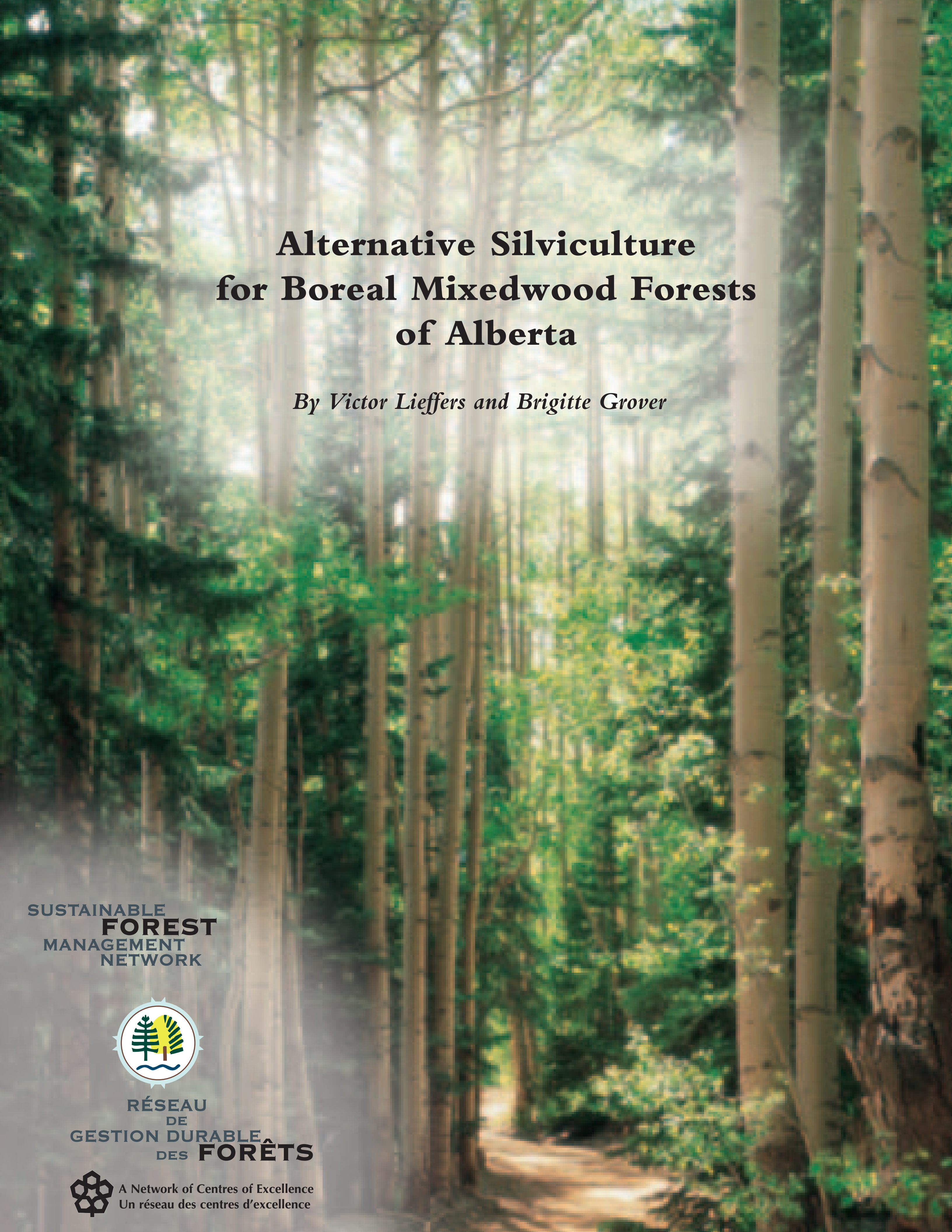

Alternative Silviculture for Boreal Mixedwood Forests of Alberta

By Victor Lieffers and Brigitte Grover

SUSTAINABLE FOREST MANAGEMENT NETWORK

RÉSEAU DE GESTION DURABLE DES FORÊTS

A Network of Centres of Excellence
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THE SUSTAINABLE FOREST MANAGEMENT NETWORK

Established in 1995, the Sustainable Forest Management Network (SFM Network) is an incorporated, non-profit research organization based at the University of Alberta in Edmonton, Alberta, Canada.

The SFM Network's mission is to:
- Deliver an internationally-recognized, interdisciplinary program that undertakes relevant university-based research;
- Develop networks of researchers, industry, government, Aboriginal, and non-government organization partners;
- Offer innovative approaches to knowledge transfer; and
- Train scientists and advanced practitioners to meet the challenges of natural resource management.

The SFM Network receives about 60% of its $7 million annual budget from the Networks of Centres of Excellence (NCE) Program, a Canadian initiative sponsored by the NSERC, SSHRC, and CIHR research granting councils. Other funding partners include the University of Alberta, governments, forest industries, Aboriginal groups, non-governmental organizations, and the BIOCAP Canada Foundation (through the Sustainable Forest Management Network/BIOCAP Canada Foundation Joint Venture Agreement).

