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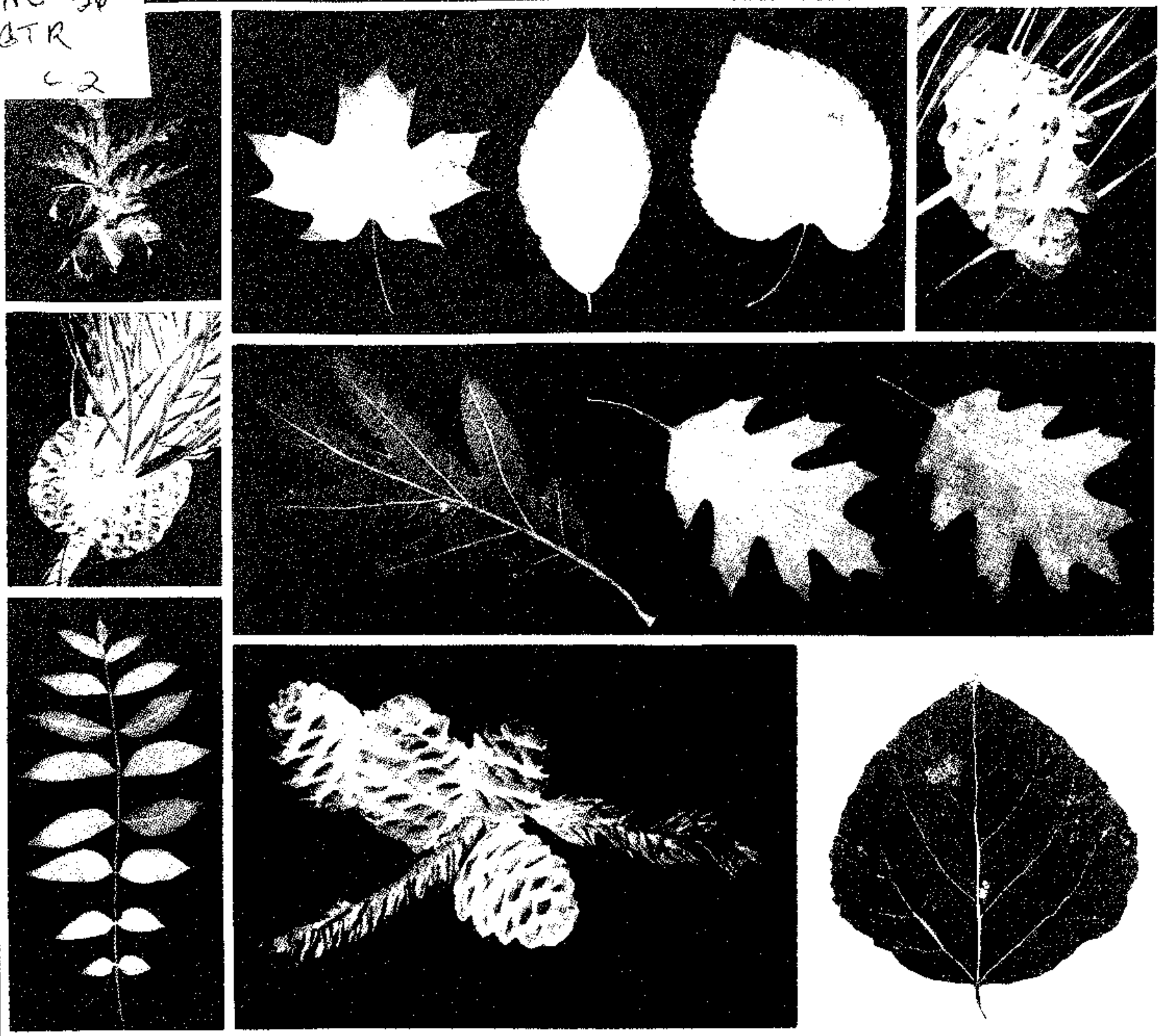

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manager's handbook for ASPEN IN THE NORTH CENTRAL STATES

GENERAL TECHNICAL REPORT NC-36

NORTH CENTRAL FOREST EXPERIMENT STATION   FOREST SERVICE   U.S. DEPARTMENT OF AGRICULTURE

Other Manager's Handbooks are:

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FOREWORD

This is one of a series of manager's handbooks for the important forest types of the north central States. The purpose of this series is to present the land manager with the latest and best information available on handling these types. Timber production is dealt with more than other forest values because it is usually a major management objective and more is generally known about it. However, ways to modify management practice to maintain or enhance other values are included if sound information is available.

The author has, in certain instances, drawn freely on unpublished information provided by scientists and managers outside his specialty. He is also grateful to the several technical reviewers throughout the region who made many helpful comments.

The handbooks have a similar format, highlighted by a "Key to Recommendations". Here the manager can find in logical sequence the management practices recommended for various stand conditions. These practices are based on research, experience, and a general silvical knowledge of the predominant tree species.

All stand conditions, of course, cannot be included in the handbooks. Therefore, the manager must use technical skill and sound judgment in selecting the appropriate practice to achieve the desired objective. The manager must also apply new research findings as they become available so that the culture of these important forest types can be continually improved.

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ASPEN
IN THE NORTH-CENTRAL STATES

Donald A. Perala, *Silviculturist*
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SILVICAL HIGHLIGHTS

The bulk of the aspen[1] in the north central States is in Minnesota, Wisconsin, and Michigan where 13 million acres (one-fourth of the commercial forest land) of aspen type contain 80 percent of the aspen growing stock; the rest of the growing stock is in conifer types (7 percent) and other hardwood types (13 percent). Quaking and bigtooth aspens occur on nearly every soil type but grow best on deep, well drained soils.

Aspens are highly sensitive to shade, soil compaction, fire, and mechanical injury to the root system. The species grows rapidly, thins itself naturally from competition, insects, and diseases, and matures in 30 to 70 years; occasional trees will survive 100 years or more. Without disturbance, aspen stands will be replaced by more tolerant or longer-lived associates.

Aspen typically sprouts many thousands of suckers per acre from the shallow parent root system after a stand has been opened by fire, windthrow, or cutting. The suckers arising from the same tree are genetically identical to the parent and are called a "clone". Suckers of the same clone have uniform characteristics, but suckers of different clones can vary widely – especially in bigtooth aspen. Single clones typically cover 1/10 to 1/5 acre, occasionally up to 4 acres.

MANAGEMENT OBJECTIVES AND NEEDS

About one-third of the aspen-birch forest type in Minnesota, Wisconsin, and Michigan is growing much below potential. The management objectives considered in this handbook are to improve yields of timber, water, or wildlife in this forest type while minimizing impact on the landscape.

The recommended silvicultural system for growing and reproducing aspen is complete clearcutting at rotation age to regenerate pure, fully stocked stands of suckers. In young stands that were not established by complete clearcutting, the residual trees need to be removed as early as possible. One or two thinnings to control stand density are needed to greatly increase the yield and shorten rotations for saw logs and veneer, but thinning is not recommended for fiber production. The manager will need considerable skill and wisdom to balance the output of timber, water, and wildlife while maintaining a pleasing landscape.

KEY TO RECOMMENDATIONS

The following key recommends the management techniques that will improve the yields of timber and water, or increase wildlife for given stand and site conditions and objectives. Not every possible situation can be covered in detail, so the manager must choose the alternatives that come closest to describing his condi-

[1] *For scientific names of plants and animals, see Appendix, p. 27.*

tions. If growing aspen is not reasonable, alternate species are recommended.

The timber recommendations will have some effect on water, wildlife, and landscape values. These effects are discussed in the appropriate sections (p. 9-12) where modified or alternative practices are recommended.

Start with the first pair of like-numbered statements. Choose the statement that better describes your forest and find either a number, a partial recommendation and number, or a final recommendation. If a number is given, find that pair of statements and continue the process until a final recommendation is reached. The page numbers refer you to appropriate discussion in the "Management Considerations" section that follows.

1.	Site index 60 or greater (p. 3)	WELL SUITED FOR ASPEN TIMBER MANAGEMENT . . 2
1.	Site index less than 60 (p. 3)	POORLY SUITED FOR ASPEN TIMBER MANAGEMENT . . 10
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7.	Stand is pure, well stocked (p. 5)	HARVEST WHEN MERCHANTABLE, CONVERT TO CONIFERS (p. 9)
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8.	Stand mixed	9
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9.	Stand is other conifers or hardwoods mixed	PROMOTE SUCCESSION (p. 6)
10.	Timber management is objective	CONVERT TO CONIFERS (p. 9)
10.	Watershed or wildlife management is objective	11
11.	General area is less than 25 percent aspen	MAINTAIN ASPEN (p. 3)
11.	General area is more than 25 percent aspen	12
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12.	Watershed or other wildlife management is objective	MAINTAIN ASPEN (p. 3)
13.	General area is less than 15 percent conifers	CONVERT TO CONIFERS (p. 5, 6, 9)
13.	General area is more than 15 percent conifers	MAINTAIN ASPEN (p. 3)

TIMBER MANAGEMENT CONSIDERATIONS

Controlling Stand Establishment

The land manager must decide what species to grow and the end products for those species. These decisions will be influenced considerably by market conditions; the relative local abundance of aspen, hardwood, and conifer types; the long-term availability of aspen and other species; watershed, wildlife, and esthetic objectives; and the productivity of forest soils for various species.

Estimating Site Productivity

Site Index Curves

Site index is commonly determined by comparing the mean total height and age of dominants and codominants with published site index curves. Site indices are expressed in even units of 10 feet at age 50, the class interval being 56 to 65 for site index 60, for example. Use site index curves (see Appendix, fig. 12) to estimate site index for quaking aspen. Up to age 50 the estimates will be reasonably accurate throughout most of the north central area; after age 50 accuracy can drop significantly because of local variation in height growth. The only curves for bigtooth aspen are from northern Lower Michigan (see Appendix, fig. 13). When these curves are used elsewhere for bigtooth aspen, the site index estimates are likely to be less accurate.

