WHITE PAPER

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How to Prepare a Silvicultural Prescription for Uneven-aged Management[1]

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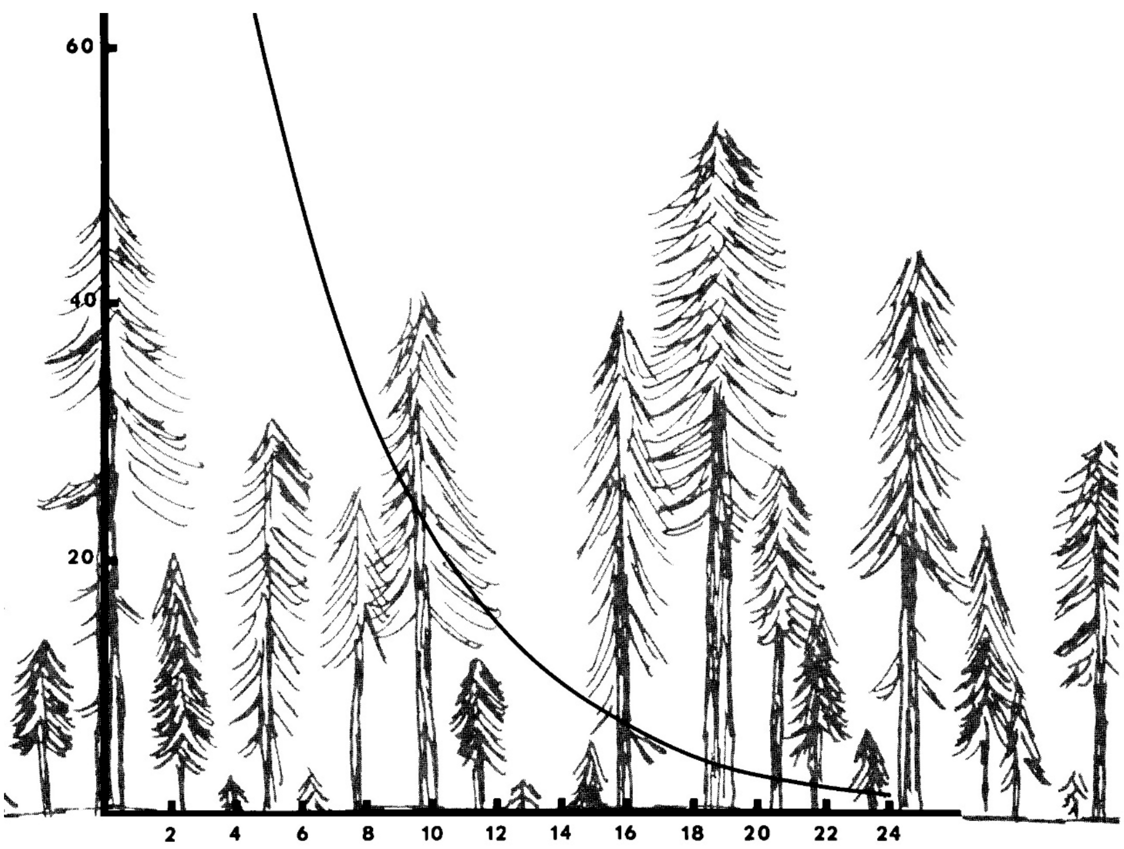

[1] White papers are internal reports; they receive only limited review. Viewpoints expressed in this paper are those of the author – they do not necessarily represent views of USDA Forest Service.

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INTRODUCTION

Much of this introduction section provides historical background for an uneven-aged management discussion. Context for this Introduction is based almost entirely on viewpoints from the early 1990s, when uneven-aged management moved to the forefront as a backlash response to widespread clearcutting during the 1980s (Guldin 1996).

Uneven-aged management has been a subject of interest in the Forest Service for many decades (USDA Forest Service 1978). For a time, we did not favor the use of uneven-aged management. Many reasons were given, including a lack of knowledge and some of the pest problems associated with this silvicultural system. Now, with increased knowledge and shifting objectives for national forest management, we favor use of uneven-aged management in appropriate situations, to meet desired future conditions and land management objectives.

Some of this change in policy and organizational philosophy came about because of Forest Plans, and it is exemplified by a Chief's decision for the Ouachita NF, where uneven-aged management was identified as <u>the</u> primary management method for an entire national forest (in response to a Sierra Club lawsuit about clearcutting).

What happened during the late 1980s forest planning process? During development of Forest Plans, we described desired future conditions. Then, we went to the public to find out what they wanted for their National Forests. During this step, we failed to keep our focus on desired future conditions. Instead, we allowed the debate to center on silvicultural systems – in other words, on the methods rather than the objectives.

The public wanted continuous high forest cover and a more complex forest structure than would result from clearcutting, but we ended up debating the merits of uneven-aged management versus clearcutting. Few options between clearcutting and uneven-aged management were examined to any significant extent.

Along the way, many publics viewed uneven-aged management as a proverbial 'free lunch' – free regeneration, no investment needed for stand tending, good for all resources, natural and pretty (and, perhaps it also cures baldness🙂). Many potential problems with uneven-aged management were either not recognized or glossed over: insects and diseases, soil compaction concerns, harvest limitations, potential to create dysgenic conditions, and difficulty in implementation, to name a few.

Fortunately, during the allocation phase of a Forest Planning process, most Region 6 National Forests considered uneven-aged management, but they did not allocate specific land areas to just this silvicultural system. This strategy – not embedding a specific silvicultural system or cutting method in a land management allocation – allows decision makers and silviculturists to identify areas compatible with uneven-aged management, and situations where it can effectively meet DFCs and objectives.

Concerns in early 1990s about whether Region 6 could meet a mandate for uneven-aged management led to formation of a committee of silviculturists, officially designated by the Regional Forester. The committee, tasked with addressing uneven-aged management and its application in Region 6, was comprised of Forest Silviculturists from all Eastside national forests. The charter of this committee included these items:

1. Evaluate state of the art in uneven-aged management, both from a science point of view and education.
2. Gain consistent application and understanding of uneven-aged management by conducting field reviews and technology transfer.
3. Revise our organizational systems to accommodate uneven-aged management. This includes reporting procedures, targets, and other processes.
4. Recommend a process ensuring that uneven-aged management proposals would not repeat past problems associated with this silvicultural system.

Inherent in all this emphasis on uneven-aged management is a need for education, from a technical to applied level. This need includes silviculturists, technicians, and practitioners working in a variety of resource areas.

In the early 1990s, it was also accepted that an organizational model for uneven-aged management was needed, and whatever was ultimately developed should incorporate at least these two concepts:

- First, uneven-aged management is not an appropriate framework for management. It is merely a silvicultural system that includes certain cutting methods for perpetuating a forest. Instead of focusing on uneven-aged management per se, we need to focus on desired future conditions necessary to reach our management objectives for a stand, forest, planning area, or landscape.
- Second, we need to change our characterization of a stand, and its treatment, from the cutting methods to be used, to its desired structures. For example, rather than calling for an uneven-aged cutting method, we need to state that continuous forest cover is needed to meet desired future conditions. So, rather than moving away entirely from clearcutting as a cutting method (e.g., a prescription's stated objective should never be to 'avoid clearcutting'), we need to stress a management objective, such as providing continuous high forest cover.

We must recognize and acknowledge that there are many ways to achieve desired future conditions (DFCs) for our stands and forests. Alternative treatments may be non-traditional; nevertheless, they must be based on a foundation of silvics, ecological principles, and an understanding of stand dynamics. In addition, we need to emphasize a landscape perspective because it allows us to evaluate a combination of structures, densities, and compositions, and to develop systems and methodologies to achieve these DFCs.

Clearly, we are moving toward development of forests and stands with more diverse structures (O'Hara 2014). We need to foster wider understandings and perspectives, not only for vertical forest structure but also for species composition and its role in influencing new forests. Silviculturists and others need to be rigorous when testing and developing new methodologies, and uneven-aged management qualifies as a 'new methodology' for areas, or contexts, where it hasn't been used much before.

In summary, uneven-aged management is legitimate as a silvicultural system, but it is not valid as a management objective. It is merely one of many options for providing desired future conditions.

HISTORICAL CONTEXT. In October 1983, the Pike and San Isabel National Forests (located in south-central Colorado, on the southern Front Range) held a timber workshop, part of which was devoted to training about uneven-aged management. During the workshop, participants visited an uneven-aged spruce-fir stand for which a prescription and marking guide had been prepared. The original version of this white paper was prepared, as uneven-aged management training material, for the October 1983 timber workshop (Powell 1987).

A primary objective of this white paper is to present some technical considerations for preparing an uneven-aged management prescription and marking guide by using what is referred to as the 'BDq' method (Fiedler 1995, O'Hara 1995).

Further information about uneven-aged management, a silvicultural system, and individual-tree selection and group selection, cutting methods in the uneven-aged silvicultural system, is provided in a white paper: "Silvicultural Activities: Description and Terminology" (Powell 2018).

THE ZEN OF UNEVEN-AGED MANAGEMENT

As I work on this white paper, I reflect on more than 40 years of experience as a forester and silviculturist. As one might expect, my thoughts about silvicultural systems and their associated cutting methods have evolved quite a bit over that time. And, I suspect the same evolution occurs for most foresters during their career.

Early on, most of us are drawn to the simplicity and directness of even-aged management, especially when implemented as clearcutting. But, as our skills evolve, we come to appreciate the subtle nuances of sophisticated approaches such as uneven-aged management. Not to say that uneven-aged management begins to feel like the best option anywhere; after all, a 'one-size-fits-all' approach is no more appropriate for uneven-aged cutting than it is for even-aged management.

As we become open to the possibilities of uneven-aged management, learning to recognize that it may be a good fit for some objectives and stand conditions, we also come to realize that uneven-aged management can challenge us as professionals. In fact, uneven-aged management can provide a welcome respite when continuing the same-old, even-aged prescriptions begins to feel like nothing more than going through the motions.

Without continuing to sound like the 'Dr. Phil' of silviculture – when a forester has reached a point of 'silvicultural enlightenment' by gladly welcoming uneven-aged management into their professional life, they begin to feel like a whole and complete practitioner!

To summarize: I encourage you not to dismiss uneven-aged management out-of-hand because of its reputation for being overly complex and viable only for a research context. Our contemporary tools allow all the mechanics of uneven-aged regulation to be completed easily, and although an uneven-aged prescription shouldn't be applied everywhere, it is certainly a viable option for appropriate management situations.

WHAT IS AN UNEVEN-AGED FOREST OR STAND?

As defined in the Glossary, appendix A, uneven-aged management involves manipulation of a forested stand for continuous high-forest cover, recurring regeneration of desirable species, and orderly growth and development of trees through a range of age classes to provide a sustained yield of forest products (USDA Forest Service 1978).

Selection cutting, which is associated with uneven-aged management, involves removal of both immature and mature trees, either in groups or individually, to create or maintain an uneven-aged stand structure.

Since uneven-aged management is generally applied in uneven-aged stands, it will be helpful to discuss the differences between even-aged and uneven-aged stands. Three silvicultural systems have been identified (see Powell 2018), and each of them is tied to a particular stand structure, as described by figure 1.

Foresters often classify stands by using their age-class distribution. Strictly defined, an even-aged stand is one in which all trees are the same age (as in a plantation), but in common field usage, even-aged stands can have ages ranging up to 20 percent of the rotation length (Helms 1998).

[Historically, as described in Baker 1934, "an even-aged forest is often defined as one in which there is no more than 20 years' difference between the oldest and youngest trees" (Baker 1934, p. 201). For a 100-year rotation length, 20 years and 20 percent are the same value, so there is no difference. For other rotation lengths, results would obviously differ between these definitions, but they are minor.]

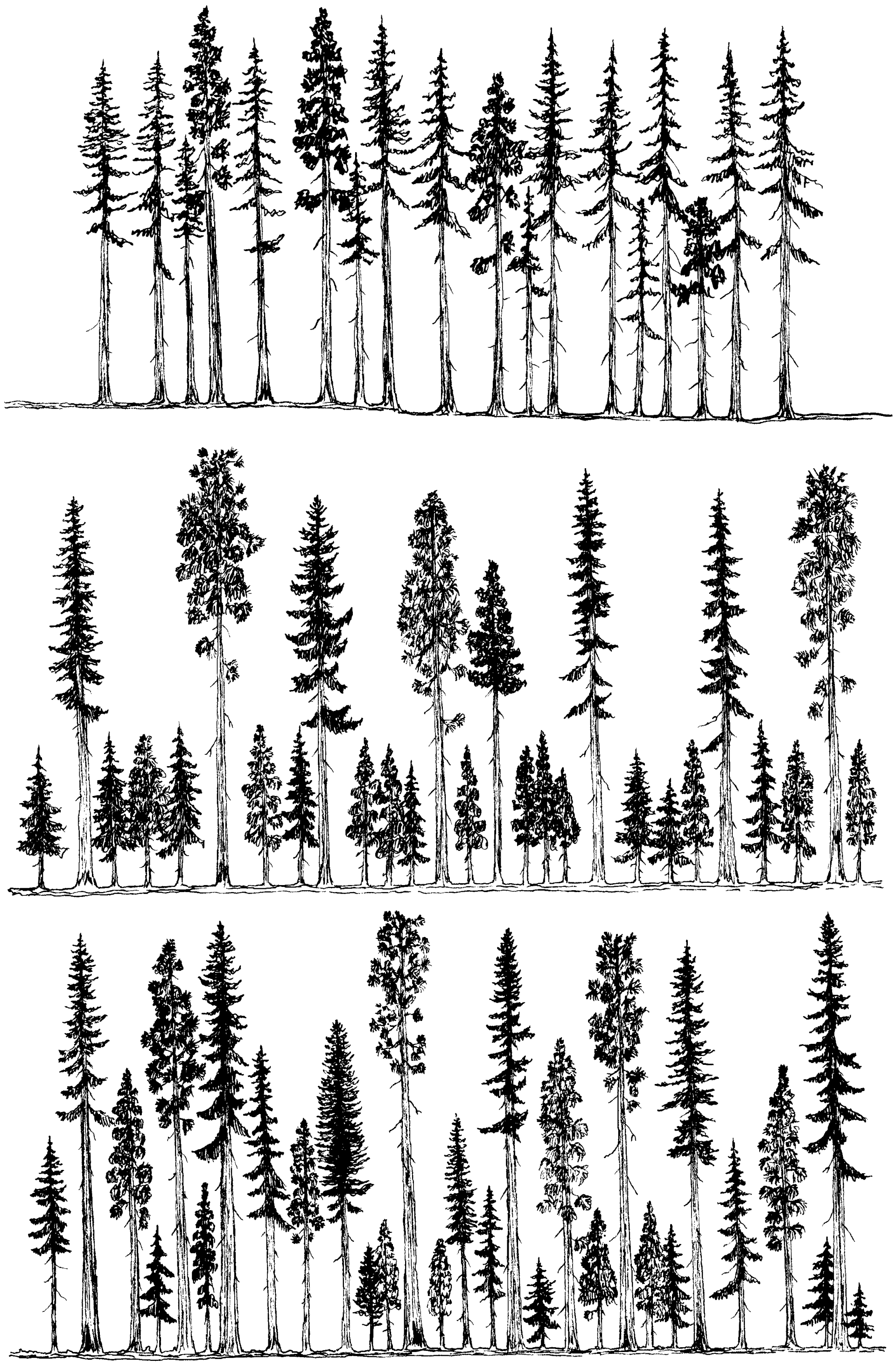


Figure 1 – Three common stand structures. Single-storied stands (top) tend to be even-aged and perpetuated with the even-aged silvicultural system; two-storied or irregular stands (middle) tend to be multi-aged and perpetuated with the two-aged silvicultural system; multi-storied stands (bottom) tend to be uneven-aged and perpetuated with the uneven-aged silvicultural system.

Even-aged stands have a 'bell-shaped' diameter distribution, as shown in figure 2. Uneven-aged stands have at least three distinct age classes, and often have gaps in their age-class distribution. They tend to have a diameter distribution with an 'inverse-J' shape (fig. 2), and this inverse-J or 'reverse-J' diameter distribution is central to the regulation and prescription preparation elements discussed in this white paper.

The main biological differences between even-aged and uneven-aged stands are compared in table 1 (adapted from Daniel et al. 1979).

Table 1: Differences between even-aged and uneven-aged management.

	EVEN-AGED MANAGEMENT	UNEVEN-AGED MANAGEMENT
Canopy characteristics	A level, shallow canopy on slender stems (for unmanaged, fully-stocked stands).	A deep, irregular canopy with sturdy boles.
Age cohorts	Tend to be comprised of a single age cohort, which may be stratified into crown-class layers (dominant, codominant, etc.).	Tends to be comprised of multiple age cohorts, each of which may be stratified into crown classes.
Wind hazard	Windthrow hazard can be high, especially for shallow-rooted species.	Wind hazard can be quite low when multi-layered canopies are present.
Small trees	Small trees are suppressed; release may be unlikely.	Small trees are future crop trees, and it is assumed they will respond to release.
Seral status and composition	Typically promotes a high percentage of shade-intolerant, early-seral species.	Generally promotes a high percentage of shade-tolerant, late-seral species.
Regeneration	Typically occurs over a short time period (20% or less of rotation length, in years).	Typically occurs continuously, or over a long timeframe.
Seed source	Seed produced mostly by seed trees left in preparatory or seed cuts.	Seed produced from many trees; less control over its source.
Timber harvest damage	Seedlings/saplings not usually exposed to much damage during later harvest entries.	It can be difficult to protect seeds/saps from logging damage, especially for individual-tree selection cutting.
Timber harvest frequency	For regeneration cutting, only one or two entries during a century.	For regeneration cutting, may be entering the same acreage every few decades.
Site protection	Site is usually exposed to erosion and harsh conditions during regeneration.	Small openings are almost always protected by adjacent trees.
Site control	Site may be lost to competing vegetation during regeneration; unwanted vegetation is easier to control.	Site conditions are usually stable; undesirable vegetation can be difficult to control.
Hazards	Subject to serious fire, insect, and disease losses, but only at certain points.	Pest problems less likely to be catastrophic, but long-term, may be more serious.
Degree of skill and supervision	Requires less skill and expertise overall; sale administration may be easier.	Requires high skill and expertise; sale administration may be quite complex.
Slash/debris	Intermittent, heavy accumulations that add to insect and fire hazard. Easier to treat with prescribed fire.	Continuous production of light slash – low insect and fire hazard. More difficult to treat with fire (except jackpot burning).

Sources/Notes: Adapted from Daniel et al. (1979).

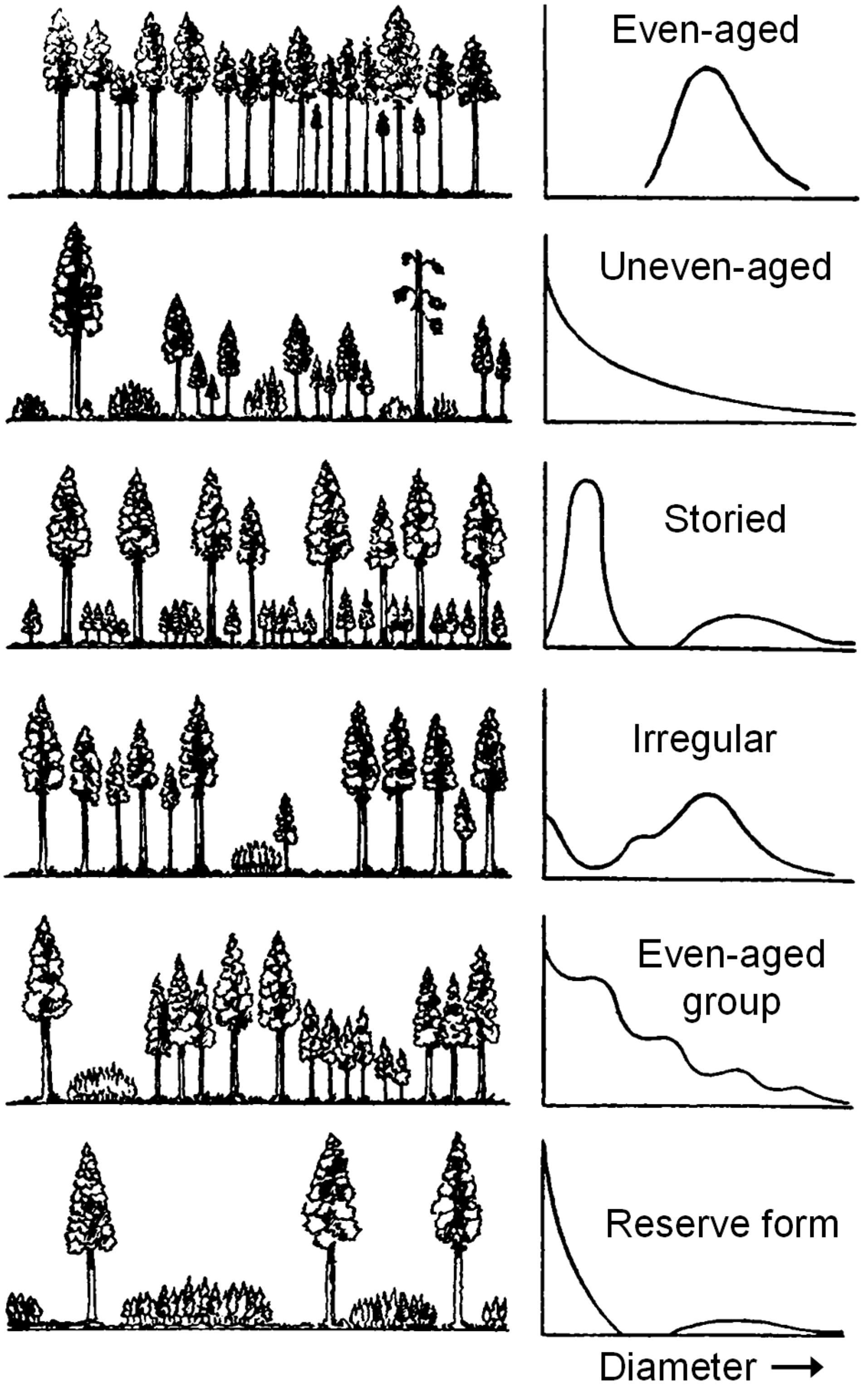


Figure 2 – Forest stands have a variety of diameter distributions (adapted from Daniel et al. 1979, p. 44; originally from Baker 1934, p. 202). Even-aged stands tend to have a bell-shaped distribution, whereas uneven-aged stands generally follow a reverse- or inverse-J distribution.

UNEVEN-AGED MANAGEMENT IN A PLANNING CONTEXT

As described in the Introduction section of this white paper, keen interest in uneven-aged management arose in the early 1990s as sort of a 'backlash' response to high amounts of clearcutting during the 1980s. Another response to the 'clearcutting era' was adoption of an *ecosystem management* paradigm by the Forest Service in the early- to mid-1990s (Guldin 1996).

Traditionally, uneven-aged management was considered for management settings emphasizing continuous forest cover, such as scenic byways and roadside corridors, cabins or summer home developments, and developed recreation sites. But in response to the clearcutting controversy, uneven-aged management was also considered for undeveloped (backcountry) areas with a dispersed recreation emphasis.

The scientific literature provides many examples of situations where uneven-aged management effectively satisfied specific management objectives relating to forest composition or structure as wildlife habitat (Graham and Smith 1983, Guldin 1996, Kenefic and Nyland 2000, Medin and Booth 1989). And, uneven-aged management can clearly offer advantages over even-aged management for other objectives, desired future conditions, issues, or concerns (table 2).

Table 2: Compatibility of uneven-aged management (UEAM) with common land management objectives, issues, and concerns.

Objective/Issue/Concern	Compatibility With UEAM	Comments
Developed recreation	High	Recreation sites need continuous forest cover
Dispersed recreation	Moderate	Can provide long-term landscape diversity
Economic efficiency	Low	Usually less efficient than even-aged management (EAM)
Livestock grazing	Low-High	Low with moist/cold forest; high with dry forest
Maintain site productivity	Moderate	Careful timber harvest avoids site damage
Minimize animal damage	Moderate	Gophers can be high; ungulate browsing is moderate
Minimize disease hazard	Low	EAM is more flexible for a full range of diseases
Minimize fire hazard	Moderate	Regular thinnings can manage crown-fire hazard
Minimize insect hazard	Low	EAM better meets stand age/composition concerns
Minimize soil erosion	Mod/High	Careful harvest and continuous cover minimize erosion
Minimize wind hazard	Low/Mod	On wind-prone sites, EAM provides more flexibility
Promote animal diversity	Low/Mod	Diversity of EAM options favors more animal guilds
Promote plant diversity	Low/Mod	Diversity of EAM options favors more plant groups
Protect site from exposure	Mod/High	UEAM provides more options than EAM
Regenerate intolerant species	Low/Mod	EAM offers more silvicultural options for intolerants
Regenerate tolerant species	High	UEAM offers much flexibility; EAM is generally limited
Riparian area management	High	For stream shade, UEAM is more suitable than EAM

Objective/Issue/Concern	Compatibility With UEAM	Comments
Treat or remove slash	Low	Larger EAM openings allow more activity fuels options
Tree improvement/genetics	Mod/Low	Selection cutting is least intense improvement option
Visual quality/aesthetics	High/Mod	Foreground options high; mid/background options low
Water quality	Mod/High	Careful harvest and providing soil cover is important
Water yield augmentation	Low/Mod	Group selection can be used to redistribute snowpack
Wildlife habitat: avian	Moderate	EAM can favor shrubs needed for neotropical birds
Wildlife habitat: big game	Low	EAM has more options for meeting cover/forage needs
Wood fiber production	Moderate	UEAM favors a lower proportion of merchantable trees

Sources/Notes: UEAM is uneven-aged management; EAM is even-aged management.

WHICH STANDS QUALIFY FOR UNEVEN-AGED MANAGEMENT?

An uneven-aged approach can be ideal for harsh sites where it is important to prevent forest from transitioning to persistent nonforest communities of shrubs or herbs. Harsh sites are found most often at lower treeline (such as climax ponderosa pine sites) or upper treeline (subalpine fir or whitebark pine woodlands).

Climax ponderosa pine sites illustrate how a shade-intolerant species can dominate uneven-aged stands. But for mesic sites, you should expect that an uneven-aged management regime will cause stands containing a mix of tolerant and intolerant species to eventually shift away from the intolerant species, and toward the tolerant species.

If management objectives emphasize early-seral, shade-intolerant species, especially when shade-tolerant associates are abundant (affecting seed rain and regeneration potential), then selection cutting favors increasing percentages of shade-tolerant species.

For circumstances where tolerant species are present, uneven-aged management may be possible for short stretches, but the compositional trends described in this section result in a constant struggle to maintain acceptable percentages of shade-intolerant species. Group-selection cutting utilizing maximum group size (2 acres), however, may provide opportunities to maintain reasonable numbers of intolerant species.

Due to shade tolerance and successional life history traits, uneven-aged management is seldom possible for early-seral, shade-intolerant species like lodgepole pine, western larch, and ponderosa pine, even when management direction emphasizes objectives other than continuous forest cover. Since life history traits can vary markedly from one species to another, they provide important insights into whether uneven-aged management will be suitable for a management context (e.g., Johnson and Fryer 1989).

Table 3 shows seven primary forest types (species) occurring in the Blue Mountains of northeastern Oregon, southeastern Washington, and west-central Idaho, and it summarizes their suitability for uneven-aged management.

Table 3: Suitability of seven conifers for uneven-aged management in the Blue Mountains.

Forest Type/Species	Biophysical Environment (Powell et al. 2007) Cold Forest	Moist Forest	Dry Forest
Ponderosa pine	Not Found Here	Not Appropriate	Appropriate
Douglas-fir	Not Appropriate	Not Appropriate	Appropriate
Western larch	Not Appropriate	Not Appropriate	Not Appropriate
Lodgepole pine	Not Appropriate	Not Appropriate	Not Appropriate
Grand fir	Not Appropriate	Appropriate	Not Appropriate
Engelmann spruce	Appropriate	Appropriate	Not Found Here
Subalpine fir	Appropriate	Not Appropriate	Not Found Here

Notes: Ratings are based on the predominant situation for each species, and they consider how its successional status varies by biophysical environment. A species is considered more appropriate for uneven-aged management if it is a late-seral species for a biophysical environment. Ratings also consider species durability and insect/disease resilience to some extent, and whether uneven-aged management would be implemented as group or individual-tree selection cutting.

When completing presale planning for project areas where uneven-aged management is being contemplated, these factors should generally be considered:

1. Selection cutting can be attempted in a wide variety of stands, but regulation of growing stock is easiest in stands that are already multi-storied or uneven-aged (figs. 1, 3). Stands should have good vigor and not be highly defective. They can contain some shade-intolerant trees but shouldn't be dominated by them because regeneration occurs in shaded or partial-shade conditions.
2. For most management settings, uneven-aged management seems best adapted to stands with a high component of climax species. As described earlier, selection cutting for ponderosa pine is accomplished easier on sites where it is climax (e.g., ponderosa pine plant associations) than for areas where it's successional to Douglas-fir or grand fir. Because of their shade intolerance, successional stands of lodgepole pine or western larch provide few opportunities to practice uneven-aged management. But remember that not all stands of lodgepole pine are early-seral; climax stands of this forest type (and they do exist) could be managed effectively by using group selection cutting.
3. The site and species to be managed must tolerate frequent entries. Areas with fragile soils may not qualify. Neither may stands of less-durable tree species.
4. Unroaded areas require a high initial investment to develop an acceptable road system. Volumes removed in the first entry will often be lower than those produced by using even-aged cutting methods; in unroaded areas, this could have a major effect on a timber sale's financial viability. [Due to contemporary USFS policy prohibiting new road construction, this is no longer a major factor.]
5. Stands managed by using an uneven-aged cutting method usually require more administration than areas regulated with even-aged management. Sale layout

and logging requirements are typically complex, often resulting in sale preparation costs being higher than for even-aged management. For example, most uneven-aged management will require use of designated skid trails, a sale preparation activity (and cost) that was not widely used, historically, with clearcutting and other even-aged regeneration cutting methods.

6. Low volumes per acre, and low-value products (small-diameter trees), are often removed at each entry, especially on sites of low productivity.

CONSIDERATIONS FOR UNEVEN-AGED MANAGEMENT

Two regeneration cutting methods are used during implementation of uneven-aged management: individual tree selection and group selection.

Individual tree selection involves removal of individual trees rather than groups of trees (figs. 3-4). This cutting method provides maximum flexibility in choosing trees to cut or leave, but it is applicable primarily in uniformly spaced stands with irregular or all-aged structures. As described earlier in this white paper, this cutting method inevitably increases the proportion of shade-tolerant species in mixed-species stands.

Group selection is an ideal cutting method in uneven-aged stands with a groupy or clumpy structure. For mixed stands, it can be used to maintain a higher proportion of shade-intolerant species than individual-tree selection, in which case large group sizes are more effective than small ones. When groups approach maximum size (about 2 acres), they can resemble small-patch clearcuts or group shelterwood openings.

Group selection differs from small-patch clearcutting because its intent is to create, and maintain, a balance of age or size classes as a mosaic of small, intermixed groups.

This difference highlights an important distinction between uneven- and even-aged management: regulation of growing stock. Regulating a forest (a large tract composed of many stands) is based on volume and yield for uneven-aged management, and treated area (acreage) for even-aged management. In a classical forest management context, 'area control' is used for even-aged management, and 'volume control' is used for uneven-aged management (Davis et al. 2001).

When considering that uneven-aged management involves working across all size classes, some of which are merchantable and some not (although every acre is not necessarily treated in each entry), it is obvious that stand structure exerts more influence on how an uneven-aged forest is regulated than the number of acres being treated.

Because neither individual-tree nor group selection creates large openings, uneven-aged management is most compatible with stands where management objectives emphasize providing continuous forest cover, either from overhead shade (individual-tree selection) or from side shade cast into small openings (group selection).

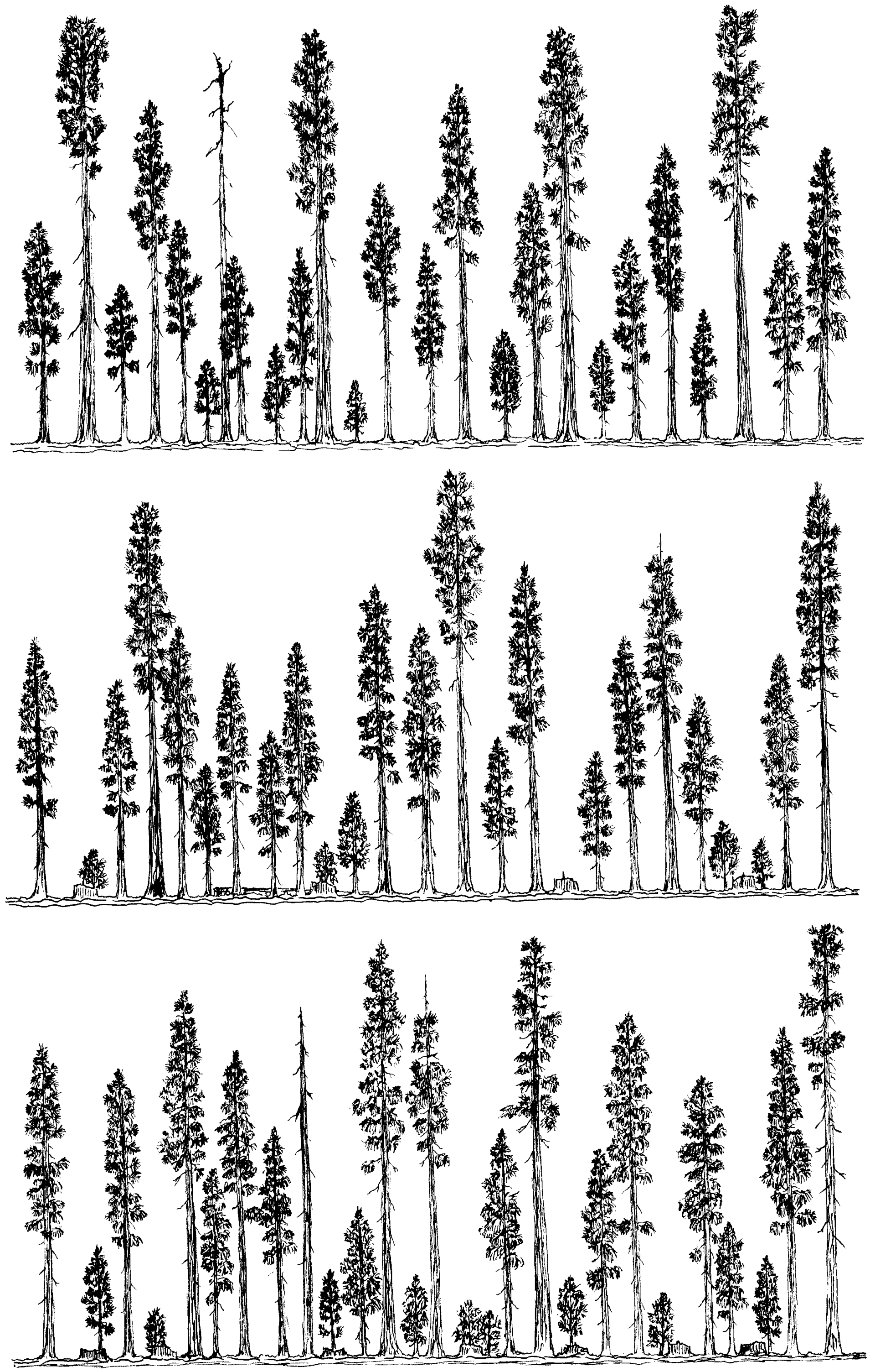


Figure 3 – Applying individual-tree selection in a ponderosa pine forest. An untreated stand (top) has a range of tree sizes. In the first entry (middle), note how four mature trees were removed. The second entry (bottom) continues this cutting intensity. Selection cutting provides opportunities to create and maintain heterogeneous stand structures for dry forests (Franklin et al. 2013).