KNOWLEDGE EXCHANGE AND TECHNOLOGY EXTENSION PROGRAM

The SFM Network completed approximately 270 research projects from 1995 – 2003. These projects enhanced the knowledge and understanding of many aspects of the boreal forest ecosystem, provided unique training opportunities for both graduate and undergraduate students and established a network of partnerships across Canada between researchers, government, forest companies and Aboriginal communities.

The SFM Network's research program was designed to contribute to the transition of the forestry sector from sustained yield forestry to sustainable forest management. Two key elements in this transition include:
- Development of strategies and tools to promote ecological, economic and social sustainability, and
- Transfer of knowledge and technology to inform policy makers and affect forest management practices.

In order to accomplish this transfer of knowledge, the research completed by the Network must be provided to the Network Partners in a variety of forms. The KETE Program is developing a series of tools to facilitate knowledge transfer to their Partners. The Partners' needs are highly variable, ranging from differences in institutional arrangements or corporate philosophies to the capacity to interpret and implement highly technical information. An assortment of strategies and tools is required to facilitate the exchange of information across scales and to a variety of audiences.

The preliminary KETE documents represent one element of the knowledge transfer process, and attempt to synthesize research results, from research conducted by the Network and elsewhere in Canada, into a SFM systems approach to assist foresters, planners and biologists with the development of alternative approaches to forest management planning and operational practices.

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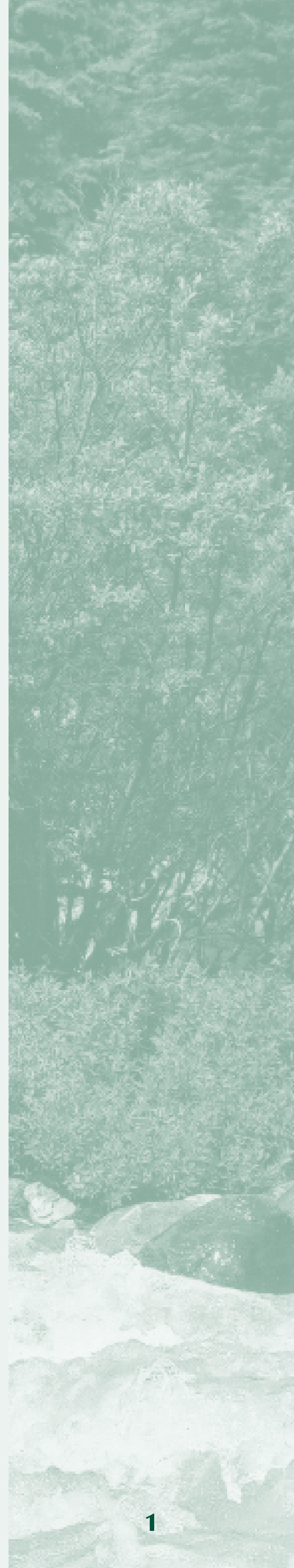

Alternative Silviculture for Boreal Mixedwood Forests of Alberta

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March 2004

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Introduction

In the last third of the 20th century traditional plantation management of boreal mixedwood forests has lead to treatments that have attempted to grow aspen and spruce in separate stands. This has simplified forest management planning, and in some cases made the logging/regeneration system relatively inexpensive. The regeneration of the spruce in relatively pure plantations, however, has not always been easily accomplished; indeed, silvicultural foresters have identified white spruce regeneration in mixedwood stands as their most difficult problem (Lieffers and Beck 1994). Also, the traditional plantation management of these mixedwood stands (i.e. unmixing these forests), has been criticized by some as an unnatural means of managing the forest. Managing these forests as mixed species stands, often with the aspen and spruce establishing at different times, offers an attractive alternative to traditional plantations as it works within natural successional patterns and processes (Lieffers *et al.* 1996).

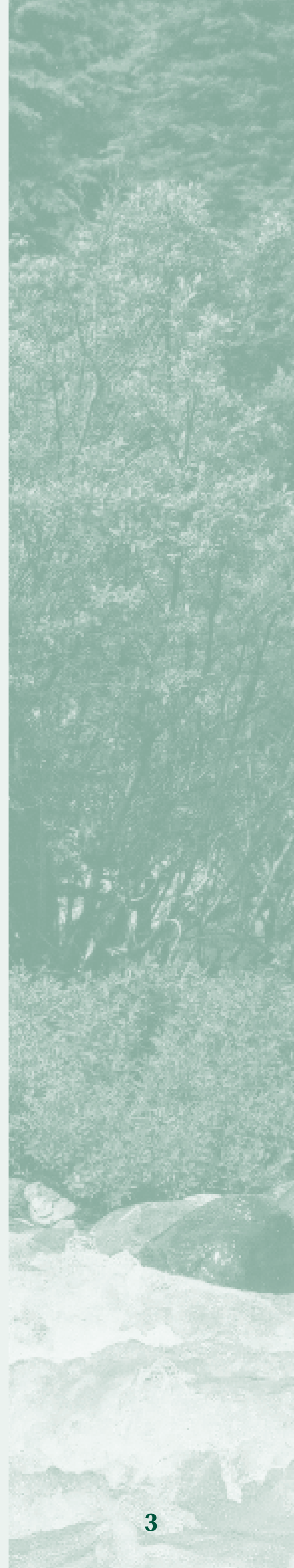
This report highlights some alternative silviculture procedures that maintain boreal mixedwood forests. These include: underplanting white spruce seedlings in maturing aspen stands and harvesting regimes that remove the mature aspen overstory and release the understory spruce (ie. understory protection harvesting) for further growth. We highlight in bold references relating to research papers that were produced using the Network of Centers of Excellence in Sustainable Forest Management (SFMN) resources. A more scholarly review of these topics, providing preliminary means of estimating stocking levels (**Greene *et al.* 2002**), prediction of understory light (**Lieffers *et al.* 1999**), establishment of trees in understories (**Greene *et al.* 1999**) and growth of advance regeneration (**Messier *et al.* 1999**) has been completed.