The genetic variation between clones can sometimes cause considerable error in aspen site index estimation (see Appendix, fig. 14). To accurately estimate site index where clonal growth differences are pronounced, measure two dominant aspens in each of three clones representative of the stand. The average height of the three clones along with tree age will give reliable site index values. Sampling only the tallest clone or clones could overestimate site index by 5 to 10 percent.

Soil Examination

Site index curves are not reliable for stands less than 20 years old, or in stands where growth was slowed because of fire, or because partial cutting left dense overstories. To estimate site index in such stands, use soil and topographic features instead of heights (see Appendix, tables 1 and 2). Soil surveys by the USDA Soil Conservation Service and other agencies can also be very useful (fig. 1).

Alternative Species

Only site index 60 or better should be considered for aspen timber management although poorer sites can be managed for aspen for other purposes. Conifers are usually more productive than aspen on poorer sites so the land manager may wish to convert to conifers. The land manager may also wish to convert better aspen sites to other species. The following tabulation gives quaking aspen site index values and the corresponding site index for some alternative species:

Figure 1. – *This aspen stand has a measured site index of 42. Since the stand originated after fire, the true site index of the stand is underestimated. A soil examination is needed to accurately assess the potential productivity of the site.*

If quaking aspen site index is:	Then site index for these species is: Red pine	Basswood	Paper Birch
40	46	44	40
50	50	50	47
60	54	56	55
70	59	62	62
80	63	68	70

Regenerating Aspen

Basic Requirements

For best aspen sucker regeneration: (1) the soil must be well drained and aerated, and (2) the parent stand must have a minimum aspen density of 50 trees or 20 square feet basal area per acre. To stimulate suckering, allow heat and light to reach the forest floor by removing as much of the overstory as possible, preferably all trees 2 inches or more in d.b.h. (as little as 10 to 15 square feet basal area of residual overstory will slow sucker growth by 35 to 40 percent) (fig. 2). In some cases the understory may also need to be controlled. Harvesting the overstory in summer helps in this regard.

Figure 2. – *One-year-old quaking aspen root sprouts (suckers).*

Site Preparation

Harvesting the old stand helps prepare the site for regenerating aspen, but some harvesting methods are better than others in this respect. Full-tree or tree-length harvesting scarifies and eliminates enough competing vegetation during felling and skidding that further site preparation is often unnecessary. On the other hand, traditional or "shortwood" harvesting must usually be followed by additional site preparation. Of course, stands that are not commercially harvestable must also be treated. Table 3 (Appendix) lists how effective in encouraging suckering various site preparation techniques are under certain overstory, understory, and forest floor conditions.

Options to encourage suckering include shearing, chainsaw felling, girdling, treating with herbicides, and prescribed burning. Discing and roller chipping are not recommended because their stimulation of suckering is often negated by damage they do to the parent roots (fig. 3).

Figure 3. – *Discing or roller chopping disturbs the parent root stock and reduces sucker growth and survival.*

Shearing is the most successful mechanical site preparation method. A sharp blade and shearing on frozen soils will least disturb the parent root system and maximize sucker production.

Girdle or treat with herbicides[2] only in fully stocked stands. (In poorly stocked stands every tree is needed to increase suckering, so all should be sheared or chainsaw felled instead.) Girdling or chemical treatment are most efficient on trees over 5 inches d.b.h. Girdles should penetrate to the sapwood and encircle the stem completely. Diluted herbicides such as 2,4-D amine, 2,4,5-T, or picloram can be injected 1/4- to 1/2-inch into the sapwood as close to the tree base as possible, or be sprayed on the tree base in oil solution any time during the snow-free season.

Aerial spraying during July 15 to August 15 with 3 lbs. 2,4-D ae (acid equivalent) in 5 gallons of water mixture per acre will control paper birch and aspen residual trees. Substitute 2,4,5-T for 2,4-D if red oak is present. Although the aspens will be top-killed, they will resprout the next year to provide a fully stocked stand. Harvested stands should be sprayed within 1 year.

[2] *See Pesticide Precautionary Statement, p. 28.*

Prescribed burning should be used only by personnel experienced in fire behavior and fire weather. It is recommended only when other site preparation methods are impractical or in poorly stocked, brushy, or sodded stands. Although burning increases suckering, it also tends to slow sucker growth. Harvested stands should be burned within 1 year; the best time is in the spring before growth starts. If snow still lies in the surrounding timber, or if the surrounding timber is hardwood, the burn can be easily confined to the harvested area (see "Prescribed Burning" and table 4 in Appendix).

Stocking Standards

By age 2, when most suckering will have occurred, sucker stands should exceed 85 percent milacre stocking, or about 4,000 to 5,000 stems per acre (fig. 4). As stocking drops below 4,000 per acre at age 2, the chances that the stand will develop to an economically operable density decrease rapidly with small increases in mortality. The development of sucker stands should be checked periodically (see "Forecasting Future Operability" and fig. 15, Appendix).

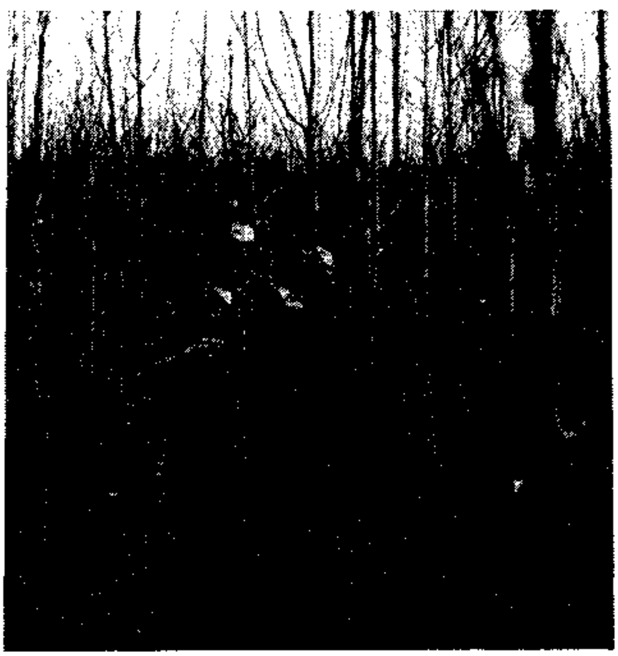

Figure 4. — *Regeneration of dense sucker stands is the best guarantee of high aspen productivity.*

Controlling Composition

Competition

If an aspen stand is properly regenerated at maturity, it will outgrow other regenerating species; these then may develop as an understory. Overtopping trees left after harvest, however, strongly suppress aspen growth, and should be removed in initial site preparation or by cleanings and thinnings within 10 years.

Growing Conifers with Aspen

Only white spruce and balsam fir can easily be managed concurrently with aspen. In fact it is difficult to manage spruce and fir to the exclusion of aspen, and vice-versa, where they exist together. The total fiber yield may be greater in these mixed stands than if pure stands of any one species are grown (fig. 5).

Figure 5. — *Aspen and balsam fir can be grown together for landscape variety and forest crop diversity.*

Where mature aspen has an understory of immature spruce-fir, clearcut the aspen at age 30 to 50 to release the conifer understory. Openings in the conifer canopy will be large enough to allow good aspen sucker development in scattered patches. Manage the conifers either by group selection, shelterwood, or diameter limits according to age structure and the proportion of aspen. Make shelterwood and diameter limit cuttings to encourage advance spruce-fir regeneration when the aspen component is minor or scattered. Clearcut mature aspen and conifers to regenerate a fully stocked aspen sucker stand. If advance reproduction is sparse, clearcuts should be small (preferably less than 20 acres); large clearcuts should not exceed 200 feet in width and their length should be oriented perpendicular to prevailing winds since conifer seeds must blow in from outside. Although spruce-fir regeneration will be minor the next 10 to 20 years, by the time aspen is mature again, understory conifers will be re-established and the cycle can be repeated indefinitely.

Promoting Succession

Pines or northern hardwoods often become established as an understory in aspen. Pines cannot be easily managed concurrently with aspen so the aspen can be removed carefully whenever operable. Aspen does not compete well with northern hardwoods and should be removed in partial cuts to recommended densities for northern hardwoods.

Expanding "Plus" Clones

Variation in some aspen stands is enormous; yield can differ as much as 200 percent between clones on the same site. Since much of this variation is genetic, an opportunity for stand improvement exists both during thinnings and during the regeneration cut.

During thinnings, favor the best ("plus") clones for crop trees. Be alert for obvious traits such as superior stem form and growth rate, lack of branchiness, and resistance to hypoxylon canker and heart rot (fig. 6). In mixed stands of bigtooth and quaking aspen on dry exposed sites, generally favor bigtooth because of its superior growth and greater resistance to diseases and insects. However, as soil moisture increases, quaking aspen often tends to perform better and should be favored.

Identify the boundary of plus clones and remove competing poor ("minus") clones during thinning. Do not, however, open the stand excessively, but maintain full stocking by leaving minus trees where necessary (see Appendix, fig. 16). The suckers that arise from the minus clones will soon die from shading.

Suckering of minus clones can also be controlled during the regeneration cut. The fall or spring 2 years before harvest, favor plus clones resistant to heart rot (indicated by the absence of conks) by basally spraying competing minus clones. Or during felling (when susceptibility to decay is most obvious) spray the exposed cambium of cut stumps of competing minus clones. In both cases, use 2 gallons of Tordon 155[2,3] in 100 gallons of fuel oil and thoroughly wet the treated areas. As an alternative, girdle minus clones in the summer 2 years prior to harvest to reduce suckering. Do not delay harvesting more than 2 years after girdling or chemical treatment because a significant amount of wood may deteriorate after the trees die.

Figure 6. – *Well formed, disease-resistant clones on good sites are required in a thinning program to produce saw logs and veneer bolts.*

Do not treat minus trees more than 50 feet beyond a plus clone to assure full stocking with aspen suckers. Several rotations will probably be needed to replace most minus clones since plus clones can be extended by only 20 to 40 feet each rotation, but the quality of the stand will be steadily upgraded each rotation.