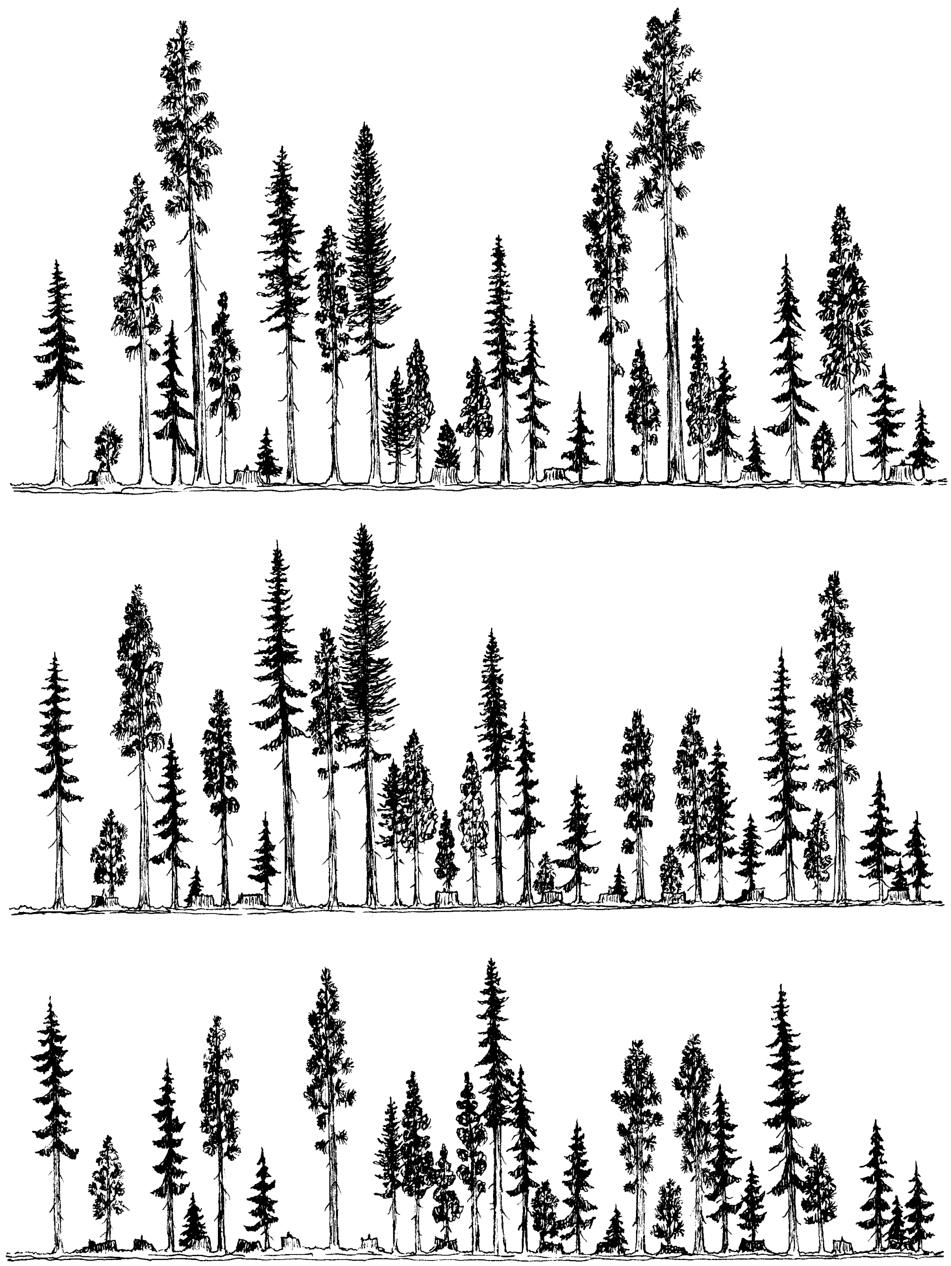


Figure 4 – Applying individual-tree selection in a mixed-conifer forest. All three panels show results after cutting (1st, 2nd, and 3rd entries, top to bottom). Note how top height decreases as mature trees are gradually removed. If the maximum tree-diameter objective (D factor in a BDq approach) is close to the largest tree diameter present in an untreated stand, then top height eventually recovers to a point comparable with pre-treatment conditions. The progression shown here in tree height, tree spacing, and species mix is common during the 'stand conversion' phase, which involves converting an existing stand structure to a regulated, managed, uneven-aged structure.

Uneven-aged management can be problematic if featured species are susceptible to insects, pathogens, parasites (dwarf mistletoe), and stem wounding during stand tending operations. If objectives emphasize timber production, for example, stands with a large proportion of grand fir or subalpine fir may be productive for gross cubic-foot growth, but they are seldom impressive in terms of net (usable) cubic-foot production. The main reason for a wide disparity between gross and net production is that true firs often experience stem decay and other forest health factors limiting their capability to provide merchantable wood products (Cochran 1998, Filip and Schmitt 1990).

In a traditional implementation of uneven-aged management, stands are selected not only in view of their existing and potential species composition (e.g., ecological site potential), but also after carefully evaluating their existing structure. If candidate stands are not uneven-aged already, they should preferably exhibit an irregular structure (figs. 1-2) because it can often be converted to an uneven-aged diameter distribution within a few cutting cycles.

If uneven-aged regulation will occur by using the classical BDq approach, then existing stands could be evaluated by considering how closely their existing conditions align with your BDq objectives: residual basal area (B factor), diameter of largest reserve trees (D factor), and a diminution quotient (q factor) expressing the ratio between number of trees per acre in successive diameter classes (Fiedler 1995).

Stands whose existing characteristics deviate significantly from desired BDq objectives might not be appropriate for uneven-aged management unless a land owner is willing to accept that numerous cutting cycles could be required before reaching a balanced age and size distribution (Cochran 1992).

Uneven-aged management has advantages and disadvantages – pluses and minuses.

Some potential advantages of uneven-aged management are:

1. Selection cutting is the only method capable of regenerating and perpetuating an uneven-aged stand (although many uneven-aged stands will regenerate themselves without man's intervention).
2. Establishing reproduction is usually easy because sites are protected, and a prolific seed source is often present. The need to practice artificial regeneration, and incur its high costs, is rare with uneven-aged management.
3. Site protection is maximized – there is little direct exposure to sunlight and wind.
4. Selection cutting may be the best method available for protection of sensitive aesthetic sites, such as recreation areas and heavily-traveled road corridors.
5. Stands managed with selection cutting are generally more resistant to windthrow and snow breakage because of their deep, irregular canopies. Windthrow resistance can be an important consideration in saddles, upper slope positions, and other topographic settings with high windthrow risk.
6. Maintaining high water quality is easy with selection cutting, especially if

specified roads, temporary roads, and designated skid trails are properly located and maintained.

7. A large amount of vertical diversity is provided by uneven-aged stands, which favors wildlife species requiring late-seral or old-growth habitats.

Some potential disadvantages of uneven-aged management are:

1. Logging costs are higher than for most even-aged cutting methods. But, the preparatory cut of a three-step shelterwood may be as costly as selection cutting in many of our spruce-fir forests.
2. There is high potential for damage to the residual stand, which includes our future crop trees, from logging operations and slash treatment. This disadvantage is especially appropriate for individual-tree selection.
3. Layout, marking, administration, and other operational tasks require great skill. Beware: the skill levels needed to properly apply uneven-aged management are seldom available on a typical seasonal marking crew!
4. Stem quality and product value is lower than for even-aged stands, especially on poor sites. This occurs because trees in uneven-aged stands can generally maintain full crowns for much of their lives. Since self-pruning is inhibited, more knots and other grade defect is an ultimate result.
5. Livestock grazing is not generally possible because herbage production is very low, and grazing damage to regeneration would be unavoidable. Uneven-aged management also provides less forage for deer and elk than would typically be produced by using even-aged cutting methods.
6. It may be difficult to keep detailed inventory records for uneven-aged management. When group selection is used, it can be hard to keep track of individual groups, and schedule them for follow-up inventories (such as regeneration stocking surveys) and cultural treatments including noncommercial thinning.
7. It can be difficult to predict future growth and yield for selection cutting methods. In the mid-1980s, when this white paper was first prepared, modeling software for simulating uneven-aged management was limited; now, many more options are available, especially when considering the Forest Vegetation Simulator (FVS) and its varied extensions.
8. If applied incorrectly, selection cutting can result in a high-grade, with a genetically inferior stand being the ultimate result.
9. It’s difficult to scarify seedbeds or complete other site preparation tasks like prescribed burning, especially for individual tree selection. This means that regeneration of true firs and other species capable of utilizing organic seedbeds (litter/duff) are favored over species requiring mineral soil such as pines and larch.

10. Insect and disease problems may worsen when using uneven-aged management, particularly when applying individual-tree selection. Some examples of pest intensification that can accompany selection cutting are:
    a. Uneven-aged stands often have a multi-layered or multi-canopied structure, creating an ideal ‘feeding ladder’ for western spruce budworm. You should consider budworm ‘feeding ladder’ implications before prescribing individual-tree selection and creating multi-layered stand structures.
    b. Note that this same concern applies to ladder fuels. When small trees occur as an understory component in multi-layered stands, they also function as ladder fuels by facilitating a transition from surface fire to passive (torching) or active crown fire.
    c. Frequent stand entries are not a prerequisite for uneven-aged management, but they will often be needed for highly productive sites. If frequent entries cause increased wounding of residual trees, a silviculturist should expect high levels of rust-red stringy rot (Indian paint fungus), red ring rot, and other stem or butt decays.
    d. Partial cutting and frequent stand entries can create problems with root diseases. Although spread of annosus root disease is particularly apparent with partial cutting (resulting in a need to use borax treatments for freshly cut fir stumps), uneven-aged management could also contribute to armillaria root disease, black stain root disease, and laminated root rot.
    e. Uneven-aged management may create shaded environments, ideal conditions for shade-tolerant species on mixed-conifer sites. Managers should consider that when using uneven-aged management, they may be swapping pest-resistant ponderosa pine (an early-seral, shade-intolerant species) for pest-susceptible grand fir and Douglas-fir (late-seral, shade-tolerant trees).
    f. Individual-tree selection will generally be unacceptable for management of a widespread and destructive parasite of both ponderosa pine and Douglas-fir: dwarf-mistletoe (at least for pure stands of either tree species).
11. Selection cutting is not compatible with a full range of logging systems. Small, maneuverable machinery can successfully harvest the range of tree sizes produced by uneven-aged management. Large equipment and cable yarding systems are most likely not effective in similar stands. Horse logging, however, can be an attractive alternative for uneven-aged stands on gentle terrain.

Since group selection differs from individual-tree selection, and because much of the previous discussion about disadvantages of uneven-aged management focused primarily on individual-tree selection, it is helpful to highlight specific advantages and disadvantages of group selection.

Some advantages of group selection cutting are:

1. Less tolerant trees can be maintained in a stand composition. In some areas, intolerant species are more valuable commercially (ponderosa pine on Douglas-fir or grand fir sites), or wildlife objectives emphasize species diversity (retaining small aspen clones or lodgepole pine inclusions within an uneven-aged spruce-fir stand, for instance).
2. Logging damage is reduced by concentrating equipment movement in openings.
3. Logging costs are reduced because cut trees are concentrated.
4. Marking is easier (and generally faster) because markers focus on identifying groups, rather than evaluating individual trees.
5. Treating slash is easier because it is concentrated in harvest openings, where it can be burned or masticated (but doing so may damage advance regeneration).

Some disadvantages or dangers of group selection cutting are:

1. There may be a tendency to make groups so large that an essential benefit of uneven-aged management – site protection and environmental modification – is diminished or lost altogether.
2. Harvest entries tend to emphasize removal of mature trees in groups; release and weedings, thinnings, improvement cuttings, and other cultural operations in immature trees may be overlooked.
3. When large groups are used, aesthetic advantages of uneven-aged management may be compromised.

CASE STUDY: MATURITY SELECTION SYSTEM

When timber sales began on Blue Mountains national forests around 1910 or so, a silvicultural system being used for dry ponderosa pine forests was called selective cutting or a 'maturity selection system' (as described in Meyer 1934, Munger 1941, Munger et al. 1936, and other sources in References section). Although originally intended for application in dry ponderosa pine forests of western U.S., this system was conceptually attractive and it was eventually adapted for west-side Douglas-fir forests (Ames 1931, Curtis 1998), and for loblolly, longleaf, and other southern pines.

When applied in ponderosa pine forests, maturity selection aimed to remove about two-thirds of a virgin stand in the first entry. Silvicultural goals of this system were to cut over a forest rapidly in order to save decadent timber (from 'ravages' of fire, bark beetles, and decay), to maintain an uneven-aged structure by retaining part of an original stand, and to leave an overwood to provide seed and shelter for young reproduction. By reserving a portion of an original stand (app. one-third), it was thought that periodic entries could be made at intervals of one-fourth to one-third of a typical rotation length. Tentatively, a rotation age of 180 to 200 years was considered, and this resulted in a cutting cycle interval of 40 to 60 years (Weidman 1921).

Whether this maturity selection system qualified as ‘true selection’ – Was it really uneven-aged management? – was a question debated often in the early 20th century (Meyer 1930, O’Hara et al. 2010).

For eastern Oregon and Washington, historical dry forests were usually open, irregular or uneven-aged stands with a preponderance of mature and overmature ponderosa pine trees. Sometimes, these stands had dense clumps of seedling reproduction in forest openings, but often regeneration occurred as uniformly distributed seedlings struggling beneath an overstory (Munger 1917). A suppressed seedling cohort was small and inconspicuous, but it had surprising capacity to recover and respond quickly after an overstory was removed (a dry-forest white paper, F14-SO-WP-Silv-04, has more info).

Age range of these stands was unbalanced and could scarcely be referred to as uneven-aged. For example, two 20-acre plots from Whitman NF showed that for all live trees 4 inches DBH and greater, 9% was in the 20-100-year age class, 22% in the 100-200-year class, 45% in the 200-300-year class, 6% in the 300-400-year class, 15% in the 400-500-year class, and 3% in the 500-600-year class. So, 69% of virgin stocking was more than 200 years old (not counting reproduction less than 4 inches DBH) and then, 200 years was a maximum rotation age being used for ponderosa pine. On other plots totaling 417 acres, it was found that 67 to 74 percent of live trees were larger stems over 12 inches DBH (and presumably these were older stems) (Weidman 1921).

Once early foresters recognized that age-class structures of unmanaged stands tended to be skewed (unbalanced), it quickly led to tree-vigor classification systems to help prioritize which older trees should be removed first, and which trees could reasonably be reserved until subsequent cutting cycles. An initial vigor classification system was developed by Duncan Dunning for Sierra Nevada mixed-conifer forests (Dunning 1928), and it was designed specifically to be used with selection (uneven-aged) forests.

As attempts were made to apply Dunning’s system beyond the Sierras, it was soon learned that it did not provide enough classification detail to handle a full range of situations. This led to F.P. Keen’s vigor classification system for ponderosa pine, which became widely used in a Pacific Northwest pine region (Keen 1936). Keen’s system was especially valuable because it incorporated bark-beetle susceptibility, a major concern after western pine beetle reached outbreak levels across wide portions of the western U.S. in the early 1930s in response to Dust Bowl drought conditions (Person 1931).

Early inventory data (as reported by Weidman 1921) suggest that unmanaged ponderosa pine forests had a stand structure opposite what is expected for a balanced, uneven-aged condition, where young (small) trees greatly outnumber old (large) ones. And, when older maturity-selection cuttings were examined on private land near Galena, it was found that advance reproduction responded well after timber harvest, resulting in an even-aged stand of saplings and poles.

As a result of studies and observations about maturity-selection cutting, Weidman (1921) came to the following conclusions about how it was being implemented in ponderosa pine forests of eastern Oregon and Washington:

- An even-aged successional structure in ponderosa pine is an established fact (as based on his review of Galena maturity selection cuttings).
- An even-aged forest is developing on older private cuttings, and on heavily-cut national forest timber sale areas, regardless of silvicultural intent (i.e., even-aged results occurred despite maturity selection cutting).
- Maturity selection cutting, as practiced, did not result in a balanced uneven-aged structure, as intended, and Weidman believed it could not do so when considering ecology (e.g., silvics) of ponderosa pine.
- If maturity selection cutting was continued, then managers should recognize that it will create a 'conversion' structure, persisting for perhaps 100 years or more, before stands would approach a balanced uneven-aged condition.
- Clearcutting, with protection of established advance regeneration, could be an acceptable silvicultural alternative for ponderosa pine forests, although four or five seed trees per acre should be retained to guard against fire losses, and to 'seed up' any openings created by timber harvest. Seed trees should be retained for an entire rotation (i.e., implementing this recommendation would ultimately lead to a two-aged silvicultural system).

REGULATING AN UNEVEN-AGED STAND STRUCTURE

After considering pros and cons of uneven-aged management, and then identifying stands that qualify for this silvicultural system, it's now time to begin developing a management regime by regulating their diameter distribution.

In even-aged management, yields are regulated by controlling area in each age-class, and rotation length – time required to grow trees to maturity (Daniel et al. 1979, Davis et al. 2001). Managed, even-aged tracts contain stands of varying ages.

For uneven-aged management, yields are regulated by controlling growing stock. Managed stands are characterized by trees of many sizes, and ages, occurring individually or in groups. Since an entire stand is treated (or evaluated for treatment) under uneven-aged management, proportional area objectives (treat ¼ of the area), a common approach for even-aged methods, are typically irrelevant for uneven-aged management.

As an example: If a silviculturist states that 25 percent of an area will be treated by using group-selection cutting, it could be a tip-off that an even-aged treatment (group shelterwood or small-patch clearcutting) is really being used because regulation is apparently based on area (25% of the stand acreage), not on growing stock.

Here is the point: If growing stock is truly ‘controlling’ stand entries, then we would expect that 20% of stand area may be treated in one entry, but perhaps 28% will be treated in the next entry. These variations reflect that from one treatment to the next, differing amounts of stand acreage will be treated for the same volume output.

The moral of this regulation story is that a silviculturist should not expect that once an uneven-aged stand (forest) has been regulated, it will provide a consistent amount of <u>treatment area</u> for each cutting cycle. An expectation of consistent volume for each cutting cycle, however, is reasonable for uneven-aged management, but the amount of stand acreage being treated to produce a certain volume will fluctuate depending on which portions of a diameter distribution are being emphasized during an entry.

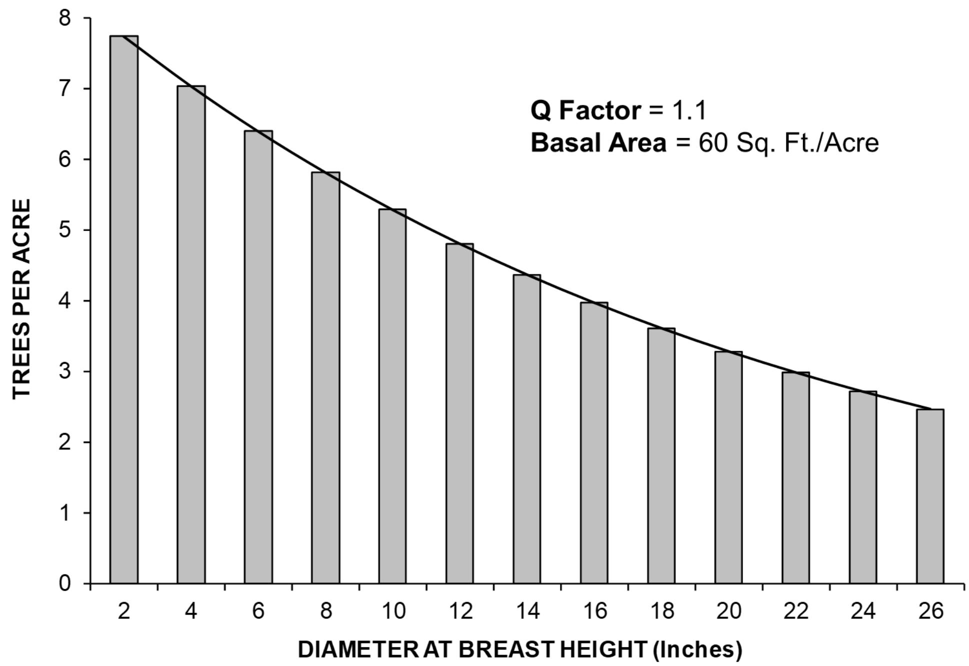
If group selection cutting is used, and if many groups being removed in a cutting cycle are in an 18-24" size class, then it is not surprising that less stand area will be treated than if the same amount of volume had come mostly from groups in a 7-12" size class. Stocking differences cause similar variation – high-density 18-24" groups require less treatment area, for the same volume, than low-density 18-24" groups.

Many approaches were developed for controlling stand structure in uneven-aged stands (or in irregular stands being converted to an uneven-aged structure). In addition to the BDq method utilized for this white paper, approaches using stand density index (Cochran 1992, Long and Daniel 1990, Ex and Smith 2013), leaf-area index (O’Hara 1996, O’Hara and Valappil 1999, O’Hara et al. 2003), and a European system called Plenter or Plenterung (described in appendix 3) are also available.

A References section provides literature sources for a variety of approaches to uneven-aged regulation (see Baker et al. 1996, O’Hara and Gersonde 2004, and others). Some references relate to uneven-aged management as practiced in eastern hardwood forests, or in Europe, but they are included nonetheless because similar regulation principles apply to both eastern and western forests (Alexander and Edminster 1977b).

Remainder of this white paper describes what is traditionally referred to as a ‘Q factor’ or ‘BDq’ approach. Historically, it was the most common approach for North America (Meyer 1943; O’Hara 1995, 2002), and it has early roots in Europe (de Liocourt 1898). A BDq approach defines a desirable (target) stand structure by using a negative exponential or reverse-J diameter distribution (fig. 5), in combination with factors controlling maximum tree size (D factor) and residual basal area (B factor).

When plotted mathematically, the slope of a BDq diameter distribution is described by a q factor (fig. 5), which is a ratio of trees in one diameter class to number of trees in the next <u>smaller</u> diameter class. Selecting a q factor of 1.5 results in a 6-inch diameter class having 1.5 times more trees than an 8-inch class, and the 8-inch class has 1.5 times more trees than a 10-inch class (and so forth).



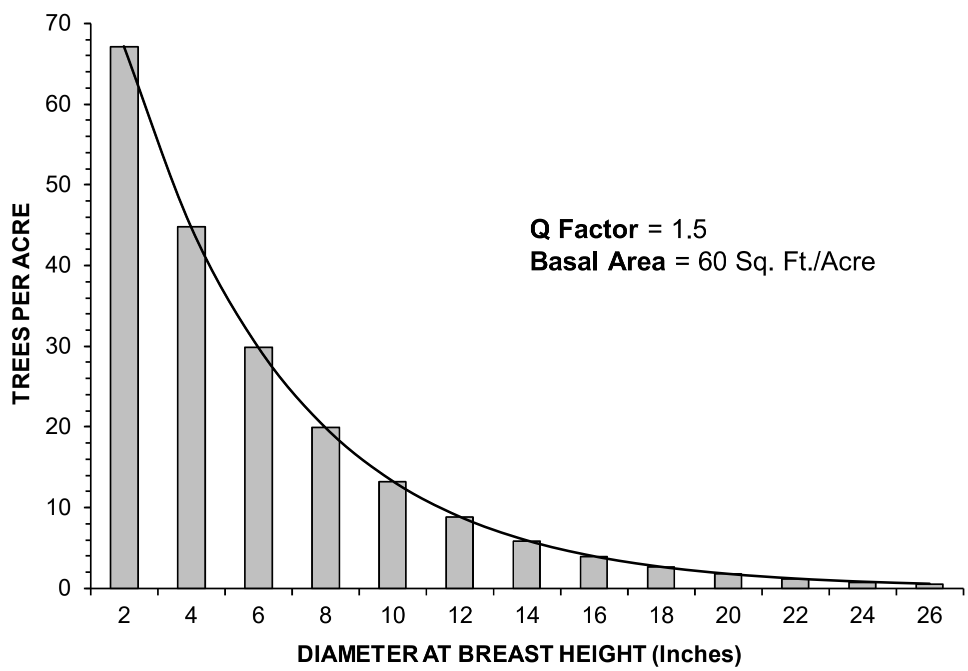


Figure 5 – A negative exponential diameter distribution, which is used for a BDq approach. Slope of a line is referred to as a q factor or diminution quotient. Number of trees per acre in each diameter class is controlled partly by a basal area objective for a stand (B factor in BDq; 60 square feet per acre for both examples here). End-point of a diameter distribution is set by using a maximum diameter objective (D factor in BDq; 26 inches for both examples here). These examples show how q factor influences trees per acre; both examples use the same B (60 square feet/acre of basal area) and D (26" DBH maximum tree size) factors, but differing q factors cause big changes in the resulting diameter distribution. [Figure 6, next page, depicts a q factor in logarithmic form.]

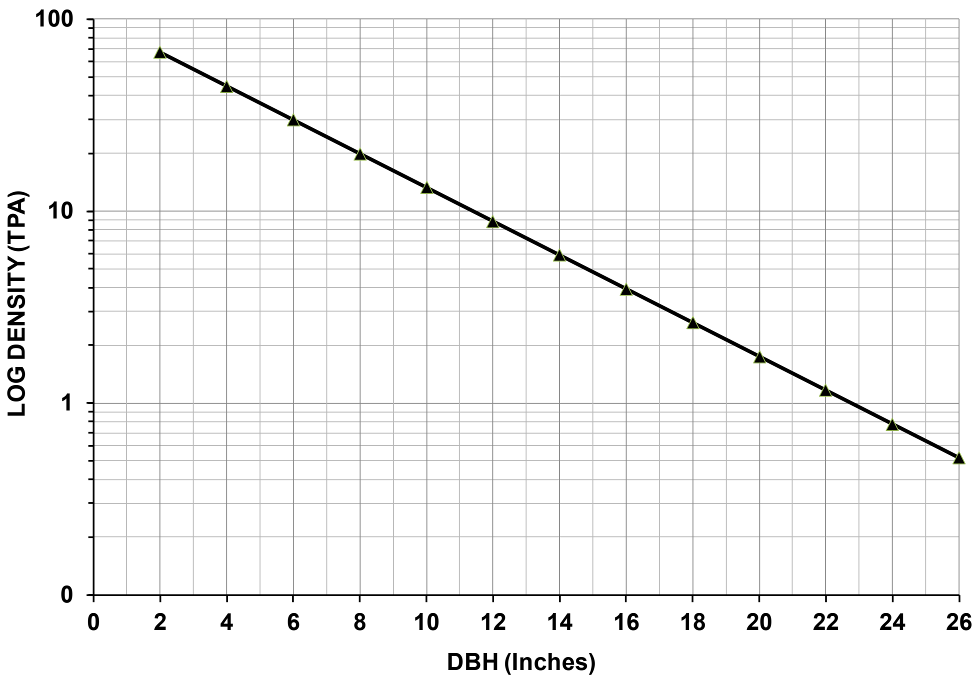


Figure 6 – A q factor of 1.5, a residual basal area (B factor) of 60 square feet per acre, and a maximum tree size (D factor) of 26 inches, with tree density (TPA, Trees Per Acre) plotted on a logarithmic scale instead of a numeric scale. [Compare this straight-line result with curving q-factor lines in figure 5.]

Since q factor is a negative exponential mathematical distribution, it can be plotted as a straight line by expressing tree density in logarithmic units. Figure 6 shows a q factor of 1.5, a B factor of 60, and a maximum tree size (D factor) of 26 inches, which is the same data presented in the bottom half of figure 5, but in figure 6, tree density (the vertical or y-axis) is plotted as a logarithmic scale. Note how converting the y-axis to a logarithmic scale caused the reverse-J diameter distribution in the bottom half of figure 5 to be transformed into a straight, down-sloping line (and its slope is -1.5, the q factor).

Figure 5 presents two dramatically different diameter distributions, even though both use the same amount of basal area (60 square feet per acre) and the same maximum tree size (26 inches DBH). The only factor that varies in figure 5 is the q factor.

Figure 5 illustrates that a low q factor (1.1 in upper half of fig. 5) results in a relatively 'flat' diameter distribution curve, whereas a higher q factor (1.5 in lower half of fig. 5) creates a distribution whose slope declines relatively steeply from small to large diameter classes.

Figure 5 demonstrates that the shape of a diameter curve depends mostly on the q factor you select. Figure 7 demonstrates that when total stand basal area is varied, for the same q-factor value, it has no bearing on the shape of resulting diameter curves. Varying stand basal area, however, does raise or lower the height of a curve.

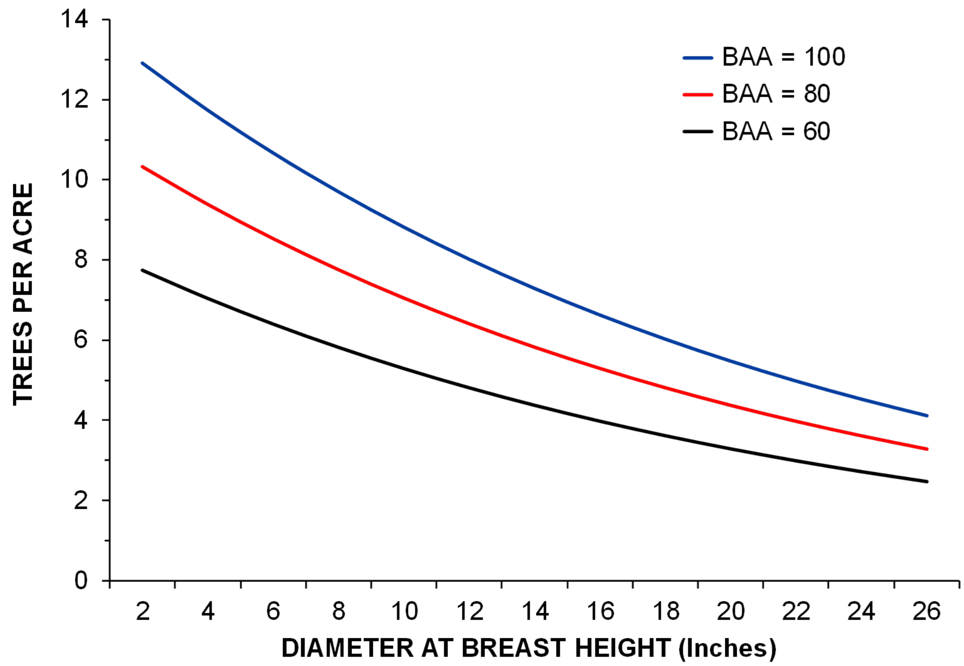


Figure 7 – Varying diameter distribution curves related to differences in residual stand basal area (B factor in BDq approach). Changing a residual basal area amount (BAA, or basal area per acre) does not cause a change in shape or slope of a curve; however, an increasing BAA amount raises height of a curve, and a decreasing BAA amount lowers height of a curve. (All curves use a q factor of 1.1.)

Once you've decided to implement uneven-aged management by using a BDq approach to regulation, the following objectives must be established:

1. An optimum diameter-class distribution must be described (figs. 5, 6) – this is the q factor of a BDq approach. The q factor is often referred to as a diminution quotient because it controls the diminution (reduction) rate for trees per acre stocking across diameter classes (fig. 5). But another important function of a q factor is to determine how a whole-stand basal area value (objective) will be distributed across a range of 2-inch diameter classes.
2. A maximum tree size (diameter) objective must be established – this is the D factor of the BDq approach. This maximum tree size objective specifies one of the end-points for a target diameter distribution (fig. 5).
3. A total stocking objective must be determined, traditionally by using basal area – this is the B factor of the BDq approach. Although the B factor is based on basal area, not on stem count, this factor exerts the most control over number of trees per acre shown in figure 5. In actuality, the number of stems per acre in each diameter class shown in figure 5 results from a synergistic interaction between a whole-stand stocking objective (basal area per acre) and a diminution quotient (q factor) controlling steepness of the curve in figure 5. To put it another way – a B factor (basal area per acre) controls total stocking for a stand, a q factor

(diminution quotient) controls how stocking is distributed across a range of 2-inch diameter classes, and a D factor (maximum tree size) controls where the diameter-class distribution stops.

Figures 5 and 7 describe and illustrate how changing two of these factors (B or q) results in a differing number of stems in each diameter class.

4. An optimum cutting cycle must be determined. Existing tree and stand growth rates, and site productivity as it influences future (potential) growth rates, should be considered when selecting a cutting cycle.
5. A strategy should be developed for converting the existing stand to a desired condition. A <u>desired condition</u> is based on diameter-class distribution, maximum tree size, and whole-stand stocking (residual basal-area) objectives – these are the BDq factors described in items 1, 2, and 3 above.
6. A strategy (e.g., a silvicultural prescription and associated marking guide) should be developed for converting an existing diameter distribution to a desired one, and then maintaining the desired distribution, through time, once it has been reached.

The balance of this paper describes a procedure for developing silvicultural prescription information incorporating the regulation objectives given above.

PRESCRIPTION PREPARATION PROCEDURE

This section provides a step-by-step process for regulating an uneven-aged stand structure. It is somewhat long because it provides the 'meat' of this white paper. Specialized terms about uneven-aged regulation are defined in appendix 1.

The process is best described by using a step-by-step example. I selected a relatively uneven-aged stand of Engelmann spruce and subalpine fir for this exercise (but the subalpine fir is corkbark fir, a recognized variety with distinctive pale, thick, corky bark).

The example stand is in the San Isabel National Forest of south-central Colorado. It is virtually a pure stand of Engelmann spruce, although corkbark fir seedlings and suppressed quaking aspen saplings are also present to a limited extent. It occurs in the Wet Mountains at an elevation of 11,000 feet, and it is called the 'Greenhorn' stand.

1. **Graph the stand table** by using data from a stand examination or another inventory program that provides stem counts, on a per-acre basis, by diameter class. Checking the stand exam printout for the Greenhorn stand shows that all 'non-cull,' growing-stock stems above the seedling size class are Engelmann spruce (fig. 8).

   Seedlings are not shown in figure 8, but they are plentiful for the Greenhorn stand – there are 682 growing-stock seedlings per acre, and all but 27 of them are Engelmann spruce.