1. Underplanting

Benefits

In many mixedwood sites, white spruce can establish naturally in the understory of the aspen provided that a spruce seed source and suitable seedbed are available. There are numerous stands, however, which are capable of growing spruce, but do not have a spruce component because of fire history or lack of a seed source. If spruce could be established in these types of stands prior to logging of the aspen, these established spruce stands could be swapped for other mixedwood stands that naturally regenerate to relatively pure stands of aspen. A relatively assured way of developing a spruce understory in aspen dominated mixedwood sites is by underplanting (Stewart *et al.* 2000). The goal is to develop a cohort of understory spruce that are well-established by the time the overstory is removed (1 to 3 m tall; large enough to be seen by the machine operators at the time of logging of the overstory hardwood).

Planting in advance of logging has two advantages over the clearcut and plant regime. First it allows the spruce to be established prior to logging of the aspen stand. In essence, this allows an overlap of the rotation of the spruce under the previous rotation of the aspen, thereby increasing the overall yield of the site over a hundred year period. Second, shade tolerant conifers can complete their establishment phase under the hardwoods, thereby benefiting from the shelter of the aspen. A healthy stand of maturing hardwoods results in light levels that are too low to allow shade intolerant grasses and herbs to dominate the site. It is recognized that spruce growth can be severely retarded by the dense aspen canopies of some young aspen stands between 15 and 25 years old (**Lieffers *et al.* 2002**) (Figure 1). By the time the stand is 60 years old, however, the aspen canopies transmit sufficient light for establishment and acceptable growth of the spruce. Maturing aspen allow transmission of between 20 and 50% of full sunlight (**Lieffers *et al.* 2002**). However, 20% light is needed for good survival of understory white spruce seedlings (**Lieffers and Stadt 1994, Wright *et al.* 1998**), 40% light is sufficient to result in maximum height growth and 60% light results in nearly maximum diameter growth. Light can be modelled in harvested mixedwood stands using MIXLIGHT (**Stadt and Lieffers 2000**), a model that estimates light at any point and height in a stand using techniques that track the path of light through the individual crowns of trees.



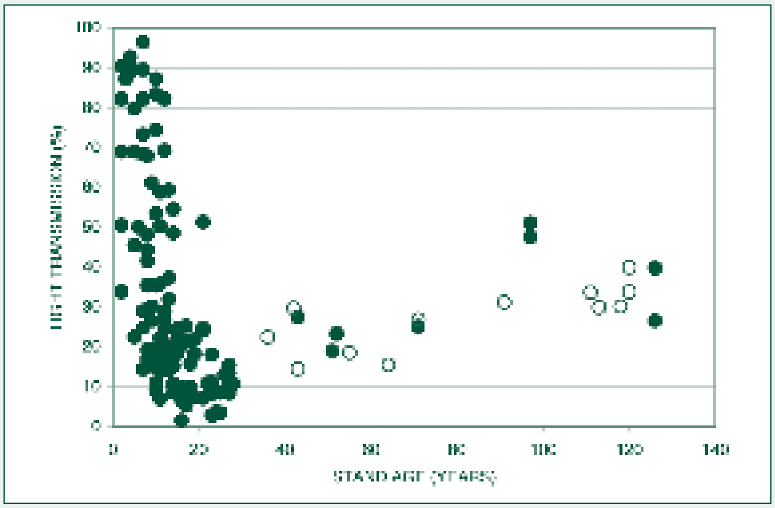


Figure 1. Light transmission through the tree canopy of aspen stands in the boreal mixedwood forests of Alberta. Taken from **Lieffers *et al.* 2002**.

The aspen canopy can act as a nurse crop to the understory (Figure 2), reducing the incidence of spruce photoinhibition from high light (Man and Greenway, pers. Comm.), preventing most damage from late season frosts, moderating temperature and humidity extremes (Man and Lieffers 1999; Groot 1999; Marsden *et al.* 1996) and controlling competing vegetation. A further benefit of establishing spruce late in the development of the aspen stand is to ensure that the developing spruce are not damaged by leader whipping as they reach the lower branches of the aspen canopy.