Improving Growth

The practices that control stand establishment and composition will markedly affect stand growth. Generally, dense stands are initially more pest resistant and will yield more fiber at maturity than more moderately stocked stands. On the other hand, trees in dense stands do not grow in diameter as quickly as moderately stocked stands and will yield less sawtimber and veneer.

[3]*Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

Yields can be increased by (1) thinning and (2) adjusting rotation ages to maximize mean annual increment. Both options are recommended for growing sawtimber and veneer; for fiber, only adjusting the rotation age is recommended.

Thinning

Only well-formed, disease-resistant clones on sites 70 and better can yield significant amounts of sawtimber and veneer. Generally, a single commercial thinning is recommended (schedule A as follows). However, site index 80 or better stands will produce substantially more sawtimber and veneer if precommercially thinned as well (schedule B). In schedule A, thin once at about age 30 when basal area has surpassed 120 to 140 square feet. Leave about 240 trees and 60 to 70 square feet per acre. In schedule B, the precommercial thinning should leave 550 trees per acre at about age 10 when the trees are still small enough to be easily felled by hand (fig. 7). Thin a second time at about age 30 when basal area has surpassed 130 square feet per acre. Leave 200 trees and 80 to 90 square feet per acre. Delay the regeneration cut in either schedule as long as the stand is healthy and shows little sign of heart rot -- age 50 to 60 in most cases.

Assuming a regeneration cut at age 55, schedules A and B in site index 80 aspen would average 12 to 14 inches d.b.h., compared to 9.5 inches without thinning. Thinning produces up to 140 percent more veneer and up to 40 percent more sawtimber than without thinning, with the greatest gains from the two-thinning schedule (see Appendix, fig. 17). Thinning can produce the same amount of sawtimber in 10 years less time, or the same amount of veneer in 14 years less time than without thinning.

The smaller trees and tops of crop trees could give these additional yields of whole chips:

Schedule	Commercial thinning	Regeneration cut	Rotation total
	-- (fresh weight, tons per acre) --		
A	54 (4.3)[4]	63	117
B	41 (5.7)	65	106

[4] *Mean diameters in parentheses.*

Figure 7. – *The first thinning at about age 10 should leave 550 trees per acre.*

Thinnings need only remove other species competing in or above the aspen overstory, not those in the understory. Always remove poor risk aspen; never remove potential crop trees. Uniform spacing is not critical except that large openings (which can cause aspen sunscald) should be avoided. Because the material removed in thinnings is small diameter, we recommend chipping the whole tree to improve utilization.

Rotation Length

The regeneration cut should be timed to maximize mean annual increment of the products desired. (Economic rotations are usually 5 to 10 years shorter.) Generally, the larger the product, and the lower the site index, the longer will be the rotation. However, in some areas, low site index aspen deteriorates earlier than high site aspen and should be harvested first.

Rotation lengths for quaking and bigtooth aspen in the Lake States by product, site index class, and with and without thinning, are given in Appendix, table 5. Stands managed for sawtimber and veneer on rotations of 50 to 70 years must be chosen carefully and inspected often for signs of deterioration. Shorten the rotation if there will be significant loss and consider another product for the next rotation.

Damaging Agents and Control Measures

Diseases

A common disease in young aspen stands is "shepherd's crook", which usually only blackens and kills back the terminal. New growth recovers the following year and no control is feasible or necessary.

Hypoxylon canker commonly infects stands of all ages and is the only disease causing significant mortality over recommended fiber rotation lengths. About 3 percent of the Lake States aspen trees are killed annually by this infection (fig. 8). Bigtooth aspen is five times as resistant as quaking aspen. The only known control is to maintain full stocking throughout the rotation to assure at least partial replacement of growth loss. Cultural techniques to encourage the expansion of resistant clones or bigtooth aspen clones into quaking aspen clones would increase stand resistance to infection (see "Expanding 'Plus' Clones"). Where it is difficult to obtain full sucker stocking and the infection rate is high, conversion to other species is recommended (see "Stocking Standards").

Figure 8. — *Hypoxylon canker of aspen, the second-most important pathogen of aspen in the Lake States. The scalpel is embedded in the central portion of a canker.*

Heart rot decays the heartwood of stands nearing maturity and is the main limitation to growing aspen on veneer rotations exceeding 50 or 60 years (fig. 9). Losses to this disease are not serious for shorter rotations. Heart rot probably enters bark wounds or dead branch stubs. In the first stage of decay the wood is still firm but later becomes discolored enough to cause degrade in lumber; in the final stage the heart rot becomes soft, punky, and is often large enough to cull a log. If the decay is small or firm, the log can be held in a turning chuck and rotary veneer yield will be little affected. On the average, the final (soft) stage of decay will reduce gross merchantable yields by 1, 2, 5, and 10 percent at ages 40, 50, 60, and 70, respectively. If all stages of decay are considered, 8, 12, 16, and 20 percent defect, respectively, will be found. Sporophores or "conks" indicate that the final decay stage extends 2 to 5 feet above and below the conk, depending on their number and size, but the absence of conks does not necessarily mean the absence of decay.

Besides age, tree vigor and inherent resistance influence decay. Vigorous, fast growing trees are relatively resistant, although the relationship between decay and site index is not consistent. Since certain clones are considerably more decay resistant than others on the same site, inherited resistance is probably more important than site index. No controls are known for the disease except to make the regeneration cut early enough to avoid unacceptable losses.

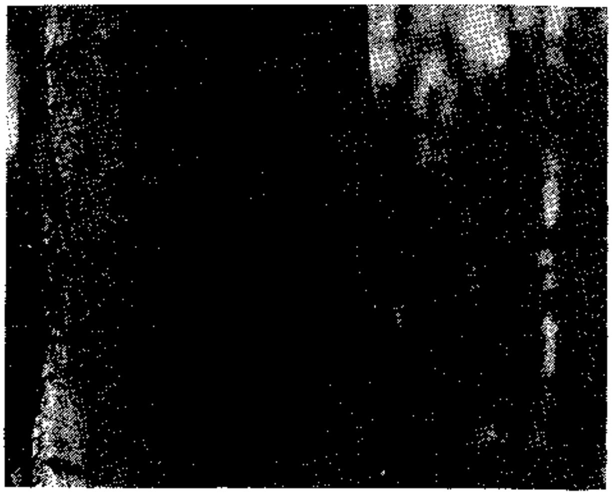

Figure 9. – *Conk of* Phellinus igniarius – *the main deterrent to growing aspen to old ages.*

Insects

Once past the juvenile stage, aspen is seldom killed directly by insects. However, insects such as the poplar borer may enhance mortality by weakening the tree or providing infection courts for pathogens. A number of other wood borers can damage and kill young suckers. Pole-size and mature stands are more susceptible to defoliating insects such as the forest tent caterpillar and the large aspen tortrix. Even repeated defoliation does not cause much direct mortality, except on sites with high water tables – the main effect is temporary loss in growth. No direct insect control is now practiced in aspen although dense sucker stands should be regenerated to minimize borer damage.

Fire

Aspen stands are relatively low in flammability and fires are easily controlled. However, even surface fires can either kill or injure aspens and cause significant growth loss and early stand breakup. Fire should be excluded from aspen stands except for regeneration and even then excessively hot fires should be avoided.

Weather

New spring growth can be killed by frost, but growth resumes and little permanent damage results. Aspen is prone to windthrow or breakage, particularly when weakened by boring insects or disease. Young sucker stands can be seriously damaged and sometimes killed back by hail.

Improperly Timed Silvicultural Practices

Soil compaction from heavy machines can reduce future aspen yields 5 to 10 percent by lowering soil aeration required for vigorous suckering. The potential for compaction is most severe on wet soils having a high clay content, and is minimal on dry sandy soils. Disperse skidding to minimize compaction during the summer by mechanized logging. Winter logging causes less soil compaction than summer logging, but does not disturb competing vegetation as much – a factor to consider on brushy aspen sites. Shearing for aspen regeneration should always be done when soils are frozen.

Conversion to Conifers

Aspen stands to be converted to conifers should first be harvested of all usable material. Prepare the site mechanically by shearing, roller chopping, or barrel scarifying, or treating chemically between July 15 and August 15 with picloram plus 2,4-D (0.5 pounds + 2 pounds per acre) in 10 to 20 gallons water per acre.[2] Plant suitable conifers the following spring.

Release conifers from aspen suckers as needed using 2,4-D or a 50 percent mixture with 2,4,5-T when oak or other hardwoods are present. Use total rates of 3 pounds per acre in 4 to 5 gallons water mixture for aerial spraying; 3 pounds per acre in 10 to 20 gallons for ground spraying. White spruce and red pine are safe to release after July 1 but release is best after July 15. Jack pine is not safe to release until August 1. Complete the release operations by August 15. Where chemicals cannot be used, hand release during the growing season (June, July, early August) to lessen regrowth of aspen.

OTHER RESOURCE CONSIDERATIONS

Water

Aspen forests can have considerable impact on water yield, depending on how they are managed. Harvesting (either intermediate thinnings or regeneration clearcuts) on a sustained yield forest will have little impact on water yield, quality, or timing, because only 1/30 to 1/60 of the total acreage is cut during any 1 year. However, an individual watershed that is completely clearcut may yield 3 to 4.5 inches more water the first few years after cutting. This yield diminishes with time; after 6 to 7 years the new stand will differ little in water yield from mature aspen. Few nutrients are lost after clearcutting because of rapid vegetation growth. Sedimentation is insignificant; most sediment results from construction of roads and skid trails and can be avoided. Timing of peak flow from a clearcut watershed may be advanced by 4 days. Converting aspen to conifers has the most significant long-term effect on water yields. A pure aspen stand will yield 2.5 inches more water annually than a pure stand of red pine because it intercepts less precipitation. As long as conifers are maintained, water yields will remain lower than if the watershed were left in aspen.