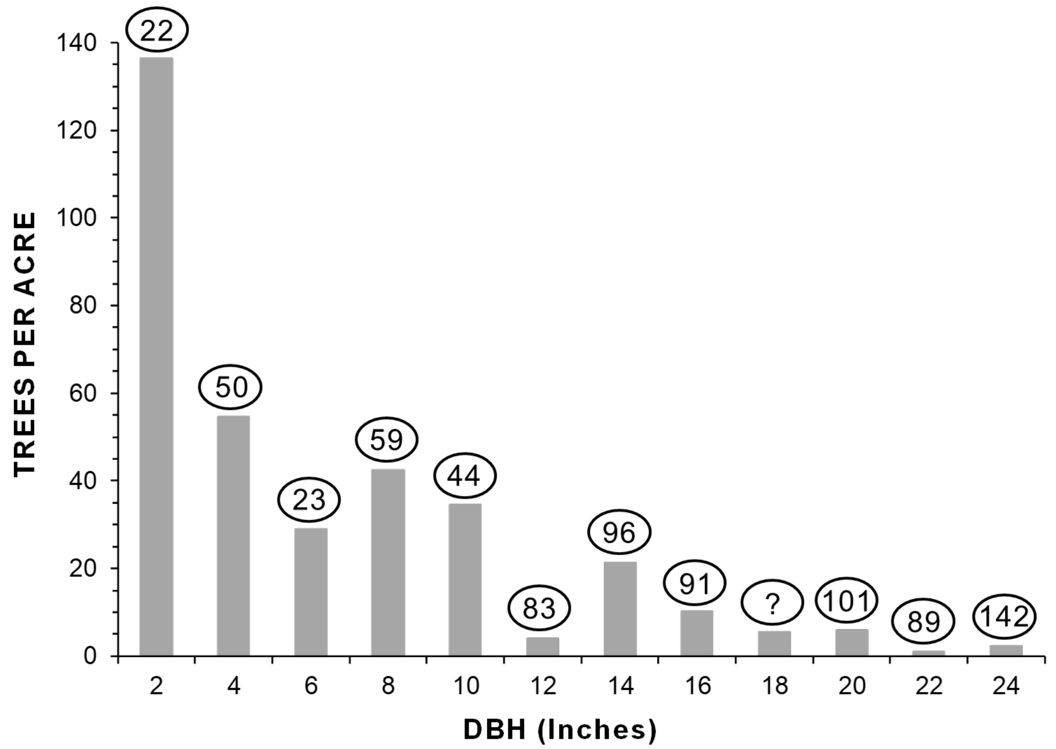


Figure 8 – Existing diameter distribution for Greenhorn example stand. The height of each column shows number of trees, per acre, by diameter class; numbers above each column show average age of trees in a diameter class.

This chart demonstrates the value of completing an intensive stand exam for areas where uneven-aged management will be used. An intensive exam where growth sample trees are selected for a wide spectrum of diameter classes provides useful growth and age data, and it allows you to examine diameter/age relationships as I've done here.

The information in figure 8 came from a stand examination report. Preparing a chart (graph) of stand exam density information can provide useful information about stand dynamics and development. Here is what I surmise from figure 8, and the associated stand exam information, for our Greenhorn example stand.

a. The existing diameter distribution closely approximates a reverse-J distribution, and diameter classes have a range of ages, which suggest that if the stand is not uneven-aged already, it is heading there quickly.
b. Now, what might fig. 8 imply if diameter classes had been relatively close in age? Under those circumstances, I would assume we have an even-aged, single-cohort stand that differentiated into crown classes in response to inter-tree competition (with large-diameter stems being dominant/codominant trees, medium-diameter stems being intermediate trees, and small-diameter stems being suppressed/overtopped trees) (Oliver and Larson 1996).
c. The age data included with fig. 8, however, suggests that the Greenhorn stand is comprised of three distinct cohorts: relict trees from a previous disturbance

event (24-inch diameter class, 142 years of age); maturing trees (12 to 22-inch diameter classes, 83 to 101 years of age); and immature trees (2 to 10-inch diameter classes, 22 to 59 years of age).

Figure 9 provides basal area information by diameter class, with three age cohorts separated by dashed lines, and it also shows total basal area by cohort.

d. The stand examination printout shows that abundant seedling regeneration exists for the Greenhorn stand. In addition to 682 growing-stock seedlings per acre (655 spruce; 27 corkbark fir), there are an additional 3,565 'cull' seedlings per acre of spruce and fir combined (all are non-growing-stock). So, total seedling 'load' for this example stand is app. 4,247 stems per acre!

e. The stand examination printout shows that 27 non-growing-stock aspen saplings per acre are present in the Greenhorn stand.

<u>Note</u>: If group selection is prescribed, this information could be helpful for rejuvenating aspen. If aspen saplings are assumed to indicate location of relict aspen root system, then initial groups could be placed in areas with aspen saplings.

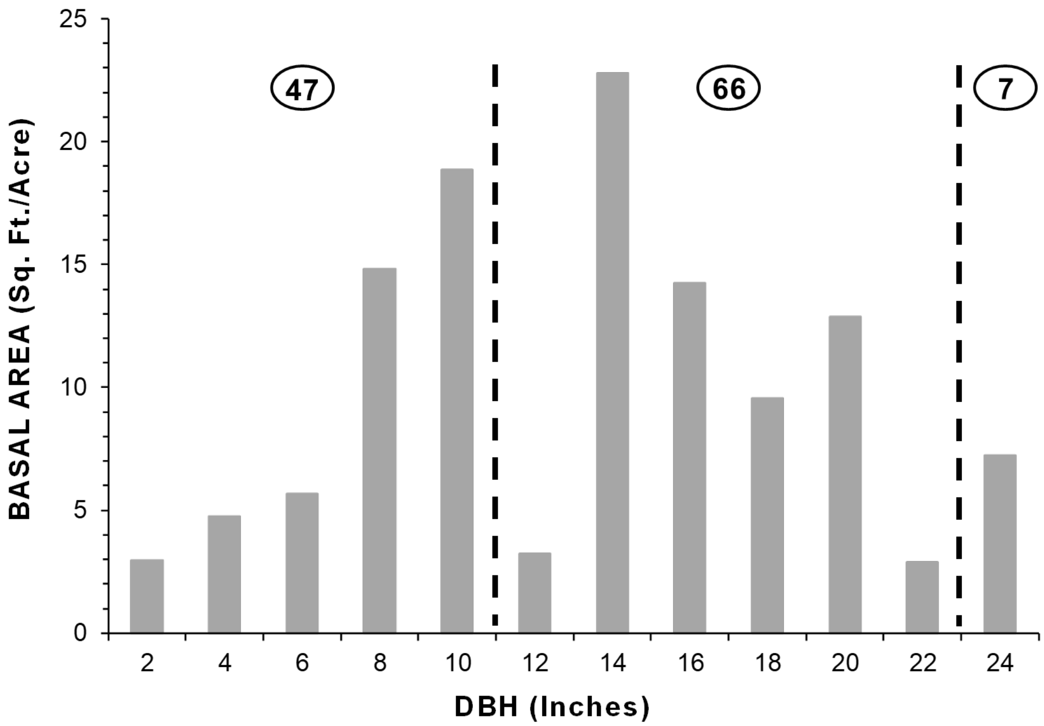


Figure 9 - Existing diameter distribution for our Greenhorn example stand. The height of each column shows basal area, in square feet per acre, by diameter class. Dashed vertical lines show presumed cohort breaks; circled numbers above each section show total basal area for the cohort. When using the BDq approach to uneven-aged stand regulation, it is not necessary to prepare charts with Basal Area as the stand density (y-axis) metric rather than stems (trees) per acre. But, since basal area is important for marking guides and silvicultural prescriptions, it is often helpful to prepare a chart like this to examine basal area relationships during the prescription preparation process.

2. **Choose a maximum diameter tree size to be grown – this is the D factor in a BDq approach.** For our Greenhorn stand, I chose a maximum diameter of 24 inches. Our stand exam data suggests that once dominant Engelmann spruce trees have reached maturity for Rocky Mountain environments (by app. 140 years of breast-height age under unmanaged conditions, according to fig. 8), they will have a 24-inch diameter. For this reason, 24 inches was selected as the D factor.

   How about using historical inventory data to help select a D factor? After all, wouldn't historical data provide a good indication about potential tree size, especially for areas where unmanaged reference stands no longer exist? Historical data is always informative, but I urge caution with this approach. Munger (1917), for example, provides very useful information about stand characteristics for unmanaged, old-growth dry forests of the Blue Mountains near the turn of the 20th century. His information provides insights about potential tree sizes attainable under unmanaged conditions, and it reflects conditions produced by a fully functional fire regime (fire regimes now are not fully functional because most fires are suppressed, and Native American ignitions no longer occur).

   Munger's (1917) data shows that the Austin-Whitney tract produced 30-inch trees in 450 years; the Lookingglass Creek tract produced 30-inch trees in 310 years; the Parker's Mill tract produced 36-inch trees in 450 years (30" trees in 340 years); and the Winlock's Mill tract produced 30-inch trees in 350 years.

   Munger (1917) provides useful historical context for site capability (what is maximum tree diameter for typical dry-forest sites of the Blue Mountains under a fully functional, low-severity fire regime?), but I doubt you'll be willing to consider time spans of 310 to 450 years for your prescription's management regimes.

   Research results, site-index curves, and managed-stand yield tables varying by tree species could provide useful indications of maximum tree diameter, along with a time frame required to reach maximum diameter under managed conditions.

3. **Choose a residual basal area objective – this is the B factor in a BDq approach.** For management of our Greenhorn stand, I chose a residual basal area objective of 80 square feet per acre. For late-seral, shade-tolerant spruce-fir stands of the central Rocky Mountains, 80 square feet of basal area per acre is the lowest basal area that appears to be a realistic timber management goal (Alexander and Edminster 1977b).

   Selecting a residual basal area should consider site productivity and its effect on stockability (e.g., stand density carrying capacity). Stockability reflects the amount of stand density a site can support and still produce acceptable tree growth.

   Specific stocking-level recommendations have been developed for the Blue Mountains (Cochran et al. 1994; Powell 1999, 2013); some of them are presented in table 4 by potential vegetation group, tree species, and stocking threshold. Table 4 can help you decide how much residual basal area to retain.

Table 4: Tree density for the Blue Mountains, expressed as basal area per acre, for four stocking thresholds and three potential vegetation groups.

Potential Vegetation Group[1]	Tree Species	TREE DENSITY (Basal Area per Acre[2]) LLMZ	ULMZ	FS	Max[3]
Dry Upland Forest	Ponderosa pine	31	46	110	137
	Interior Douglas-fir	69	104	139	173
	Western larch	66	99	131	164
	Lodgepole pine	62	93	151	189
	Engelmann spruce	[Not applicable for this PVG]			
	Grand fir	116	174	232	290
	Subalpine fir	[Not applicable for this PVG]			
	Mixed composition[4]	44	66	119	148
Moist Upland Forest	Ponderosa pine	63	94	162	202
	Interior Douglas-fir	81	122	162	203
	Western larch	93	140	187	233
	Lodgepole pine	62	93	146	182
	Engelmann spruce	101	151	202	252
	Grand fir	134	201	268	335
	Subalpine fir	86	130	173	216
	Mixed composition[4]	89	133	182	227
Cold Upland Forest	Ponderosa pine	34	51	87	108
	Interior Douglas-fir	86	129	173	216
	Western larch	91	137	182	228
	Lodgepole pine	62	92	137	171
	Engelmann spruce	94	140	187	234
	Grand fir	94	141	189	236
	Subalpine fir	100	151	201	251
	Mixed composition[4]	72	108	150	187

[1] Potential vegetation group (PVG) is a mid-scale unit in the potential vegetation hierarchy (Powell et al. 2007).

[2] Basal area per acre values pertain to a quadratic mean diameter of 10 inches and an irregular stand structure except for lodgepole pine, which pertains to an even-aged structure.

[3] LLMZ is lower limit of the management zone; ULMZ is upper limit of the management zone; FS is full stocking; and Max is maximum density.

[4] Mixed composition is a weighted average based on these species mixes:
Dry upland forest: 70% ponderosa pine, 20% Douglas-fir, and 10% grand fir.
Moist upland forest: 30% Douglas-fir, 20% western larch, 20% lodgepole pine, and 30% grand fir.
Cold upland forest: 10% Douglas-fir, 10% western larch, 50% lodgepole pine, 20% Engelmann spruce, and 10% subalpine fir.

If our spruce-fir stand was in the Blue Mountains instead of the central Rockies, I would have selected a residual basal area objective of 90 square feet per acre because when referring to table 4, it better approximates the lower limit of the management zone (LLMZ) for Engelmann spruce for Cold Upland Forest sites in the Blue Mountains.

Caution/Caveat: The LLMZ values in table 4, however, are most applicable for intermediate cutting methods (commercial thinning, improvement cutting, etc.), not for regeneration cutting. When setting a residual basal area (BA) value, a silviculturist should provide extra growing space for regeneration (reduce residual BA to account for regeneration), *especially if individual-tree selection cutting is being used*.

When considering regeneration needs, selecting a B value of 60 or 70 may have been appropriate for our Greenhorn stand, *but only if individual-tree selection was being used*. When setting a B value for group selection cutting, it may not be necessary to 'build in' extra growing space for regeneration because the cutting method itself promotes tree regeneration (by creating open conditions).

4. **Choose a diminution quotient for the stand –** this is the q factor in a BDq approach. A q factor is the ratio of trees in one diameter class to those in an adjoining (smaller) class. For example, a q factor of 1.5 means that the 4-inch diameter class should have 1.5 times more trees than the 6-inch class. Some points to consider when deciding which q factor to use:
   a. Low q factors emphasize large-diameter trees and discriminate against smaller size classes.
   b. Low q factors result in smaller differences in number of stems between DBH classes; the opposite is true for high q factors (Alexander and Edminster 1977).
   c. High q factors emphasize small-diameter trees; less stocking in larger diameter classes is produced.
   d. Are markets present for small trees (fuelwood, Christmas trees, etc.)? If not, avoid a high q factor unless funds for noncommercial thinning are available.
   e. If markets for both small- and large-diameter trees are available, consider a q factor close to a stand's existing diameter distribution.

   For this white paper, I assumed that markets are available for a wide range of diameter classes and, therefore, I chose a q factor that best fits the stand's existing diameter distribution. Choosing a q factor close to a stand's existing distribution (akin to a 'go with the flow' philosophy) allows quicker attainment of a desired stand structure, and initial harvests will be less severe environmentally.

   Because the existing stand has moderate tree density in most diameter classes (see fig. 8), I will evaluate what I consider to be three 'middle of the road' q factors: 1.1, 1.3, and 1.5 (if we were working with hardwood forests in the eastern US, 1.1 would not be considered a middle-of-the-road option; for western conifer types, however, a q factor of 1.1 should be evaluated for most forest types). If the current structure had been skewed in one direction or another, I would have evaluated q factors emphasizing either smaller (1.1 or 1.2) or larger (1.6 or 1.7) trees.

Remember that a current stand structure does not have to dictate a future one; an existing stand could have many small-diameter trees, but you still might choose a q factor emphasizing large stems because markets are better for those size classes.

5. **Determine a K factor from table 5 for the q factors you want to evaluate.**

   Note: The K factors in table 5 are meant to be used with 2-inch diameter classes only. If you want to regulate an uneven-aged stand by using 1-inch diameter classes (not recommended because it involves what I believe to be an unnecessary amount of detail), table 5 will not help you prepare q factor reference curves.

   Since I would like to evaluate q factors of 1.1, 1.3, and 1.5, the K factors I'll need are 18.76, 35.84, and 74.84, respectively (these values were taken from table 5 for the 24-inch DBH line, and the 1.1, 1.3, and 1.5 q-factor columns).

6. **Divide a K factor obtained from table 5, for each q factor being evaluated, into a residual basal-area objective (the B factor in BDq).** The result of this calculation is the number of trees in the largest size class (24-inch DBH class for our example).

   How should we select a B factor? At this stage of the process, we should remember that we are not yet evaluating any silvicultural options.

   Our objective now is to determine which q factor best approximates the stand's existing diameter distribution (because, in step 4, we decided to choose a q factor that best fits our stand's existing diameter distribution).

   For this reason, I decided to use a B factor of 120 because the stand's existing basal area, for diameters ranging from 1 to 24.9 inches (the 2-inch to 24-inch DBH classes, inclusive), is 119.9 square feet per acre (rounded to 120).

   a. For a q factor of 1.1, the result is 6.40 trees/acre for 24-inch trees (120/18.76).
   b. For a q factor of 1.3, the result is 3.35 trees/acre for 24-inch trees (120/35.84).
   c. For a q factor of 1.5, the result is 1.60 trees/acre for 24-inch trees (120/74.84).

7. **Multiply the result from step 6 by a q factor to compute the number of trees in the next smaller diameter class.** Since the number of 24-inch trees was computed to be 6.40 for a q factor of 1.1, 3.35 for a q factor of 1.3, and 1.60 for a q factor of 1.5, the number of trees per acre (TPA) in the 22-inch diameter class is:

   a. 7.0 for a q factor of 1.1 (6.40 TPA for 24" class times 1.1);
   b. 4.4 for a q factor of 1.3 (3.35 TPA for 24" class times 1.3);
   c. 2.4 for a q factor of 1.5 (1.60 TPA for 24" class times 1.5).

   Now, continue with this same process (multiply TPA in the 22" class by the q factor being evaluated) until you've computed the number of trees for each 2-inch diameter class. For our q factors of 1.1, 1.3, and 1.5, calculation results are presented in table 6.

Table 5: K factors for a range of maximum diameter tree sizes (D factor), and for 10 q factors.

D Factor	q=1.1	q=1.2	q=1.3	q=1.4	q=1.5	q=1.6	q=1.7	q=1.8	q=1.9	q=2.0
8	0.70	0.75	0.80	0.85	0.91	0.98	1.04	1.11	1.19	1.27
10	1.32	1.44	1.59	1.74	1.92	2.11	2.32	2.55	2.80	3.08
12	2.23	2.52	2.85	3.22	3.66	4.16	4.72	5.37	6.11	6.94
14	3.52	4.09	4.77	5.58	6.56	7.72	9.10	10.74	12.67	14.94
16	5.27	6.30	7.60	9.21	11.23	13.75	16.87	20.73	25.47	31.29
18	7.57	9.33	11.64	14.67	18.62	23.76	30.44	39.07	50.16	64.34
20	10.51	13.38	17.32	22.71	30.11	40.20	53.94	72.50	97.49	130.80
22	14.20	18.70	25.15	34.44	47.80	66.97	94.32	133.16	187.96	264.51
24	18.76	25.58	35.84	51.35	74.84	110.28	163.54	242.95	359.93	532.17
26	24.32	34.38	50.28	75.58	115.95	180.18	281.53	441.00	687.27	1068.03
28	31.03	45.53	69.63	110.10	178.22	292.46	482.98	797.08	1312.80	2140.33
30	39.04	59.55	95.43	159.04	272.16	473.11	826.96	1442.84	2491.36	4216.45
32	48.53	77.04	129.65	228.27	414.01	762.40	1406.55	2609.76	4703.43	8719.33
34	59.69	98.75	174.85	325.80	627.11	1225.25	2400.99	4658.48	9152.22	16355.00
36	72.72	125.57	234.38	463.17	947.28	1966.27	4098.87	8578.80	16480.00	32717.50

Sources/Notes: K factor is a mathematical coefficient used when making diameter regulation calculations. It is derived from information presented in Alexander and Edminster (1977b); specifically, it was calculated by dividing their Table 2 values by their Table 4 values for a specific 2-inch diameter value. White paper text describes how K factors presented in this table can be used to formulate a diameter distribution, for any combination of q factor ('q=' columns) and maximum tree diameter (D factor column) included in this table, and for a specified value of residual stand basal area (the B factor in a BDq approach). Note: I made calculations for D factors down to 2 inches (because data to do so was available in tables 2 and 4 of Alexander and Edminster 1977b), but I did not include D factors below 8 inches in this table because I find it hard to conceive of a situation where a silviculturist would design an uneven-aged management regime featuring a maximum tree size objective (D factor) of only 2, 4, or 6 inches. But, if I am incorrect in this assumption, you could easily calculate K factors for 2, 4, or 6 inches by using data contained in Alexander and Edminster 1977b (see their tables 2 and 4).

Table 6: Trees per acre (TPA), and basal area per acre (BAA), for q factors of 1.1, 1.3, and 1.5, and a residual basal area (B) value of 120.

DBH Class	Basal Area Per Tree	q factor = 1.1		q factor = 1.3		q factor = 1.5	
		TPA	BAA	TPA	BAA	TPA	BAA
24	3.14	6.4	20.1	3.3	10.5	1.6	5.0
22	2.64	7.0	18.6	4.4	11.5	2.4	6.3
20	2.18	7.7	16.9	5.7	12.3	3.6	7.9
18	1.77	8.5	15.0	7.4	13.0	5.4	9.6
16	1.40	9.4	13.1	9.6	13.4	8.1	11.3
14	1.07	10.3	11.0	12.4	13.3	12.2	13.0
12	0.79	11.3	8.9	16.2	12.7	18.3	14.3
10	0.55	12.5	6.8	21.0	11.5	27.4	14.9
8	0.35	13.7	4.8	27.3	9.5	41.1	14.3
6	0.20	15.1	3.0	35.5	7.0	61.6	12.1
4	0.09	16.6	1.4	46.2	4.0	92.5	8.1
2	0.02	18.3	0.4	60.0	1.3	138.7	3.0
Total		136.8	120.0	248.9	120.0	412.9	120.0

Notes: DBH classes are shown in inverse order because the process described in this white paper makes calculations for the 24-inch class first, and proceeds downward from there by successive 2-inch classes. In the column headings, TPA is Trees Per Acre; BAA is Basal Area per Acre. BAA calculations are made by multiplying the Basal Area per Tree values (col. 2, in square feet per acre) by the TPA values for each q factor shown in columns 3, 5, and 7.

8. **Now that our initial mathematical gyrations are complete, it's time to plot the reference curves for q factors of 1.1, 1.3, and 1.5.** For this step in our process, it is important that q factor reference curves be plotted, as trees per acre, on the same chart containing the existing stand data (existing stand data is presented as a column chart in fig. 8).

   Our Greenhorn stand's existing diameter distribution, and reference curves for q factors of 1.1, 1.3, and 1.5 for a residual basal area (B factor) of 120 square feet per acre, are provided as figure 10.

9. **Compare the existing stand structure with plotted reference curves and decide which q factor 'fits' best.** At this point in the process, you may want to refer to step 4, which describes why we decided to choose a q factor that best fits our existing diameter distribution. As step 4 notes, this prescription preparation process does not require you to pick a q factor close to an existing diameter distribution, although choosing to do so is often advantageous for stands that are already uneven-aged. When evaluating figure 10, we reach the following conclusions:
   a. A q factor of 1.5 is a good fit for 2-, 8-, 18- and 22-inch diameter classes.
   b. A q factor of 1.3 is a good fit for 4-, 6-, 16-, 20-, and 24-inch diameter classes.
   c. A q factor of 1.1 is a good fit for the 16-inch diameter class.

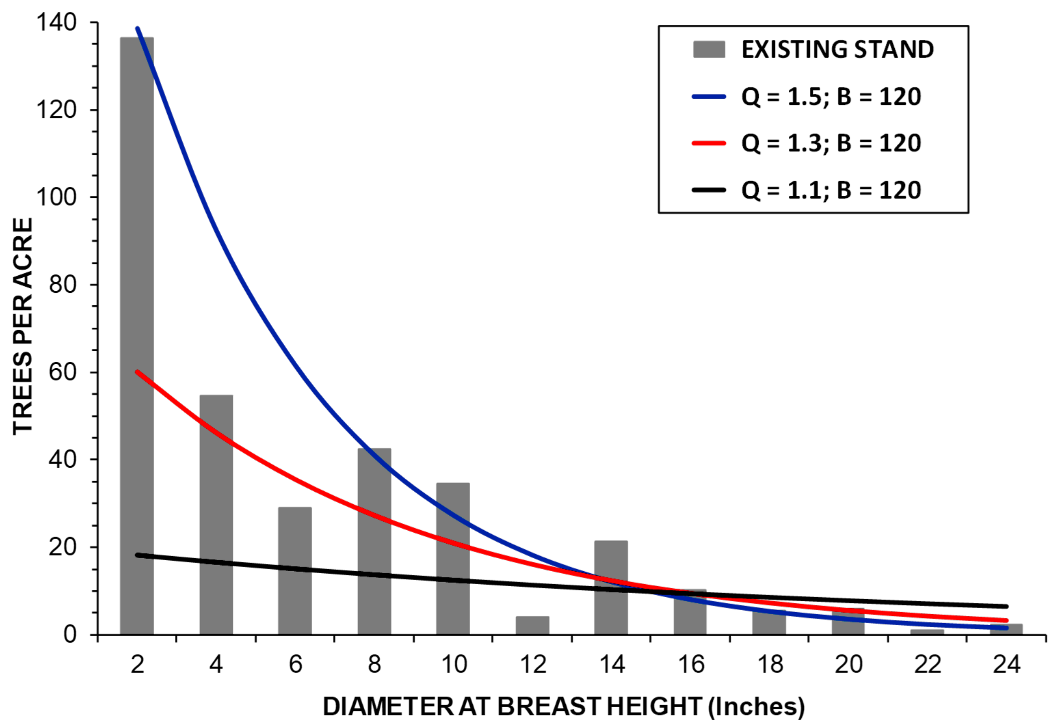


Figure 10 – Existing stand (gray columns) compared with 3 q-factor reference curves. The existing stand (see fig. 8), and all three reference curves, utilize a residual basal area (B factor in BDq approach) of 120 square feet per acre, so everything here is being compared on the same basal-area basis. This chart is designed to help identify which of the reference curves best fits the stand's existing diameter distribution and, for this reason, the stand's existing basal area (120 sq. feet/acre) is used for the calculations (step 4 provides more detail about this objective). Note that a B factor of 120 will not be used to prepare a silvicultural prescription for the Greenhorn stand because it is too high!

Figure 10 indicates that when considering pros and cons of the three q factors we evaluated, a q factor of 1.3 is closest to the Greenhorn stand's existing diameter distribution. Therefore, *we will use a q factor of 1.3 to prepare an uneven-aged prescription for the Greenhorn stand*.

10. **Summarize the BDq factors that will be carried forward to prepare a prescription for uneven-aged management.** At this point in the prescription preparation process, we have now made choices for all three factors in a BDq approach.
    - Step 3 described why we decided to use a residual basal area (B factor) of 80 sq.ft./acre (recall that when evaluating which q factor best fits our stand's existing condition, which is step 6, we used its existing basal area of 120 sq.ft./acre; for the prescription, we selected a 'target' B factor of 80 sq.ft./acre).
    - Step 2 described that for prescription purposes, we will use a maximum tree size (D factor) of 24 inches.
    - Step 9 described that for prescription purposes, we will use a diminution quotient (q factor) of 1.3.

Any combination of the B, D, and q factors defines a unique stand structure. As I've demonstrated in this white paper, the diameter distribution of a desired (target) stand will vary depending on how you select values for these three parameters.

11. **Prepare a table comparing existing tree densities with those we hope to achieve in the future (desired stand condition).** This comparison is included as table 7. I also prepared another chart showing existing and desired (future) tree densities (desired condition is the same as a reference curve for a q factor of 1.3 and a B factor of 80 square feet per acre). This chart is included as figure 11.

    By using table 7 and figure 11, it's easy to see which diameter classes have excess stocking and which have a deficit of trees. *Table 7 will be very useful when preparing a prescription for the Greenhorn stand*.

    After preparing table 7, you may want to graphically compare the desired and residual stand structures. Such a plot would show how close the residual and desired structures would be after an initial harvest. I've prepared this plot for our example stand and it's included as the bottom portion of figure 11.

12. **Choose a cutting cycle.** How should a cutting cycle be selected? You could consider the following factors when making this decision:
    A. *Site Quality.* Highly productive sites respond more quickly to a cultural treatment than those with low productivity. This means that short cutting cycles can be used for highly productive sites, including a cycle as short as 10 years.
    B. *Projected Volume Production.* Harvest viability is usually controlled by an economic or merchantability threshold; below a threshold harvest volume (removal of 2,500 board feet or more per acre, for example), an entry may not be economically viable.

       If a stand can't grow fast enough to produce a threshold harvest volume in a specified timeframe (10 years, let's say), then it's fruitless to consider that time period as a cutting cycle.

       A corollary to item A above: *Since highly productive sites will add volume faster than low-quality sites, they will reach a threshold merchantability volume most quickly, and they can be managed by using shorter cutting cycles*.

       Usually, cutting cycle alternatives will be evaluated during your growth and yield simulations, and simulation results will typically identify which cutting cycle is optimal.
    C. *Other Resource Considerations.* If an uneven-aged stand is in an area with high erosion potential, sensitive soils, or Forest Plan objectives emphasizing wildlife solitude or water-yield augmentation, long cutting cycles may be selected regardless of a site's potential productivity or projected volume production.

Table 7: Existing, desired, excess/cut, and residual/leave diameter distributions for the Greenhorn example stand (numbered columns (top row) are described after this table).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
DBH	**BA/Tree**	**Existing Stand**		**Desired Stand**		**Excess/Cut**		**Residual/Leave**	
(Inch)	(SF/Ac)	TPA	BAA	TPA	BAA	TPA	BAA	TPA	BAA
2*	.02	136.3	3.0	40.0	0.9	0.0	0.0	136.3	3.0
4	.09	54.5	4.8	30.8	2.7	0.0	0.0	54.5	4.8
6	.20	28.9	5.7	23.7	4.6	0.0	0.0	28.9	5.7
8	.35	42.5	14.8	18.2	6.4	24.3	8.5	18.2	6.4
10	.55	34.6	18.9	14.0	7.6	20.6	11.2	14.0	7.6
12	.79	4.1	3.2	10.8	8.5	0.0	0.0	4.1	3.2
14	1.07	21.3	22.8	8.3	8.9	13.0	13.9	8.3	8.9
16	1.40	10.2	14.2	6.4	8.9	3.8	5.3	6.4	8.9
18	1.77	5.4	9.5	4.9	8.7	0.5	0.9	4.9	8.7
20	2.18	5.9	12.9	3.8	8.2	2.1	4.6	3.8	8.2
22	2.64	1.1	2.9	2.9	7.7	0.0	0.0	1.1	2.9
24	3.14	2.3	7.2	2.2	7.0	0.1	0.2	2.2	7.0
Total		347.1	119.9	165.9	80.0	64.4	44.7	282.7	75.2

* Does not include the seedling size class (682 growing-stock seedlings per acre).
Solid red line at 7" DBH (e.g., red line between 6" and 8" rows) shows minimum threshold diameter. Dashed red lines after 12" and 18" DBH delimit diameter groups used for the prescription and marking guides (appendix 3).

COLUMN DESCRIPTIONS

1: DBH class, with each class encompassing 2 inches (2-inch class = 1.0 to 2.9-inch trees).
2: Basal area of a tree with a diameter equal to the midpoint of the diameter class.
3: Density of live, growing-stock trees (typically taken from a stand exam report).
4: Multiply the value in column 2 by tree density in column 3 to compute these basal area values.
5: Density of live, growing-stock trees associated with a q factor of 1.3 and a B factor of 80; TPA values were computed by using steps 6 (K factor) and 7 (q factor) of the prescription preparation procedure.
6: Multiply the value in column 2 by tree density in column 5 to compute these basal area values.
7: Subtract the value in column 5 from the value in column 3 unless column 5 is larger, in which case 0 is entered in this column. Always enter a value of 0 for all classes below your 'minimum threshold diameter,' which is usually 5 or 7 inches DBH depending upon whether a multi-product timber sale will be prepared. For this example, a minimum threshold diameter of 7 inches is used; a red line shows the diameter break for a minimum threshold diameter.
8: Multiply the value in column 2 by tree density in column 7 to compute these basal area values.
9: Subtract the value in column 7 from the value in column 3 (existing tree densities) to compute these residual tree stocking values.
10: Multiply the value in column 2 by tree density in column 9 to compute these basal area values.

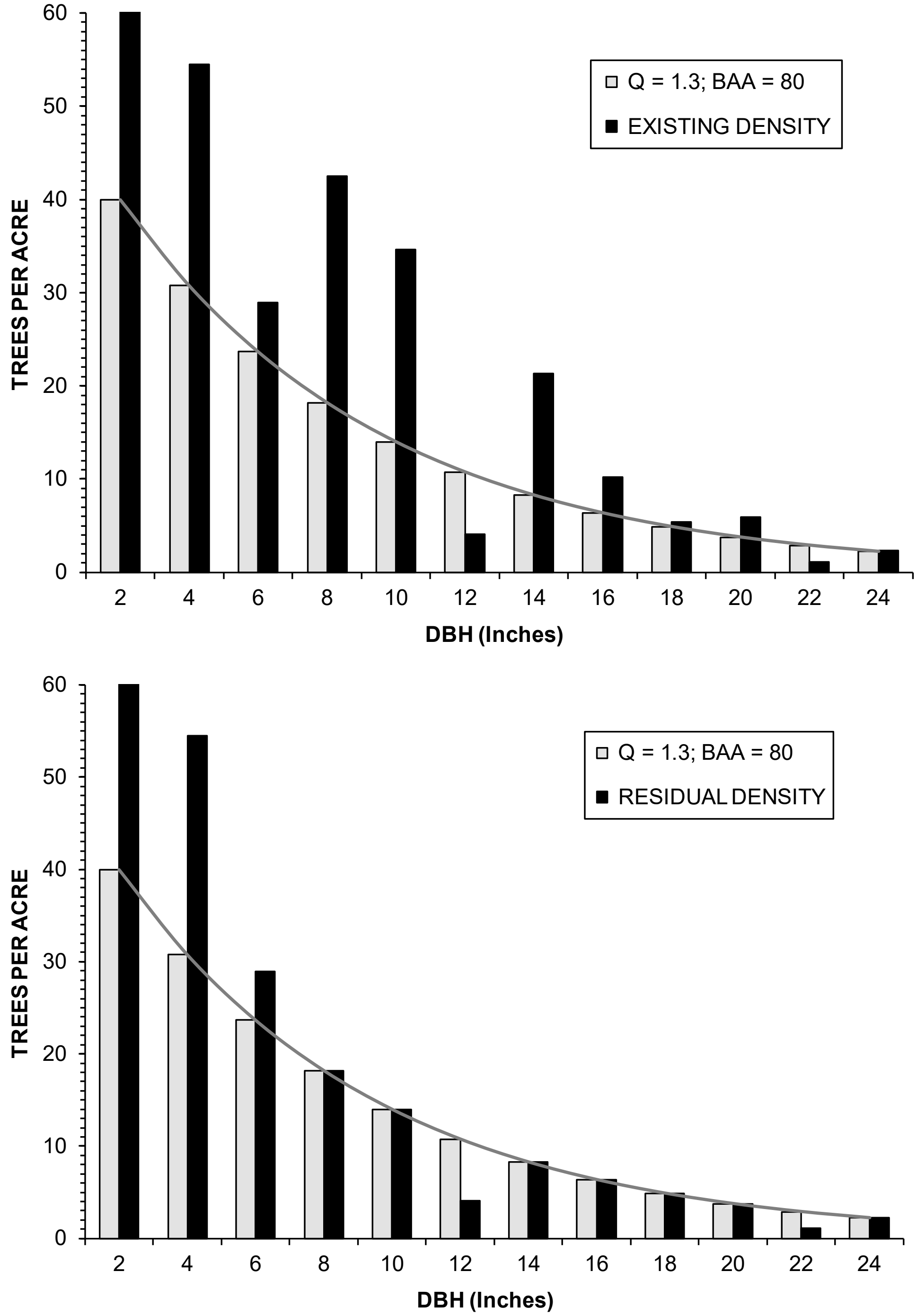


Figure 11 – Existing density versus target density (above), and residual density versus target density (below). In both charts, gray columns and a gray line show the same diameter distribution (trees per acre for a q factor of 1.3 and a B factor of 80 square feet per acre). In the upper chart, black columns show existing tree density; black bars extending above the gray line include excess stocking; black bars occurring below the gray line indicate deficit stocking. In the lower chart, black bars show residual (post-harvest) density – excesses for the 8, 10, 14, 16, 18, and 20 dbh classes are now gone because they were harvested.