Figure 2. Spruce underplanted in aspen stands near Edson, and Fawcett Lake, Alberta.

Hardwood canopies can also reduce the occurrence of terminal weevil and spruce budworm in mixed species stands (Taylor et al. 1996; MacLean 1996). Understory conditions favour self-pruning of lower branches and produce trees with superior form (Smith *et al.* 1997). Symbiotic relationships such as sharing of resources through mycorrhizae (Simard et al. 1997) and improved site nutrient cycling (Kelty 1992) have been found in mixedwood forests. All these factors can lead to better performance during the establishment phase in understory versus clearcut grown conifers, however 5 years after planting, growth of pure stands of spruce was usually superior in clearcuts (DeLong 2000).

Growing aspen and white spruce in a mixed setting also increases productivity of the landbase as compared to monocultures (Kabzems and Senyk 1967; Opper 1981; MacPherson *et al.* 2001). Preliminary data suggests that aspen volume is the same in pure aspen stands as it is in aspen stands with a white spruce understory, at least until the spruce becomes a significant component of the stand. Consequently, white spruce can be "grown for free" on a "deciduous" landbase for quite some time. This management strategy will take advantage of the benefits of an aspen nurse crop for the establishment of white spruce seedlings, but will remove the overstory before it becomes a liability.

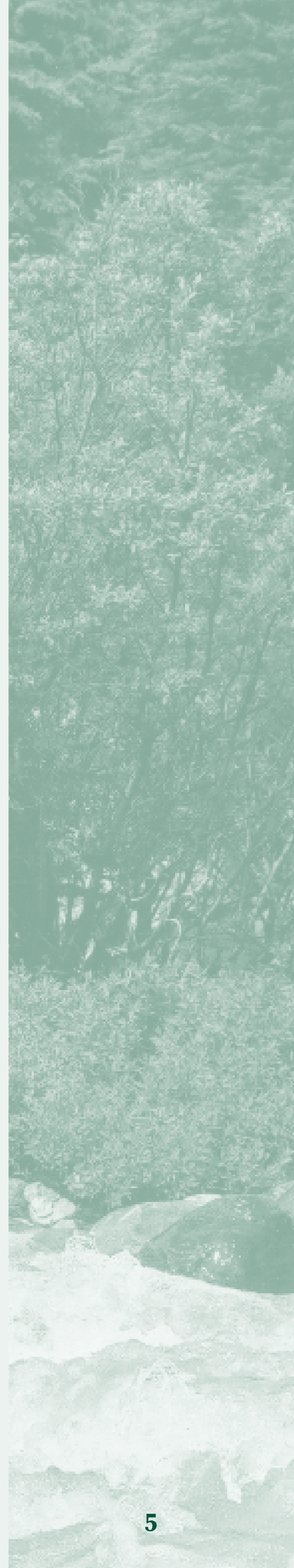
Underplanting Trials

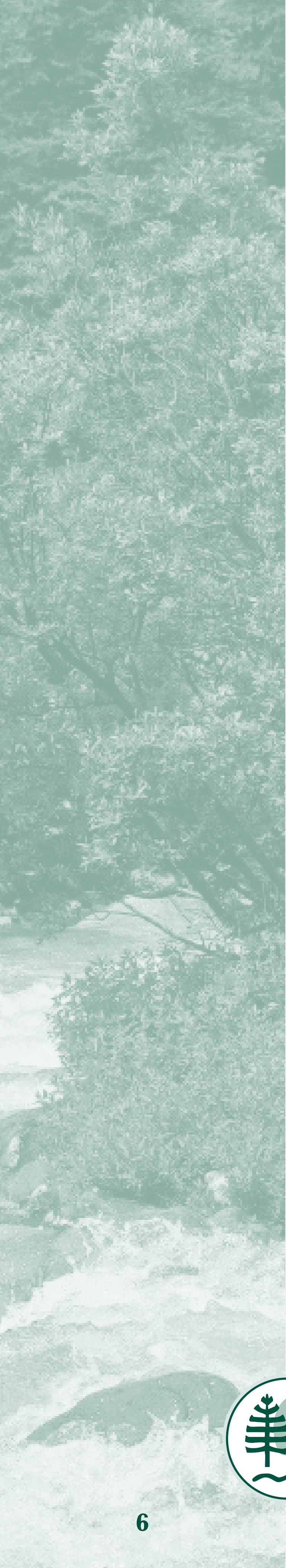
Forest companies initiated underplanting trials during the last decade providing preliminary data on stand selection and white spruce survival/performance. Alberta-Pacific Forest Industries Inc. (Al-Pac) started underplanting trials in 1994 with mixed results. The early trials employed understory site preparation, in most cases spot site preparation with a MERI-crusher mounted on a Bobcat. White spruce seedling survival was excellent on all but 3 of 26 underplanted sites. In these cases high seedling mortality was most likely due to competition by *Calamagrostis canadensis* in one case, and *Alnus crispa* in the other two. The use of site preparation was eliminated in 1997 when assessments showed that many of the aspen adjacent to the site prepared spots were dying. This mortality was attributed to root injury in combination with drought stress from several dry years following treatment.