Wildlife

Game Species

Ruffed grouse utilize aspen stands of all ages. Juvenile sucker stands at age 2 (12,000 to 14,000 stems per acre) up to about age 10 (6,000 to 8,000 per acre) are important brood habitats for grouse. Sapling and pole stands aged 10 to 25 are preferred overwintering and breeding cover. Aspen stands older than age 25 (when stem densities usually fall below 2,000 per acre) are devoid of breeding grouse but serve as nesting cover and as a very important food source. A primary year-round food of grouse is aspen leaves and buds, best provided by stands nearing maturity. The staminate (male) flower buds of aspen are the most important nutritive source for grouse. Some male clones preferred by grouse may be 30 percent richer in proteins than male clones that are not eaten. Finally, snow accumulates earlier and deeper in aspen stands than in conifer stands. This provides burrowing cover, which is very important during most winters.

To increase ruffed grouse, aspen should be clearcut on a 40- to 50-year rotation, in patches no larger than 10 acres in each 40 acres, and at 10-year intervals. Male clones that grouse prefer should be favored during intermediate thinnings and during regeneration cuts (see "Expand Plus Clones"). Intermediate thinnings or short rotations are not recommended for grouse management.

White-tailed deer rely heavily on the aspen type, especially for spring and fall range, and for winter range within 1/2-mile of winter cover types (fig. 10). Herbaceous and shrubby growth associated with aspen is usually more abundant because the intolerant aspen admits more sunlight to the forest floor than do the more tolerant hardwoods and conifers. The quality and availability of herbaceous vegetation in the spring and fall greatly affect the vigor of northern deer herds. Conifer cover during winter to minimize body heat loss is even more important. Pure aspen or hardwood stands offer poor insulation and protection from wind compared to dense stands of lowland conifers (especially northern white-cedar), balsam fir, or pines.

Deer populations can be increased by limiting aspen clearcuts to 40 acres (preferably 20 acres) and by short rotation management (25 to 30 years on 5- to 10-year intervals) of aspen stands within 1/2 mile of winter deer yards. (The cutting schedule recommended for grouse could also be applied for deer, with somewhat reduced benefits.) Ideal deer range should be 15 to 20 percent scattered conifer stands, and 5 to 10 percent sodded and brushy openings (which are important spring and fall feeding areas). Hardwood forest types should contain 25 to 35 percent of their area in aspen stands, and 25 percent of the aspen should be 1 to 10 years old.

Moose are dependent upon the aspen community to provide a large amount of browse. For moose management, clearcuts can be up to 100 acres; the stand composition should be similar to that for deer.

Figure 10. — *Moose, white-tailed deer, and beaver are some of the wildlife species that depend on aspen for food and cover. (Deer and moose photos courtesy of Minnesota DNR.)*

Smaller Birds and Mammals

Beaver populations should be controlled so they will not over-utilize riparian aspen forests by repeatedly cropping sucker stands. Repeated cropping can result in death of the stand and food scarcity for future populations.

Cavity nesting birds and mammals can be encouraged by leaving standing dead snags. These will not interfere with sucker regeneration of the new stand. Numerous songbirds, such as the Nashville warbler, a variety of sparrows, hermit thrush, and others, need all elements of food and cover -- from herbaceous openings and early stages of forest succession (such as aspen) to stands of mature and old-growth timber.

Rare and Endangered Species

Three rare or endangered species using the aspen type are the bald eagle, osprey, and eastern timber wolf. All are protected by Federal and State laws. The following tabulation lists restrictions on management activities for osprey and eagle nest trees:

Distance from nest	Osprey nests	Eagle nests
Up to 350 ft.	No activity anytime	No activity anytime
350 to 650 ft.	No activity March to July	Thinning and pruning OK (no clearcutting) October to mid-February; no activity rest of year
700 and beyond	Normal activities OK	--
700 ft. to 1/4 mile		Normal activities October to mid-February only; no activities rest of year

If areas more than 1/4 mile away are visible from the eagle nest, the outer zone can be extended to 1/2 mile in that direction. Roads and trails within 1/4 mile of eagle nests should be closed where possible. Scattered old-growth trees, particularly the pines, should be reserved as much as possible for future nest trees.

The timber wolf generally requires no special habitat management beyond good management for deer, moose, and beaver. These are the primary prey of wolves and habitat manipulation for them will serve the wolf as well.

Landscape

Aspen is dominant and highly visible in the landscape of northern forests. Because it is abundant and predominantly maintained through clearcutting, how it is managed will have important impacts upon the landscape and recreation experiences. Aspen landscape management is needed most in stands in the foreground of scenic areas, travel corridors, use areas, and water bodies frequented by and readily visible to large numbers of forest visitors. Important factors to be considered in avoiding unsightly management practices are *viewing distance, size, shape, edge, distribution or spacing, timing, vistas,* and *operations.*

The foreground (0 to 1/2 mile) and middleground (1/2 to 3 miles) landscape zones are most important because they are most readily seen. The background zone (3 miles +) is important when it is highly visible and provides a scenic backdrop.

Foreground landscapes can be enhanced by:

1. Providing vistas that expose and frame scenic features.
2. Utilizing clearcuts to create visual variety by opening up dense stands, and breaking up straight lines of timber with curved lines and irregular openings.
3. Leaving attractive trees and snags and those of special interest.
4. Providing diversity in plant species, age class, size, and type.
5. Using transition vegetation along edges.
6. Varying the sizes and shapes of cuts.
7. Converting to other vegetative types.

An aspen regeneration cut has less impact if its *size* does not dominate and if it is varied and in scale with natural or man-made openings that may occur in the landscape. The apparent size of a cut can be reduced by restricting the amount of cut area seen from any one viewing position. Factors such as distance, shape, and screening provided by intervening ridges or other landforms and islands or clumps of vegetation help to limit the apparent size of cuts.

Irregular, free-form *shapes* that follow natural projections, indentations, soils, and topographic features expose smaller areas of clearcut to view. Avoid cutting boundaries in long straight unnatural edges or in geometric shapes which clash with natural landscape forms.

Clearcut openings whose *edges* contrast sharply with the surrounding timber can be "feathered" to soften such contrasts. Make use of existing openings as part of edge. Thin into adjacent stands to develop an irregular loose appearance and spacing. Develop a diversity of plants in species, size, and texture, to help soften edge (fig. 11).

Regularly spaced clearcuts of nearly the same size and shape are seldom visually pleasing. *Dispersal* and *irregular spacing* should be used to avoid a repetitious pattern.

Aspen harvests should be scheduled so that sufficient *time* elapses before new areas are cut to allow dulling and greening of the old cuts. Stands immediately adjacent to previous clearcuts should not be scheduled for a regeneration cut until a stand of trees has been established on the old cut. This difference in age will create variety and contrast in the sequence of cutover areas.

Where possible, consider cutting carefully selected trees or groups of trees or utilize clearcuts to open *vistas* through the timber. This can provide temporary or permanent views of outstanding physical features (rock outcrops, lakes, streams), and panoramas of the forest landscape. Leave clumps of birch, spruce, and other conifers to frame and give scale and dimension to the view. Vista openings need not be permanent. As changes occur in the forest scene, new openings can be developed to show the best views. Less attractive views can be allowed to close in.

Close control over harvest *operations* is as important as design. The best planning can be defeated by uncontrolled harvesting. The basic requirement is that the operation appear neat and organized. In all areas of heavy public use, harvesting should be limited to the minimum recreation season. In highly visible areas, harvest in the dormant season when leaves are absent to reduce the unsightliness of slash. Consider winter logging to avoid disturbance of ground vegetation. Stumps in the foreground should be low and the slash concealed by natural features, or lopped or chipped and scattered. Cut rather than girdle or herbicide trees in cultural treatments. In clearcuts, remove all standing trees that are dead, dying, damaged, culls, whips, or saplings (except for "special interest" trees). Remove all industrial debris from the operation. Keep damage from equipment and machinery to a minimum.

In site preparation, consider the visual impacts of the machinery and methods used. Skid trails, landings, and logging roads should flow with landforms and should be stabilized and seeded progressively as operations are completed. In locating landings, consider their potential use as wildlife openings, hunter parking areas, and campgrounds. Foregrounds are in effect display windows demanding more complete treatment and attention. Accomplishment of a workman-like job along travelways, waterways, use areas, and in aspen management operations in general will go a long way in meeting landscape objectives.

Figure 11. -- *These aspen clearcuts have been planned to minimize impact to the landscape by following irregular topographical and vegetation type boundaries, feathering edges, leaving special interest trees, and opening vistas.*