13. Put the stand data into a growth and yield simulator and test alternative management regimes. Simulations will show how soon the classes with deficits will reach optimum stocking, and how many seedlings must become established following each entry to assure perpetuation of an uneven-aged condition.

Growth and yield simulations also provide valuable information about the outputs or consequences associated with a management regime, including estimates of residual basal area, quadratic mean diameter, residual stem density, and average stand height after harvest.

Completing growth and yield simulations for our Greenhorn example stand could incorporate the following considerations:

A. *Calibrate the model's mortality performance*. Our example stand has gross growth of 54.8 cubic feet per acre per year (cf/ac/yr), mortality of 31.8 cf/ac/yr from spruce beetle activity, and a resultant net growth of 23 cf/ac/yr. Simulations with differing values for the model's mortality parameters should be made until one is obtained with a net growth rate close to that for your stand.
Note About Calibration: You should be careful about calibrating mortality when it is related to an episodic factor such as bark-beetle activity. 'Background' mortality controlled by factors such as intertree competition (e.g., stand density) is appropriately addressed by calibration because it can be thought of as a 'constant,' at least if existing stand conditions are maintained, but episodic mortality is not what you would expect your stand to experience all the time. If your modeling system (FVS, for example) accounts for an episodic agent (spruce beetle for our example stand) in the base model or an associated extension (and I don't believe that FVS directly accounts for spruce beetle activity), then you could safely calibrate mortality by including its near-term effects because when stand conditions change after treatment, the model or extension will adjust episodic mortality rates. But, if a base model or extension does not account for an agent, then you might want to consider not adjusting background mortality rates because they could be maintained for many simulation cycles, an undesirable outcome for bark beetles and other agents that respond to management activities.

B. *Spending quite a bit of time on mortality calibration is warranted,* especially if stand growth and volume production are important considerations. If the model has different parameters for large-tree and small-tree mortality, it may be helpful to examine differing combinations of them to obtain a satisfactory result.

C. *Examine your stand's mortality circumstances closely* to determine if tree death is related mostly to intertree competition from overstocking/high density, or if it occurs primarily in response to a specific damage agent. [Refer to your stand's inventory printout or stand exam reports for this information.] For our example stand, most recent mortality is attributable to spruce beetle activity.

D. *Future and ongoing spruce beetle susceptibility can be rated* by using four factors (Schmid and Frye 1976): (1) basal area; (2) physiographic location; (3) average diameter of overstory trees; and (4) canopy proportion comprised of spruce.
For our Greenhorn example stand, rating results are:
<u>Basal area</u>: moderate risk (total basal area falls between 100 and 150 sq. ft./ac.).
<u>Physiographic location</u>: moderate risk (as based on measured site index value).
<u>Average overstory diameter</u>: moderate risk (Average Stand Diameter, for live spruce trees ≥ 10" only, falls between 12" and 16").
<u>Spruce proportion</u>: high risk (> 65% of overstory canopy is spruce).
Note that silvicultural treatments can be used to address three of the four spruce beetle rating factors; the only factor that functions as a constant is physiographic location, which relates to site index and biophysical conditions.

E. *The most common modeling system is the Forest Vegetation Simulator (FVS)* (Dixon 2015), which has specific geographical variants available for most areas of the country. Unfortunately, FVS does not have a specific 'extension' for spruce beetle, so it is not capable of directly tracking spruce beetle susceptibility changes during a simulation. However, changes in three of the four factors described above can be easily tracked through time by examining model output, or by using an FVS Compute keyword to calculate those spruce beetle susceptibility parameters periodically and report them along with other simulation results.

F. *If FVS is being used, use SDIMAX keywords to calibrate mortality* related to inter-tree competition and stand density. SDIMAX parameters will vary by ecological setting (plant association) and by tree species. For the Blue Mountains, specific default values of SDIMAX have been established for combinations of plant association and tree species (Powell 2014).

G. *Make simulations to examine alternative prescriptions* after mortality calibration and other preparatory work has been completed. The following prescriptions were tested for our Greenhorn example stand:

   1. *Selection cutting with a 10-year cutting cycle*. Seedlings were established after each entry, a residual basal area of 80 square feet per acre was used, and trees were removed from all diameter classes after first cutting all trees 26-inches DBH and larger.

      [For most modeling systems, a minimum threshold diameter of 5 or 7 inches will be used for commercial harvests – only trees larger than the minimum diameter will be harvested. This means you will need to include non-harvest keywords to adjust tree density for noncommercial diameter classes below the minimum threshold value.]

   2. *Selection cutting with a 20-year cutting cycle*. Otherwise, the same specifications as for number 1 above.

Note: I didn't evaluate selection cutting with a 30-year cutting cycle because this site's productivity (site index of 78 feet at 100 years) results in too much volume production to reasonably analyze longer cutting cycles (30 or 40 years). Average harvest volume was about 2,500 board feet per acre with a 10-year cutting cycle, and 5,500 board feet per acre with a 20-year cutting cycle, once the stand's diameter distribution had been regulated.

H. *Evaluate the prescription simulations and modify them if necessary.*

Growth and yield simulations were completed for our example stand. If you are using FVS for growth simulation, consider using a keyword called THINQFA, "thinning using a Q-factor approach" (Dixon 2015). Keep in mind that the THINQFA keyword schedules a thinning from a specified diameter range for any species, species group, or all species to a residual density target (B factor). Residual density (B factor), however, can be specified as basal area per acre, trees per acre, or stand density index. The diameter distribution of the residual stand, for the specified diameter range, will approximate, as closely as possible, an inverse, J-shaped curve determined by a specified diminution quotient (q factor).

Note: When existing density is high (200 or more square feet of basal area per acre), you'll probably want to reach your residual basal area goal in stages. Otherwise, the first entry may be too severe, resulting in unacceptable damage to the residual stand, windthrow, or an excessively large percentage of the stand area being treated in one entry. As a general rule-of-thumb, an initial entry shouldn't remove more than about 40 percent of the existing basal area (and most likely less than 40% for high windrisk situations).

In uneven-aged stands with high susceptibility to spruce beetle attack, pressure to meet a residual basal area objective in one entry (rather than stages) may be especially great. [Spruce beetle susceptibility is rated by using four criteria (Schmid and Frye 1976) but stands with more than 150 square feet per acre of basal area are generally in a high-risk category.]

14. **Incorporate data from table 7, figure 11, and growth and yield modeling in a silvicultural prescription.** I've attempted to do this for our example stand, and the resulting prescription is included in appendix 3.
15. **If the prescription is too complex for direct use by your marking crew, translate the first entry into marking guides.** Once again, I've attempted to do this, and the result is included in appendix 3.

A note regarding the prescription phase (steps 14 and 15) – a wise silviculturist once told me: "Good physicians do not prescribe treatment without first examining the patient, and so it should be with silviculturists." I've examined the patient (our Greenhorn stand) and the result, a site diagnosis, is included in appendix 3. My recommended cutting method, group selection, is described in figures 12-15.

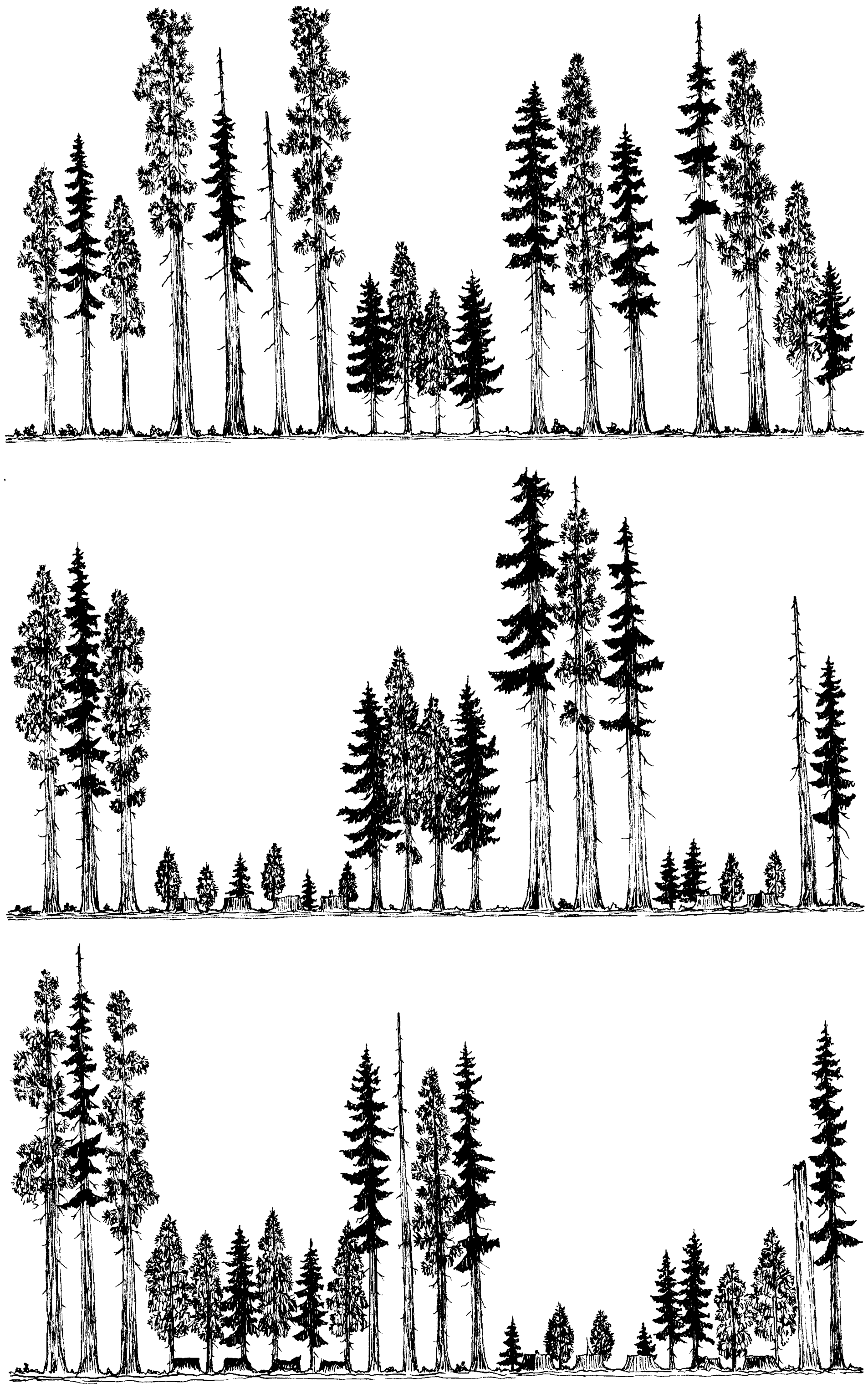
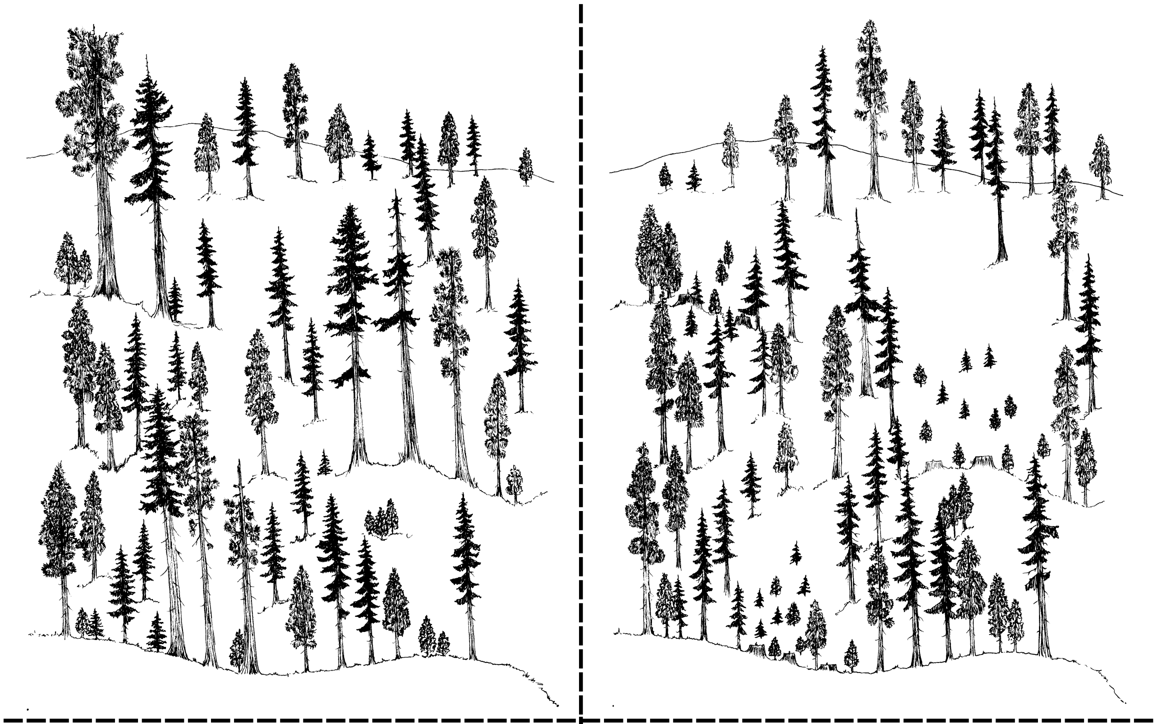


Figure 12 – Group selection cutting (side view). Note that this cutting method is generally used with a naturally groupy or clumpy stand structure (top). As cutting cycles progress (middle and bottom views), groups in varying diameter classes are removed according to uneven-aged diameter distribution objectives.



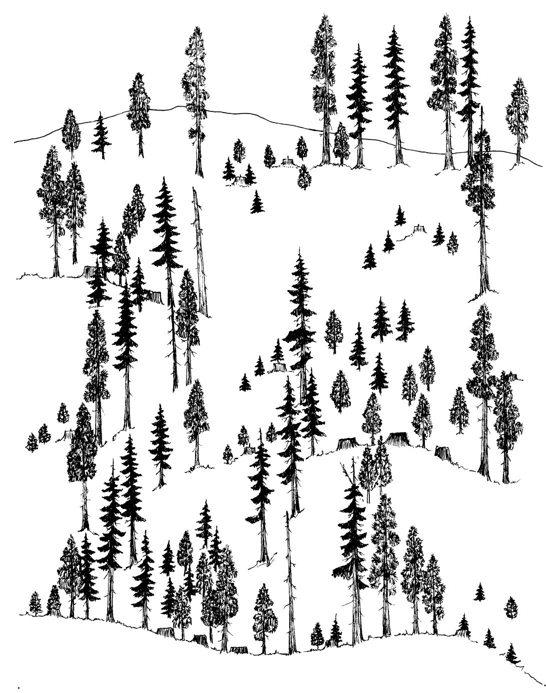


Figure 13 – Group selection cutting method (landscape perspective). A naturally groupy or clumpy stand (upper left) is best used with this uneven-aged method. In response to uneven-aged diameter distribution objectives, natural groups or clumps are identified and removed successively during multiple cutting cycles (upper right and lower right). As each group is harvested, young trees are established by natural regeneration or by outplanting (artificial reforestation). As uneven-aged management progresses, groups regenerate, mature, and are harvested according to parameters established by using the BDq approach to diameter regulation.

Figure 14 – Implementation of group selection cutting. Our untreated stand (top) has a moderately dense overstory of Engelmann spruce, along with good representation of sapling-sized spruce trees and abundant regeneration comprised mostly of Engelmann spruce, along with a smattering of corkbark fir and remnant aspen. Bottom image shows group selection marking. Note the presence of old stumps, showing that this stand has been harvested previously. The small clump in the exact center has been marked for removal with red paint slashes. As uneven-aged management is implemented in this stand and its residual basal area falls toward 80 square feet per acre, we would expect ongoing levels of spruce beetle activity to moderate.

Figure 15 – Results of group selection cutting. This image was acquired immediately after the timber harvest activity had occurred. It effectively conveys the relatively small size of group-selection openings created during the sale. The silvicultural prescription and marking guide called for creating openings in accordance with natural group/clump size, but never wider than 5-8 tree heights because of the stand's water-yield Forest Plan management allocation (fig. 16). In almost every instance, actual group size turned out to be smaller than that constraint. Note that down logs are left as wildlife habitat, and to provide shade for planted spruce seedlings.

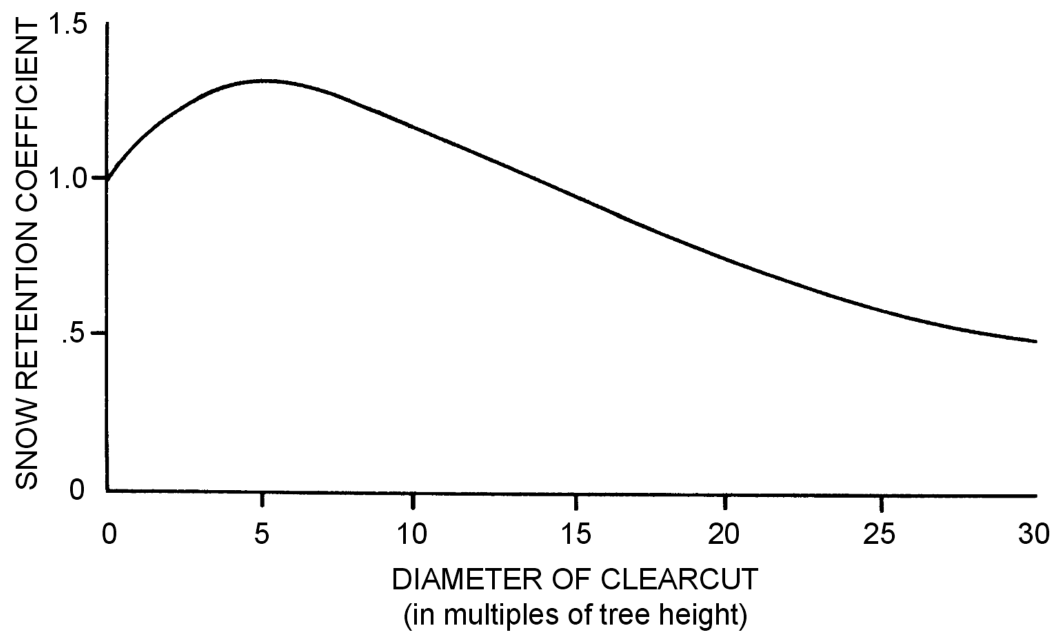


Figure 16 – Snow retention variations with opening size (EPA 1980). For subalpine-zone, spruce-fir forests of the southern Rocky Mountains, snow retention varies with opening size. For this reason, silviculturists can exert a strong influence how much snow is retained on a forested site, and thereby available for melt the following spring, by how opening sizes are designed.

For national forests in semi-arid portions of western U.S., water management is a major consideration because most population centers are in low-elevation valley locations, and much of their water supply is produced from national forests in adjacent mountainous areas. A primary consideration is water yield – can forest management be used to produce more water than would normally occur (Anderson et al. 1976)?

But other forestry considerations involve water quality and floods – some areas in a 'monsoon belt' of the southwestern US (Arizona, New Mexico, Utah, and southern Colorado) receive frequent summer precipitation in high-intensity thunderstorms. For monsoon areas, active management is often geared toward providing forest conditions that maintain a high infiltration capacity and soil protection, including uncompacted soils and intact forest floors (high-functioning litter and duff layers). These measures allow rainfall to remain on site rather than running off and contributing to flash floods and erosion.

Pike and San Isabel National Forests in south-central Colorado, where the example stand for this white paper is located, has a Forest Plan management allocation, 9B, that emphasizes using forest management treatments to increase water yields. As described in the Forest Plan's Final Environmental Impact Statement: "The greatest opportunity for increasing water yield is by creating small openings in the subalpine forest. Research has shown that snow accumulation patterns are optimum when openings are five to eight tree heights in diameter, are protected from the wind and are interspersed so they are five to eight tree heights apart. This results in about 40 percent of a timber stand in small openings with 60 percent of the stand remaining to shelter the openings" (USDA Forest Service 1984, p. III-105).

The Forest Plan states that openings of 5 to 8 tree heights in diameter are optimal for redistributing the snowpack in such a way as to maximize water yield increases.

HOW ABOUT AREA BETWEEN GROUPS?

Historically, many silviculture texts emphasized the importance of <u>not</u> treating areas between groups when implementing group selection regeneration cutting. The reason for this admonition involves complexity: it can be quite difficult to apply a mix of regeneration cutting (group selection) and intermediate cutting (commercial thinning, release, improvement cutting, etc.) *in the same stand or unit at one time*.

Think about it: for most management situations, a single treatment unit (stand or cutting unit) receives only one 'commercial' prescription for each entry (cutting cycle), regardless of whether it pertains to a regeneration or intermediate cutting method – a shelterwood seed cut, an improvement cutting, etc. One or the other method would be implemented for a unit or stand, but generally not both in the same treatment unit.

Often, a prescription also includes 'cultural' (noncommercial) activities to be accomplished after a commercial entry has finished – reforestation, noncommercial thinning, or similar treatments. The combination of a commercial treatment, and one or more noncommercial treatments, for a single cutting cycle is common, but it is relatively rare to have a situation where regeneration cutting, and a 'commercial' intermediate cutting, are both prescribed *for the same unit and the same entry*.

Note that this discussion involves prescriptions, and not trees. I recognize that it is common to have one prescription deal with a variety of tree sizes and their associated merchantability (commercial versus noncommercial). When prescribing a shelterwood seed cut, for example, we would expect both small and large commercial-size trees to be removed, from below, and to have some (or all) of the noncommercial trees be removed as well. But, specifications for how all these tree classes would be handled (retained or removed) will be covered in only one prescription – for the seed cut.

Now, back to the group-selection situation. This scenario could happen: a silviculturist prescribes group selection for an entire stand, with markers using specifications contained in a prescription (and marking guide) to evaluate natural tree groups and decide to either retain or remove an entire group. But if a silviculturist is also concerned about the health and vigor of untreated areas between groups (will they be in good shape in 20 years, when the next cutting cycle occurs?), then an intermediate treatment such as improvement cutting may be prescribed for areas between the groups.

Group selection and improvement cutting being used in the same cutting cycle requires preparation of two prescriptions (or a "prescription within a prescription"): one Rx provides specifications for group selection and another provides specifications for improvement cutting. If you attempt this scenario, I recommend that each treatment be marked separately (e.g., two passes through the unit) and preferably be done by different marking crews.

As mentioned at the beginning of this section, early silviculture texts addressed the complexity described here by stating that none of the area between groups should be treated. Only groups could be entered during a cutting cycle; no 'non-group' area could be treated in any way, either commercially or noncommercially.

For group-selection cutting, I do not agree with adopting a complete 'hands off' approach for areas between groups. However, I urge you to be judicious about using group selection and intermediate cutting in the same unit and at the same time. If not applied carefully, it could result in a botched, mish-mash outcome that would unnecessarily complicate future management for the stands (units) involved.

HOW ABOUT UNMERCHANTABLE TREES?

The Prescription Preparation Procedure section of this white paper utilizes all 2-inch size classes down to, and including, the 2-inch diameter class. The 0-inch diameter class (seedlings), however, is traditionally not included because seedlings do not have any basal area (and are unaffected by the B factor). But, I encourage you to include the seedling class (0" DBH) when making trees-per-acre calculations. Some sources (including Alexander and Edminster 1977b) truncate their diameter-distribution calculations so they end with the 4-inch or 6-inch class because trees below that class are unmerchantable.

When examining diameter distribution (stand regulation) alternatives, I believe it is important to ignore merchantability and include every 2-inch diameter class. For this reason, all tables and charts included in this white paper include a full range of 2-inch classes, beginning with the 2-inch class on the low end. [And, I could have easily included the 0-inch class for all trees-per-acre calculations. If you refer to the silvicultural prescription section (appendix 3), I did include the 0-inch class for the prescription.]

It is also important to include all diameter classes when completing stand examinations or other inventories. Although seedling data may not be as important when making diameter distribution calculations because they don't contribute to basal area, and basal area is an important variable in a BDq regulation approach, it is extremely important to collect seedling information during field inventories!

Some literature sources in the References section, including Alexander and Edminster (1977b), describe a process for making mathematical calculations for diameter distributions that begin at 4 inches or 6 inches on the low end. If you are interested in doing this, then refer to Alexander and Edminster (1977b, p. 7) for instructions about how to make the calculations.

I strongly recommend that your diameter distribution calculations include every 2-inch diameter class from 2 inches up to your maximum tree size (24 inches, 26 inches, 32 inches, or whatever you select as an upper diameter limit). You need to know what is happening with all portions of your target diameter distribution – the 2-inch class dictates how many trees are available to move into the 4-inch class, and so forth. (And, it is just as important to know if too many trees are expected to move into a class.)

Including information about small diameter classes, primarily for stand regulation and prescription preparation purposes, does not imply that small trees are merchantable. This concept is clearly illustrated in table 7 – every diameter class between 2 and 24 inches is shown because they are all important when calculating a diameter distribution, but a red line between the 6- and 8-inch classes clearly shows a separation between merchantable and unmerchantable stems.

WHAT IT TAKES TO MAKE UNEVEN-AGED MANAGEMENT WORK

Proper application of uneven-aged management is complex, especially when compared with even-aged management. If you decide to prescribe selection cutting, you need these items to really make it work:

1. **Detailed stand information.** Better information than we are now gathering is often needed for uneven-aged management. A typical stand examination, even if completed to intensive (survey level 4) standards, won't provide usable information if only 1 point is sampled for every 10 acres of site area. Remember that an old "1 point for every 10 acres" guideline, used in many Regions for almost as long as stand examinations have been completed, was designed to apply to basal area only. When preparing a silvicultural prescription for uneven-aged management, good information about tree density is as important as accurate data about basal area.
2. **A silvicultural prescription.** A silvicultural prescription should incorporate stand regulation and diameter distribution objectives, as discussed in the Prescription Preparation Procedure section of this white paper. It should also describe desired conditions expected in the future. Treatment specifications should be detailed enough that the prescription could be used for follow-up monitoring and evaluation. If marking guides are used, a prescription probably has more utility for post-treatment monitoring than it does for on-the-ground preparation of an initial harvest entry (but a prescription is a prerequisite for preparation of marking guides).
3. **Good stand records.** A silvicultural prescription, and the stand structure objectives it contains, must be retained to be fully useful. Uneven-aged management won't work if we set different stand regulation objectives for each entry. Follow-up information (regeneration surveys, post-treatment examinations, etc.) is important for evaluating all silvicultural treatments, but especially so for uneven-aged management. Reaching a desired diameter distribution will require establishment of natural regeneration after each entry; maintenance of good stand records (in site folders and computerized data base systems such as FSVeg and FACTS) will be the easiest way to

monitor and evaluate our progress toward these objectives.

4. **Tight control.** A silvicultural prescription for uneven-aged management is more complex and detailed than those prepared for even-aged cutting methods. Prescription objectives will never be attained if sloppy layout, marking, or logging result in a woods job having little resemblance to a desired stand structure.
5. **Skilled help.** Both a professional-level prescription and technician-level marking must be done with more expertise than we're accustomed to using. Markers must not only select cut trees based on damages, vigor, form, and other typical evaluation criteria, but they also need to keep detailed records on tree-tally forms, or by using tally-whackers, as marking progresses. Cut-tree selection is complicated further because all diameter classes (above a minimum threshold diameter) are generally treated; this differs from even-aged, partial cutting where nothing except large, co-dominant and dominant trees are left.
6. **Discipline.** A long-term commitment is needed. Sometimes, managers don't want to be tied down with a long-term plan or prescription, especially if they perceive it as unduly restricting their future flexibility. Occasionally, an employee new to an area may be unwilling to find out what their predecessor intended for a stand, much less execute the next step as it was planned. [Or, they may be unable to find this information, especially if stand-level record-keeping has not been completed well.]
7. **Willingness to learn.** If you are trying this silvicultural system for the first time, look for local examples and practice on a small area first. Be aware of, and understand, the risks you are taking, and that mistakes may be inevitable. Because each implementation is a new learning opportunity, be creative and innovative, and bear in mind that we often learn best from our mistakes. Start slowly on a forgiving area, so any lessons you learn come with minimal pain.

Unfortunately, many practitioners of the art of uneven-aged management haven't been able (or willing?) to consider the items discussed in this section. The result was not unexpected – widespread dissatisfaction with uneven-aged management, and a national trend beginning in the late 1940s or early 1950s toward exclusive use of even-aged cutting methods (USDA Forest Service 1978).

[Please don't misconstrue my editorial comment here – I readily admit that a trend toward exclusive use of clearcutting and even-aged management was based on much more than just dissatisfaction with early attempts at uneven-aged management.]

USING COMMON SENSE WITH UNEVEN-AGED MANAGEMENT

Uneven-aged management acquired a tarnished reputation because it's perceived to be cumbersome, complex, impractical, and uneconomical. For some situations, these claims are true and uneven-aged management shouldn't be used.

A few thoughts about when and how to use uneven-aged cutting methods:

1. **Work in areas with high resource values.** Uneven-aged management is well suited to sensitive road corridors, developed recreation sites, and administrative sites, but only if they're valuable enough to guarantee that a good job will result.

   Often, timber values in the outback are not high enough to prevent a hasty job. High preparation and administration costs for selection cutting may put undue pressure on sale layout personnel to remove all the big or high-value stumpage. The result could be another example of a 'mill cut' or 'high-grade' operation under the guise of uneven-aged management.
2. **Don't try too much.** Limit the amount of uneven-aged management you attempt. With limited labor and financial resources, attempts to manage thousands of acres by using individual-tree or group selection could result in a series of botched partial cuts. <u>A bottom line</u>: don't bite off more selection than you can successfully chew!
3. **Make your job easier when possible.** It is more practical to prepare marking guides based on 5- or 6-inch diameter classes than the 2-inch classes used in the Prescription Preparation Procedure section. You should, however, use the 2-inch diameter classes to prepare your inverse-J curves and compare stand tables (Table 7), but aggregate them into larger classes for marking purposes.

   If you're preparing a multi-product timber sale, it might be possible to work with 5 diameter classes: 1- to 5-inch trees, 6- to 10-inch trees, 11- to 15-inch trees, 16- to 20-inch trees and 21-inch and greater trees. Since 1- to 5-inch trees are below your merchantability threshold and won't be marked, markers only have four classes to worry about (and keep records on as marking progresses).

   If a multi-product sale isn't used, four diameter classes might be appropriate: 1- to 6-inch trees, 7- to 12-inch trees, 13- to 18-inch trees and 19-inch and greater trees. Since the 1- to 6-inch trees won't be marked, markers only have three classes to keep track of. [This approach is used for our Greenhorn example stand – see my diameter-class breaks shown with red lines in table 7.]

   For the initial entry, aggregating 2-inch diameter classes into larger groupings works best when adjacent classes have a similar condition, such as excess trees that should be harvested or a stocking deficit. When adjacent, 2-inch classes include a mix of treatment needs, including some classes with excess trees and others with deficits, aggregation will likely not work as well.
4. **Guides for choosing a Q factor are subjective.** Keep in mind that your objectives in practicing uneven-aged management are to:

   a) establish good conditions for regeneration, tree growth, and stand development;
   b) provide a sustained yield of wood products; and
   c) maximize yield by establishing a harvest system where removals equal growth.

As you gain experience with uneven-aged management, you'll discover which q factors are best meeting these objectives while simultaneously producing the stand structure you want.

5. **Work with the existing stand structure whenever possible.** A stand's existing diameter distribution should influence your choice of a q factor and other regulation objectives. Any attempt to 'strong-arm' a certain diameter distribution in a stand where it doesn't really fit is a good way to make a difficult job even harder.
6. **Pay close attention to tree marking.** Timber marking provides clear direction to fallers during timber harvest, and it allows us to select individual trees with the greatest potential to respond positively to the treatment being prescribed.

   Marking is challenging work, particularly for UEAM prescriptions, and it should be conducted by highly qualified employees. Ideally, UEAM markers will be familiar with timber cruising, silviculture, and harvest operations, including falling and skidding principles. Here are some marking mechanics to consider:

   a. The residual stand should not be composed of 'left-overs' (Fiedler 1995, p. 106); it should consist of individuals specifically identified and selected for retention.
   b. Marking should be done in the quickest and least costly manner: mark-to-leave, mark-to-cut, or a combination of the two.[2]
   c. In addition to the typical process of marking a ring or slash at breast height, and short vertical stripes or splotches as a stump mark, consider utilizing two colors (if allowed by your marking policies) to help support your marking guides: "Cut all the fir except those marked with blue, and leave all other species except those marked with orange."
   d. UEAM can require high precision levels in terms of tree falling control and direction. Consider marking trees that need to be felled in a specific direction with a vertical arrow on the side to which the tree must be felled.
   e. For individual-tree selection harvests, rub trees may be needed to protect residual trees from skidding damage, especially at places where skid trails turn.

      Consider marking rub trees as leave trees, and then have a sale administrator re-mark them for removal after skidding is finished. For UEAM operations, it is common to plan on 3-5% of total volume being allocated to wounded trees that will eventually be removed when logging is nearly complete.
   f. For UEAM prescriptions, markers will need to periodically ensure that target residual basal area (and stand structure) objectives are being achieved. Generally, this monitoring is best achieved by swinging a prism or angle gauge as marking operations progress.

[2] Note that Aho et al. (1983) recommend leave-tree marking when working with true firs such as grand fir, at least when accounting for residual tree damage for stands where some true firs will be retained.

APPENDIX 1: TERMINOLOGY AND DEFINITIONS

Active management. Planned, intentional actions in an area specifically designed to obtain a desired objective or result (Boise Cascade Corporation 1996).

Advance regeneration. Trees that have become established naturally under a mature forest canopy *and can develop normally if the overstory is removed or killed*.

Basal area. Cross-sectional area of a single tree stem, including bark, measured at breast height (4½ feet above ground surface on upper side of the tree); also, the cross-sectional area of all stems in a stand and expressed per unit of land area (e.g., basal area per acre).

B factor. In a BDq approach to uneven-aged management, B factor pertains to a residual basal area objective for a managed, uneven-aged stand, expressed in square feet per acre, such as 80 square feet per acre of basal area.