Some trials established in 1997, 1998 and 2000 experienced high mortality due to snowshoe hare browsing. The snowshoe hare population cycle peaked in 2000, and the highest rate of browsing by hares was encountered in 1999 and 2000. Sites with low incidence of damage from snowshoe hare browsing were either void of understory shrubs or were located within large aspen stands (i.e. offered little cover for snowshoe hares or were distant from prime hare habitat).

Site Selection

White spruce seedling performance is certainly linked to light penetration through the canopy, however, data collected from field trials could not be directly correlated to canopy closure or light measurements. Many factors contribute to variation in performance such as ecosite influences, quality of planting stock and/or planting crew, and understory shrub layer.





When selecting sites for underplanting, the following conditions should be considered.

1. Select deciduous dominated stands on upland sites ecosites that are capable of supporting spruce-deciduous mixtures (use ecosite guide books).
2. The deciduous overstory should be within one or two decades of harvest and be mostly still healthy and vigorous.
3. There should be few canopy gaps (C-density or 50-70% crown closure) and aspen crowns are still densely covered with leaves.

These types of stands can usually be planted without site preparation, with planters adjusting their spacing slightly to avoid vigorous shrubs. In deciduous stands with thin crowns and many overstory gaps, there is often a dense understory layers of shrubs (beaked hazel, green alder), tall herbs or dense grass. These stands cannot be successfully underplanted without treatments to control the shrub/herb layer in the nearby vicinity of planted seedlings.

Density and spacing of underplanting should take into account future overstory harvesting methods (some harvest systems are described below). Future skid trails and landings can be identified and left unplanted, if similar harvesting methods are anticipated in the future.

Future Underplanting Research

Although many companies are now experimenting with underplanting, tools for stand selection still need to be refined and the implications for stand growth and yield need to be determined. There is also a need to evaluate the performance of underplanted white spruce in relation to ecosite. Since underplanting represents an ecologically and economically feasible alternative to clearcut and planting operations, research on site selection, specific planting stock for understory environments, methods to retard hare browsing, and means to predict or control understory competition are still required.

2. Understory Protection

Many 60 to 80 year old aspen stands have a spruce understory. Objectives of understory protection are to harvest as much of the aspen as possible while leaving a large percentage of the understory spruce undamaged. One of the major difficulties of retaining the spruce relates to blowdown of the residual spruce after logging the aspen. Understory trees have very slender stems and shallow roots making them vulnerable to windthrow. Hence, much of the development of systems to protect understory have focussed on ways to minimize blowdown.

As a shade adapted species, white spruce seedlings can survive in the understory for a long time, even with severely reduced growth rates. Even if suppressed for extended periods of time by dense juvenile aspen stands, white spruce retains the ability to quickly release when light conditions improve. Released spruce trees can experience growth up to 350% over that of pre-release growth rates (Lees 1966; Steneker 1963; Yang 1989). After understory protection/careful logging, the conifers are well-established and likely will not require expensive vegetation control.

Research Trials

Early studies (Lees 1966 and Steneker 1963) experimented with individual tree release, followed by Brace (1992) and Navratil *et al.* (1994) who explored methods of releasing white spruce understories at the stand level. These trials minimized disturbance by equipment, while at the same time allowed the understory trees to gradually adapt to the increased wind load of the open stand. By 5 years post harvest, the spruce growth was 25% greater than the pre-harvested stand, even taking into account the 25-50% volume loss on skid trails (MacIsaac, pers. comm.). The Hotchkiss experiment which started in 1992 (Navratil *et al.* 1994) has given the forest industry great guidance as to the possible harvest designs that protect 50-60% of the understory, maintain equipment productivity and minimize windthrow. Following early trials by the Canadian Forest Service, industry has taken the initiative in experimenting with various designs of understory protection.

Meta-analysis of understory release treatments (Man, 2002) showed that the mean cumulative growth of released spruce trees after understory protection is 61% greater in height, 73% greater in diameter, 132% greater in volume, and 4% greater in survival as compared to unreleased trees. Best growth response for height and volume occurred in trees that were 7-9m tall, and for diameter in trees that were 9-11m tall.

Studies on the effect of understory protection on structure and biodiversity are limited. Bradbury *et al.* (2003) studied the changes in biodiversity in blocks harvested while protecting understories. Biodiversity-related benefits associated with stands treated with understory protection include enhanced snag recruitment, vascular plant communities, songbird communities, fungal communities, as well as densities of red and flying squirrels similar to un-harvested mixedwood stands. **Mourelle *et al.* (2003)** found increased vascular plant species richness in blocks after understory protection harvest as compared to uncut controls.

Harvest Designs

Alberta-Pacific Forest Industries Inc. (Al-Pac) and Vanderwell Contractors (1971) (Vanderwell) started a joint trial in 1997 releasing white spruce understories using a two-pass design copied from the Hotchkiss experiment (Figure 3). Intensive monitoring plots were established to measure blowdown, white spruce release, and aspen regeneration on the skid trails. After successfully implementing the two-pass design, the companies also used single pass and other modified designs on subsequent cuts. The following descriptions outline the general designs as well as some recommendations resulting from the trials.