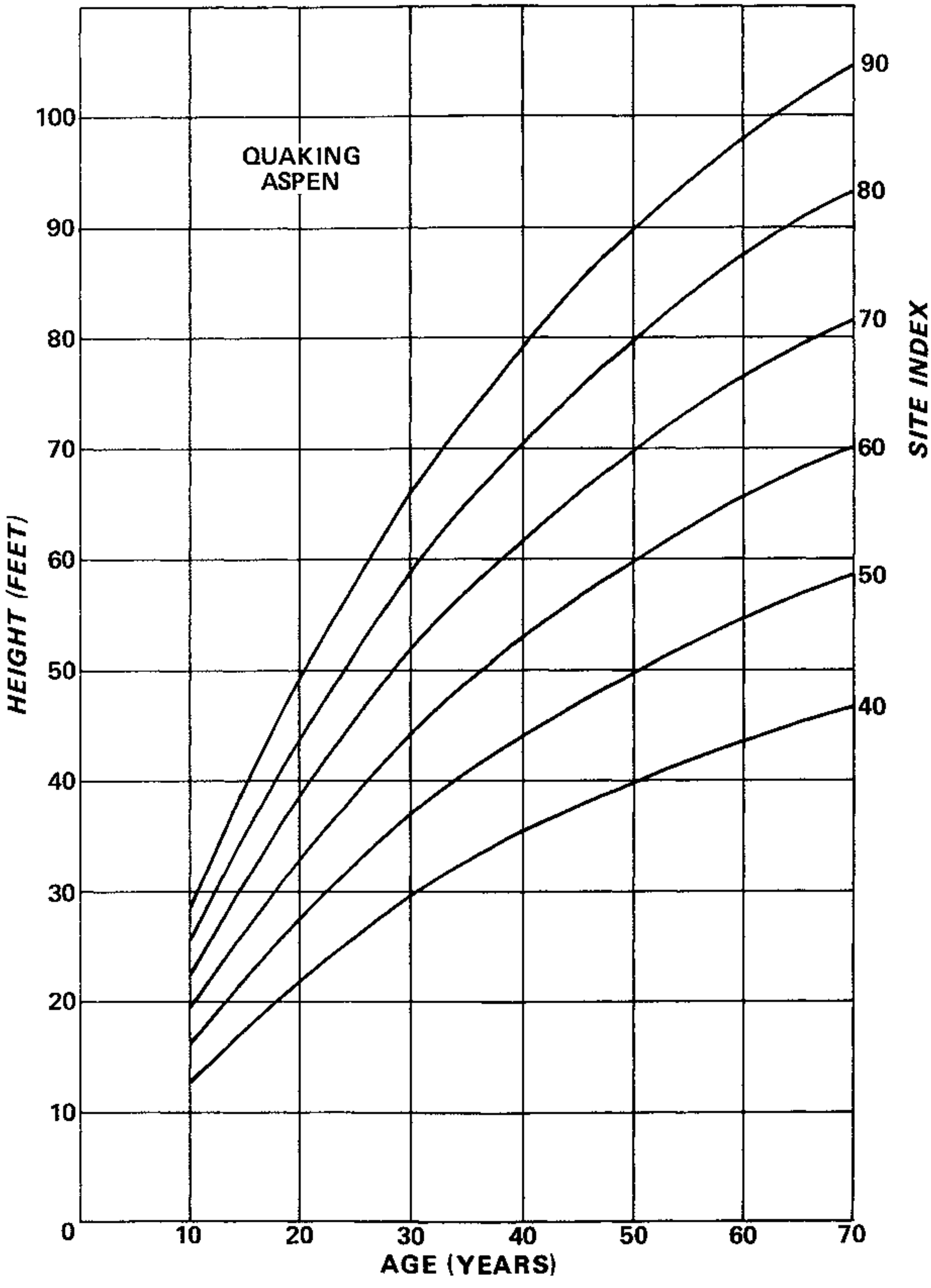

Figure 12. -- *Site index curves for quaking aspen in the north-central States (Lundgren and Dolid 1970).*

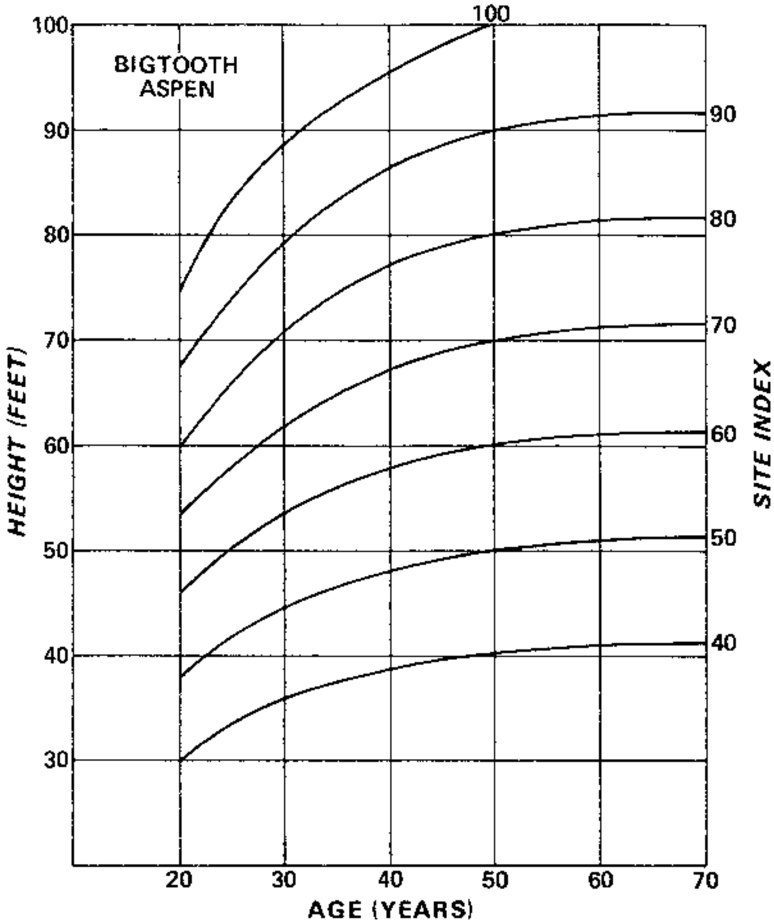

Figure 13. — *Site index curves for bigtooth aspen in northern Lower Michigan (adapted from Graham* et al. *1963).*

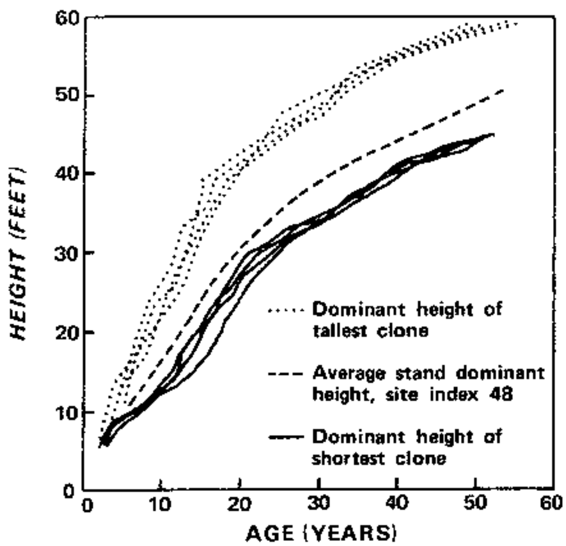

Figure 14. — *Height-age curves for the tallest and shortest clones of bigtooth aspen growing on the same site illustrating the need to sample more than one clone for site index determination (Zahner and Crawford 1963).*

Table 1. – *Estimated site index for quaking aspen in the Lake States based on soil texture and moisture regime (Stoeckeler 1960)*

Moisture regime	Percent silt-plus-clay in top 36 inches				
	<10	10-20	21-50	51-70	71+
	Height at 50 years, feet[1]				
Water table 2.5 to 8 feet	70	70	70	70	70
Well drained[2], with improved water holding capacity[3]	65	70	75	80	70
Well drained[2]	50	60	70	80	70
Poorly aerated[4]	60	60	60	50-60	50-60
Excessively drained[5]	40	40	55	70	70

[1]Calcareous parent material will increase site index about 5 feet. Stands exposed to wind or subject to rapid surface drainage (ridges, knolls) or on the upper half of 30 percent slopes with SE, S, SW, or W aspects will have 10 to 15 feet lower site index.

[2]No strong mottling within 1 foot of surface. Water tables deeper than 8 feet.

[3]Underlain at 2 to 3 feet with soils of greater water holding capacity (30 to 90 percent silt + clay).

[4]Strong mottling within 1 foot of surface, or water table closer than 2.5 feet.

[5]Droughty gravel is within 2 to 3 feet of surface soil and greater than 3 feet in thickness. Also includes soils where rock content exceeds 50 percent of the top 3-foot soil volume.

Table 2. – *Estimated site index for bigtooth or quaking aspen*[1] *on well-drained sandy soils, northern Lower Michigan (adapted from Graham* et al. *1963)*

Topography	Soil moisture category					
	Permeable subsoil, dry to 5 feet in summer	Depth to impermeable stratum[2]: 12 inches or less	Depth to impermeable stratum[2]: 13 inches to 18 inches	Depth to impermeable stratum[2]: 19 inches to 5 feet	Subsoil mottled	Water table within 5 feet
	Height at 50 years, feet[3]					
Flat uplands	30	30	40-50	50-60	60-70	70-80
Brow of slope	30-40	30-40	30-50	40-50	50-60	60-70
Upper slope: steep	30	30	30-40	40-50	50-60	60-70
Upper slope: moderate	30-40	30-40	30-50	40-50	50-60	60-70
Upper slope: gentle	30-40	30-40	30-50	40-60	50-70	70-80
Lower slope	30-40	40-50	50	60	70	80-90
Base of slope	30	40	50-60	60-70	80	90-100
Flood plain					80	80-100

[1]For quaking aspen reduce site index by 5 feet.

[2]Hardpans, clays, and fine compacted silts.

[3]Converging slopes or draws will raise site quality 10 feet above table values. Gravel (not washed layers) mixed in upper soil also will tend to raise site index. South-facing slopes will be lower than north-facing slopes. Where a range is given, the lower values are associated with coarse sands and the higher values with loamy sands; fine sands are intermediate.

Table 3. – *Effectiveness of harvesting and site preparation techniques for encouraging suckering*

Harvest option	Additional site preparation options available	Effectiveness for encouraging suckers where: Overstory contains noncommercial Conifers	Hardwoods[1]	Understory is brushy	Forest floor is sodded
Full-tree or tree-length system	Usually none needed	good	good	good	good
Shortwood system or No commercial harvest	Felling or girdling	good	good[3]	poor	poor
	Shearing	good	good	good	good
	Stem herbiciding	fair to good	good[3]	poor	poor
	Crown herbiciding (aerial)	poor	good[2]	fair	poor
	Prescribed burning	good[4]	good[4]	good	good

[1]Includes aspen.

[2]Recommended only for aspen, paper birch, and red oak.

[3]Do not girdle aspen in poorly stocked stands; fell instead to increase suckering.

[4]Effectiveness will be poor in unharvested stands with little ground fuel.

Prescribed Burning

At least 10 tons (fresh weight) of slash less than 3 inches diameter are needed per acre for a burn hot enough to kill standing residuals. Generally, mature stands exceeding 60 to 80 square feet basal area will have at least 10 tons of slash after conventional harvesting. The more evenly the slash is distributed, the more overstory will be killed. Stands that have not been harvested normally will not have sufficient fuel to burn hot enough to kill much of the overstory. In these cases fire will nevertheless reduce understory competition and blacken the forest floor which will elevate spring soil temperatures to encourage suckering. Surviving trees – especially aspen – should be felled to maximize suckering.