BDq approach. A variety of approaches have been developed for uneven-aged stand regulation. A BDq approach involves regulating stand structure by using three factors: residual basal area (B factor) specifying how much stand basal area will be retained after each cutting cycle; maximum tree diameter (D factor) specifying the largest tree size to be managed for (larger, unregulated trees could be retained for wildlife or other purposes, but these 'ghost trees' will be ignored when making BDq calculations); and optimum diameter-class distribution (q factor) specifying a diminution rate for trees per acre across 2-inch diameter classes. [Definition follows usage in this white paper.] *Also see*: B factor; D factor; J curve; maximum diameter; Q factor; and reserve growing stock.

Cleaning. An intermediate treatment completed in stands where trees are sapling-sized or smaller. Its sole purpose is to release one or several favored species from the dominance of one or more undesirable species (Daniel et al. 1979).

Climax. A culminating seral stage in plant succession for any given site where, in the absence of catastrophic disturbance, the vegetation has reached a highly stable condition and undergoes change very slowly (Dunster and Dunster 1996). A self-replacing community that is relatively stable over several generations of the dominant plant species, or very persistent in comparison to other seral stages (Kimmins 1997).

Cohort. A group of trees developing after a single disturbance, commonly consisting of trees of similar age, although one cohort can include a considerable span of ages ranging from seedlings or sprouts to trees that predate the disturbance (Helms 1998). Stands are often characterized as single-cohort or multicohort depending on whether they contain one or several cohorts (Oliver and Larson 1996).

Crown class. A categorization or classification of trees based on their crown position relative to adjacent trees within the same canopy stratum; four primary crown classes are recognized: Dominant, Codominant, Intermediate, and Subcanopy (Suppressed).

Cutting cycle. A planned interval, in years, between partial harvests in an uneven-aged stand (Helms 1998).

Cutting method. Intentional application of commercial or noncommercial activities in a tree stand that are designed to obtain regeneration or otherwise establish a new stand or tree cohort (regeneration cutting methods), or to tend (culture) an existing stand by modifying its species composition, stand density, or vertical structure (intermediate cutting methods such as release, thinning, weeding, etc.) (Smith et al. 1997).

D factor. In the BDq approach to uneven-aged management, D factor pertains to a maximum tree size objective for a managed, uneven-aged stand, expressed as a diameter, such as 24" DBH.

Diameter distribution. In the context of uneven-aged management, diameter distribution refers to a desired number of trees in each diameter class for a managed, uneven-aged stand. It can be portrayed as a mathematically-derived curve, the shape of which is controlled by a stand's q factor, residual basal area (B factor), and maximum tree diameter (D factor).

Diminution quotient. Generally viewed as a synonym for q factor (and see that glossary term). Diminution quotient expresses how stocking levels diminish, across diameter classes, for a diameter distribution progressing from small diameter classes (relatively many stems) to large diameter classes (relatively few stems). A diminution quotient (q factor) of 1.5 is a ratio of tree decline (diminution) for adjacent, 2-inch classes (mathematically, when number of stems in the 2-inch class is divided by number of stems in the 4-inch class, the ratio is 1.5; conversely, when number of stems in the 4-inch class is multiplied by 1.5, the result is number of stems in the 2-inch class).

Ecosystem management. Management driven by explicit goals, executed by policies, protocols and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function (Christensen et al. 1996).

Forest. An ecosystem characterized by a more or less dense and extensive tree cover, often consisting of stands varying in characteristics such as species composition, structure, age class, and associated processes, and commonly including meadows, streams, fish, and wildlife (Helms 1998).

Forest density management. Cutting or killing trees to increase intertree spacing and to accelerate growth of remaining trees; manipulation and control of forest (tree) density to achieve one or more resource objectives. Forest density management is often used to improve forest health, to open the canopy for selected trees, to maintain understory vegetation, or to promote late-successional characteristics for biological diversity (Helms 1998).

Forest health. Perceived condition of a forest based on concerns about such factors as its age, structure, composition, function, vigor, presence of unusual levels of insects or disease, and resilience to disturbance. Note that perception and interpretation of forest health is influenced by individual and cultural viewpoints, land management objectives, spatial and temporal scales, relative health of individual stands comprising the forest, and appearance of the forest at any point in time (Helms 1998).

Forest management. Generally, a branch of forestry concerned with its overall administrative, economic, legal, and social aspects, and with application and coordination of its essentially scientific and technical aspects such as silviculture, protection, and regulation (Doliner and Borden 1984).

Forest stand. A contiguous group of trees sufficiently uniform in age-class distribution, composition, and structure, and growing on a site of sufficiently uniform quality, to be a distinguishable unit (Helms 1998).

Group selection cutting. Removal of small groups of trees to meet predetermined diameter distribution, residual basal area, and species composition objectives. The distance across an opening created by this cutting method is usually no more than 1 to 8 times the surrounding tree height, up to a maximum size of 2 acres.

Growing space. An intangible measure of total resources of a site (sunlight, moisture, nutrients, etc.) that are available to a plant (Helms 1998). Growing space refers to availability of all resources needed by a plant to exist on a given site (O'Hara 1996).

Improvement cutting. Cuttings made in poletimber or sawtimber stands to improve their composition and quality, mainly by removing trees of undesirable species, form, or condition from the main canopy.

Individual-tree selection cutting. Removal of selected trees from specified size or age classes, over an entire stand area, to meet predetermined diameter distribution, residual basal area, and species composition objectives.

Intermediate treatment. Any silvicultural "manipulation in a stand that occurs between two regeneration periods" (Daniel et al. 1979). Intermediate treatments include a wide range of practices, including those classified as 'release cuttings' (cleaning, improvement cutting, thinning, etc.), along with fertilization, pruning, and prescribed fire.

J curve. A diminution quotient (q factor) curve expressing a desired diameter distribution for an uneven-aged stand. For large q factors, curve shape resembles an inverse or reverse 'J'.

K factor. A mathematical coefficient that simplifies computing the number of trees in the largest diameter class when regulating the diameter distribution of an uneven-aged stand.

Leave tree. A tree retained after even-aged regeneration cutting – leave tree characteristics are the same as for reserve trees (see that glossary term), but fewer are retained per acre than when prescribing reserve trees. As described for reserve trees, leave trees are retained for purposes other than regeneration, and they comprise a minor portion of the stand, which is defined as less than 10% of full stocking. For the Blue Mountains, full-stocking values are provided, by plant association and tree species, in Cochran et al. (1994) and Powell (1999).

Low thinning. Removal of trees from lower crown classes, layers, or strata to favor those in upper crown classes, layers or strata; also referred to as "thinning from below."

Marking guide. A marking guide provides written direction, typically prepared by a certified or qualified silviculturist, and silvicultural guidelines or specifications for selecting trees to retain, or optionally trees to remove, to accomplish specific stand management objectives. Marking guides provide operational direction and guidelines to implement a detailed silvicultural prescription. They are written in such a way as to convey detailed specifications, and to clarify concepts and silvicultural terminology, related to why and how trees are selected and marked to implement a specified cutting method in a designated stand or treatment unit.

Maximum diameter. Largest diameter (DBH) that trees can reach before cutting. For the BDq approach to uneven-aged management, this D factor, along with specified q factor and residual basal area values, control a stand's diameter distribution.

Natural regeneration. Renewal of a forest community by natural (as compared to human) means, such as tree seedling establishment from seed produced on-site or from adjacent areas, or from seed brought in by wind currents, birds, or animals.

Overstocked. Forestland supporting more trees than normal, or more trees than full stocking requires (Dunster and Dunster 1996). In an overstocked forest stand, tree density is so high that intense intertree competition occurs, and large trees are taking growing space away from small trees in a density-dependent process called self-thinning.

Overstory. In a forest with more than one story (layer), overstory is that portion of the tree canopy forming the uppermost layer; in a two-storied forest (stands with two clearly defined canopy layers), the tallest trees form the overstory and the shortest trees the understory (Helms 1998).

Partial cutting. Harvest operation in which only certain trees are removed from a stand of merchantable trees.

Q factor. Ratio of trees in one diameter class to those in an adjoining (smaller) class. Low q factors have less difference in the number of trees in adjacent diameter classes than high q factors. High q factors result in a curve whose shape is like an inverse or reverse 'J'. Also see: diminution quotient (and, I believe q factor relates to quotient-factor, reinforcing a relationship between the q factor and diminution quotient terms).

Reforestation. Natural or artificial renewal of a forest ecosystem by establishing trees. Also called regeneration.

Release cutting. Cuttings that free young trees (seedlings or saplings) from the competition of undesirable trees threatening to suppress them. Release cuttings are generally considered to form the broadest grouping of intermediate treatments, including weeding, cleaning, liberation, improvement cuttings, and thinnings (Daniel et al. 1979).

Reserve growing stock. Specified stocking to be retained after an uneven-aged entry; usually expressed in terms of basal area. Typically referred to as *residual basal area*.

In the BDq approach to uneven-aged management, reserve growing stock is controlled by the B factor (B refers to basal area).

Reserve trees. Live trees, pole-sized or larger, retained in either a dispersed or aggregated manner after a regeneration period under clearcutting with reserves, seed-tree with reserves, shelterwood with reserves, group selection with reserves, or coppice with reserves regeneration methods. Reserve trees are retained for objectives other than regeneration, such as provision of future snags (e.g., green-tree replacement trees). It is assumed that reserve trees occupy at least 10% of a stand's growing space, and this is further defined as 10% or more of the full-stocking density management level. For the Blue Mountains province, full-stocking values are provided, by plant association and tree species, in Cochran et al. (1994) and Powell (1999).

Residual trees. Trees remaining in an area following tree harvest, thinning, or other disturbance events such as insect or disease outbreaks and wildfire.

Rotation. In even-aged systems, the period (in years) between regeneration establishment and final cutting (Helms 1998). Note that the National Forest Management Act requires that rotation age must be the same as, or greater than, culmination of mean annual increment age.

Selective cutting. A system in which groups of trees, or individual trees, are periodically removed from the forest by using economic criteria aimed at maximizing commodity revenues, rather than trying to meet silvicultural objectives such as regeneration (Dunster and Dunster 1996). Compare with: group selection cutting, and individual-tree selection cutting.

Shade tolerance. Capacity of trees to grow satisfactorily in the shade of, and in competition with, other trees (Helms 1998). Also see: tolerance.

Silvicultural prescription. A planned series of treatments designed to change current forest structure to one meeting the goals and objectives established for an area (Helms 1998). A prescription is a written statement or document defining the outcomes to be attained from silvicultural treatments. The outcomes are generally expressed as acceptable ranges of the various indices being used to characterize forest development (Dunster and Dunster 1996).

Silvicultural system. A planned series of treatments for tending, harvesting, and reestablishing a stand of trees. Note that a series of treatments typically involves both regeneration cutting methods and intermediate cutting methods. Three silvicultural systems are recognized: even-aged, two-aged, and uneven-aged.

Silvicultural treatment. A process or action that can be applied in a controlled manner, according to the specifications of a silvicultural prescription or forest plan, to provide actual or potential benefits (Hoffman et al. 1999).

Silviculture. A forestry discipline applying techniques or practices to manipulate forest vegetation by directing stand and tree development, and by creating or maintaining desired conditions. Silviculture is based on an ecosystem concept emphasizing a need to evaluate the many abiotic and biotic factors influencing the choice and outcome of silvicultural treatments and their sequence over time, and long-term consequences and sustainability of management regimes. [Definition developed from multiple sources.]

Stocking. The amount of anything on a given area, particularly in relation to what is considered optimum; in silviculture, an indication of growing-space occupancy relative to a pre-established standard.

Thinning. Silvicultural treatment in immature forests designed to reduce tree density and improve growth of residual trees, enhance forest health, or recover potential mortality resulting from intertree competition (Helms 1998).

Timber stand improvement. Treatments in immature forests to improve the composition, structure, condition, health, and growth of tree stands. The goal of timber stand improvement activities is to improve forest health, or to accomplish other objectives by regulating stand density, removing competing vegetation and fuel ladders, and maintaining soil productivity.

Tolerance. A forestry term expressing the relative ability of a plant (tree) to complete its life history, from seedling to adult, under the cover of a forest canopy and while experiencing competition with other plants (Harlow et al. 1996). In general ecology usage, tolerance refers to the capacity of an organism or biological process to subsist under a given set of environmental conditions. Note that the range of conditions under which an organism can subsist, representing its limits of tolerance, is termed its ecological amplitude (Helms 1998).

Tree harvest. Felling, skidding, on-site processing, and loading of trees onto trucks for transport to a market, or to an off-site facility for further processing (Helms 1998).

Understory. All vegetation growing under a forest overstory. In some cases, understory is only considered to be small trees (e.g., in a forest comprised of multiple canopy layers, the taller trees form the overstory, the shorter trees the understory); in other instances, understory is assumed to include herbaceous and shrubby plants in addition to trees. When understory refers to trees only, other plants (herbs and shrubs) are often called an undergrowth to differentiate between these two components (Helms 1998).

Uneven-aged silvicultural system. Manipulation of a forest or stand for continuous high-forest cover, recurring regeneration of desirable species, and orderly growth and development of trees through a range of age classes to provide a sustained yield of forest products. Treatments to develop and maintain uneven-aged stands are individual-tree and group selection cutting methods.

Weeding. An intermediate treatment with objectives like those for cleaning, except weeding frees seedlings or saplings from competition with ground vegetation, vines, and shrubs. Compare with: cleaning.

APPENDIX 2: GREENHORN STAND EXAM REPORT

* LOC-SITE 103510-0010 *	* FOREST 12 DISTRICT 3 SURVEY DATE 8309 *	* NET MERCH FACTORS PAGE TYPE 1 *
* COMBINATION RUN *	* DATA FOR UNEVEN-AGED MANAGEMENT WORKSHOP *	* SAMPLE POINTS 11 SAMPLE TREES 88 *
* SPRUCE-FIR SAWTIMBER *	* ORIGIN DATE 1895 STAND ACRES 40 *	* BAF 0 FPS 300 GP 0 SURVEY TYPE 4 *

** P E R A C R E M E A S U R E M E N T S B Y T R E E C L A S S **

MEASUREMENT	DESIRABLE	ACCEPTABLE	GROWINGSTK	CULL	LIVE	SND DEAD	TOTAL	CV%(TOTAL)	SE%(TOTAL)	70%CI(TOTL)
TREES (0IN+)	888.	142.	1029.	3245.	4275.	4.	4279.	108.	32.	1492.
BASAL (5IN+)	80.	28.	108.	0.	108.	7.	115.	46.	14.	17.
CUBIC (5IN+)	1832.	545.	2377.	0.	2377.	159.	2536.	50.	15.	409.
SCRIB (9IN+)	7207.	1417.	8624.	0.	8624.	669.	9293.	55.	16.	1659.
SCRIB (7IN+)	7295.	1840.	9135.	0.	9135.	669.	9804.	52.	15.	1628.

* GROSS VOLUME PER ACRE OF LIVE TIMBER SPECIES *

SCRIB7+	SCRIB8+	SCRIB9+	MER-CU5+	TOT-CU3+
10822.	10441.	10285.	2571.	2811.

* OF LIVE OTHER SPECIES 3 INCHES+ DRC (CHOJNACKY, INT-339) *

JUNIPER	PINYON	OAK	OTHER HARDWOOD	TOTAL
0.	0.	0.	0.	0.

* P E R A C R E D E A D T O T A L S T E M C U B I C V O L (5IN+) *

SOUND DEAD: STANDING	DOWN;	NONSOUND DEAD: STANDING;	TOTAL
182.	0.	0.	182.

* L O D G E P O L E T R E E S (5IN+) *

OPEN CONES	CLOSED CONES	NO CONES
0.%	0.%	0.%

* P E R A C R E S T A N D A V E R A G E S *

STORY	DBH	HEIGHT	AGE	STEMS	BA	CUBIC(5IN+)	SCRIB(9IN+)
UNDER	1.4	7	20	943	28	287.93	184.04
OVER	13.0	59	90	86	87	2088.66	8440.37
TOTAL	10.4	50	75	156	108	2376.59	8624.41

* N U M B E R O F S T A N D I N G S N A G S *
* P E R A C R E *

HARD	SOFT	QMD(5IN"+)
0	0	.0

* LIVE MISTLETOE TREES PER ACRE *

DBH	LODGEPOLE	DOUGFIR	PONDEROSA	OTHERS
0-5"	0.	0.	0.	0.
5IN+	0.	0.	0.	0.

* HAWKSWORTH MISTLETOE RATING *

UNDERSTORY	OVERSTORY	TOTAL
0	0	0

* SPRUCE BEETLE RISK *

3

** P E R C E N T O F N O N S T O C K E D P O I N T S P E R A C R E D U E T O **

OTHER	>75% HIGH BRUSH	>75% LOW BRUSH	>75% SOD	>75% DUFF	>75% SLASH	>25% NONSTOCKED NOT OVERTOPPED	>25% NONSTOCKED OVERTOPPED
0.	0.	0.	0.	0.	0.	0.	0.

** P E R C E N T O F N O N S T O C K A B L E P O I N T S P E R A C R E D U E T O **

OTHER	ROCKY MTN JUNIPER	BEDROCK- BOULDERS	POOR SOIL DRAINAGE	SOIL DEPTH	SOIL EROSION	CLAY CONTENT	CLIMAX NC SPECIES
0.	0.	0.	0.	0.	0.	0.	0.

** P E R A C R E G R O W I N G S T O C K G R O W T H A N D M O R T A L I T Y **

ANNUAL PER ACRE GROWTH BASED ON 17 TALLIED GROWTH TREES

MEASURE	INGROWTH	ACCRETION	GROSS	MORT	LOG.	NET
CUBIC(5IN+)	.0	54.8	54.8	31.8	.0	23.0
SCRIB(9IN+)	349.7	159.2	509.0	133.7	.0	375.2
STEMS(5IN+)	.00			.84	.00	

ANNUAL PER ACRE MORTALITY BY CAUSE

MEASURE	INSECT	DISEASE	FIRE	ANIMAL	WEATHER	SUPP.	UNKNOWN
CUBIC(5IN+)	31.80	.00	.00	.00	.00	.00	.00
SCRIB(9IN+)	133.74	.00	.00	.00	.00	.00	.00
STEMS(5IN+)	.84	.00	.00	.00	.00	.00	.00
STMS(1-4.9)	.00	.00	.00	.00	.00	.00	.00

** N U M B E R O F L I V E S T E M S P E R A C R E D A M A G E D B Y **

DAMAGE	0-4.9IN	5-8.9IN	9IN+	DAMAGE	0-4.9IN	5-8.9IN	9IN+	DAMAGE	0-4.9IN	5-8.9IN	9IN+
1- NONE	4036.4	49.9	80.9	22- BUTT ROT	.0	.0	1.2	61- SUPPRESSION	81.8	.0	.0
76- UNHEAL. FOL.	.0	12.5	1.7	79- SWEEP & CROOK	.0	9.0	1.1				

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* LOC-SITE   103510-0010 *    * FOREST 12  DISTRICT  3  SURVEY DATE 8309 *    * NET MERCH FACTORS          PAGE TYPE 2 *
*    COMBINATION RUN     *    * DATA FOR UNEVEN-AGED MANAGEMENT WORKSHOP *    * SAMPLE POINTS  11  SAMPLE TREES  88 *
* SPRUCE-FIR   SAWTIMBER *    * ORIGIN DATE 1895          STAND ACRES  40 *    * BAF 0  FPS 300  GP 0  SURVEY TYPE 4 *
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*** * P E R   A C R E   S T A N D   S U M M A R Y   O F   L I V E   G R O W I N G   S T O C K   T R E E S * ***

DIAMETER (INCHES)	TOT STM	HWD STM	AVG DBH	AVG HGT	TOT BA	HWD BA	TOT CUB	HWD CUB	TOT SCB	HWD SCB	TOT INT	HWD INT	SFT DBH AN. INC	HWD DBH AN. INC	SFT HT AN.INC	HWD HT AN.INC	SFT AGE	HWD AGE
0- .9	681.8	.0	.0	1.7	.0	.0	0.	0.	0.	0.	0.	0.	.00	.00	.160	.000	12.	0.
1- 1.9	54.5	.0	1.2	7.5	.5	.0	0.	0.	0.	0.	0.	0.	.05	.00	.000	.000	22.	0.
2- 2.9	81.8	.0	2.3	13.3	2.4	.0	0.	0.	0.	0.	0.	0.	.05	.00	.000	.000	22.	0.
3- 3.9	54.5	.0	3.5	20.0	3.7	.0	0.	0.	0.	0.	0.	0.	.04	.00	.400	.000	50.	0.
4- 4.9	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	.04	.00	.400	.000	50.	0.
5- 5.9	14.9	.0	5.8	22.0	2.7	.0	13.	0.	0.	0.	0.	0.	.18	.00	.825	.000	23.	0.
6- 6.9	14.0	.0	6.9	40.0	3.6	.0	48.	0.	0.	0.	0.	0.	.18	.00	.825	.000	23.	0.
7- 7.9	33.5	.0	7.4	44.2	10.0	.0	154.	0.	362.	0.	0.	0.	.10	.00	.506	.000	59.	0.
8- 8.9	9.0	.0	8.6	40.0	3.6	.0	52.	0.	148.	0.	0.	0.	.10	.00	.506	.000	59.	0.
9-10.9	34.6	.0	9.5	50.4	17.3	.0	316.	0.	1037.	0.	1255.	0.	.13	.00	.665	.000	44.	0.
11-12.9	4.1	.0	11.0	61.0	2.7	.0	62.	0.	228.	0.	276.	0.	.07	.00	.334	.000	83.	0.
13-14.9	21.3	.0	13.7	63.2	21.8	.0	522.	0.	2060.	0.	2492.	0.	.09	.00	.378	.000	96.	0.
15-16.9	10.2	.0	16.2	68.8	14.5	.0	384.	0.	1615.	0.	1955.	0.	.08	.00	.307	.000	91.	0.
17-18.9	5.4	.0	17.5	64.9	9.1	.0	226.	0.	964.	0.	1166.	0.	.00	.00	.000	.000	0.	0.
19-20.9	5.9	.0	19.9	69.5	12.7	.0	340.	0.	1498.	0.	1813.	0.	.12	.00	.403	.000	101.	0.
21-22.9	1.1	.0	21.0	57.0	2.7	.0	60.	0.	258.	0.	312.	0.	.08	.00	.185	.000	89.	0.
23-24.9	2.3	.0	23.9	76.8	7.3	.0	199.	0.	964.	0.	1166.	0.	.10	.00	.282	.000	142.	0.
25-26.9	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	.00	.00	.000	.000	0.	0.
27-28.9	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	.00	.00	.000	.000	0.	0.
29-30.9	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	.00	.00	.000	.000	0.	0.
31-99.9	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	.00	.00	.000	.000	0.	0.
0-99.9	1029.1	.0	.0	.0	114.8	.0	2377.	0.	9135.	0.	10436.	0.	.00	.00	.000	.000	0.	0.

*** * S I T E   T R E E   I N F O R M A T I O N * ***

							SITE/BASE USING TOTAL TREE AGE			* SITE/BASE USING DBH AGE *		
SPECIES	DBH AGE	TOT AGE	HEIGHT	CLASS	SURVEY YIELD	GROSS YIELD	BRICKELL	ALEXANDER	HORNIBROOK	ALEXANDER	MINOR	EDMINSTER
ENGELMANN SPRUCE	23.	38.	22.	1.	45.	0.	30./50	0./100	0./100	76./100	0./100	0./100
ENGELMANN SPRUCE	44.	59.	46.	1.	59.	0.	40./50	0./100	0./100	79./100	0./100	0./100
ENGELMANN SPRUCE	91.	106.	71.	1.	69.	0.	46./50	0./100	0./100	75./100	0./100	0./100
ENGELMANN SPRUCE	83.	98.	61.	1.	57.	0.	39./50	0./100	0./100	68./100	0./100	0./100
ENGELMANN SPRUCE	79.	94.	63.	1.	62.	0.	42./50	0./100	0./100	73./100	0./100	0./100
ENGELMANN SPRUCE	85.	100.	73.	2.	73.	0.	48./50	0./100	0./100	80./100	0./100	0./100
ENGELMANN SPRUCE	47.	62.	60.	1.	79.	0.	51./50	0./100	0./100	95./100	0./100	0./100
AVERAGE ENGELMAN	65.	80.	57.	1.	63.	0.	42./50	0./100	0./100	78./100	0./100	0./100

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* LOC-SITE 103510-0010 * * FOREST 12 DISTRICT 3 SURVEY DATE 8309 * * NET MERCH FACTORS PAGE TYPE 3 *
* COMBINATION RUN * * DATA FOR UNEVEN-AGED MANAGEMENT WORKSHOP * * SAMPLE POINTS 11 SAMPLE TREES 88 *
* SPRUCE-FIR SAWTIMBER * * ORIGIN DATE 1895 STAND ACRES 40 * * BAF 0 FPS 300 GP 0 SURVEY TYPE 4 *

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** E C O L O G I C A L S U M M A R Y O F A L L L I V E T R E E S (COOL-MOIST TO WARM-DRY) **

TREES DIAMETER	ENGELM SPRUCE	CORKBK ALPFIR	WB/BC PINE	LODGE PINE	ASPEN	DOUG FIR	WHITE FIR	PONDER PINE	COTTON WOOD	LIMBER PINE	OTHER SOFT	PINYON PINE	JUNI PER	OTHER HARD	TOTAL
.0- .0	3572.7	272.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	3845.5
.1- .9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1.0- 2.9	190.9	.0	.0	.0	27.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	218.2
3.0- 4.9	54.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	54.5
5.0- 6.9	28.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	28.9
7.0- 8.9	42.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	42.5
9.0-10.9	34.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	34.6
11.0-12.9	4.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	4.1
13.0-14.9	21.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	21.3
15.0-16.9	10.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	10.2
17.0-18.9	5.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	5.4
19.0-20.9	5.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	5.9
21.0-22.9	1.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.1
23.0-24.9	2.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	2.3
25.0-26.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
27.0-28.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
29.0-99.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0- 4.9	3818.2	272.7	.0	.0	27.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	4118.2
5.0- 8.9	71.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	71.4
9.0-99.9	85.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	85.0
.0-99.9	3974.5	272.7	.0	.0	27.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	4274.5
BASAL AREA															
.0- 4.9	6.9	.0	.0	.0	.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	7.5
5.0- 8.9	20.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	20.0
9.0-99.9	88.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	88.2
.0-99.9	115.1	.0	.0	.0	.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	115.7

** P E R A C R E P O I N T S U M M A R Y O F S T E M S & B A S A L A R E A (ALL LIVE TREES) **

	*********** T I M B E R	S P E C I E S	*************						******* O T H E R	S P E C I E S	*******						ALL TREES	
POINT	------------ TREES PER ACRE	-------------					BASAL AREA		------- TREES PER ACRE	------				BASAL AREA			MISTLETOE	
NUMB.	0-5"	5-9"	9-12"	12-99"	ALL	SOFT	LIVE	SOFT	0-3"	3-9"	9-99"	ALL	SOFT	LIVE	SOFT		TREES	DMR
1	300.0	163.5	59.7	12.5	535.7	535.7	90.0	90.0	.0	.0	.0	.0	.0	.0	.0		.0	.0
2	1200.0	100.4	.0	96.7	1397.2	1397.2	171.2	171.2	.0	.0	.0	.0	.0	.0	.0		.0	.0
3	1200.0	.0	162.8	55.8	1418.5	1418.5	180.0	180.0	.0	.0	.0	.0	.0	.0	.0		.0	.0
4	4800.0	.0	.0	81.5	4881.5	4881.5	120.0	120.0	.0	.0	.0	.0	.0	.0	.0		.0	.0
5	300.0	.0	113.4	25.1	438.5	138.5	96.5	90.0	.0	.0	.0	.0	.0	.0	.0		.0	.0
6	1500.0	.0	.0	110.3	1610.3	1610.3	121.6	121.6	.0	.0	.0	.0	.0	.0	.0		.0	.0
7	6000.0	.0	.0	.0	6000.0	6000.0	47.9	47.9	.0	.0	.0	.0	.0	.0	.0		.0	.0
8	13200.0	422.0	.0	38.5	13660.5	13660.5	200.0	200.0	.0	.0	.0	.0	.0	.0	.0		.0	.0
9	1200.0	.0	.0	58.0	1258.0	1258.0	81.6	81.6	.0	.0	.0	.0	.0	.0	.0		.0	.0
10	12000.0	99.2	.0	.0	12099.2	12099.2	40.0	40.0	.0	.0	.0	.0	.0	.0	.0		.0	.0
11	3600.0	.0	90.5	30.0	3720.6	3720.6	123.7	123.7	.0	.0	.0	.0	.0	.0	.0		.0	.0

* LOC-SITE 103510-0010 * * FOREST 12 DISTRICT 3 SURVEY DATE 8309 * * NET MERCH FACTORS PAGE TYPE 4 *
* COMBINATION RUN * * DATA FOR UNEVEN-AGED MANAGEMENT WORKSHOP * * SAMPLE POINTS 11 SAMPLE TREES 88 *
* SPRUCE-FIR SAWTIMBER * * ORIGIN DATE 1895 STAND ACRES 40 * * BAF 0 FPS 300 GP 0 SURVEY TYPE 4 *

- P E R A C R E S T A N D T A B L E S U M M A R I E S F O R T I M B E R S P E C I E S O N L Y -

ENGELMANN SPRUCE (093)

DIAMETER (INCHES)	STEMS DES	STEMS ACC	STEMS SND CULL	STEMS ROTN CULL	STEMS SALV	STEMS MORT	BASAL AREA DES	BASAL AREA ACC	BASAL AREA CULL	BASAL AREA SND DEAD	CUBIC VOLUME DES	CUBIC VOLUME ACC	CUBIC VOLUME CULL	CUBIC VOLUME SND DEAD	SCRIBNER VOLUME DES	SCRIBNER VOLUME ACC	SCRIBNER VOLUME SND DEAD	SAWLOG CUB 7+ DES	SAWLOG CUB 7+ ACC	SAWLOG CUB 7+ SND DEAD
0- .9	627.3	27.3	2918.2	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1- 2.9	81.8	54.5	54.5	.0	.0	.0	1.1	1.8	.3	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3- 4.9	54.5	.0	.0	.0	.0	.0	3.7	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5- 6.9	14.9	14.0	.0	.0	.0	.0	2.7	3.6	.0	.0	13.	48.	0.	0.	0.	0.	0.	0.	0.	0.
7- 8.9	9.1	33.4	.0	.0	.0	.0	2.7	10.9	.0	.0	39.	166.	0.	0.	87.	423.	0.	36.	150.	0.
9-10.9	26.4	8.2	.0	.0	.0	.0	13.6	3.6	.0	.0	255.	61.	0.	0.	853.	184.	0.	230.	55.	0.
11-12.9	4.1	.0	.0	.0	.0	.0	2.7	.0	.0	.0	62.	0.	0.	0.	228.	0.	0.	56.	0.	0.
13-14.9	21.3	.0	.0	.0	.0	.0	21.8	.0	.0	.0	522.	0.	0.	0.	2060.	0.	0.	470.	0.	0.
15-16.9	10.2	.0	.0	.0	.0	.0	14.5	.0	.0	.0	384.	0.	0.	0.	1615.	0.	0.	346.	0.	0.
17-18.9	5.4	.0	.0	.0	.0	4.2	9.1	.0	.0	7.3	226.	0.	0.	159.	964.	0.	669.	204.	0.	143.
19-20.9	4.1	1.7	.0	.0	.0	.0	9.1	3.6	.0	.0	238.	102.	0.	0.	1047.	451.	0.	214.	92.	0.
21-22.9	.0	1.1	.0	.0	.0	.0	.0	2.7	.0	.0	0.	60.	0.	0.	0.	258.	0.	0.	56.	0.
23-24.9	1.1	1.2	.0	.0	.0	.0	3.6	3.6	.0	.0	92.	107.	0.	0.	440.	524.	0.	86.	101.	0.
25-26.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27-28.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29-30.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31-99.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0- 4.9	763.6	81.8	2972.7	.0	.0	.0	4.8	1.8	.3	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5-99.9	96.7	59.7	.0	.0	.0	4.2	80.0	28.2	.0	7.3	1832.	545.	0.	159.	7295.	1840.	669.	1641.	454.	143.
0-99.9	860.3	141.5	2972.7	.0	.0	4.2	84.8	30.0	.3	7.3	1832.	545.	0.	159.	7295.	1840.	669.	1641.	454.	143.