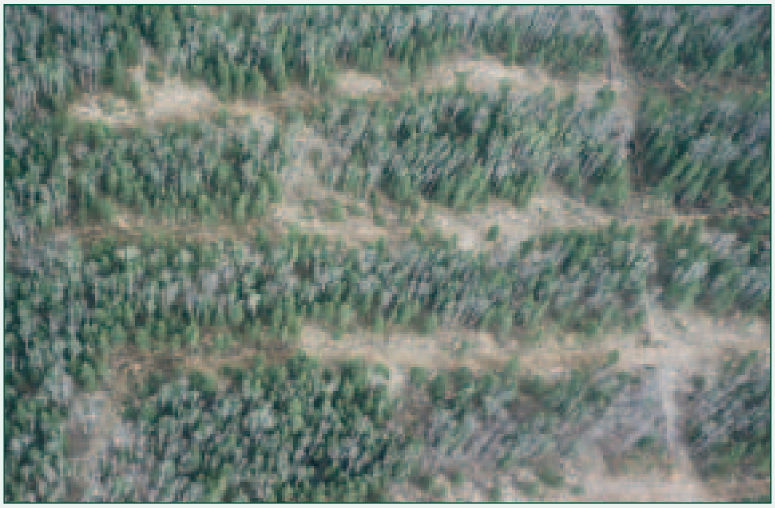


Figure 3. Two pass strip cut understory protection near Calling Lake, Alberta.

Some operational rules are common and recommended for all designs;

1. Skid trails should be oriented perpendicular to the prevailing winds (North-South) as recommended by Navratil *et al.* (1994).
2. Skid trail length should be restricted to 350m as skidding productivity may be too low beyond that distance.
3. If possible, understory protection should be done on frozen ground or under very dry conditions, as concentrated skidding can lead to soil compaction.
4. In most instances (unless the understory is very small and a fully stocked spruce stand is required) skid trails and decking areas should be regenerated to deciduous species.
5. To promote suckering, logging should be done either on dry or frozen soil conditions and using equipment with high floatation tires to prevent soil disturbance.
6. If there are natural or planned openings (such as decking areas) greater than 1 tree length in diameter, no aspen overstory should be removed in the reach area for 10m surrounding such openings. This is necessary to reduce blowdown losses.
7. To reduce damage to standing white spruce trees during skidding, high stumps should be left as rub posts along the side of the skid trail and, most importantly, at the edge of skid trail and landing.

Harvest Design #1 Two-Pass System

The Two-pass system should be used when blowdown risk is very high, such as on wet sites, where the understory is very tall, or when skid trails cannot be placed in the required orientation due to terrain. This system requires a second entry and is therefore recommended only when road access to the area is good. Skid trails should be spaced 48m apart (center to center) based on 8m wide skid trails. The feller buncher (or harvester) will reach 8m to either side of the trail removing all aspen. When the released understory has become windfirm after approximately 3-8 years, the same 8m-8m-8m design will remove the aspen from the leave area (Figure 4). At least 5% of the aspen should be retained in the reach areas of the second entry.

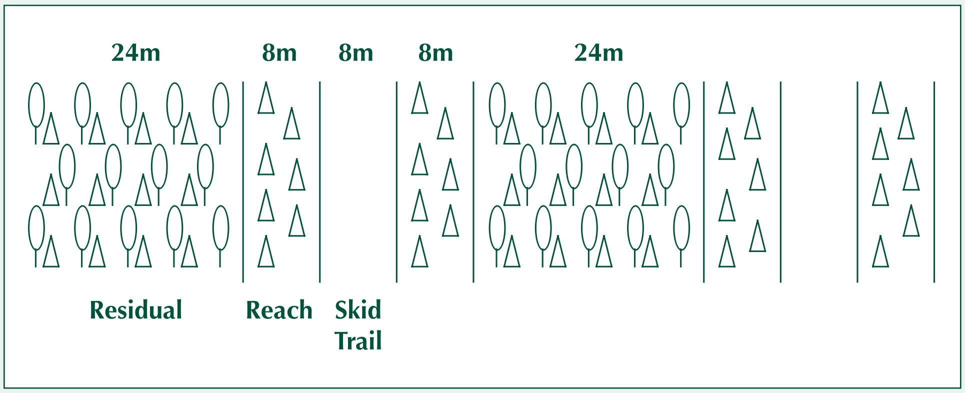


Figure 4. Diagram of Harvest Design #1 Two-Pass System

The following factors were learned from the first trials:

Aspen regeneration was satisfactory in the first year after logging but heavy browsing affected aspen regeneration negatively.

Harvest Design # 2 Single-Pass System (17% Aspen Retention)

This system will be used most often by Al-Pac and Vanderwell until blowdown risks of Design #3 are confirmed. Based on a skid trail width of 8m, skid trails are spaced 29m apart. The feller-buncher harvests aspen for 8 m on either side of the skid trail. This results in a 5m wide strip of retained aspen between the reach areas (Figure 5).