An 8- to 12-foot wide fireline should surround the burn. Paper birches within 100 feet inside of the fireline should be felled to avoid burning birch bark being blown outside the line. After backfiring the downwind side of the burn, start headfires just upwind of the backfire in progressive strips 50 to 100 feet wide. After a safe area has burned out, a single headfire can be lit from the upwind side.

Table 4 prescribes the burning weather needed for the kinds of slash typical of harvested and unharvested aspen stands exceeding 60 to 80 square feet basal area will calculated by using the reference cited.

Forecasting Future Operability

To forecast the future operability of poorly stocked stands, estimate:

(1) Site index

(2) Present age

(3) Present number of live stems per acre over 6 inches tall

(4) Number of stems that died during the last year. (These are easy to distinguish from stems that died earlier; leaf buds, fine twigs, and bark will be nearly intact compared to older mortality.)

Divide the number of dead stems by the total live *and* dead stems to estimate the present mortality rate.

Using the mortality rate and present age, use figure 15 to determine a *base number* of stems per acre.

Also, on figure 15 find a *correction factor* that corresponds to the site index.

Multiply the *base number* by the *correction factor* to determine the minimum number of stems per acre needed at present to assure a yield of 10 cunits per acre (total bolewood) at age 40.

An example: a site 70, age 10 stand has 2,000 live stems and 400 dead. The mortality rate is (400/2,000 + 400) = 0.17. Entering figure 15 we find the base number is approximately 3,500 (interpolate when necessary). Adjusting for site, 3,500 x 1.5 = 5,250 live stems are presently needed to yield 10 cunits per acre at age 40. Unless the mortality rate drops to about 0.14, 2,000 stems are inadequate. Therefore, this stand should be inspected annually to determine if the high mortality rate continues. Keep in mind that mortality can vary considerably from year to year so a several-year trend is needed to predict the probable fate of the stand.

For stands at age 20 or older, basal area is a more reliable indicator of future yields. These minimum basal areas are needed to assure 10 cunits per acre at age 40:

Site index	Age 20	Age 30	Age 40
	(minimum basal area, ft^2/acre)		
80	6	19	34
70	8	22	38
60	12	27	43
50	22	38	52

Figure 15 should be consulted also as described above to assess risk based on estimated mortality rate.

Table 4. – *Prescribed burning weather for aspen*

Observed and computed burning variables	Continuous slash (<25 percent conifer)	Continuous slash (≥25 percent conifer)	Little slash
Fuel Model[1]	D	I	F
Air temperature	>65°F	>50°F	>65°F
Relative humidity	<35 percent	<50 percent	<35 percent
Ignition component[1]	40-50	40-50	40-50
Energy release component[1]	14-17	14-17	6-8
Spread component[1]	4-7	2-6	2-4
Burning index[1]	13-21	10-21	3-4
Wind	6-12 mph	6-12 mph	6-12 mph
Number of days since rain exceeding 0.1 inch	>5	>3	>5

[1]See Deeming, *et al.* (1972) for description and calculation.

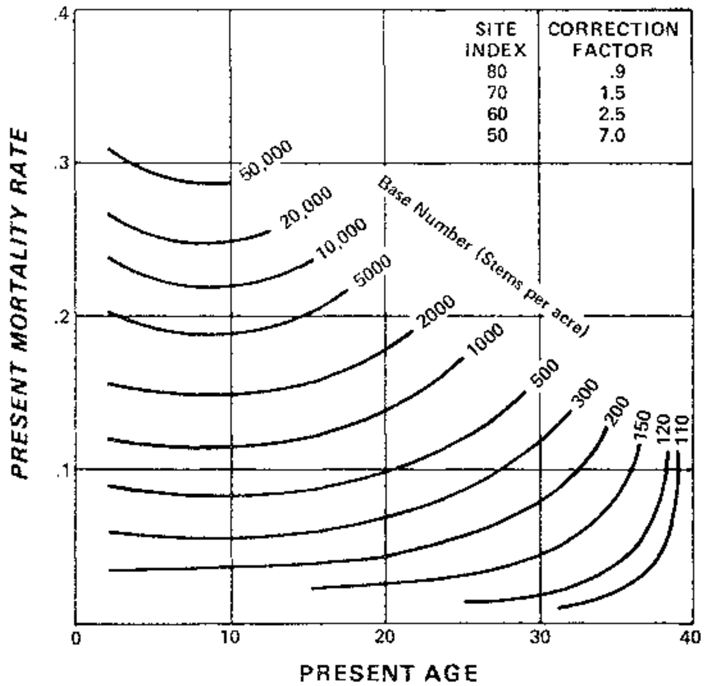

Figure 15. -- *Minimum stocking chart for aspen to reach 10 cunits per acre at age 40, based on age, mortality rate, and site index.*

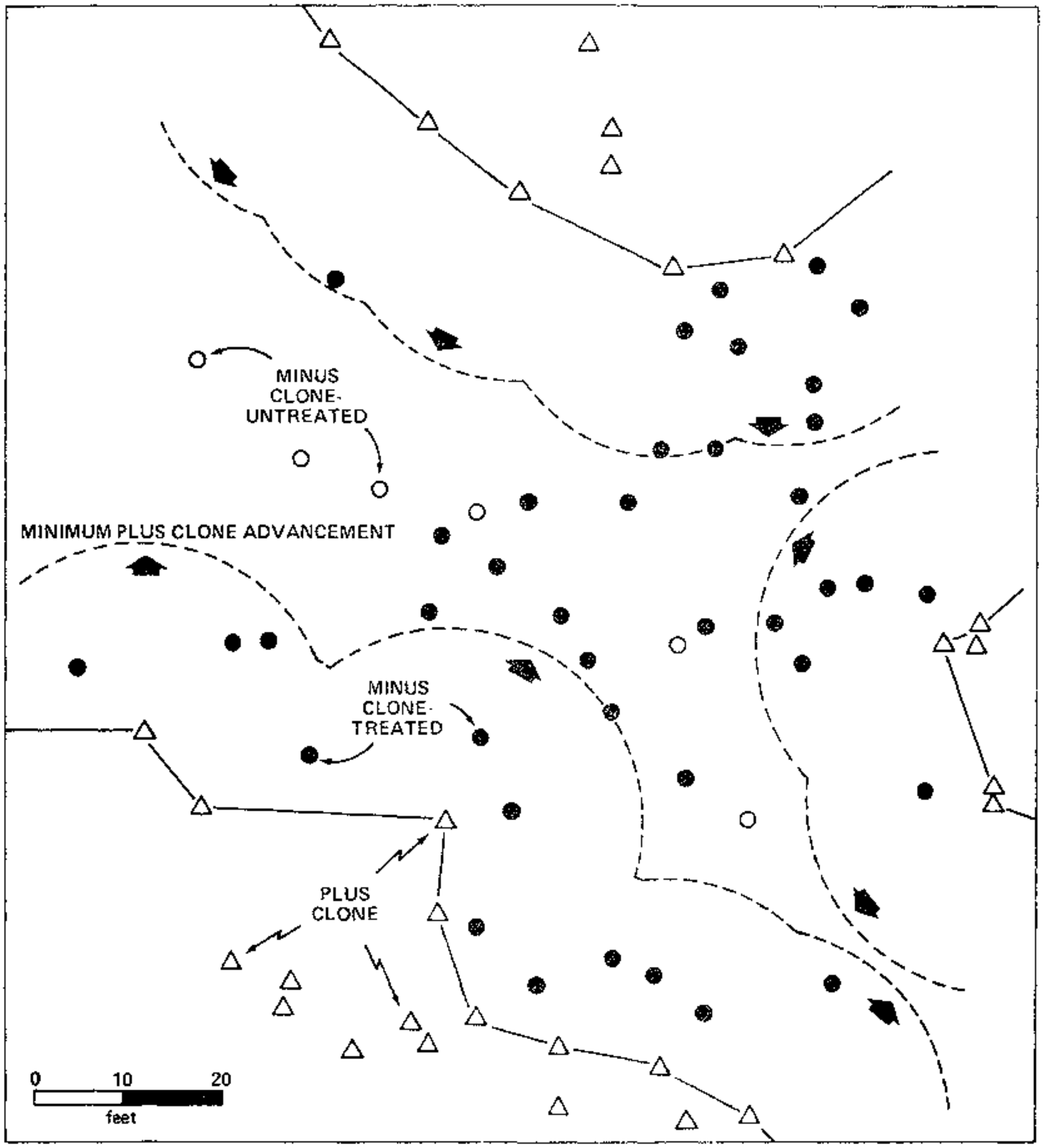

Figure 16. -- *Management scheme to increase the extent of plus clones. Killing the minus trees will allow the plus clones to sucker and extend in the direction of the arrows. The untreated minus trees are needed to provide full sucker stocking outside of the minimum effective suckering range (20 feet) of the plus clones. This example is for a previously unthinned stand, age 50.*