CORKBARK FIR (018)

DIAMETER (INCHES)	STEMS DES	STEMS ACC	STEMS SND CULL	STEMS ROTN CULL	STEMS SALV	STEMS MORT	BASAL AREA DES	BASAL AREA ACC	BASAL AREA CULL	BASAL AREA SND DEAD	CUBIC VOLUME DES	CUBIC VOLUME ACC	CUBIC VOLUME CULL	CUBIC VOLUME SND DEAD	SCRIBNER VOLUME DES	SCRIBNER VOLUME ACC	SCRIBNER VOLUME SND DEAD	SAWLOG CUB 7+ DES	SAWLOG CUB 7+ ACC	SAWLOG CUB 7+ SND DEAD
0- .9	27.3	.0	245.5	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1- 2.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3- 4.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5- 6.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7- 8.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9-10.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11-12.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13-14.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15-16.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17-18.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19-20.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21-22.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23-24.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25-26.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27-28.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29-30.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31-99.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0- 4.9	27.3	.0	245.5	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5-99.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0-99.9	27.3	.0	245.5	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

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**************************************************************************************************************************
* LOC-SITE   103510-0010 *    * FOREST 12  DISTRICT  3  SURVEY DATE 8309 *    * NET MERCH FACTORS        PAGE TYPE 4 *
*   COMBINATION RUN      *    * DATA FOR UNEVEN-AGED MANAGEMENT WORKSHOP *    * SAMPLE POINTS  11  SAMPLE TREES  88 *
* SPRUCE-FIR   SAWTIMBER *    * ORIGIN DATE 1895          STAND ACRES  40 *   * BAF 0  FPS 300  GP 0  SURVEY TYPE 4 *
**************************************************************************************************************************
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-PER ACRE STAND TABLE SUMMARIES FOR TIMBER SPECIES ONLY-

ASPEN (746)

DIAMETER (INCHES)	STEMS DES	STEMS ACC	STEMS SND CULL	STEMS ROTN CULL	STEMS SALV	STEMS MORT	BASAL AREA DES	BASAL AREA ACC	BASAL AREA CULL	BASAL AREA SND DEAD	CUBIC VOLUME DES	CUBIC VOLUME ACC	CUBIC VOLUME CULL	CUBIC VOLUME SND DEAD	SCRIBNER VOLUME DES	SCRIBNER VOLUME ACC	SCRIBNER VOLUME SND DEAD	SAWLOG CUB 7+ DES	SAWLOG CUB 7+ ACC	SAWLOG CUB 7+ SND DEAD
0- .9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1- 2.9	.0	.0	27.3	.0	.0	.0	.0	.0	.6	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3- 4.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5- 6.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7- 8.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9-10.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11-12.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13-14.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15-16.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17-18.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19-20.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21-22.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23-24.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25-26.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27-28.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29-30.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31-99.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0- 4.9	.0	.0	27.3	.0	.0	.0	.0	.0	.6	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5-99.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0-99.9	.0	.0	27.3	.0	.0	.0	.0	.0	.6	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ALL TIMBER TREES

DIAMETER (INCHES)	STEMS DES	STEMS ACC	STEMS SND CULL	STEMS ROTN CULL	STEMS SALV	STEMS MORT	BASAL AREA DES	BASAL AREA ACC	BASAL AREA CULL	BASAL AREA SND DEAD	CUBIC VOLUME DES	CUBIC VOLUME ACC	CUBIC VOLUME CULL	CUBIC VOLUME SND DEAD	SCRIBNER VOLUME DES	SCRIBNER VOLUME ACC	SCRIBNER VOLUME SND DEAD	SAWLOG CUB 7+ DES	SAWLOG CUB 7+ ACC	SAWLOG CUB 7+ SND DEAD
0- .9	654.5	27.3	3163.6	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1- 2.9	81.8	54.5	81.8	.0	.0	.0	1.1	1.8	.9	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3- 4.9	54.5	.0	.0	.0	.0	.0	3.7	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5- 6.9	14.9	14.0	.0	.0	.0	.0	2.7	3.6	.0	.0	13.	48.	0.	0.	0.	0.	0.	0.	0.	0.
7- 8.9	9.1	33.4	.0	.0	.0	.0	2.7	10.9	.0	.0	39.	166.	0.	0.	87.	423.	0.	36.	150.	0.
9-10.9	26.4	8.2	.0	.0	.0	.0	13.6	3.6	.0	.0	255.	61.	0.	0.	853.	184.	0.	230.	55.	0.
11-12.9	4.1	.0	.0	.0	.0	.0	2.7	.0	.0	.0	62.	0.	0.	0.	228.	0.	0.	56.	0.	0.
13-14.9	21.3	.0	.0	.0	.0	.0	21.8	.0	.0	.0	522.	0.	0.	0.	2060.	0.	0.	470.	0.	0.
15-16.9	10.2	.0	.0	.0	.0	.0	14.5	.0	.0	.0	384.	0.	0.	0.	1615.	0.	0.	346.	0.	0.
17-18.9	5.4	.0	.0	.0	.0	4.2	9.1	.0	.0	7.3	226.	0.	0.	159.	964.	0.	669.	204.	0.	143.
19-20.9	4.1	1.7	.0	.0	.0	.0	9.1	3.6	.0	.0	238.	102.	0.	0.	1047.	451.	0.	214.	92.	0.
21-22.9	.0	1.1	.0	.0	.0	.0	.0	2.7	.0	.0	0.	60.	0.	0.	0.	258.	0.	0.	56.	0.
23-24.9	1.1	1.2	.0	.0	.0	.0	3.6	3.6	.0	.0	92.	107.	0.	0.	440.	524.	0.	86.	101.	0.
25-26.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27-28.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29-30.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31-99.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0- 4.9	790.9	81.8	3245.5	.0	.0	.0	4.8	1.8	.9	.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5-99.9	96.7	59.7	.0	.0	.0	4.2	80.0	28.2	.0	7.3	1832.	545.	0.	159.	7295.	1840.	669.	1641.	454.	143.
0-99.9	887.6	141.5	3245.5	.0	.0	4.2	84.8	30.0	.9	7.3	1832.	545.	0.	159.	7295.	1840.	669.	1641.	454.	143.