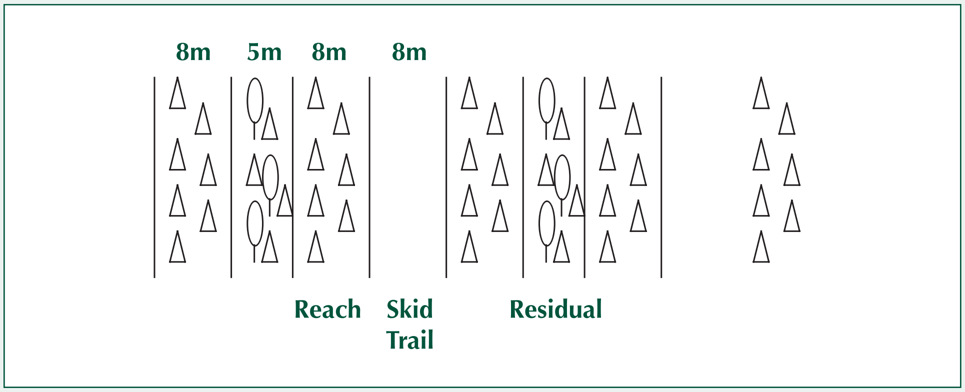


Figure 5. Diagram of Harvest Design #2 Single Pass System (17% Aspen Retention)

The following factors were learned from the first trials:

In a head to head trial of Designs #1 and #2 by Vanderwell in 1998, there was little difference in blowdown (assessed in 2000). Trials showed 0.76% blown down in the single pass system vs. 0.14% in the two-pass block. Although blowdown rates were higher in the single pass block, blowdown rates of less than 1% in either system were considered to be acceptable.

Harvest Design # 3 Single-Pass System (8.5% Aspen Retention)

This system needs evaluation and is currently used when blowdown risks are minimal (small understory or low slenderness co-efficient of understory spruce). Based on a skid trail width of 8m, skid trail spacing alternates between 29m and 24m. The feller buncher harvests aspen for 8m on either side of the skid trail. This results in a 5m wide strip of retained aspen between every second reach area (Figure 6).

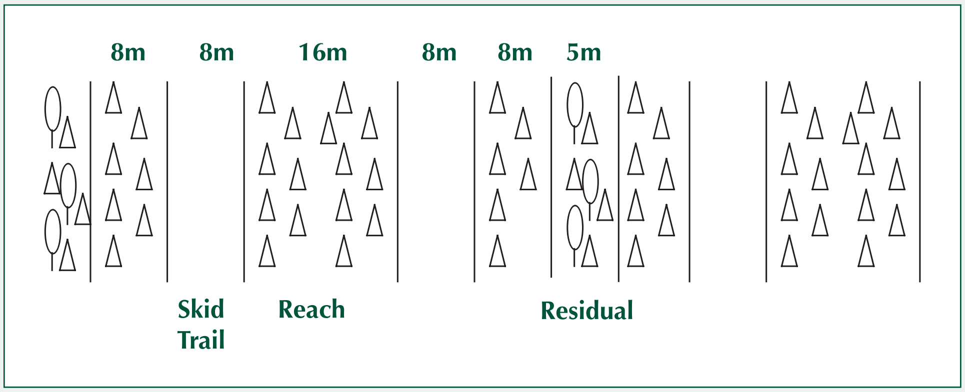


Figure 6. Diagram of Harvest Design #3 Single Pass System (8.5% Aspen Retention)

Harvest Design #4 Single-Pass With Narrow Skid Trails

Ainsworth Lumber Company Ltd. began its understory protection program in 1996 to explore different amounts of aspen residuals, layout of skid trails versus buncher operator decision, and blowdown rates. The latest trials are exploring complete removal of all aspen from the reach area of 3 skid trails (approx. 19m spacing) alternating with a 25m wide aspen retention area (Figure 7).

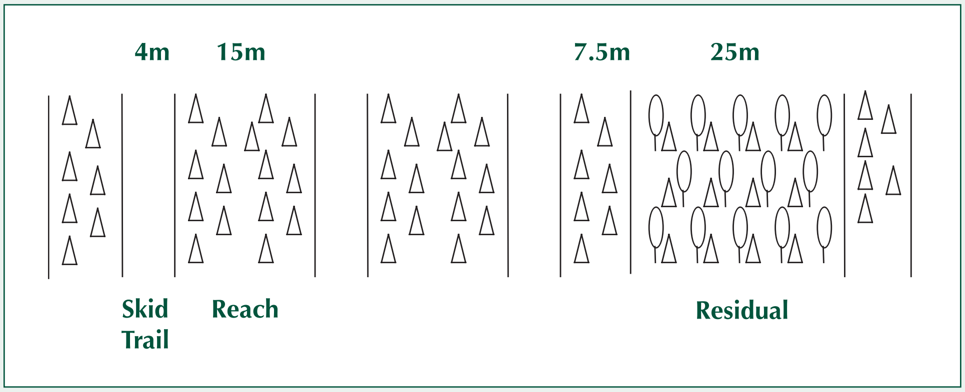


Figure 7. Diagram of Harvest Design #4 Single Pass System With Narrow Skid Trails

