stage, from the competition of distinctly older, overtopping trees (Smith *et al.* 1997) • overstorey trees must be considered for treatment when they are a detriment to the continued development of the regenerating stand (e.g. excessive shading) • a liberation treatment may be conducted by cutting, girdling, or chemical treatment • a liberation treatment by cutting is similar to a removal cutting of a seed tree or shelterwood method in which overstorey trees are removed after regeneration has become established; in liberation treatments, however, the overstorey trees were not left intentionally to provide seed, or shelter, or to accumulate additional growth
Promotion of Conifer	• conifer understorey is released when the overstorey is treated
Promotion of Hardwood	N/A
CR Conditionally Recommended Practices	N/A
D Developmental Practices	N/A
NR Not Recommended Practices	• a liberation treatment is not recommended as a component of a silvicultural treatment package for the management of hardwoods
Considerations for Implementation	• selection of a liberation method (cutting, girdling, or chemical treatment) should consider the size of trees to be killed or removed, the impacts of the treatment on the regenerating stems, and the promotion of undesirable vegetative reproduction of hardwoods; the following methods may be used (after Smith *et al.* 1997): **Cutting** • provides an opportunity to capture some merchantable volume from overstorey trees • felling of large, undesirable stems without utilizing them is the most expensive form of liberation treatment • felling should only be considered as the method of liberation when the felled trees may be removed from the stand causing minimal damage to reproduction, or when the retention of standing dead stems may constitute a safety hazard (e.g. adjacent to travel corridors)

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Tending/Intermediate Stand Treatment: Liberation Treatment (cont.)

	Comments
Considerations for Implementation (cont.)	**Girdling** • girdling should encompass the entire tree, in a wide strip, down to the sapwood • insufficient girdling may render the treatment ineffective; insufficient girdling includes not completely encircling the entire stem, using narrow girdles (such as those that result from single incisions), or making shallow girdles that leave the cambium partially intact; in those instances, the remaining cambium may have sufficient contact, or may form callous bridges across the girdle, that permit the flow of sufficient water and nutrients so that the tree is not killed • girdling may be completed with axes or chainsaws; methods should consider safety and the efficiency and effectiveness of the treatment in killing the stem • girdling may be completed by "peeling" strips of bark off the stem after making two continuous cuts around the stem of the tree; this treatment is completed in the spring when the bark is loose; 20 cm wide strips are advised to ensure that the cambium is exposed to desiccation • methods that interrupt the upward flow of stored substances from the roots result in increased suckering or sprouting in hardwood species **Chemical Treatments** • chemical treatments may be completed by stem injection or selective spray (see Chemical Tending fact sheet, page 60) • this is an effective treatment for mid-size and smaller trees, and increases worker safety relative to cutting and girdling • treatments that rely on chemical translocation should consider the seasonal variation in phloem and xylem transport • chemical treatments may be applied alone or in conjunction with girdling treatments; chemical treatments are more effective than girdling alone in preventing suckering
Opportunities	• girdling may be combined with chemical injection treatments to improve the effectiveness of the treatment
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Tending/Intermediate Stand Treatment: Commercial Thinning	
	Comments
Overview	• the objective of commercial thinning is increased stem growth in the residual stems with the potential for positive financial return (Smith *et al.* 1997) • there has been some recent experience with commercial thinning in plantations in Ontario's boreal mixedwood forest
Promotion of Conifer	• commercial thinning of a black spruce stand in northeastern Québec (Lussier 2001), and of a balsam fir stand in northwestern Ontario, both showed no response to thinning in the residual stands; however, Weetman *et al.* (1975, 1980), Weetman *et al.* (1980) in Québec showed promising responses for black spruce on an upland site, and little loss due to increased blowdown
Promotion of Hardwood	• results of commercial thinning in aspen in Québec showed increased individual tree size, but decreased total volume/ha after 25 years (Doucet 2000) • commercial thinning of aspen in Minnesota is restricted to better than average sites (David *et al.* 2001)
CR Conditionally Recommended Practices	N/A
D Developmental Practices	• commercial thinning is a developmental practice in boreal mixedwood management in Ontario for softwood pure or softwood dominated stands that have a history of density regulation; although there has been operational experience in the boreal forest, there is still a need to assess the growth response for this treatment, particularly for boreal mixedwood species; stands with a history of density regulation offer the most potential for a growth response in residual stems
NR Not Recommended Practices	• commercial thinning is a not recommended practice under other boreal mixedwood conditions (i.e. stands that are not softwood pure or softwood dominated or have no history of density regulation)
Considerations for Implementation	• commercial thinning retains the original species composition of the overstorey • intensity of thinning (amount of basal area removal) greatly affects volume production in the residual stand (Lussier 2001) • stands should be assessed using the slenderness coefficient and other criteria to determine the susceptibility to windthrow (refer to Wind Damage, Section IV) • care must be taken to protect the advance growth if it is part of the desired future stand condition • care must be taken not to cause unacceptable levels of damage to residual stems
Opportunities	• with an approved monitoring program, commercial thinning can be carried out; there is much to learn about the interaction of site, thinning intensity, type of thinning, effects of varying species compositions, and stand age at time of thinning and their impact on the duration and amount of response in the residual stand • commercial thinning emulates a non-stand-replacing disturbance such as a low-severity, understorey fire, insect or disease damage, or moderate wind, snow, or ice damage
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