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*******************************************************************************************************************
* LOC-SITE   103510-0010 *    * FOREST 12  DISTRICT  3  SURVEY DATE 8309 *    * NET MERCH FACTORS      PAGE TYPE 5 *
*    COMBINATION RUN     *    * DATA FOR UNEVEN-AGED MANAGEMENT WORKSHOP *    * SAMPLE POINTS  11  SAMPLE TREES  88 *
* SPRUCE-FIR   SAWTIMBER *    * ORIGIN DATE 1895          STAND ACRES  40 *    * BAF 0  FPS 300  GP 0  SURVEY TYPE 4 *
*******************************************************************************************************************
```

STAND SUMMARY MANAGEMENT AREA 9B

**** RIS CARD TYPE 5 DATA ****

TREE SURVEY TYPE:	4	BF SW:	9135
TREE SURVEY DATE:	0	CUBIC SAW SW:	2110
FOREST TYPE:	SF	CUBIC SAW HW:	0
STAND SIZE CLASS:	9	CUBIC POLE SW:	267
PCT NON STOCK:	0	CUBIC POLE HW:	0
ORIGIN DATE:	1895	CUBIC CULL:	0
DBH:	10	CUBIC SND DEAD:	159
HT:	50	PCT DOWN SND DEAD:	0
BA:	108	HARD SNAGS:	0
TOTAL TREES:	4275	SOFT SNAGS:	0
LARGE TREES:	156	GROSS CUBIC GROWTH:	55
SEROTINY:	0	CUBIC MORT:	32
DAMAGE:	76 (UNH. FOLIAGE)		
MISTLETOE:	0 (ABSENT)		
BEETLE RATING:	3		

**** LIVE TREE STOCKING ****

* BASAL AREA X DBH **

1-4	5-8	9-15	16-99
8	20	47	41

**** BASAL AREA X SPECIES GROUP (1"+) *****

FIR	SPR	PP	OP	LP	DF	AS	OH	OS
0	115	0	0	0	0	1	0	0

TREES(1+)	BAA	QMD	SDI	AGE	MAI	PAI	YIELD	SCRIB(7+)	CUBIC(7+)
429	116	7.0	242	92	25	23	63	9135	2316

APPENDIX 3: Site Summary, Diagnosis, Prescription, and Marking Guide

Site Summary for Site 103510-10

Forest: San Isabel **District:** San Carlos **PolyID:** 103510/10 **Mgmt Area:** 9B

Survey Type:	4 (Intensive)	**Vegetation Cover Type:**	CE
Survey Date:	09/1983	**Total Canopy Cover:**	65
Slope Percent:	15	**Canopy Layers:**	3
Slope Position:	Moist Sidehill	**Structural Stage:**	UR
Aspect:	Northeast	**Seral Status:**	Late
Elevation:	11,000	**Successional Stage:**	Mature
Plant Association:	ABLA2/EREX	**Size Class:**	9 (Sawtimber)
Plant Community Type:		**Origin Date:**	1895
Plant Association Group:	Cool Moist	**Quad. Mean Diameter:**	7”
Potential Vegetation Group:	Moist Forest	**Overstory Height:**	50’
Bedrock Geology:	Basalt (extrusive)	**Total Basal Area (5”+):**	119
Soil Texture:	Loam	**Stand Density Index:**	242
Soil Depth:	35-40 inches	**Total Trees (0”+):**	4275
Erosion Hazard:	Low	**Larger Trees (5”+):**	156
Compaction Hazard:	Moderate	**Gross Growth (5”+):**	55
Wind Risk:	Moderate	**Net Growth (5”+):**	23
Disturbance Regime:	Upland/Long Cycle	**Damage/Death #1:**	Spruce beetle
Fuel Loading:	~ 6 tons/acre	**Damage/Death #2:**	Suppression
Fuels Photo Number:	45 (GTR INT-98)	**Mistletoe Rating:**	0 (absent)
Fire Regime:	Mixed to Lethal	**Spruce Beetle Rating:**	3
Recreation Opp Spectrum:	Roaded Natural	**Serotiny Rating:**	0 (absent)
Visual Quality Objective:	NTE Modification	**Site Index (Feet/Base):**	78/100
Existing Visual Condition:	Changes not noticed	**Site Index Species:**	PIEN
Visual Absorp. Capacity:	Medium	**Hard Snags:**	0
Grazing Use:	Low	**Soft Snags:**	0

------ SUMMARY OF LIVE TREE STOCKING ------

Basal Area/Acre by Size Class

1-4.9”	5-8.9”	9-14.9”	15-20.9”	21”+
8	20	47	31	10

Canopy Cover by Layer (Top to Bottom)

Layer 1	Layer 2	Layer 3
35	20	10

Basal Area/Acre by Tree Species (Warm-Dry to Cool-Moist)

JUOC	PIPO	PSMEG	LAOC	PICO	PIEN	ABGR	ABLA2	Other
0	0	0	0	0	117	0	1	1

Selected Stand Attributes

Trees Per Acre (1”+)	Basal Area Per Acre (1”+)	QMD (1”+)	SDI (1”+)	Productivity (CF/Ac/Yr)	Scribner Volume Per Acre (7”+)	Cubic Volume Per Acre (5”+)
429	119	7.0	242	63	9,135	2,316

Note: Stand exam data was verified during walk-through reconnaissance activities.

Diagnosis: General Narrative

This uneven-aged stand consists mostly of immature Engelmann spruce. It is adjoined by a willow site to the northeast, a grass site (meadow) to the southeast, a road on the south, and other spruce/fir sites to the west. Charcoal evidence indicates that the area experienced a severe fire in the past (at least 100 years ago).

Most of the dominant spruce trees run from 60 to 140 years (total age). Stand structure is variable; certain areas have a dense overstory and no understory, whereas others are more open and support a variety of tree sizes. Remnant aspen occurs as small inclusions.

The existing condition is a clumpy, uneven-aged stand of Engelmann spruce and subalpine (corkbark) fir, with minor amounts of quaking aspen. Advance spruce and fir regeneration is abundant throughout the site (totaling more than 4,000 seedlings per acre).

The desired future condition is a vigorous, uneven-aged stand of spruce and fir, with small inclusions of healthy quaking aspen.

Diagnosis: Treatment Alternatives

1. Defer treatment for now.
2. Remove the overstory and manage the existing understory of advance regeneration.
3. Perpetuate an uneven-aged structure with group selection entries on a cutting cycle of 10 to 30 years.
4. Perpetuate an uneven-aged structure with individual-tree selection entries on a cutting cycle of 10 to 30 years.

Diagnosis: Recommended Treatment and Rationale

Group selection is the preferred alternative. The stand's overstory is naturally clumpy, and group selection will readily perpetuate this structure while simultaneously increasing water yield.

Overstory removal is not recommended because it would do little to improve water yield, maintain wildlife habitat and, based on the overstory's age and condition, it is premature now.

Deferring treatment will prolong high levels of spruce beetle activity and tree mortality.

Individual-tree selection could be implemented to perpetuate an uneven-aged condition, but it is not recommended for these reasons:

1. Individual-tree selection will not increase water yield (MA 9B) to anywhere near the same extent as would be obtained from group selection cutting.
2. The clumpy overstory is a better fit with group selection than individual-tree selection.
3. Spruce beetle activity will continue increasing as the overstory matures, and individual-tree selection would contribute more to future beetle risk than group selection.
4. Individual-tree selection will create other insect and disease issues as tree wounds occur during logging; increasing subalpine fir levels are susceptible to balsam woolly adelgid.
5. Individual-tree selection would not be able to capitalize on opportunities to rejuvenate aspen for situations where remnant aspen root system still exists.

For the preferred alternative's first entry, group location should prioritize stand areas where remnant aspen root system is present. This approach will allow the initial cutting to create growing space for spruce regeneration, and to also rejuvenate aspen in small openings.

Initial treatments will establish small openings of ½ to one acre each (opening size depends on size distribution of existing spruce clumps). To redistribute snowpack and augment water yield, group widths should never exceed 5 to 8 tree heights (see FP management area 9B).

Prepared by: /s/ Dave Powell **Date**: 9/30/1983

Silvicultural Prescription for Site 103510-10

Forest Plan Objectives: Manage forest vegetation to increase water yields (Forest Plan Management Area: 9B). Stand 103510-10 is classified as spruce-fir forest cover type. For the spruce-fir forest cover type, MA 9B has these timber standards and guidelines:

Rotation length: 90-180 years.
Growing stock level (e.g., Myers 1967): 60-160.
Cutting cycle: 10-50 years.
Adopted Visual Quality Objective: Modification.
Minimum tree stocking: 150 trees per acre.
Minimum regeneration height: 6 feet.
Permissible cutting methods: clearcutting and selection.

EXISTING STAND CONDITION	DESIRED FUTURE CONDITION
Clumpy or groupy, uneven-aged stand of Engelmann spruce, subalpine fir (minor), and quaking aspen (occurs as suppressed saplings only). Advance spruce and fir regeneration is abundant; much of it is suppressed.	Vigorous, uneven-aged stand of Engelmann spruce, subalpine fir, and quaking aspen. When possible, initial treatments should reestablish an early-seral stage of aspen dispersed throughout the site as small clones.

PRESCRIPTION ACTIVITIES AND SPECIFICATIONS

The site diagnosis evaluated two uneven-aged regeneration cutting methods: individual-tree selection and group selection.

As described in the diagnosis, this silvicultural prescription is designed to implement uneven-aged management (UEAM) for site 103510-10 by using group selection, along with intermediate cutting methods for areas not being regenerated during a cutting cycle (entry).

The future stand will be regulated by using the BDq method to establish a desired diameter distribution – B is residual basal area; D is maximum tree size (diameter, in inches at breast height); q is a diminution quotient specifying the ratio of trees in adjoining diameter classes.

These BDq specifications are used for this prescription:

B: 80 square feet per acre of basal area. This stocking level is set low enough to account for regeneration needs; for a cool moist plant association, it provides enough growing space, created as small openings (groups), for regeneration establishment. This B factor also reflects a reasonably high level of site occupancy.

D: 24 inches DBH maximum tree size. This tree size corresponds with tree maturity for sites like those supporting our Greenhorn stand (site 103510-10). Trees > 24" will not be included in the regulated diameter distribution, but 24"+ trees could be retained as green-tree replacements for existing snags, as wildlife habitat, or for other non-silvicultural purposes.

q: 1.3 diminution quotient – the ratio of trees in adjoining 2-inch diameter classes is 1.3; the 8-inch class has 1.3 times as many trees as the 10-inch class, which has 1.3 times as many trees as the 12-inch class, and so forth. A q factor of 1.3 is the ‘Goldilocks’ value – it best fits the stand’s existing diameter distribution, and it does not put too much emphasis on small trees (q=1.5) or large trees (q=1.1); it is just right.

With these BDq specifications, the desired future diameter distribution is as follows (red lines delineate diameter groups established later in this prescription):

DBH Class (Inches)	Trees Per Acre	Basal Area Ft.^{2} Per Acre
0	52.0	0.0
2	40.0	0.9
4	30.8	2.7
6	23.7	4.6
8	18.2	6.4
10	14.0	7.6
12	10.8	8.5
14	8.3	8.9
16	6.4	8.9
18	4.9	8.7
20	3.8	8.2
22	2.9	7.7
24	2.2	7.0
Total	218.0	80.0

Cutting Cycle. Three cutting-cycle alternatives were considered: 10, 20, and 30 years. Stand entries will utilize a cutting cycle of 20 years. The productivity (site index) and associated growth rates of this site are not high enough to support a 10-year cycle, and a 30-year cutting cycle results in more volume being removed, and more stand area being treated in a single entry, than is desirable for UEAM in the spruce-fir forest type.

Diameter Groups. The existing stand has a broadly uneven-aged or irregular structure, with three age cohorts recognized from the stand exam data: 0-10" DBH trees less than 60 years of age; 12-22" DBH trees from 80 to 100 years of age; and 24" DBH trees in an older cohort averaging 140 years of age.

Although diameter distribution calculations utilize 2-inch diameter classes, the stand's natural clumps tend to contain a wider diameter distribution than just 2 inches. Therefore, 2-inch diameter classes were 'lumped' into four groups for prescription and marking purposes. Each group contains three adjoining, 2-inch classes to form a 6-inch diameter group.

For this prescription, four diameter groups are used:

0-6.9" DBH trees: this group contains seedlings, saplings, and poles smaller than a minimum merchantability threshold of 7 inches. These trees occur in the 0- (seedling), 2-, 4-, and 6-inch diameter classes shown in the stand exam data.

For purposes of group selection marking, natural clumps comprised primarily of trees in the 0-6.9" DBH class are ignored.

Note: these trees are not ignored for cultural (intermediate) cuttings, such as noncommercial thinning or release and weeding.

This grouping is referred to as the 0-6" DBH group in the prescription below.

7-12.9" DBH trees: these trees occur in the 8-, 10-, and 12-inch diameter classes shown in the stand exam data.

This grouping is referred to as the 8-12" DBH group in the prescription below.

13-18.9" DBH trees: these trees occur in the 14-, 16-, and 18-inch diameter classes shown in the stand exam data.

This grouping is referred to as the 14-18" DBH group in the prescription below.

19-24.9" DBH trees: these trees occur in the 20-, 22-, and 24-inch diameter classes shown in the stand exam data.

This grouping is referred to as the 20-24" DBH group in the prescription below.

Group Selection Treatments. The existing stand is multi-cohort and qualifies as irregular now, but is trending quickly toward a balanced, uneven-aged diameter distribution. The first entry, and perhaps some of the 2nd entry as well, will be directed toward conversion – adjusting the existing diameter distribution so it more closely matches the target distribution.

As existing groups or clumps of overstory trees are removed during a conversion process, new cohorts will become established and they will be periodically thinned.

As described in the Diagnosis, the stand's existing overstory condition features trees occurring primarily as natural clumps – most overstory stems in a clump are similar in age and tend to occur in a similar diameter range.

Overstory treatment will focus on naturally occurring clumps or groups of trees – either an entire group will be identified for removal and will be marked as such, or an entire group will be identified for retention. In other words, mark or leave an entire group.

There will be NO partial cutting in a group!

Group sizes will be carefully monitored to meet Forest Plan requirements, and to ensure that no groups exceed 2 acres in size (a national acreage limitation for uneven-aged management).

Group Size/Area. The stand's Forest Plan management allocation is 9B, which emphasizes using forest management treatments to increase water yields. As described in the Forest Plan's Final Environmental Impact Statement: "The greatest opportunity for increasing water yield is by creating small openings in the subalpine forest. Research has shown that snow accumulation patterns are optimum when openings are five to eight tree heights in diameter, are protected from the wind and are interspersed so they are five to eight tree heights apart. This results in about 40 percent of a timber stand in small openings with 60 percent of the stand remaining to shelter the openings" (USDA Forest Service 1984, p. III-105).

National silviculture standards state that openings created by group selection cutting cannot be larger than 2 acres; openings larger than 2 acres should be planned and regulated as small-patch clearcuts in the even-aged silvicultural system.

For this prescription, the primary determinant of group-selection opening size is natural group characteristics; any natural group size of 2 acres or less is appropriate to consider for treatment.

A stand exam for site 103510-10 (Sept. 1983) showed an average overstory tree height of 50 feet (see site summary). The Forest Plan states that openings of 5 to 8 tree heights in diameter are optimal for redistributing the snowpack in such a way as to maximize water yield increases.

The following table provides opening sizes for 8 multiples of a 50-foot overstory tree height:

Tree Height: Multiples of 50 Feet	Circular Opening: Diameter (Feet)	Circular Opening: Radius (Feet)	Circular Opening: Area (Acres)
1	50	25	0.05
2	100	50	0.18
3	150	75	0.41
4	200	100	0.72
5	250	125	1.13
6	300	150	1.62
7	350	175	2.21
8	400	200	2.88

Sources/Notes: The Pike and San Isabel National Forests Land and Resource Management Plan states that openings of 5 to 8 tree heights in diameter are desired for increasing water yields in subalpine forests. Mean overstory tree height for site 103510-10 is 50 feet. This table provides calculation results for circular-opening multiples of a 50-foot tree height; the Forest Plan, however, does not stipulate a circular opening shape. The gray-shaded portion of this table shows that opening areas for 5 to 8 tree heights range from 1.13 acres (5 heights) to 2.88 acres (8 heights).

For the group selection cutting method, national standards do not allow openings larger than 2 acres. Therefore, openings larger than 2 acres will not be used for site 103510-10, even if natural group size dictates an opening larger than 2 acres (an uncommon situation for this site).

Natural groups of less than 5 tree heights are common for site 103510-10, so group-selection cutting units of that size will also be common. ***Data in a red box above shows ideal situations for this prescription*** – natural groups that are 5 or 6 times the diameter of mean overstory tree height maximize opportunities to increase water yield (Forest Plan MA 9B) while simultaneously maintaining group size below the 2-acre maximum permissible size for group selection cutting.

Activity Fuel Treatments. Since the Greenhorn stand adjoins a major road with high levels of summertime use, group-selection units near the road will be harvested by using whole-tree yarding, and piles created near an opening's perimeter will be burned during autumn or early winter.

Groups well removed from the road can be harvested in a conventional way (bole-only), with slash lopped and scattered to less than 24 inches in depth.

For groups where remnant aspen root system exists, tops and other slash can be jack-strawed to heights exceeding 24 inches to help protect existing and future aspen suckers from elk browsing damage.

Small-Tree Treatments. Immediately after the first commercial timber-sale entry to harvest groups of overstory trees, a noncommercial hand thinning treatment will be completed in openings created by overstory harvest to thin patches of overstocked spruce and fir regeneration, and to cut undesirable small trees such as limber pine, bristlecone pine, and lodgepole pine.

Due to expected logging damage, it is not anticipated that all harvested groups will have sufficient amounts of undamaged advance regeneration to warrant noncommercial thinning.

One objective of noncommercial thinning treatments is to leave a residual stand featuring at least 60% spruce, and no more than 40% fir, primarily to address economic (merchantability) considerations and to manage future susceptibility of subalpine fir to balsam woolly adelgid.

Small-tree noncommercial thinning will occur in two portions of stand 103510-10 during this cutting cycle – group selection openings, and untreated areas assigned to the 0-6" DBH group.

When noncommercial thinning occurs in advance regeneration present in the group selection openings created during this cutting cycle, retain thrifty, undamaged Engelmann spruce saplings as the 1st priority, followed by thrifty, undamaged subalpine fir saplings as a 2nd priority.

Stocking objectives for the 0” DBH class are relatively low (see desired future diameter distribution table earlier in this Rx) – only 52 stems are needed, but the objective is 60 stems to provide a small buffer to account for future mortality.

Undamaged saplings should be retained as the 1st option to meet the seedling/sapling stocking objective, although undamaged seedlings can be retained (with the same species preference) if insufficient numbers of undamaged saplings are available.

For the 0-6” DBH groups, the same species preferences apply.

For this UEAM prescription, trees per acre and basal area objectives (see desired future diameter distribution table earlier in this Rx) are additive, so retention stocking objectives for 0-6” DBH groups being noncommercially thinned are as follows: <u>146.5 (147) stems/acre</u> for trees between 1-foot in height (seedling class) and 6.9” DBH (total stem count for the 0-, 2-, 4-, and 6-inch diameter classes), and <u>8.2 (8) feet^2/acre of basal area</u> (total basal area for the 0-, 2-, 4-, and 6-inch diameter classes).

Regeneration Treatments. The prescribed cutting method (Group Selection; FACTS code 4152) qualifies as an uneven-aged harvest, a regeneration harvest, and a final harvest.

After harvest and slashing activities have been completed, it is anticipated that most of the openings will support ample amounts of advance regeneration. Following harvest and slashing, it is anticipated that sufficient amounts of advance, undamaged regeneration will be present to meet Forest Plan standards for stocking levels (150 per acre) and sapling height (6-foot minimum).

> ***Contingency Measure***: Group selection openings should be examined by using a systematic, grid-type regeneration survey.
>
> 1. If ≥ 70% of regeneration survey plots are adequately stocked (at least 150 acceptable seedling-size stems per acre), then reforestation treatments will not be scheduled.
> 2. If < 70% of the regeneration survey plots are adequately stocked, examine the regeneration survey plot map to determine which portions of a group have non-stocked or understocked holes, and schedule those areas for fill-in planting with 2-0 bare-root Engelmann spruce planting stock.

This prescription document provides overarching concepts and principles for an integrated treatment regime for site 103510-10. However:

Detailed specifications are provided only for activities included in the 1st cutting cycle.

Remainder of this prescription provides activities (left column), and specifications for an activity (right column). Refer to the FACTS user guide for database codes for each activity.

Further information about many of the activities included in this prescription is provided in a white paper: “Silvicultural Activities: Description and Terminology” (Powell 2018).

I assume that a detailed stand examination will be completed before designing and prescribing treatments for cutting cycle 2. After completing a new exam, I expect that a new site diagnosis will also be completed.

The diagnosis should address at least 3 questions:

1. Do stand exam results appropriately reflect on-the-ground conditions?
2. Should the management regime described here be continued? Do future conditions meet expectations from this prescription? Specifically, does the future diameter distribution seem to be approaching the desired distribution shown on page 2 of this Rx?
3. How about small trees, which are particularly important for uneven-aged management? Is quantity, quality, and species composition of regeneration acceptable, and is cultural work (fill-in planting; noncommercial thinning) needed for small trees?

The remainder of this prescription describes silvicultural activities for cutting cycle (CC) number 1, and their specifications, in a tabular format.

For the Activity and Timing column, three items are provided for each table entry:

1. **Activity** – name of a treatment or activity being prescribed.
2. **Scope** – verbiage stating whether an activity is prescribed for an entire site (location 103510, site 10), or should be constrained to just a portion of it.
3. **Year** – estimated time when an activity should occur, as based on a prescribed treatment order, with preparation of an initial regeneration cutting entry (layout and marking of group selection units for cutting cycle 1) shown as year 1. Year-timing for all subsequent activities follows consecutively from the year for initial layout and mark activity.

<table>
<tr><th>ACTIVITY AND TIMING</th><th>TREATMENT SPECIFICATIONS</th></tr>
<tr><td>Activity: Layout and Mark group selection openings (Cutting Cycle #1).
Scope: entire site.
Year: 1-3.</td><td>Remove small groups or clumps of trees, being sure to stay with the natural group size. Always mark or leave an entire group. After identifying a natural group, assign it to one of the four diameter categories summarized in this table:
<table>
<tr><th>DBH Group</th><th>Cut Trees TPA</th><th>Cut Trees BAA</th><th>Leave Trees TPA</th><th>Leave Trees BAA</th><th>Cut:Leave Percents</th></tr>
<tr><td>0-6" DBH</td><td>0</td><td>0</td><td>220</td><td>14</td><td>0:100</td></tr>
<tr><td>8-12" DBH</td><td>45</td><td>20</td><td>36</td><td>17</td><td>55:45</td></tr>
<tr><td>14-18" DBH</td><td>17</td><td>20</td><td>20</td><td>27</td><td>47:53</td></tr>
<tr><td>20-24" DBH</td><td>2</td><td>5</td><td>7</td><td>18</td><td>24:76</td></tr>
</table>
Cut (excess) stems will be harvested by targeting a specified number of groups with a predominance of trees in the diameter-group range; leave (residual) stems will be addressed by retaining a specified number of groups with a predominance of trees in the diameter-group range.
Note: All data in this chart pertains to existing stocking levels, with leave trees approximating desired stocking by diameter class (except for the 0-6" DBH class, which shows no removals because groups in that diameter range will not be treated by using timber harvest. Noncommercial thinning will be considered for the 0-6" groups). BDq portion of this prescription provides desired stocking levels by 2-inch diameter class.</td></tr>
</table>

ACTIVITY AND TIMING	TREATMENT SPECIFICATIONS
	CUT AND LEAVE NARRATIVES: **0-6" DBH groups**: Do not cut any of these groups; all groups are retained and considered for noncommercial thinning. **8-12" DBH groups**: Cut half of these groups; leave half of these groups. **14-18" DBH groups**: Cut half of these groups; leave half of these groups. **20-24" DBH groups**: Cut ¼ of these groups; leave ¾ of these groups. Note: Since the 8-12" and 14-18" groups have the same prescription (cut half of the groups; leave half of the groups), it will be permissible to combine them into one large group (8-18" DBH), but only for this 1st cutting cycle (CC1).
Activity: Post-Treatment Evaluation. **Scope:** group-selection openings and unharvested 0-6" DBH groups. **Year:** 4-5.	Evaluate group-selection cutting units to determine if desired results were obtained. In addition to treated areas, evaluate seedling and sapling groups (0-6" DBH class, unharvested this entry) and decide if release and weeding is needed for them. If stocking levels for 0-6" DBH groups exceed 300 stems per acre or 30 square feet of basal area per acre, then a release and weeding treatment should be completed.
Activity: Spruce Beetle Control. **Scope:** entire site. **Year:** 4-5.	Evaluate spruce beetle populations and initiate treatment if necessary. If population measurements indicate that suppression measures are warranted, consider using pheromone traps as a primary response measure (placed in non-host type), with selective harvest/burning or trap trees used only as a secondary measure (see Bentz and Munson (2000) for treatment ideas). Consult Forest Health Protection guidelines to identify a threshold level of affected trees (number per acre) to trigger a suppression response.
Activity: Post-Harvest Regeneration Survey. **Scope:** group-selection openings. **Year:** 4-5.	After harvest and slash treatments are finished for the group-selection cuttings, complete surveys in a representative sample of treated openings to determine the quantity, spacing, species composition, and quality of surviving regeneration. By convention, the BDq approach uses the 2-inch diameter class as its lowest regulation unit. But, if a q factor of 1.3 is applied to the 2-inch class (40 stems) to generate an estimated stocking level for the 0-inch class (e.g., seedlings), then the result is 52 stems. So, establishment of at least 60 acceptable, free-to-grow seedlings, per acre, in each harvested group (this is the 52-stem seedling objective plus 8 additional as a buffer for expected mortality from a variety of causes) should ensure a

ACTIVITY AND TIMING	TREATMENT SPECIFICATIONS
	sustainable diameter distribution meeting BDq goals. At least 60% of the 60 well-formed seedlings/saplings per acre should be Engelmann spruce (e.g., at least 36 spruce seedlings/saplings per acre, and 24 other species per acre).
Activity: Natural Regeneration Certification. **Scope:** group-selection openings. **Year:** 5-6.	If regeneration meets minimum specifications contained in the Forest Plan (150 or more seedlings per acre at least 6-feet in height), certify that these requirements have been met. FP minimum regeneration standards (150 stems per acre) are greater than what is required for this prescription (60 stems per acre). Therefore, *remediation measures, including fill-in planting, should only be considered when necessary to meet prescription minimums*. <u>Note</u>: The National Forest Management Act, and its implementing regulations (36 CFR), require that a cutover area contain the minimum number, size, distribution, and species composition of regeneration, as specified in an area's Forest Plan, within 5 years of selection cutting. I don't foresee problems meeting FP objectives relating to minimum number (150), distribution, or species composition of regeneration, but local experience suggests that it requires a relatively long length of time for naturally regenerated spruce seedlings to reach 6 feet in height, so harvested groups could continue to qualify as openings for many years after treatment. In other words, it may take longer than 5 years for regeneration in cutover areas to meet minimum size standards (6 feet).
Activity: Stand Examination. **Scope:** entire site. **Year:** 21-23.	Complete an intensive stand examination with a sampling intensity of at least 1 sample point for each 5 acres. Consider a stratified sample design where stratum 1 consists of regenerating group openings created by timber harvest (group selection cutting) during cutting cycle 1, stratum 2 consists of 0-6" DBH groups that were noncommercially thinned during cutting cycle 1, and stratum 3 consists of untreated groups in the 8-12" DBH, 14-18" DBH, and 20-24" DBH diameter groups (in other words, stratum 3 consists of stand areas where predominant tree size is greater than 6.9" DBH and no harvest activity occurred during cutting cycle 1). It is recognized that stratum 1 areas will have variable treatments – some openings will require limited amounts of noncommercial thinning, and some openings will not require any thinning. This concept assumes that stratum 1 areas, regenerating group openings, will ultimately converge and have

ACTIVITY AND TIMING	TREATMENT SPECIFICATIONS
	similar characteristics, regardless of whether they had a non-commercial thinning or were reforested with fill-in planting.
Activity: Site Diagnosis. **Scope:** entire site. **Year:** 21-23.	Complete a site diagnosis after an intensive stand examination has been conducted. Design a diagnosis to examine the following questions and issues: 1. Do stand examination results appropriately represent existing site conditions? 2. Does group selection cutting (e.g., created openings) appear to be meeting regeneration objectives from the Forest Plan? 3. In early spring, do group selection openings contain more snow than adjacent, uncut areas? 4. Do snow redistribution patterns, as related to group-selection opening placement, appear to be contributing to water yield increases? 5. Does a 20-year cutting cycle appear to be well-aligned with vegetation recovery rates and water-yield objectives? 6. When evaluating vegetation response and recovery following group-selection cutting, how much of a 20-year cutting cycle period is providing water-yield benefits? 7. Does regeneration established in 1st-cycle group selection openings reach a 6-foot height (Forest Plan standard) in 20 years?
Activity: Silvicultural Prescription. **Scope:** entire site. **Year:** 21-23.	Use diagnosis results, especially responses to questions and issues listed above, to prepare a silvicultural prescription for the 2nd group-selection cutting cycle for this site. Compare stand exam results with desired (future) diameter distribution (provided earlier in this Rx), and determine if entries created during the 1st cutting cycle contributed to meeting the diameter distribution objectives. When preparing treatment specifications for the 2nd cutting cycle, use new stand exam results to prepare a revised table comparing existing, desired, excess/cut, and residual/leave diameter distributions for site 103510-10 (similar format to table 7 in this uneven-aged management white paper).
Activity: Layout and Mark group selection openings (Cutting Cycle #2). **Scope:** entire site. **Year:** 24-26.	This is the 2nd cutting cycle for group selection cutting in site 103510-10. Use results from a new stand examination, site diagnosis, and silvicultural prescription (all scheduled for year 21-23) to prepare a table showing cut and leave trees, and cut:leave percentages. Use a similar format as was used for the Layout and Mark activity for year 1-3 (page 71). Use the results to prepare a marking guide for cutting cycle 2.

Group Selection Marking Guide

You'll be marking in the southeast corner of this site, approximately 40 acres in all.

The silvicultural prescription calls for group selection, a regeneration cutting method in the uneven-aged silvicultural system.

You should expect to find a stand with small clumps or groups of Engelmann spruce and corkbark fir trees, most of which are still relatively young, vigorous, and growing well.

Occasionally, you'll find an area with remnant aspen present, mostly in the form of suppressed, sapling-sized trees. In addition to low vigor from conifer-caused suppression, many of the aspen saplings have been damaged by wildlife browsing.

When it is reasonable to do so, include remnant aspen stems in a group marked for removal so the harvest activity could potentially rejuvenate aspen. [As a rule of thumb, try not to extend group boundaries more than 200 feet beyond their natural extent just to include remnant aspen.]

Spruce beetle, a bark-beetle species affecting Engelmann spruce trees only, has been active in the stand for 5 years or more. Spruce beetle prefers to attack large-diameter spruce, especially in stand areas where basal area is 150 square feet per acre or higher.

When it is reasonable to do so, adjust unit boundaries to include recent pockets of spruce beetle activity. Spruce beetle activity is widespread, so unit boundaries should not need to be adjusted for long distances to include beetle-caused tree mortality.

The volume to be marked is relatively light in most areas, averaging about 2,500 board feet per acre. All this volume will occur in groups; the area between groups is not included in this marking guide.

Your marking objectives are:

1. Concentrate on recognizing the natural groups or clumps before deciding whether to mark or leave them. Many groups are small, averaging a quarter-acre or less in size.
2. All trees in a group will be marked or left. There will be no partial cutting in the groups! *Keep in mind that once a group has been identified for removal, thrifty trees with high potential for future growth will be removed along with trees having low potential for future growth*. Get over it – this is how group selection works!
3. The primary objective of this entry is to remove half of the groups where more than half of the trees are between 7 and 18.9 inches in diameter. To do this properly, you should:
   A. Identify naturally-occurring groups (pre-mark training will help with this task). Groups will vary in size, and the spacing, between groups, also varies across the treatment area.
   B. Assign each group to one of the following classes:
      1. More than half the trees are from 0 to 6.9 inches diameter.
      2. More than half the trees are from 7 to 18.9 inches diameter.
      3. More than half the trees are from 19 to 24.9 inches diameter.
      4. More than half the trees are 25 inches or more in diameter.

Note: You can best accomplish this task by measuring some of a group's trees with a D-tape or Biltmore stick. Although it's considered obsolete, a Biltmore stick is probably faster than a D-tape. Don't estimate diameters unless you're checking yourself often.

C. Record on a tree-tally sheet, or by using tally-whackers, the number of diameter groups you've encountered, and how many of them have been marked for removal.
Note: For purposes of this mark, the 7-12.9" and 13-18.9" groups have been combined into a single, 7-18.9" group because they have the same prescription (mark half the groups, retain half the groups).
[Two tally-whackers might work well for this group – one to record how many 7-18.9" DBH groups have been found, and the other to keep track of how many were marked.]

D. Harvest units will be cut-tree marked with red paint. Handle groups in the following way:

1. **0-6.9" DBH group:** No marking in this group because it consists of sub-merchantable trees. All groups will be retained and evaluated for a release and weeding treatment (e.g., noncommercial thinning). Record how many of these groups are present. Consider marking the location of these groups with plastic flagging because they will be revisited during a walk-through evaluation for noncommercial thinning needs.
2. **7-18.9" DBH group:** Mark half of these groups; retain half of these groups. Keep track of how many total groups were encountered and, if possible, do so by using the original diameter-class breaks: 7-12.9" groups, and 13-18.9" groups. Regardless of whether two groups are tracked with 6-inch classes, or whether one large group with a 12-inch class is tracked, the marking is the same – retain half the groups; cut half the groups.
3. **19-24.9" DBH group:** mark ¼ of these groups for removal; retain ¾ of these groups. Record how many of these total groups are present.
4. **25"+ DBH group:** mark every group where more than half the trees are 25 inches or more in diameter.

4. Don't mark any groups where more than half the trees are from 0 to 6.9 inches in diameter.
5. All cut trees are to be marked with red paint (stump and breast-height marks). Stump marks should be low on the bole (6 inches or lower), on the downhill side of the tree, and should not be on surface roots.
6. Breast-height marks should face away from the Greenhorn road.
7. There will not be any leave-tree marking on this sale (exclusive of boundaries).
8. Even though this site is not steep or rocky, be careful and always think about safety. Drive carefully!

Release and Cleaning (Noncommercial Thinning) Marking Guide

Information in this marking guide is derived from a section in the silvicultural prescription called "Small-Tree Treatments."

A silvicultural prescription provides background information for this marking guide. For background and context, review the silvicultural prescription, and another marking guide (Group Selection Marking Guide), before attempting to implement this guide.

After an initial entry of group-selection units has been completed (cutting cycle 1 harvests), walk-through evaluation surveys should be used to examine two stand situations and determine if a noncommercial stocking-control treatment is needed and warranted.

These two situations are as follows:

1. *Natural groups consisting of trees in the 0 to 6.9" DBH class*. These groups were identified, and tracked, during an initial mark when cutting cycle 1 group selection units were laid out. [Group selection marking guide provides more information about these groups.]
2. *Harvested group selection units containing advance regeneration*. Many groups in 7-18.9" DBH classes contain advance regeneration consisting of both seedlings and saplings (according to stand exam results, much of site 103510-10 supports seedling stocking levels of 4,000 stems per acre).

Only the two situations described above will be examined and considered for noncommercial thinning.

A. Do not evaluate inter-group areas (untreated areas dispersed between cutting cycle 1 group selection units) for a noncommercial thinning unless they are assigned to the 0-6.9" DBH class.

B. No untreated area from cutting cycle 1 <u>that is dominated by merchantable trees</u> (stems ≥ 7" DBH) should be considered for a noncommercial thinning – they will be left to develop on their own and will be evaluated for group-selection treatment in cutting cycle 2.

Your noncommercial marking objectives are:

1. If stocking levels of seedling and sapling trees (defined here as those in the 0-6.9" DBH class) exceeds 300 stems per acre, or 30 square feet of basal area, then schedule and prepare the area for a release and cleaning noncommercial treatment.
   <u>Note</u>: Refer to the glossary of this white paper for definitions of release and cleaning.
2. Release and cleaning are intermediate treatments completed in areas where predominant tree size is saplings and seedlings. As described in item #1, *saplings are defined here to include small poles up to 6.9" DBH*.
3. As described in the silvicultural prescription, *seedling-sapling stocking objective for uneven-aged management in site 103510-10 is 147 stems per acre*. This agrees closely with Forest Plan minimum stocking levels of 150 stems per acre averaging at least 6 feet in height.
4. Square spacing distance associated with a residual stocking level of 150 stems per acre is <u>17 feet</u>. Therefore, thrifty saplings and seedlings will be retained in release & cleaning areas on an average spacing of 17 feet.

5. Leave trees should preferably be Engelmann spruce. **At least 60% of leave trees must be spruce unless spruce is unavailable**. No more than 40% of leave trees should be corkbark (subalpine) fir, limber, lodgepole, or bristlecone pines, or other conifer species.
6. ***When aspen seedlings or saplings are present, leave all of them, regardless of their condition or competitive situation***.
7. Undamaged, thrifty spruce saplings are the 1st retention priority, followed by thrifty fir saplings as a 2nd priority. If fir sapling retention might exceed the "no more than 40% requirement," then retain some thrifty spruce seedlings to replace some of the fir saplings.
8. When cutting surplus stems beyond the minimum objective of 150 trees per acre, they should be lopped and scattered to a height of 24 inches or less.
9. When aspen seedlings or saplings are present, then cut conifer stems may be concentrated around them to suppress elk browsing pressure. These cut stems can be maintained whole, rather than being lopped into smaller pieces.

APPENDIX 4
PLENTERUNG: AN AGE-OLD PARADIGM FOR SUSTAINABILITY

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The earliest protocols regulating harvest of trees date from 1200-1300 A.D. in central Europe. These regulations dictated tree harvest at specific locations in the communal forests, specified quantities or volumes to be removed, and the harvest times, all under supervision of an elected official, the forester! The original harvest method was selective or individual tree harvest, named Plenterung.

In medieval times, these communal forests played a vital role in local rural economies by supplying fuel wood that was used daily for cooking meals, heating homes, and for the manufacturing and processing of forest products and foods. A population explosion around 1600 caused the emergence of commerce, the industrial revolution, and urbanization.

During 1600-1800, central Europe was ravaged by religious and feudal wars resulting in concentrating political powers in large industrial cities, with capitalistic economic control over the lands and their natural resources. Forest resources were rapidly depleted and logging activities encroached deep into the valleys and mountains. All the European forests would have disappeared, except the last remnants were saved by discovery of new energy sources like coal, oil, gas, and electricity to fuel the industrial plants.

The remaining heavily degraded forest, the so-called Mittelwald, was an open forest dominated by a few overstory trees, and a dense coppice of repeatedly-cut and resprouting hardwoods to be used as fuel wood. The conifers, lacking sprouting ability, mostly disappeared. The age-old conservative Plenterung system was effectively destroyed.

In the 1870s, the new science of forestry was born in Germany and France, primarily to remedy these degraded forest wastelands for economic reasons. The initial techniques were to remove the entire Mittelwald and start replanting cleared areas with conifers, notably Norway spruce (*Picea abies*), white fir (*Abies alba*), and Scots pine (*Pinus sylvestris*). Thus, even-aged forest management was born, and with it, silviculture, mensuration, forest economics, forest engineering, and forest genetics. Improvements were made in thinning and harvesting schedules, soil amendments, and insect and pest controls, and trees were projected as unsawn planks with monetary (dollar) returns!

Despite vigorous political control efforts, Plenterung survived in isolated mountainous communities of the Alps.

During the 20th century with unprecedented world population explosion, long-term global effects of a capitalistic even-aged forest management system created international concerns and controls revolving around global warming, preserving global biodiversity, gene pools and threatened or endangered species, clearcutting tropical and temperate rainforests, loss of top-soil and soil fertility by soil erosion, and issues surrounding monocultures.

Plenterung emerges today as an alternative method to even-aged forest management. Its science was perfected by Adolphe Gurnaud, Henri Biolley and others around 1875, but its acceptance and publication were severely limited.

Plenterung is the only proven silvicultural system regarding the forest as an ecosystem in which all its components closely interact with the site, soil, and climate. Plenterung is also a unique forest management system for constantly maintaining a dynamic, all-aged stand structure, volume, and area controls.

Plenterung relies heavily upon local natural regeneration, intensive 100% inventories to monitor stand growth in all size (age) classes every 5-7 years, and harvesting trees only when complete inventories are available to monitor all its stand variables. Individual trees are selected for harvest to improve spacing, growth, stand composition, diversity in age and species, and maintenance of the top canopy influence.

Plenterung requires a permanent intensive road net, with major haul roads and skid roads adapted to directional tree felling, no landings, and no heavy equipment entry into the stands. All stand treatments are carried out simultaneously every 5-7 years within the same permanent compartment. Before any stand treatment, 100% inventories monitor the effects of past treatments, and adjust upcoming treatments to maintain constancy of stand structure, volume, and growth.

Only the volume that can be grown within the harvest intervals may be removed.

Stand treatment consists of maintaining a constant stand structure curve covering the entire range of 2-inch DBH-classes. Harvesting is done on those trees in excess of the desired stand structure over the entire DBH range. Stand growth is precisely calculated by using repeated inventories to include stand in-growth and mortality. Using dual (before/after) inventories, stand growth can account precisely for intermediate windstorm or insect losses on a tree-by-tree basis!

Plenterung will automatically adjust to long-term cumulative impacts and stand changes with its built-in, intensive monitoring of stand performance and significant stand parameters. One of the unique features of Plenterung is that time is no factor at all in the decision-making or stand investment. Economically, it has proven to be a very stable and secure investment with steady periodic returns while maintaining full sustainability! This fact implies the total abandonment of even-aged concepts, including clear-cutting.

Plenterung strives for maintaining natural processes on a compartment basis and, by extrapolation over all compartments, on a landscape basis. Another incalculable advantage is that niches and natural habitats within the managed compartment will be rotated among gaps and preserved within the same unit area. This preserves natural biodiversity and gene pools.

Applications of Plenterung within the US have been hampered because existing stand conditions in a severely depleted forest would first require a lengthy period of restoration and investment. Long time periods are needed to attain a suitable and profitable stand structure of a mature, late-seral forest to implement and manage for a dynamic and constant multi-storied and all-species/all-aged stand structure.

Current controversies over policies promoting preservation of endangered or threatened species like the northern spotted owl, marbled murrelet, and coho salmon, coupled with re-authorizations of the Clean Air and Clean Water acts, may provide a strong impetus to apply and practice Plenterung on a broad commercial scale, at least on public lands, within the Pacific Northwest and the Redwood Region of California.

Elsewhere, Plenterung also has wide application.

- The natural forest types of the Cascades, Sierra Nevada, and Rocky Mountains are ideally suited for Plenterung application before they are clear-cut.
- The Eastside forests of ponderosa pine and their mixtures in the interior Northwest are naturally structured for Plenterung applications.
- Similarly, mixed oak and conifer forests of the eastern United States, including the Smoky Mountains, have been observed to have a well-defined Plenter-structure in their original state.

At the present time, Plenterung remains unknown to many foresters or is misunderstood.

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LITERATURE CITED AND REFERENCES

This References section provides literature sources for a variety of approaches to uneven-aged management. Although some references pertain to eastern hardwood forests or to uneven-aged management as it is practiced in Europe, which might appear to have little utility for western conifer forests, they are included because the same basic concepts apply equally well to uneven-aged management of eastern hardwood forest, Norway spruce in Europe, and western conifer forests of the interior Pacific Northwest.

Because this white paper utilizes an Engelmann spruce example stand to illustrate uneven-aged prescription principles, this References section also contains quite a few sources dealing with Engelmann spruce, subalpine fir, quaking aspen, and other subalpine-zone tree species.

With few exceptions, sources contained in this References section are available from World Wide Web in digital form, and a Digital Object Identifier (doi) is included for these items whenever possible.

[Digital object identifier is an international system used to uniquely identify, and link to, electronic versions of scientific information, primarily journal articles. A doi can be thought of as a 'catalog number' for journal articles and other non-book sources.]

All doi links pertain to formally published sources only; local analysis protocols, white papers (like this one), monitoring reports, and similar items will not have a doi.

For recent USDA Forest Service research reports (general technical reports, research papers, research notes, conference proceedings, etc.), a doi may also be available. But most reports do not yet have a doi, so a doi is generally not included for reports in this References section.

For FS research items, however, this section provides a weblink for the online Treesearch system, because most FS research reports are available for download from Treesearch.

When preparing a white paper, one of my objectives is to help users locate its references and literature citations. For journal articles or books, I provide a doi or isbn number whenever one is available. For other reference materials, a weblink is provided, although I realize that weblinks have not been stable (except for USDA Forest Service Treesearch links, which have been quite stable thus far).