Future Research on Understory Protection

New standards for stocking and regeneration performance for stands that have undergone understory protection need to be developed. Since these stands are usually uneven-aged mixtures of spruce and poplars, typical regeneration rules designed for even-aged stands after clearcutting are not appropriate. In addition, the long-term competitive dynamics of aspen regeneration on skid trails of different widths is an important research question. Presently the trend is towards maximizing protection of the white spruce understory through reducing skid trail width and expanding the feller buncher reach with specialized equipment (such as a zero tail swing buncher with extended boom). The crown expansion of residual white spruce and overshadowing of the aspen regeneration on the skid trail is expected, and subsequently, aspen regeneration may be impeded. This issue must be understood to model growth and yield of the developing stand. Thirdly, for white spruce, the size, density of spruce prior to logging and the live crown ratio should be evaluated as factors for prediction of delay in release of spruce following logging. Finally, studies on resultant stand structure and biodiversity will also be needed.

Conclusions

Mixedwood management can be promoted by employing tools that both artificially establish understory spruce in aspen dominated stands and then protect the understory during the removal of maturing aspen. Understory planting provides the means to produce late recruitment of spruce into stands, thereby establishing a spruce stand prior to the harvesting of the aspen stand. Refinement in our ability to protect understory spruce during logging of the aspen will allow us to sustain the spruce in the landscape.

Species composition should be managed at a landscape level in order to fully implement these components of mixedwood management. Where there are overlapping hardwood and softwood tenures, this will require joint planning. Understory planting and understory protection are management techniques that emulate natural processes of mixedwood forests. Future research in sustainable forest management should consider understory planting and techniques used to protect spruce understories as major foci.

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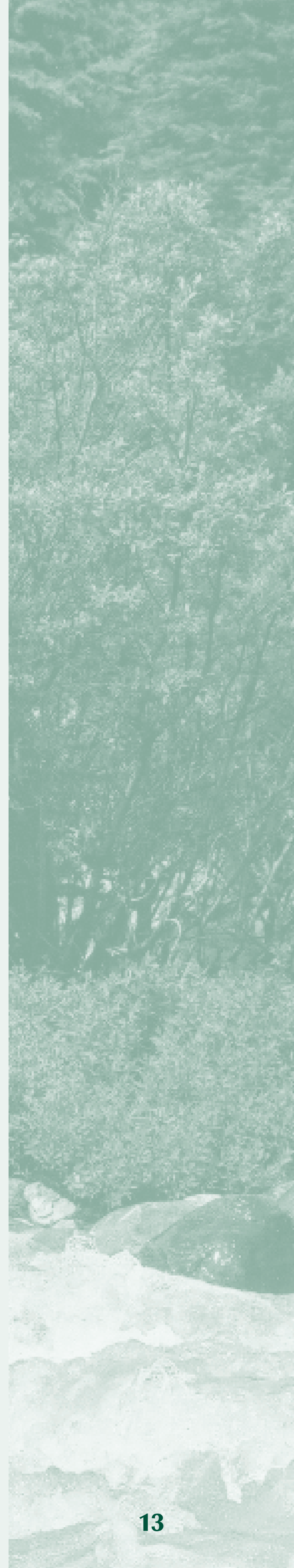

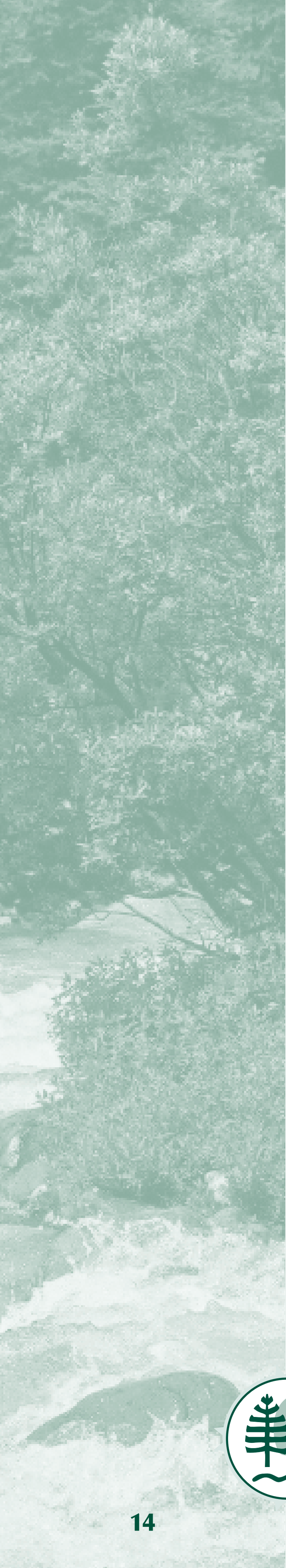

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