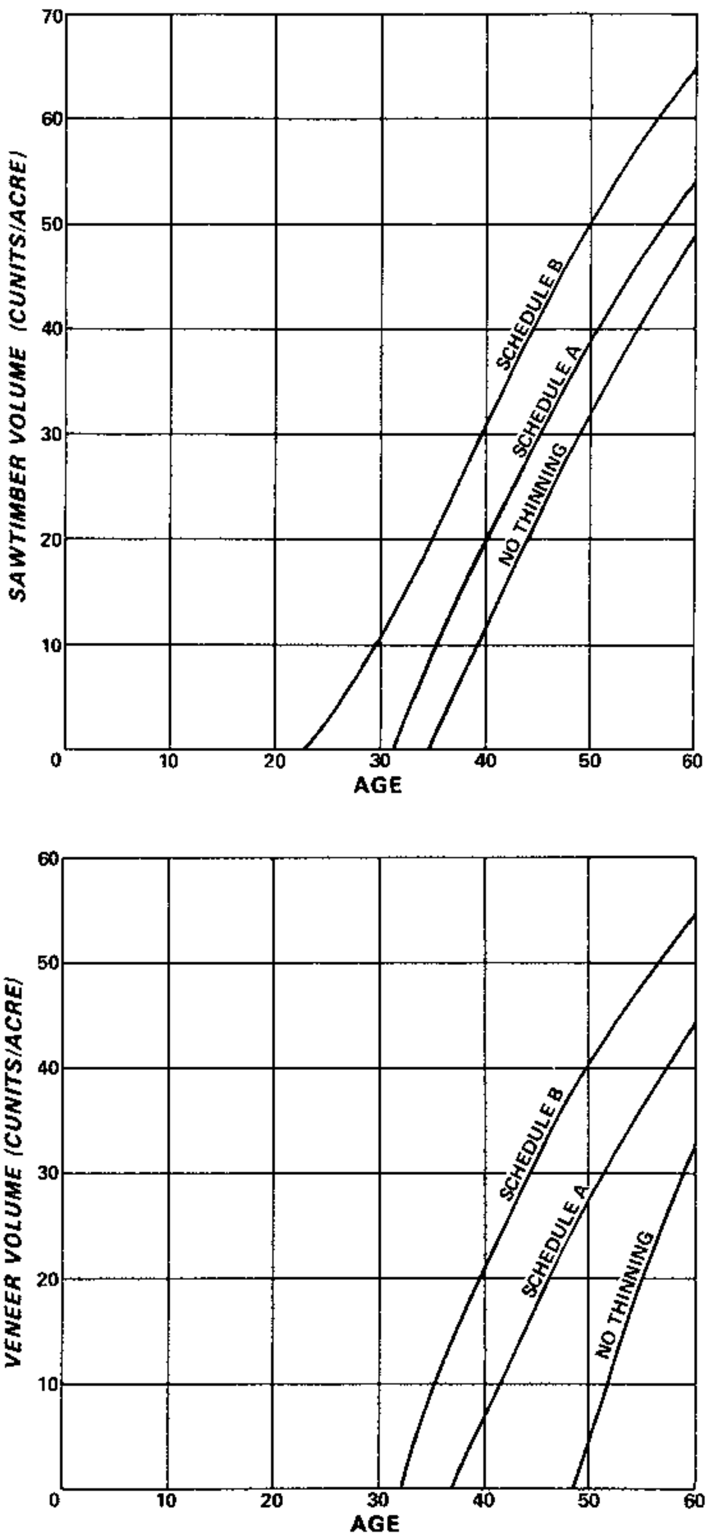

Figure 17. – *Example of yields from two thinning schedules. Schedule A = one commercial thinning, and Schedule B = one precommercial thinning plus one commercial thinning, compared to no thinning in site index 80 quaking aspen. (a) Merchantable yields of sawtimber, and (b) merchantable yields of veneer. No deductions have been made for defect.*

Table 5. – *Rotation ages*[1] *for aspen in the Lake States based on culmination of mean annual increment*

Site Index	Product: Fiber – Chips	Product: Fiber – Bolt to 4-inch top[2]	Product: Sawtimber 6-inch top	Product: Veneer 8-inch top
Feet	*Rotation age, years*			
Without Thinning				
50	35	NOT RECOMMENDED	NOT RECOMMENDED	NOT RECOMMENDED
60	35	60	NOT RECOMMENDED	NOT RECOMMENDED
70	35	55	60	NOT RECOMMENDED
80+	30	50	60	70
With Thinning				
70	NOT RECOMMENDED	NOT RECOMMENDED	60	NOT RECOMMENDED
80	NOT RECOMMENDED	NOT RECOMMENDED	50	

Estimating Growth and Yield

Estimating Yield

Yields in this handbook are in units most commonly used for each particular product. Whole-tree chips are in fresh weight tons. Pulpwood is in cords to a 4-inch top, and sawtimber and veneer is in cunits to 6- and 8-inch tops, respectively (all inside bark). These units can be converted from one to the other (table 6).

Stand volumes and weights can be estimated using stand basal area and mean stand height (table 7). (Mean stand height is the height of the tree of mean basal area, and can be determined from d.b.h./height curves, or by summation of heights weighted by d.b.h.^{2}, divided by the sum of d.b.h.^{2}.)

Next, the yield of pulpwood, sawtimber, and veneer can be estimated by multiplying the bole volume or weight from table 7 by the merchantable bole ratios in table 8. For example, a stand with 120 square feet basal area per acre, mean stand height of 80 feet, and mean stand d.b.h. of 9 inches will yield 39 cunits of bolewood, or 114 tons fresh weight of bolewood and bark per acre (from table 7). The merchantable bole ratios for pulpwood, sawtimber, and veneer are 0.91, 0.65, and 0.17, respectively (from table 8). The merchantable yield then is 39 cunits x 0.91 = 35 cunits pulpwood; 39 x 0.65 = 25 cunits sawtimber and 39 x 0.17 = 7 cunits veneer. Fresh weights are converted similarly. For direct conversion to cords in this example, the ratio is 1.15 (table 8). Therefore the stand has 39 x 1.15 = 45 cords per acre.

Predicting Growth

To project basal area 10 years in the future for quaking aspen stands, use table 9.

Future mean stand height can be predicted by following site index curves (fig. 12).

Using projected basal area (table 9) and projected height (fig. 12), projected yield may be taken from table 7. Mean stand diameter will increase 1.8 inches in 10 years. From projected yield and mean stand diameter, projected merchantable yields can also be estimated using table 8.

"Normal" yields for fully stocked aspen stands without thinnings are found in table 10 for quaking aspen and table 11 for bigtooth aspen in northern lower Michigan. (When this table is used elsewhere for bigtooth aspen, the growth estimates are likely to be less accurate.) These tables help determine the average growth and yield expected of well-stocked stands. Growth and yield of individual stands will be proportionate to basal area stocking.

Table 6. – *Conversion factors. Multiply unit measures in "from" column by factors in body of table to get unit measures in "to" columns*

From		To: Whole-tree chips (tons) Dry	Whole-tree chips (tons) Fresh	Clean chips (tons) Dry	Clean chips (tons) Fresh	Cords	Cunits[1]
		- - - - - -	- - - - - -	Multiply by	- - - - - -	- - - -	- - - -
Whole-tree chips, (tons)	Dry	1.00	1.95	0.77	1.52	0.85[2]	0.78[2]
	Fresh	.51	1.00	.38	.77	.43[2]	.40[2]
Clean chips, (tons)	Dry	1.30	2.61	1.00	1.98	1.04[3]	.82[3]
	Fresh	.66	1.30	.50	1.00	.53[3]	.41[3]
Cords		1.17[2]	2.31[2]	.96[3]	1.89[3]	1.00	.79
Cunits		1.28[2]	2.51[2]	1.22[3]	2.44[3]	1.27	1.00

[1] 1 cunit equals 100 cubic feet.
[2] Includes wood and bark.
[3] Includes wood only.

For example, 100 dry tons of wood in clean chips (without bark), are contained in 130 tons of whole-tree chips (with bark) if dry, or from 261 tons if fresh. This 100 tons is also equivalent to 198 tons of fresh clean chips, 104 cords and 82 cunits.

Table 7. — *Gross bolewood volume without bark (cunits), bolewood + bark fresh weight (tons), and complete tree fresh weight (tons); all per acre; all trees greater than 0.6-inch d.b.h. (Schlaegel 1975)*

Stand basal area	Mean stand height, ft							
	30	40	50	60	70	80	90	100
ft²/acre								
20	2[1]	3	4	5	6	7	7	8
	7[2]	9	12	14	17	19	21	24
	9[3]	11	14	17	20	23	25	28
40	5	6	8	10	11	13	15	16
	14	19	24	28	33	38	43	47
	17	23	28	34	39	45	50	56
60	7	10	12	15	17	20	22	25
	21	28	36	43	50	57	64	71
	25	34	42	50	59	67	75	83
80	10	13	16	20	23	26	29	33
	28	38	47	57	66	75	85	94
	34	45	56	67	78	89	100	111
100	12	16	20	25	29	33	37	41
	36	47	59	71	82	94	106	118
	42	56	70	84	98	111	125	138
120	--	20	25	30	34	39	44	49
	--	57	71	85	99	114	128	142
	--	67	84	100	116	133	150	166
140	--	23	29	34	40	46	51	57
	--	66	82	99	116	132	148	165
	--	78	98	116	136	155	174	193
160	--	--	33	39	46	52	59	65
	--	--	94	113	132	151	170	188
	--	--	111	133	155	177	199	220
180	--	--	37	44	51	59	66	73
	--	--	106	128	148	170	191	212
	--	--	125	150	174	199	224	248
200	--	--	41	49	57	65	73	82
	--	--	118	142	165	188	212	236
	--	--	138	166	194	220	248	275
220	--	--	45	54	63	72	81	90
	--	--	130	156	182	208	234	259
	--	--	152	182	212	242	272	302
240	--	--	49	59	68	78	88	98
	--	--	142	170	198	226	254	282
	--	--	166	199	232	264	296	329

[1]Bolewood volume from 6-inch stump to tip of tree.

[2]Bolewood + bark fresh weight from 6-inch stump to tip of tree.

[3]Complete tree fresh weight, including branches, from 6-inch stump to tip of tree.

Note: The values in Table 7 can be estimated quite accurately from stand basal area (B) and dominant stand height (H) by rules of thumb:

(1) $\frac{4\ (BxH)}{1000}$ = bolewood volume, cunits (without bark)

(2) $\frac{BxH}{80}$ = bolewood + bark fresh weight, tons

(3) $\frac{BxH}{70}$ = total tree fresh weight, tons

Equation (1) will be 2 percent low, equations (2) and (3) will be 6 and 4 percent high, respectively.

Table 8. – *Merchantable bole ratios based on top diameter inside bark and mean stand diameter (adapted from Schlaegel 1974)*

Product	Top diameter inside bark, inches	Mean stand D.B.H., inches[1]										
		5	6	7	8	9	10	11	12	13	14	15
Cunit : cunit or ton : ton conversions												
Pulpwood	4	0.30	0.60	0.77	0.86	0.91	0.94	0.95	0.96	0.97	0.97	0.98
Sawtimber	6	--	--	.31	.50	.65	.76	.84	.90	.94	.97	.98
Veneer	8	--	--	--	--	.17	.42	.58	.69	.76	.80	.83
Cunit : peeled cord conversions												
Pulpwood	4	.38	.76	.97	1.09	1.15	1.19	1.20	1.22	1.23	1.23	1.24

[1]Mean stand d.b.h., inches = $\sqrt{\frac{183\ B}{N}}$, where B is stand basal area, square feet per acre, and N is number of trees per acre.

Table 9. – *Ten-year projected basal area per acre by present age and basal area for quaking aspen stands with a site index 70 and better*[1] *(adapted from Schlaegel 1971)*

Present stand age	Present basal area per acre						
	20	40	60	80	100	120	140
Years	*Square feet*						
20	44	71	92	112	130	147	163
30	36	61	83	103	122	140	157
40	32	56	78	98	117	135	153
50	30	53	75	95	114	133	151

[1]Includes all trees 0.6 inch d.b.h. and larger. Do not use for bigtooth aspen.

Table 10. – *Normal yield tables for quaking aspen; all trees 0.6-inch d.b.h. and larger (adapted from Brown and Gevorkiantz 1934; Schlaegel 1974, 1975)*

SITE INDEX 80

Age	Dominant height	Mean dbh	Number of trees per acre	Basal area per acre	Gross yield per acre: Complete tree	4-inch top[1]	6-inch top[1]	8-inch top[1]
Years	*Feet*	*Inches*		*Sq. Ft.*	*Tons fresh wt.*	*Cords*[2]	- *Cunits*[2] -	
20	44	3.3	1490	88	53	--	--	--
30	59	4.8	880	110	89	7	--	--
40	71	6.3	600	129	125	31	5	--
50	80	8.1	400	143	160	52	25	--
60	88	10.3	265	153	191	67	44	26
70	94	12.6	185	161	212	77	58	46
SITE INDEX 70								
20	38	2.9	1800	83	46	--	--	--
30	52	4.2	1065	102	76	--	--	--
40	62	5.4	760	120	105	17	--	--
50	70	7.0	495	133	138	39	12	--
60	77	9.0	330	144	163	55	31	8
70	82	10.9	235	151	184	65	45	31
SITE INDEX 60								
20	33	2.5	2300	76	37	--	--	--
30	44	3.5	1400	94	62	--	--	--
40	53	4.5	980	110	86	2	--	--
50	60	5.9	645	122	107	23	--	--
60	66	7.6	422	133	130	40	16	--
70	70	9.3	295	139	145	49	29	10
SITE INDEX 50								
20	28	1.9	3200	60	25	--	--	--
30	37	2.7	1910	75	40	--	--	--
40	44	3.5	1300	88	56	--	--	--
50	50	4.6	856	98	75	3	--	--
60	55	5.8	580	105	88	18	--	--
70	58	7.1	400	109	95	27	9	--
SITE INDEX 40								
20	22	1.3	4100	38	12	--	--	--
30	29	1.9	2420	46	20	--	--	--
40	35	2.4	1660	54	29	--	--	--
50	40	3.2	1110	60	37	--	--	--

[1]Top diameters are inside bark.
[2]Cords and cunits are without bark.

Table 11. – *Normal yield tables for bigtooth aspen in northern Lower Michigan; all trees 0.6-inch d.b.h. and larger (adapted from Graham* et al. *1963)*

Age	Dominant height	Mean dbh	Number of trees per acre	Stand basal area per acre	Gross yield per acre: Complete tree	Gross yield per acre: 4-inch top[1]	Gross yield per acre: 6-inch top[1]	Gross yield per acre: 8-inch top[1]
Years	*Feet*	*Inches*		*Square feet*	*Tons fresh wt.*	*Cords*[2]	*Cunits*[2]	*Cunits*[2]
				SITE INDEX 80				
30	71	7.4	460	139	133	40	15	--
40	77	8.8	360	152	159	53	29	5
50	80	9.8	268	140	151	53	33	17
60	81	10.5	209	126	137	49	33	21
				SITE INDEX 70				
30	62	6.6	460	110	92	25	--	--
40	67	8.0	360	127	116	37	17	--
50	70	8.8	295	123	118	39	21	4
60	71	9.2	240	112	108	37	21	7
				SITE INDEX 60				
30	53	5.9	466	90	65	14	--	--
40	58	7.3	366	107	84	25	9	--
50	60	8.0	313	108	88	28	13	--
60	61	8.2	273	101	84	27	13	--
				SITE INDEX 50				
30	45	5.1	495	70	43	5	--	--
40	48	6.6	380	89	59	15	--	--
50	50	7.1	330	90	63	18	6	--
60	51	7.3	295	86	61	18	7	--
				SITE INDEX 40				
30	36	4.0	540	48	24	--	--	--
40	39	5.7	407	71	39	7	--	--
50	40	6.2	357	76	41	10	--	--
60	41	6.2	313	65	37	9	--	--

[1]Top diameters are inside bark.
[2]Cords and cunits are without bark.

Metric Conversion Factors

To convert	*to*	*Multiply by*
Acres	Hectares	0.405
Board feet[1]	Cubic meters	0.005
Board feet/acre[1]	Cubic meters/hectare	0.012
Chains	Meters	20.117
Cords[1]	Cubic meters	2.605
Cords/acre[1]	Cubic meters/hectare	6.437
Cubic feet	Cubic meters	0.028
Cubic feet/acre	Cubic meters/hectare	0.070
Degrees Fahrenheit	Degrees Celsius	[2]
Feet	Meters	0.305
Gallons	Liters	3.785
Gallons/acre	Liters/hectare	9.353
Inches	Centimeters	2.540
Miles	Kilometers	1.609
Miles/hour	Meters/second	0.447
Number/acre	Number/hectare	2.471
Ounces	Grams	28.350
Ounces/acre	Grams/hectare	70.053
Pounds	Kilograms	0.454
Pounds/acre	Kilograms/hectare	1.121
Pounds/gallon	Kilograms/liter	0.120
Square feet	Square meters	0.093
Square feet/acre	Square meters/hectare	0.230
Tons	Metric tons	0.907
Tons/acre	Metric tons/hectare	2.242

[1]The conversion of board feet and cords to cubic meters can only be approximate; the factors are based on an assumed 5.663 board feet (log scale) per cubic foot and a cord with 92 cubic feet of solid material.

[2]To convert °F to °C, use the formula 5/9 (°F-32) or $\frac{°F-32}{1.8}$.

Common and Scientific Names of Plants and Animals

Plants

Aspen:
- Bigtooth . . . . *Populus grandidentata*
- Quaking . . . . *Populus tremuloides*

Balsam fir . . . . *Abies balsamea*
Heart rot . . . . *Phellinus igniarius*
Hypoxylon canker . . . . . . *Hypoxylon mammatum*
Maple:
- Red . . . . *Acer rubrum*
- Sugar . . . . *Acer saccharum*

Northern white-cedar . . . . *Thuja occidentalis*
Paper birch . . . . *Betula papyrifera*
Pine:
- Jack . . . . *Pinus banksiana*
- Red . . . . *Pinus resinosa*
- White . . . . *Pinus strobus*

Shepherd's crook . . . . . . *Venturia tremulae*
White spruce . . . . *Picea glauca*

Animals

Bald eagle . . . . *Haliaeetus leucocephalus*
Beaver . . . . *Castor canadensis*
Black bear . . . . *Ursus americanus*
Borers:
- Poplar . . . . *Saperda calcarata*
- Miscellaneous . . . . *Saperda* spp., *Agrilus* spp., *Oberea* spp.

Eastern timber wolf . . . . . *Canis lupus*
Forest tent caterpillar . . . *Malacasoma disstria*
Great horned owl . . . . . . *Bubo virginianus*
Large aspen tortrix . . . . . *Choristoneura conflictana*
Osprey . . . . *Pandion haliaetus carolinensis*
Ruffed grouse . . . . *Bonasa umbellus*
Snowshoe hare . . . . *Lepus americanus*
White-tailed deer . . . . . . *Odocoileus virginianus*

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key – out of the reach of children and animals – and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

Note: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

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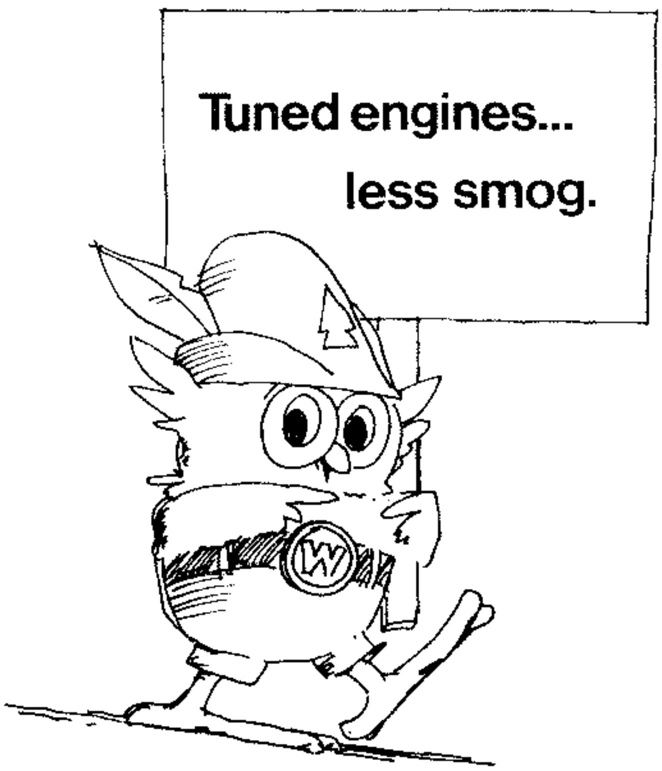
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