Adams, D.M. 1976. A note on the interdependence of stand structure and best stocking in a selection forest. Forest Science. 22(2): 180-184. doi:10.1093/forestscience/22.2.180

Adams, D.M.; Ek, A.R. 1974. Optimizing the management of uneven-aged forest stands. Canadian Journal of Forest Research. 4(3): 274-287. doi:10.1139/x74-041

Aho, P.E.; Fiddler, G.; Srago, M. 1983. Logging damage in thinned young-growth true fir stands in California and recommendation for prevention. Res. Pap. PNW-304. Portland, OR: USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p. https://www.fs.usda.gov/treesearch/pubs/25187

Alexander, R.R. 1971. Initial partial cutting in old-growth spruce-fir. Res. Pap. RM-76. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 10 p. https://archive.org/download/CAT92273268/CAT92273268.pdf

Alexander, R.R. 1973. Partial cutting in old-growth spruce-fir. Res. Pap. RM-110. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 16 p.

Alexander, R.R. 1974. Silviculture of subalpine forests in the central and southern Rocky Mountains: The status of our knowledge. Res. Pap. RM-121. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 88 p. https://www.archive.org/download/CAT92273315/CAT92273315.pdf

Alexander, R.R. 1977. Cutting methods in relation to resource use in central Rocky Mountain spruce-fir forests. Journal of Forestry. 75(7): 395-400. doi:10.1093/jof/75.7.395

Alexander, R.R. 1987. Ecology, silviculture, and management of the Engelmann spruce-subalpine fir type in the central and southern Rocky Mountains. Agric. Handb. 659. Washington, DC: USDA Forest Service. 144 p. http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1144&context=barkbeetles

Alexander, R.R.; Edminster, C.B. 1977a. Regulation and control of cut under uneven-aged management. Res. Pap. RM-182. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 7 p. https://archive.org/download/CAT92273400/CAT92273400.pdf

Alexander, R.R.; Edminster, C.B. 1977b. Uneven-aged management of old growth spruce-fir forests: cutting methods and stand structure goals for the initial entry. Res. Pap. RM-186. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 12 p. https://www.fs.usda.gov/treesearch/pubs/53276

Alexander, R.R.; Shepperd, W.D. 1984. Silvical characteristics of Engelmann spruce. Gen. Tech. Rep. RM-GTR-114. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 38 p. https://www.fs.usda.gov/treesearch/pubs/52178

Alfaro, R.I.; Maclauchlan, L.E. 1992. A method to calculate the losses caused by western spruce budworm in uneven-aged Douglas-fir forests of British Columbia. Forest Ecology and Management. 55(1-4): 295-313. doi:10.1016/0378-1127(92)90107-K

Ames, F. 1931. Selective logging on the national forests of the Douglas fir region. Journal of Forestry. 29(5): 768-774. doi:10.1093/jof/29.5.768

Anderson, H.W.; Hoover, M.D.; Reinhart, K.G. 1976. Forests and water: effects of forest management on floods, sedimentation, and water supply. Berkeley, CA: USDA Forest

Service, Pacific Southwest Forest and Range Experiment Station. 115 p. https://www.fs.usda.gov/treesearch/pubs/24048

Aplet, G.H. 1994. Beyond even- vs. uneven-aged management: toward a cohort-based silviculture. Journal of Sustainable Forestry. 2(3-4): 423-433. doi:10.1300/J091v02n03_12

Assmuth, A.; Tahvonen, O. 2018. Optimal carbon storage in even- and uneven-aged forestry. Forest Policy and Economics. 87: 93-100. doi:10.1016/j.forpol.2017.09.004

Atlegrim, O.; Sjöberg, K. 1996. Response of bilberry (*Vaccinium myrtillus*) to clear-cutting and single-tree selection harvests in uneven-aged boreal *Picea abies* forests. Forest Ecology and Management. 86(1-3): 39-50. doi:10.1016/S0378-1127(96)03794-2

Baker, F.S. 1934. Theory and practice of silviculture. 1st edition. New York: McGraw-Hill Book Company, Inc. 502 p.

Baker, J.B.; Cain, M.D.; Guldin, J.M.; Murphy, P.A.; Shelton, M.G. 1996. Uneven-aged silviculture for the loblolly and shortleaf pine forest cover types. Gen. Tech. Rep. SO-118. Asheville, NC: USDA Forest Service, Southern Forest Experiment Station. 65 p. http://www.treesearch.fs.fed.us/pubs/685

Banaś, J.; Zięba, S.; Bujoczek, L. 2018. An example of uneven-aged forest management for sustainable timber harvesting. Sustainability. 10(9): 3305 (13 p). doi:10.3390/su10093305

Bare, B.B.; Opalach, D. 1987. Optimizing species composition in uneven-aged forest stands. Forest Science. 33(4): 958-970. doi:10.1093/forestscience/33.4.958

Barnes, G.H. 1937. The development of unevenaged stands of Engelmann spruce, and probable development of residual stands after logging. Forestry Chronicle. 13(3): 417-457. doi:10.5558/tfc13417-3

Becker, R. 1995. Operational considerations of implementing uneven-aged management. In: O'Hara, K.L., ed. Uneven-aged management: opportunities, constraints, and methodologies. MFCES Misc. Pub. 56. Missoula, MT: University of Montana, School of Forestry: 67-81.

Becker, R.R.; Corse, T.S. 1997. The Flathead Indian Reservation: resetting the clock with uneven-aged management. Journal of Forestry. 95(11): 29-32. doi:10.1093/jof/95.11.29

Bentz, B.J.; Munson, A.S. 2000. Spruce beetle population suppression in northern Utah. Western Journal of Applied Forestry. 15(3): 122-128. doi:10.1093/wjaf/15.3.122

Berntsen, C.M.; Mustian, A.P.; Gibbs, C.B.; Marquis, D.A.; Gordon, D.T.; Franklin, J.F.; Foiles, M.W.; Curtis, R.O.; Hall, D.O.; Alexander, R.R.; Edminster, C.B.; Phares, R.E. 1977. Uneven-aged silviculture and management in the western United States: Proceedings of an in-service Workshop. Washington, DC: USDA Forest Service, Washington Office, Timber Management Research. 137 p.

https://www.fs.usda.gov/treesearch/pubs/32981

Betters, D.R.; Woods, R.F. 1981. Uneven-aged stand structure and growth of Rocky Mountain aspen. Journal of Forestry. 79(10): 673-676. doi:10.1093/jof/79.10.673a

Bigelow, S.W.; North, M.P. 2012. Microclimate effects of fuels-reduction and group-selection silviculture: implications for fire behavior in Sierran mixed-conifer forests. Forest Ecology and Management. 264: 51-59. doi:10.1016/j.foreco.2011.09.031

Boise Cascade Corporation. 1996. Forest ecosystem management: a graphic overview. La Grande, OR: Boise Cascade Corporation, Timber and Wood Products Division. 52 p.

Bond, W.E. 1952. Growing stock differences in even-aged and all-aged forests. Journal of Forestry. 50(9): 691-693. doi:10.1093/jof/50.9.690

Brockway, D.G.; Loewenstein, E.F.; Outcalt, K.W. 2014. Proportional basal area method for implementing selection silviculture systems in longleaf pine forests. Canadian Journal of Forest Research. 44(8): 977-985. doi:10.1139/cjfr-2013-0510

Bruner, H.D.; Moser, J.W., Jr. 1973. A Markov chain approach to the prediction of diameter distributions in uneven-aged forest stands. Canadian Journal of Forest Research. 3(3): 409-417. doi:10.1139/x73-059

Buongiorno, J.; Michie, B.R. 1980. A matrix model of uneven-aged forest management. Forest Science. 26(4): 609-625. doi:10.1093/forestscience/26.4.609

Buongiorno, J.; Dahir, S.; Lu, H.-C.; Lin, C.-R. 1994. Tree size diversity and economic returns in uneven-aged forest stands. Forest Science. 40(1): 83-103. doi:10.1093/forestscience/40.1.83

Buongiorno, J.; Peyron, J.-L.; Houllier, F.; Bruciamacchie, M. 1995. Growth and management of mixed-species, uneven-aged forests in the French Jura: Implications for economic returns and tree diversity. Forest Science. 41(3): 397-429. doi:10.1093/forestscience/41.3.397

Campbell, S.P.; Witham, J.W.; Hunter, M.L., Jr. 2007. Long-term effects of group-selection timber harvesting on abundance of forest birds. Conservation Biology. 21(5): 1218-1229. doi:10.1111/j.1523-1739.2007.00768.x

Chang, S.J. 1981. Determination of the optimal growing stock and cutting cycle for an uneven-aged stand. Forest Science. 27(4): 739-744. doi:10.1093/forestscience/27.4.739

Chang, S.J.; Gadow, K.V. 2010. Application of the generalized Faustmann model to uneven-aged forest management. Journal of Forest Economics. 16(4): 313-325. doi:10.1016/j.jfe.2010.06.002

Chapman, R.C.; Blatner, K.A. 1991. Calculating balanced diameter distributions associated with specified residual stand densities. Journal of Environmental Management. 33(2): 155-160. doi:10.1016/S0301-4797(05)80091-X

Christensen, N.L.; Bartuska, A.M.; Brown, J.H.; Carpenter, S.; D'Antonio, C.; Francis, R.;

Franklin, J.F.; MacMahon, J.A.; Noss, R.F.; Parsons, D.J.; Peterson, C.H.; Turner, M.G.; Woodmansee, R.G. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. Ecological Applications. 6(3): 665-691. doi:10.2307/2269460

Cochran, P.H. 1992. Stocking levels and underlying assumptions for uneven-aged ponderosa pine stands. Res. Note PNW-RN-509. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 10 p. http://www.treesearch.fs.fed.us/pubs/25110

Cochran, P.H. 1998. Examples of mortality and reduced annual increments of white fir induced by drought, insects, and disease at different stand densities. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 19 p. http://www.treesearch.fs.fed.us/pubs/3036

Cochran, P.H.; Geist, J.M.; Clemens, D.L.; Clausnitzer, R.R.; Powell, D.C. 1994. Suggested stocking levels for forest stands in northeastern Oregon and southeastern Washington. Res. Note PNW-RN-513. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 21 p. http://www.treesearch.fs.fed.us/pubs/25113

Cooper, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecological Monographs. 30(2): 129-164. doi:10.2307/1948549

Coordes, R. 2016. The emergence of forest age structures as determined by uneven-aged stands and age class forests. Journal of Forest Economics. 25: 160-179. doi:10.1016/j.jfe.2016.09.003

Couture, S.; Cros, M.-J.; Sabbadin, R. 2016. Risk aversion and optimal management of an uneven-aged forest under risk of windthrow: A Markov decision process approach. Journal of Forest Economics. 25: 94-114. doi:10.1016/j.jfe.2016.08.002

Curtis, R.O. 1978. Growth and yield in uneven-aged stands. In: USDA Forest Service, ed. Uneven-aged silviculture and management in the United States. Gen. Tech. Rep. WO-24. Washington, DC: USDA Forest Service, Timber Management Research: 186-201.

Curtis, R.O. 1998. "Selective cutting" in Douglas-fir: history revisited. Journal of Forestry. 96(7): 40-46. doi:10.1093/jof/96.7.40

Curtis, J.D.; Wilson, A.K. 1958. A test of group selection in Idaho ponderosa pine. Journal of Forestry. 56(3): 182-189. doi:10.1093/jof/56.3.182

Daniel, T.W.; Helms, J.A.; Baker, F.S. 1979. Principles of silviculture. 2nd edition. New York: McGraw-Hill Book Company. 500 p. isbn:0-07-015297-7

Davis, L.S.; Johnson, K.N.; Bettinger, P.S.; Howard, T.E. 2001. Forest management: to sustain ecological, economic, and social values. 4th edition. New York: McGraw-Hill Companies. 804 p. isbn:0-07-032694-0

Day, R.J. 1972. Stand structure, succession, and use of southern Alberta's Rocky Mountain forest. Ecology. 53(3): 472-478. doi:10.2307/1934235

Day, K. 1998. Stocking standards for uneven-aged interior Douglas-fir. In: Vyse, A.; Hollstedt, C.; Huggard, D., eds. Managing the dry Douglas-fir forests of the southern interior: workshop proceedings. Working Pap. 34. Victoria, BC: British Columbia Ministry of Forests, Research Branch: 37-52. http://afrf.forestry.ubc.ca/files/2012/03/Stocking-standards-for-uneven-aged-interior-Douglas-fir-1998.pdf

DeGomez, T. 2014. Guidelines for thinning ponderosa pine for improved forest health and fire prevention. Pub. AZ1397. Tucson, AZ: University of Arizona, College of Agriculture and Life Sciences, Cooperative Extension. 7 p. https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1397-2014.pdf

de Liocourt, F. 1898. On the improvement of fir forests through selective management. Bulletin trimestriel, Société forestière de Franche-Comté et Belfort: 396-409. English translation 2001 by Maria Nygren, School of Natural Resources, University of Missouri-Columbia. 11 p.

DeLuca, T.H.; Zouhar, K.L. 2000. Effects of selection harvest and prescribed fire on the soil nitrogen status of ponderosa pine forests. Forest Ecology and Management. 138(1-3): 263-271. doi:10.1016/S0378-1127(00)00401-1

DeVelice, R.L.; Ludwig, J.A.; Moir, W.H.; Ronco, F., Jr. 1986. A classification of forest habitat types of northern New Mexico and southern Colorado. Gen. Tech. Rep. RM-131. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 59 p.

Diaci, J.; Kerr, G.; O'Hara, K. 2011. Twenty-first century forestry: integrating ecologically based, uneven-aged silviculture with increased demands on forests. Forestry. 84(5): 463-465. doi:10.1093/forestry/cpr053

Dixon, G.E. 2015. Essential FVS: a user's guide to the Forest Vegetation Simulator. Fort Collins, CO: USDA Forest Service, Forest Management Service Center. 226 p. https://www.fs.fed.us/fmsc/ftp/fvs/docs/gtr/EssentialFVS.pdf

Doliner, L.H.; Borden, J.H. 1984. Pesterms: a glossary of forest pest management terms. Pest Manage. Rep. No. 3. Victoria, BC: British Columbia Ministry of Forests. 34 p.

Doolittle, W.T.; Mustain, A.P.; Gibbs, C.B.; Marquis, D.A.; Blum, B.M.; Tubbs, C.H.; Leak, W.B.; Gingrich, S.F.; Smith, H.C.; DeBald, P.S.; Engle, L.G.; Phares, R.E. 1975. Uneven-aged silviculture and management in the eastern United States. Washington, DC. USDA Forest Service, Timber Management Research. 155 p. https://www.fs.usda.gov/treesearch/pubs/32985

Ducey, M.J. 2009. The ratio of additive and traditional stand density indices. Western Journal of Applied Forestry. 24(1): 5-10. doi:10.1093/wjaf/24.1.5

Ducey, M.J. [2012]. The reverse-J and beyond: Developing practical, effective marking guides. Unpub. Rep. Durham, NH: University of New Hampshire, Department of

Natural Resources and the Environment. 14 p.

Ducey, M.J.; Knapp, R.A. 2010. A stand density index for complex mixed species forests in the northeastern United States. Forest Ecology and Management. 260(9): 1613-1622. doi:10.1016/j.foreco.2010.08.014

Duduman, G. 2011. A forest management planning tool to create highly diverse uneven-aged stands. Forestry. 84(3): 301-314. doi:10.1093/forestry/cpr014

Dunning, D. 1928. A tree classification for the selection forests of the Sierra Nevada. Journal of Agricultural Research. 36(9): 755-771. https://www.fs.usda.gov/treesearch/pubs/40886

Dunster, J.; Dunster, K. 1996. Dictionary of natural resource management. Vancouver, BC: UBC Press. 363 p. isbn:0-7748-0503-X

Eastham, A.M.; Jull, M.J. 1999. Factors affecting natural regeneration of *Abies lasiocarpa* and *Picea engelmannii* in a subalpine silvicultural systems trial. Canadian Journal of Forest Research. 29(12): 1847-1855. doi:10.1139/x99-164

Elledge, J. 2012. Using a form of point-double sampling: helping make uneven-aged management an affordable option. The Consultant. 29-37.

Emmingham, B. 1998. Uneven-aged management in the Pacific Northwest. Journal of Forestry. 96(7): 37-39. doi:10.1093/jof/96.7.37

Emmingham, W.H. 1999. Proceedings of the IUFRO interdisciplinary uneven-aged management symposium. Corvallis, OR: Oregon State University. 713 p.

Emmingham, W.H. 2002. Status of uneven-aged management in the Pacific Northwest, USA. Forestry. 75(4): 433-436. doi:10.1093/forestry/75.4.433

Emmingham, W.L.; Oester, P.; Bennett, M.; Kukulka, F.; Conrad, K.; Michel, A. 2002. Comparing short-term financial aspects of four management options in Oregon: implications for uneven-aged management. Forestry. 75(4): 489-494. doi:10.1093/forestry/75.4.489

EPA (U.S. Environmental Protection Agency). 1980. An approach to water resources evaluation of non-point silvicultural sources (a procedural handbook). EPA-600/8-80-012. [Place of publication unknown]: U.S. EPA, Office of Research and Development, Environmental Research Laboratory.

Ex, S.A.; Smith, F.W. 2013. Stand density index estimates leaf area index in uneven-aged ponderosa pine stands. Western Journal of Applied Forestry. 28(1): 9-12. doi:10.5849/wjaf.12-004

Ex, S.A.; Smith, F.W. 2014a. Evaluating forest vegetation simulator performance for trees in multiaged ponderosa pine stands, Black Hills, USA. Forest Science. 60(2): 214-221. doi:10.5849/forsci.12-054

Ex, S.A.; Smith, F.W. 2014b. Wood production efficiency and growth dominance in multiaged and even-aged ponderosa pine stands. Forest Science. 60(1): 149-156. doi:10.5849/forsci.12-010

Fajardo, A.; Goodburn, J.M.; Graham, J. 2006. Spatial patterns of regeneration in managed uneven-aged ponderosa pine/Douglas-fir forests of western Montana, USA. Forest Ecology and Management. 223(1-3): 255-266. doi:10.1016/j.foreco.2005.11.022

Farnden, C. 2000. Simulated conversion of unmanaged interior spruce-subalpine fir stands to a regulated uneven-aged structure. Forestry Chronicle. 76(3): 465-474. doi:10.5558/tfc76465-3

Farrar, R.M., Jr.; Murphy, P.A.; Colvin, R. 1984. Hope farm woodland: 33-year production in an uneven-aged loblolly-shortleaf pine stand. Journal of Forestry. 82(8): 746-749. doi:10.1093/jof/82.8.476

Fiedler, C.E. 1995. The basal area-maximum diameter-q (BDq) approach to regulating uneven-aged stands. In: O'Hara, K.L., ed. Uneven-aged management: opportunities, constraints, and methodologies. MFCES Misc. Pub. 56. Missoula, MT: University of Montana, School of Forestry: 94-109.

Fiedler, C.E.; McCaughey, W.W.; Schmidt, W.C. 1985. Natural regeneration in intermountain spruce-fir forests – a gradual process. Res. Pap. INT-343. Ogden, UT: USDA Forest Service, Intermountain Research Station. 12 p. https://archive.org/download/naturalregenerat343fied/naturalregenerat343fied.pdf

Fiedler, C.; Becker, R.; Haglund, S. 1988. Preliminary guidelines for uneven-aged silvicultural prescriptions in ponderosa pine. In: Baumgartner, D.M.; Lotan, J.E., eds. Ponderosa pine: the species and its management; symposium proceedings. Pullman, WA: Washington State University, Office of Conferences and Institutes: 235-241.

Filip, G.M.; Schmitt, C.L. 1990. R_x for *Abies*: silvicultural options for diseased firs in Oregon and Washington. Gen. Tech. Rep. PNW-GTR-252. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 34 p. https://www.fs.usda.gov/treesearch/pubs/9100

Fitzgerald, S.; Oester, P.; Parker, B. 2013. Individual tree selection (ITS) in a northeast Oregon mixed conifer forest. EM 9083. Corvallis, OR: Oregon State University, Extension Service. 8 p. http://ir.library.oregonstate.edu/xmlui/handle/1957/42986

Frank, R.M.; Blum, B.M. 1978. The selection system of silviculture in spruce-fir stands – procedures, early results, and comparisons with unmanaged stands. Res. Pap. NE-425. Broomall, PA: USDA Forest Service, Northeastern Forest Experiment Station. 15 p. https://www.fs.usda.gov/treesearch/pubs/14960

Gove, J.H. 2017. A demographic study of the exponential distribution applied to uneven-aged forests. Forestry: An International Journal of Forest Research. 90(1): 18-31. doi:10.1093/forestry/cpw042

Gove, J.H.; Ducey, M.J. 2014. Optimal uneven-aged stocking guides: an application to spruce-fir stands in New England. Forestry. 87(1): 61-70. doi:10.1093/forestry/cpt040

Gove, J.H.; Fairweather, S.E. 1992. Optimizing the management of uneven-aged forest stands: a stochastic approach. Forest Science. 38(3): 623-640. doi:10.1093/forestscience/38.3.623

Graham, R.T.; Jain, T.B. 2005. Application of free selection in mixed forests of the inland northwestern United States. Forest Ecology and Management. 209(1-2): 131-145. doi:10.1016/j.foreco.2005.01.019

Graham, R.T.; Smith, R.A. 1983. Techniques for implementing the individual tree selection method in the grand fir-cedar-hemlock ecosystems of northern Idaho. Res. Note INT-332. Ogden, UT: USDA Forest Service, Intermountain Research Station. 4 p. techniquesforimp332grah

Graham, R.T.; Jain, T.B.; Tonn, J.R. 1999. Uneven-aged silviculture in cedar-hemlock-grand-fir ecosystems of the northern Rocky Mountains. In: Emmingham, W.H., comp. Proceedings of the IUFRO interdisciplinary uneven-aged management symposium. Corvallis, OR: Oregon State University: 70-87.

Gül, A.U.; Misir, M.; Misir, N.; Yavuz, H. 2005. Calculation of uneven-aged stand structures with the negative exponential diameter distribution and Sterba's modified competition density rule. Forest Ecology and Management. 214(1): 212-220. doi:10.1016/j.foreco.2005.04.012

Guldin, J.M. 1991. Uneven-aged BDq regulation of Sierra Nevada mixed conifers. Journal of Forestry. 89(9): 29-36. doi:10.1093/jof/89.9.29

Guldin, J.M. 1991. Uneven-aged BDq regulation of Sierra Nevada mixed conifers. Western Journal of Applied Forestry. 6(2): 27-32. doi:10.1093/wjaf/6.2.27

Guldin, J.M. 1996. The role of uneven-aged silviculture in the context of ecosystem management. Western Journal of Applied Forestry. 11(1): 4-12. doi:10.1093/wjaf/11.1.4

Guldin, J.M.; Baker, J.B. 1998. Uneven-aged silviculture, southern style. Journal of Forestry. 96(7): 22-26. doi:10.1093/jof/96.7.22

Hagle, S.K. 1995. Forest health and uneven-aged management. In: O'Hara, K.L., ed. Uneven-aged management: opportunities, constraints, and methodologies. MFCES Misc. Pub. 56. Missoula, MT: University of Montana, School of Forestry: 33-50.

Haight, R.G. 1985. A comparison of dynamic and static economic models of uneven-aged stand management. Forest Science. 31(4): 957-974. doi:10.1093/forestscience/31.4.957

Haight, R.G. 1987. Evaluating the efficiency of even-aged and uneven-aged stand management. Forest Science. 33(1): 116-134. doi:10.1093/forestscience/33.1.116

Haight, R.G.; Getz, W.M. 1987. Fixed and equilibrium endpoint problems in uneven-aged stand management. Forest Science. 33(4): 908-931. doi:10.1093/forestscience/33.4.908

Haight, R.G.; Brodie, J.D.; Adams, D.M. 1985. Optimizing the sequence of diameter distributions and selection harvests for uneven-aged stand management. Forest Science. 31(2): 451-462. doi:10.1093/forestscience/31.2.451

Hall, D.O.; Bruna, J.A. 1983. A management decision framework for winnowing simulated all-aged stand prescriptions. Gen. Tech. Rep. INT-147. Ogden, UT: USDA Forest Service, Intermountain Research Station. 13 p. https://archive.org/download/CAT31118963/CAT31118963.pdf

Hanley, D.P.; Schmidt, W.C.; Blake, G.M. 1975. Stand structure and successional status of two spruce-fir forests in southern Utah. Res. Pap. INT-176. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station. 16 p. https://archive.org/download/standstructuresu176hanl/standstructuresu176hanl.pdf

Hann, D.W. 1980. Development and evaluation of an even- and uneven-aged ponderosa pine/Arizona fescue stand simulator. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station. 95 p. https://archive.org/download/developmentevalu267hann/developmentevalu267hann.pdf

Hann, D.W.; Bare, B.B. 1979. Uneven-aged forest management: state of the art (or science?). Gen. Tech. Rep. INT-50. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station. 18 p. http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1078&context=govdocs_forest

Harlow, W.M.; Harrar, E.S.; Hardin, J.W.; White, F.M. 1996. Textbook of dendrology. 8th edition. New York: McGraw-Hill. 534 p. isbn:0-07-026572-0

Harrod, R.J.; Gaines, W.L.; Hartl, W.E.; Camp, A. 1998. Estimating historical snag density in dry forests east of the Cascade Range. Gen. Tech. Rep. PNW-GTR-428. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 16 p. http://www.treesearch.fs.fed.us/pubs/3247

Hawley, R.C. 1922. The continuous forest. Journal of Forestry. 20(6): 651-661. doi:10.1093/jof/20.6.651

Heiberg, S.O. 1939. Forest soil in relation to silviculture. Journal of Forestry. 37(1): 42-46. doi:10.1093/jof/37.1.42

Helms, J.A. 1998. The dictionary of forestry. Bethesda, MD: Society of American Foresters. 210 p. isbn:0-939970-73-2

Hickman, C.A. 1990. Proceedings of southern forest economics workshop on evaluating even and all-aged timber management options for southern forest lands. Gen. Tech. Rep. SO-79. New Orleans, LA: USDA Forest Service, Southern Forest Experiment Station. 149 p. Proceedings_of_the_Southern_Forest_Econo

Hoffman, R.E.; Twery, M.J.; Alban, L.M.; Nyland, R.D. 1999. Forests and people. NE-INF-138-99. Burlington, VT: USDA Forest Service, Northeastern Research Station, Aiken Forestry Sciences Laboratory. 24 p. https://www.fs.usda.gov/treesearch/pubs/4032

Holmes, M.J.; Reed, D.D. 1991. Competition indices for mixed species northern hardwoods. Forest Science. 37(5): 1338-1349. doi:10.1093/forestscience/37.5.1338

Howe, G.E. 1989. Genetic effects of even-aged and uneven-aged silviculture. In: USDA Forest Service. Silvicultural challenges and opportunities in the 1990s; Proceedings of the National Silviculture Workshop. Washington, DC: USDA Forest Service, Timber Management Staff, Silviculture Group: 84-91.

Howe, G.E. 1995. Genetic effects of uneven-aged management. In: O'Hara, K.L., ed. Uneven-aged management: opportunities, constraints, and methodologies. MFCES Misc. Pub. 56. Missoula, MT: University of Montana, School of Forestry: 27-32.

Hyink, D.M.; Moser, J.W. 1983. A generalized framework for projecting forest yield and stand structure using diameter distributions. Forest Science. 29(1): 85-95. doi:10.1093/forestscience/29.1.85

Johnson, E.A.; Fryer, G.I. 1989. Population dynamics in lodgepole pine-Engelmann spruce forests. Ecology. 70(5): 1335-1345. doi:10.2307/1938193

Johnson, E.A.; Fryer, G.I. 1996. Why Engelmann spruce does not have a persistent seed bank. Canadian Journal of Forest Research. 26(5): 872-878. doi:10.1139/x26-095

Johnston, C.M.T.; Withey, P. 2017. Managing forests for carbon and timber: A markov decision model of uneven-aged forest management with risk. Ecological Economics. 138: 31-39. doi:10.1016/j.ecolecon.2017.03.023

Kalabokidis, K.D.; Wakimoto, R.H. 1992. Prescribed burning in uneven-aged stand management of ponderosa pine/Douglas fir forests. Journal of Environmental Management. 34(3): 221-235. doi:10.1016/S0301-4797(05)80153-7

Kaya, I.; Buongiorno, J. 1987. Economic harvesting of uneven-aged northern hardwood stands under risk: A Markovian decision model. Forest Science. 33(4): 889-907. doi:10.1093/forestscience/33.4.889

Keen, F.P. 1936. Relative susceptibility of ponderosa pines to bark-beetle attack. Journal of Forestry. 34(10): 919-927. doi:10.1093/jof/34.10.919

Kellogg, L.D.; Bettinger, P.; Edwards, R.M. 1996. A comparison of logging planning, felling, and skyline yarding costs between clearcutting and five group-selection harvesting methods. Western Journal of Applied Forestry. 11(3): 90-96. doi:10.1093/wjaf/11.3.90

Kenefic, L.S.; Nyland, R.D. 2000. Habitat diversity in uneven-aged northern hardwood stands: a case study. Res. Pap. NE-714. Newtown Square, PA: USDA Forest Service, Northeastern Research Station. 4 p. https://www.fs.usda.gov/treesearch/pubs/3756

Kerr, G. 2014. The management of silver fir forests: de Liocourt (1898) revisited. Forestry. 87(1): 29-38. doi:10.1093/forestry/cpt036

Kerr, G.; Morgan, G.; Blyth, J.; Stokes, V. 2010. Transformation from even-aged plantations to an irregular forest: the world's longest running trial area at Glentress, Scotland. Forestry. 83(3): 329-344. doi:10.1093/forestry/cpq015

Kimmins, J.P. 1997. Forest ecology; a foundation for sustainable management. 2nd edition. Upper Saddle River, NJ: Prentice Hall. 596 p. isbn:0-02-364071-5

Lafond, V.; Lagarrigues, G.; Cordonnier, T.; Courbaud, B. 2014. Uneven-aged management options to promote forest resilience for climate change adaptation: effects of group selection and harvesting intensity. Annals of Forest Science. 71(2): 173-186. doi:10.1007/s13595-013-0291-y

Leaf, C.F. 1975. Watershed management in the Rocky Mountain subalpine zone: the status of our knowledge. Res. Pap. RM-137. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 31 p. https://archive.org/download/CAT92273510/CAT92273510.pdf

Leak, W.B. 1964. An expression of diameter distribution for unbalanced, uneven-aged stands and forests. Forest Science. 10(1): 39-50. doi:10.1093/forestscience/10.1.39

Leak, W.B. 1965. The J-shaped probability distribution. Forest Science. 11(4): 405-409. doi:10.1093/forestscience/11.4.405

Leak, W.B.; Filip, S.M. 1975. Uneven-aged management of northern hardwoods in New England. Res. Pap. NE-332. Upper Darby, PA: USDA Forest Service, Northeastern Forest Experiment Station. 15 p. https://www.fs.usda.gov/treesearch/pubs/15460

Leak, W.B.; Filip, S.M. 1977. Thirty-eight years of group selection in New England northern hardwoods. Journal of Forestry. 75(10): 641-643. doi:10.1093/jof/75.10.641

Lilieholm, R.J.; Davis, L.S.; Heald, R.C.; Holeman, S.P. 1990. Effects of single tree selection harvests on stand structure, species composition, and understory tree growth in a Sierra mixed conifer forest. Western Journal of Applied Forestry. 5(2): 43-47. doi:10.1093/wjaf/5.2.43

Long, J.N. 1995. Using stand density index to regulate stocking in uneven-aged stands. In: O'Hara, K.L., ed. Uneven-aged management: opportunities, constraints, and methodologies. MFCES Misc. Pub. 56. Missoula, MT: University of Montana, School of Forestry: 110-122.

Long, J.N. 1998. Multiaged systems in the central and southern Rockies. Journal of Forestry. 96(7): 34-36. doi:10.1093/jof/96.7.34

Long, J.N.; Daniel, T.W. 1990. Assessment of growing stock in uneven-aged stands. Western Journal of Applied Forestry. 5(3): 93-96. doi:10.1093/wjaf/5.3.93

Lowdermilk, W.C. 1925. Factors affecting reproduction of Engelmann spruce. Journal of Agricultural Research. 30(11): 995-1009. https://naldc-legacy.nal.usda.gov/naldc/download.xhtml?id=IND43967040&content=PDF

Lundqvist, L. 2017. Tamm Review: Selection system reduces long-term volume growth in Fennoscandic uneven-aged Norway spruce forests. Forest Ecology and Management. 391: 362-375. doi:10.1016/j.foreco.2017.02.011

Marquis, D.A. 1975. Application of uneven-aged silviculture and management on public and private lands. In: Doolittle et al., comp. Uneven-aged silviculture and management in the eastern United States. Washington, DC: USDA Forest Service, Timber

Management Research: 26-62. https://www.fs.usda.gov/treesearch/pubs/32985

Marshall, P.L. 1996. Response of uneven-aged Douglas-fir to alternative spacing regimes: analysis of the initial impact of the spacing regimes. FRDA Report 242. Victoria, BC: Canadian Forest Service. 27 p. https://www.for.gov.bc.ca/hfd/pubs/Docs/Frr/Frr242.htm

Marshall, P.L.; Wang, Y. 1995. Above ground tree biomass of interior uneven-aged Douglas-fir stands. Working Paper WP-1.5-003. Victoria, BC: Canadian Forest Service. 23 p. http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/4134.pdf

Marshall, P.L.; Wang, Y. 1996. Growth of uneven-aged interior Douglas-fir stands as influenced by different stand structures. FRDA Report 267. Victoria, BC: Canadian Forest Service. 20 p. https://www.for.gov.bc.ca/hfd/pubs/Docs/Frr/Frr267.htm

McDonald, P.M.; Abbott, C.S. 1994. Seedfall, regeneration, and seedling development in group-selection openings. Albany, CA: USDA Forest Service, Pacific Southwest Research Station. 13 p. https://www.fs.usda.gov/treesearch/pubs/28649

McDonald, P.M.; Reynolds, P.E. 1999. Plant community development after 28 years in small group-selection openings. Res. Paper PSW-RP-241. Albany, CA: USDA Forest Service, Pacific Southwest Research Station. 17 p. https://www.fs.usda.gov/treesearch/pubs/6913

McDonald, P.M.; Anderson, P.J.; Fiddler, G.O. 1997. Vegetation in group-selection openings: early trends. Res. Note PSW-RN-421. Albany, CA: USDA Forest Service, Pacific Southwest Research Station. 7 p. https://www.fs.usda.gov/treesearch/pubs/32552

McDonald, P.M.; Fiddler, G.; Ritchie, M.; Anderson, P. 2009. Naturally seeded versus planted ponderosa pine seedlings in group-selection openings. Western Journal of Applied Forestry. 24(1): 48-54. doi:10.1093/wjaf/24.1.48

McTague, J.P.; Stansfield, W.F. 1994. Stand and tree dynamics of uneven-aged ponderosa pine. Forest Science. 40(2): 289-302. doi:10.1093/forestscience/40.2.289

Medin, D.E.; Booth, G.D. 1989. Responses of birds and small mammals to single-tree selection logging in Idaho. Res. Pap. INT-408. Ogden, UT: USDA Forest Service, Intermountain Research Station. 11 p. https://archive.org/download/responsesofbirds408medi/responsesofbirds408medi.pdf

Meyer, W.H. 1930. A method of constructing growth tables for selectively cut stands of western yellow pine. Journal of Forestry. 28(8): 1076-1084. doi:10.1093/jof/28.8.1076

Meyer, W.H. 1934. Growth in selectively cut ponderosa pine forests of the Pacific Northwest. Tech. Bull. No. 407. Washington, DC: U.S. Department of Agriculture. 64 p. https://naldc.nal.usda.gov/download/CAT86200401/PDF

Meyer, H.A. 1943. Management without rotation. Journal of Forestry. 41(2): 126-132. doi:10.1093/jof/41.2.126

Meyer, H.A. 1952. Structure, growth, and drain in balanced uneven-aged forests. Journal of Forestry. 50(2): 85-92. doi:10.1093/jof/50.2.85

Meyer, H.A.; Stevenson, D.D. 1943. The structure and growth of virgin beech-birch-maple-hemlock forests in northern Pennsylvania. Journal of Agricultural Research. 67(12): 465-484. Meyer and Stevenson 1943

Miller, M.; Emmingham, B. 2001. Can selection thinning convert even-age Douglas-fir stands to uneven-aged structures? Western Journal of Applied Forestry. 16(1): 35-43. doi:10.1093/wjaf/16.1.35

Moser, J.W., Jr. 1972. Dynamics of an uneven-aged forest stand. Forest Science. 18(3): 184-191. doi:10.1093/forestscience/18.3.184

Moser, J.W., Jr. 1976. Specification of density for the inverse J-shaped diameter distribution. Forest Science. 22(2): 177-180. doi:10.1093/forestscience/22.2.177

Moser, J.W., Jr.; Tubbs, C.H.; Jacobs, R.D. 1979. Evaluation of a growth projection system for uneven-aged northern hardwoods. Journal of Forestry. 77(7): 421-423. doi:10.1093/jof/77.7.421

Mrowka, R. 1989. Some ideas for your consideration: Group versus single tree selection – choosing between the two. Unpub. White Pap. Pendleton, OR: USDA Forest Service, Pacific Northwest Region, Umatilla National Forest, Supervisor's Office. 2 p.

Munger, T.T. 1917. Western yellow pine in Oregon. Bulletin No. 418. Washington, DC: U.S. Department of Agriculture. 48 p. https://naldc.nal.usda.gov/download/CAT87211707/PDF

Munger, T.T. 1941. They discuss the maturity selection system. Journal of Forestry. 39(3): 297-303. doi:10.1093/jof/39.3.297

Munger, T.T.; Brandstrom, A.J.F.; Kolbe, E.L. 1936. Maturity selection system applied to ponderosa pine. West Coast Lumberman. 63(11): 33, 44.

Murphy, P.A.; Farrar, R.M. 1982. Calculation of theoretical uneven-aged stand structures with the exponential distribution. Forest Science. 28(1): 105-109. doi:10.1093/forestscience/28.1.105

Myers, C.A. 1967. Growing stock levels in even-aged ponderosa pine. Res. Pap. RM-33. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 8 p. https://www.fs.usda.gov/treesearch/pubs/34763

Naumann, J.R. 1988. Uneven-aged management: Practice, issue, or cause? In: Baumgartner, D.M.; Lotan, J.E., eds. Ponderosa pine: the species and its management; symposium proceedings. Pullman, WA: Washington State University, Office of Conferences and Institutes: 243-245.

Nautiyal, J.C. 1983. Towards a method of uneven-aged forest management based on the theory of financial maturity. Forest Science. 29(1): 47-58. doi:10.1093/forestscience/29.1.47

Negron, J.F.; Allen, K.; Cook, B.; Withrow, J.R., Jr. 2008. Susceptibility of ponderosa pine, *Pinus ponderosa* (Dougl. ex Laws.), to mountain pine beetle, *Dendroctonus ponderosae* Hopkins, attack in uneven-aged stands in the Black Hills of South Dakota and Wyoming USA. Forest Ecology and Management. 254(2): 327-334. doi:10.1016/j.foreco.2007.08.018

Nisbet, J. 1893. On mixed forests, and their advantages over pure forests. London, UK: Eyre and Spottiswoode. 30 p. On Mixed Forests and Their Advantage

Nolet, P.; Kneeshaw, D.; Messier, C.; Béland, M. 2018. Comparing the effects of even- and uneven-aged silviculture on ecological diversity and processes: A review. Ecology and Evolution. 8(2): 1217-1226. doi:10.1002%2Fece3.3737

Nygren, M.; Rissanen, K.; Eerikäinen, K.; Saksa, T.; Valkonen, S. 2017. Norway spruce cone crops in uneven-aged stands in southern Finland: A case study. Forest Ecology and Management. 390: 68-72. doi:10.1016/j.foreco.2017.01.016

Nyland, R.D. 1998. Selection in northern hardwoods. Journal of Forestry. 96(7): 18-21. doi:10.1093/jof/96.7.18

Nyland, R.D. 2003. Even- to uneven-aged: the challenges of conversion. Forest Ecology and Management. 172(2-3): 291-300. doi:10.1016/S0378-1127(01)00797-6

O'Hara, K.L. 1995. Uneven-aged management: opportunities, constraints, and methodologies. MFCES Misc. Pub. No. 56. Missoula, MT: University of Montana, School of Forestry. 166 p.

O'Hara, K.L. 1996. Dynamics and stocking-level relationships of multi-aged ponderosa pine stands. Forest Science. 42(Supplement 2): 1-34. doi:10.1093/forestscience/42.s2.a0001

O'Hara, K.L. 1998. Silviculture for structural diversity: a new look at multiaged systems. Journal of Forestry. 96(7): 4-10. doi:10.1093/jof/96.7.4a

O'Hara, K.L. 2001. The silviculture of transformation – a commentary. Forest Ecology and Management. 151(1-3): 81-86. doi:10.1016/S0378-1127(00)00698-8

O'Hara, K.L. 2002. The historical development of uneven-aged silviculture in North America. Forestry. 75(4): 339-346. doi:10.1093/forestry/75.4.339

O'Hara, K.L. 2014. Multiaged silviculture: Managing for complex forest stand structures. 1st ed. New York: Oxford University Press. 213 p. isbn:9780198703068

O'Hara, K.L.; Gersonde, R.F. 2004. Stocking control concepts in uneven-aged silviculture. Forestry. 77(2): 131-143. doi:10.1093/forestry/77.2.131

O'Hara, K.L.; Kollenberg, C.L. 2003. Stocking control procedures for multiaged lodgepole pine stands in the northern Rocky Mountains. Western Journal of Applied Forestry. 18(1): 15-21. doi:10.1093/wjaf/18.1.15

O'Hara, K.L.; Ramage, B.S. 2013. Silviculture in an uncertain world: utilizing multi-aged management systems to integrate disturbance. Forestry. 86(4): 401-410. doi:10.1093/forestry/cpt012

O'Hara, K.L.; Valappil, N.I. 1995. Age class division of growing space to regulate stocking in uneven-aged stands. In: O'Hara, K.L., ed. Uneven-aged management: opportunities, constraints, and methodologies. MFCES Misc. Pub. 56. Missoula, MT: University of Montana, School of Forestry: 123-143.

O'Hara, K.L.; Valappil, N.I. 1999. Masam – a flexible stand density management model for meeting diverse structural objectives in multiaged stands. Forest Ecology and Management. 118(1-3): 57-71. doi:10.1016/S0378-1127(98)00486-1

O'Hara, K.L.; Valappil, N.I.; Nagel, L.M. 2003. Stocking control procedures for multiaged ponderosa pine stands in the inland Northwest. Western Journal of Applied Forestry. 18(1): 5-14. doi:10.1093/wjaf/18.1.5

O'Hara, K.L.; Youngblood, A.; Waring, K.M. 2010. Maturity selection versus improvement selection: lessons from a mid-20th century controversy in the silviculture of ponderosa pine. Journal of Forestry. 108(8): 397-407. doi:10.1093/jof/108.8.397

Oliver, C.D. 1980. Even-aged development of mixed-species stands. Journal of Forestry. 78(4): 201-203. doi:10.1093/jof/78.4.201

Oliver, C.D. 1995. Uneven-age stand dynamics. In: O'Hara, K.L., ed. Uneven-aged management: opportunities, constraints, and methodologies. MFCES Misc. Pub. 56. Missoula, MT: University of Montana, School of Forestry: 82-93.

Oliver, C.D.; Larson, B.C. 1996. Forest stand dynamics. Update ed. New York: John Wiley & Sons, Inc. 520 p. isbn:0-471-13833-9

Önal, H. 1995. Comment: Tree size diversity and economic returns in uneven-aged forest stands. Forest Science. 41(4): 908-911. doi:10.1093/forestscience/41.4.908

Parajuli, R.; Chang, S.J. 2012. Carbon sequestration and uneven-aged management of loblolly pine stands in the southern USA: A joint optimization approach. Forest Policy and Economics. 22: 65-71. doi:10.1016/j.forpol.2012.05.003

Parkatti, V.-P.; Assmuth, A.; Rämö, J.; Tahvonen, O. 2019. Economics of boreal conifer species in continuous cover and rotation forestry. Forest Policy and Economics. 100: 55-67. doi:10.1016/j.forpol.2018.11.003

Pearson, G.A. 1943. The facts behind improvement selection. Journal of Forestry. 41(10): 740-752. doi:10.1093/jof/41.10.740

Perry, R.W.; Thill, R.E. 2013. Long-term responses of disturbance-associated birds after different timber harvests. Forest Ecology and Management. 307: 274-283. doi:10.1016/j.foreco.2013.07.026

Person, H.L. 1931. Theory in explanation of the selection of certain trees by the western pine beetle. Journal of Forestry. 29(5): 696-699. doi:10.1093/jof/29.5.696

Pond, N.C.; Froese, R.E.; Nagel, L.M. 2014. Sustainability of the selection system in northern hardwood forests. Forest Science. 60(2): 374-381. doi:10.5849/forsci.12-113

Powell, D.C. 1987. How to prepare a silvicultural prescription for uneven-aged management. Pueblo, CO: USDA Forest Service, Rocky Mountain Region, Pike and San Isabel

National Forests. 53 p.

Powell, D.C. 1999. Suggested stocking levels for forest stands in northeastern Oregon and southeastern Washington: an implementation guide for the Umatilla National Forest. Tech. Pub. F14-SO-TP-03-99. Pendleton, OR: USDA Forest Service, Pacific Northwest Region, Umatilla National Forest. 300 p. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5405482.pdf

Powell, D.C. 2013. Stand density protocol for mid-scale assessments. White Pap. F14-SO-WP-Silv-36. Pendleton, OR: USDA Forest Service, Pacific Northwest Region, Umatilla National Forest. 67 p. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5413734.pdf

Powell, D.C. 2014. Updates of maximum stand density index and site index for Blue Mountains variant of Forest Vegetation Simulator. White Pap. F14-SO-WP-Silv-39. Pendleton, OR: USDA Forest Service, Pacific Northwest Region, Umatilla National Forest. 43 p. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3794788.pdf

Powell, D.C.; Johnson, C.G., Jr.; Crowe, E.A.; Wells, A.; Swanson, D.K. 2007. Potential vegetation hierarchy for the Blue Mountains section of northeastern Oregon, south-eastern Washington, and west-central Idaho. Gen. Tech. Rep. PNW-GTR-709. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 87 p. http://www.treesearch.fs.fed.us/pubs/27598

Pukkala, T. 2016. Plenterwald, Dauerwald, or clearcut? Forest Policy and Economics. 62: 125-134. doi:10.1016/j.forpol.2015.09.002

Pukkala, T.; Lähde, E.; Laiho, O.; Salo, K.; Hotanen, J.-P. 2011a. A multifunctional comparison of even-aged and uneven-aged forest management in a boreal region. Canadian Journal of Forest Research. 41(4): 851-862. doi:10.1139/x11-009

Pukkala, T.; Lähde, E.; Laiho, O. 2011b. Variable-density thinning in uneven-aged forest management—a case for Norway spruce in Finland. Forestry. 84(5): 557-565. doi:10.1093/forestry/cpr020

Pukkala, T.; Laiho, O.; Lähde, E. 2016. Continuous cover management reduces wind damage. Forest Ecology and Management. 372: 120-127. doi:10.1016/j.foreco.2016.04.014

Ralston, R.; Buongiorno, J.; Schulte, B.; Fried, J. 2003. WestPro: a computer program for simulating uneven-aged Douglas-fir stand growth and yield in the Pacific Northwest. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 25 p. https://www.fs.usda.gov/treesearch/pubs/5344

Raymond, P.; Prévost, M.; Power, H. 2016. Patch cutting in temperate mixedwood stands: What happens in the between-patch matrix? Forest Science. 62(2): 227-236. doi:10.5849/forsci.15-023

Raymond, P.; Royo, A.A.; Prévost, M.; Dumais, D. 2018. Assessing the single-tree and small group selection cutting system as intermediate disturbance to promote regeneration and diversity in temperate mixedwood stands. Forest Ecology and Management. 430: 21-32. doi:10.1016/j.foreco.2018.07.054

Redmond, M.D.; Kelsey, K.C. 2018. Topography and overstory mortality interact to control tree regeneration in spruce-fir forests of the southern Rocky Mountains. Forest Ecology and Management. 427: 106-113. doi:10.1016/j.foreco.2018.05.057

Reynolds, R.R. 1954. Growing stock in the all-aged forest. Journal of Forestry. 52(10): 744-747. doi: 10.1093/jof/52.10.744

Reynolds, H.G. 1966. Use of openings in spruce-fir forests of Arizona by elk, deer, and cattle. Res. Note RM-66. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p. U_S_Forest_Service_Research_Note

Roe, A.L. 1952. Growth of selectively cut ponderosa pine stands in the upper Columbia Basin. Agriculture Handbook No. 39. Washington, DC: USDA Forest Service. 29 p. Roe 1952

Roth, F. 1916. Concerning site. Journal of Forestry. 14(1): 3-12. doi: 10.1093/jof/14.1.3

Rubin, B.D.; Manion, P.D.; Faber-Langendoen, D. 2006. Diameter distributions and structural sustainability in forests. Forest Ecology and Management. 222(1-3): 427-438. doi:10.1016/j.foreco.2005.10.049

Rudolph, D.C.; Conner, R.N. 1996. Red-cockaded woodpeckers and silvicultural practice: is uneven-aged silviculture preferable to even-aged? Wildlife Society Bulletin. 24(2): 330-333. https://www.fs.usda.gov/treesearch/pubs/1297

Rutherford, W., Jr.; Shafer, E.L., Jr. 1969. Selection cuts increased natural beauty in two Adirondack forest stands. Journal of Forestry. 67(6): 415-419. doi:10.1093/jof/67.6.415

Sammi, J.C. 1961. De Liocourt's method, modified. Journal of Forestry. 59(4): 294-295. doi:10.1093/jof/59.4.291

Schmid, J.M.; Frye, R.H. 1976. Stand ratings for spruce beetles. Res. Note RM-309. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p.

Schulte, B.; Buongiorno, J.; Lin, C.-R.; Skog, K. 1998. SouthPro: a computer program for managing uneven-aged loblolly pine stands. Washington, DC: USDA Forest Service, Forest Products Laboratory. 47 p. https://www.fs.usda.gov/treesearch/pubs/5900

Seymour, R.S.; Kenefic, L.S. 1998. Balance and sustainability in multiaged stands: a northern conifer case study. Journal of Forestry. 96(7): 12-17. doi:10.1093/jof/96.7.12

Sharma, A.; Bohn, K.K.; McKeithen, J.; Singh, A. 2019. Effects of conversion harvests on light regimes in a southern pine ecosystem in transition from intensively managed plantations to uneven-aged stands. Forest Ecology and Management. 432: 140-149. doi:10.1016/j.foreco.2018.09.019

Shaw, J.D. 2000. Application of stand density index to irregularly structured stands. Western Journal of Applied Forestry. 15(1): 40-42. doi:10.1093/wjaf/15.1.40

Shepperd, W.D. 2007. SDI-Flex: a new technique of allocating growing stock for developing treatment prescriptions in uneven-aged forest stands. In: Powers, R.F., tech. ed. Restoring fire-adapted ecosystems: proceedings of the 2005 national silviculture workshop. Gen. Tech. Rep. PSW-GTR-203. Albany, CA: USDA Forest Service, Pacific Southwest Research Station: 171-180. https://www.fs.usda.gov/treesearch/pubs/25899

Silviculture Interpretations Working Group. 1992. Correlated guidelines for management of uneven-aged drybelt Douglas-fir stands in British Columbia: First approximation. Victoria, BC: British Columbia Ministry of Forests, Silviculture Branch. 57 p. https://www.for.gov.bc.ca/hfd/library/documents/bib1693.pdf

Sinha, A.; Rämö, J.; Malo, P.; Kallio, M.; Tahvonen, O. 2017. Optimal management of naturally regenerating uneven-aged forests. European Journal of Operational Research. 256(3): 886-900. doi:10.1016/j.ejor.2016.06.071

Smith, M.T.; Exline, J.D. 2002. An uneven-aged management strategy: Lessons learned. In: Verner, J. Proceedings of a symposium on the Kings River sustainable forest ecosystem project: Progress and current status. Gen. Tech. Rep. PSW-GTR-183. Albany, CA: USDA Forest Service, Pacific Southwest Research Station: 19-30. https://www.fs.usda.gov/treesearch/pubs/26091

Smith, D.M.; Larson, B.C.; Kelty, M.J.; Ashton, P.M.S. 1997. The practice of silviculture: applied forest ecology. 9th edition. New York: John Wiley & Sons, Inc. 537 p. isbn:0-471-10941-X

Spinelli, R.; Magagnotti, N.; Pari, L.; Soucy, M. 2016. Comparing tree selection as performed by different professional figures. Forest Science. 62(2): 213-219. doi:10.5849/forsci.15-062

Sterba, H. 2004. Equilibrium curves and growth models to deal with forests in transition to uneven-aged structure – application in two sample stands. Silva Fennica. 38(4): 413-423. doi:10.14214/sf.409

Sterba, H.; Monserud, R.A. 1993. The maximum density concept applied to uneven-aged mixed-species stands. Forest Science. 39(3): 432-452. doi:10.1093/forestscience/39.3.432

Sterba, H.; Monserud, R.A. 1995. Potential volume yield for mixed-species Douglas-fir stands in the northern Rocky Mountains. Forest Science. 41(3): 531-545. doi:10.1093/forestscience/41.3.531

Stout, S.L.; Marquis, D.A.; Ernest, R.L. 1987. A relative density measure for mixed-species stands. Journal of Forestry. 85(7): 45-47. doi:10.1093/jof/85.7.45

Tahvonen, O. 2016. Economics of rotation and thinning revisited: the optimality of clearcuts versus continuous cover forestry. Forest Policy and Economics. 62: 88-94.

doi:10.1016/j.forpol.2015.08.013

Tahvonen, O.; Pukkala, T.; Laiho, O.; Lähde, E.; Niinimäki, S. 2010. Optimal management of uneven-aged Norway spruce stands. Forest Ecology and Management. 260(1): 106-115. doi:10.1016/j.foreco.2010.04.006

Taylor, R.F. 1939. The application of a tree classification in marking lodgepole pine for selection cutting. Journal of Forestry. 37(10): 777-782. doi:10.1093/jof/37.10.777

Torres, I.L.; Belda, C.F. 2015. Dimensionless numbers for the sustainable harvesting of a monospecific uneven-aged forest. Canadian Journal of Forest Research. 45(11): 1535-1545. doi:10.1139/cjfr-2015-0140

Trimble, G.R.; Reinhart, K.G.; Webster, H.H. 1963. Cutting the forest to increase water yields. Journal of Forestry. 61(9): 635-640. doi:10.1093/jof/61.9.635

Troendle, C.A. 1983. The potential for water yield augmentation from forest management in the Rocky Mountain region. Water Resources Bulletin. 19(3): 359-373. doi:10.1111/j.1752-1688.1983.tb04593.x

Tubbs, C.H.; Oberg, R.R. 1978. How to calculate size-class distribution for all-age forests. Unnumbered Leaflet. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station. 5 p.

USDA Forest Service. 1978. Uneven-aged silviculture and management in the United States. Gen. Tech. Rep. WO-24. Washington, DC: USDA Forest Service, Timber Management Research. 234 p. https://archive.org/download/CAT87869577/CAT87869577.pdf

USDA Forest Service. 1984. Final environmental impact statement for the Pike and San Isabel National Forests Land and Resource Management Plan. Volume I. Chapters I-VII. Pub. 02-12-82-01. Pueblo, CO: USDA Forest Service, Rocky Mountain Region, Pike and San Isabel National Forests. Irregular pagination.

USDA Forest Service. 1992. Uneven-aged management desk guide. Loose-leaf binder. Klamath Falls, OR: USDA Forest Service. Irregular p.

van der Kamp, B.J. 1995. The spatial distribution of Armillaria root disease in an uneven-aged, spatially clumped Douglas-fir stand. Canadian Journal of Forest Research. 25(6): 1008-1016. doi:10.1139/x95-109

Vyse, A. 1999. Should we continue practicing uneven-aged silviculture in the dry Douglas-fir forests of British Columbia? In: Emmingham, W.H., comp. Proceedings of the IUFRO interdisciplinary uneven-aged management symposium. [Corvallis, OR]: [Oregon State University]: 166-170.

Wahlenberg, W.G. 1941. Methods of forecasting timber growth in irregular stands. Tech. Bull. No. 796. Washington, DC: U.S. Department of Agriculture. 55 p. http://ageconsearch.umn.edu/bitstream/169099/2/tb796.pdf

Waterhouse, M.J. 2013. Treefall in the Mount Tom group selection silvicultural systems trial in central British Columbia. Ext. Note 109. Victoria, BC: British Columbia, Ministry of Forests, Lands and Natural Resource Operations. 10 p. https://www.for.gov.bc.ca/hfd/pubs/docs/En/EN109.htm

Weidman, R.H. 1921. Forest succession as a basis of the silviculture of western yellow pine. Journal of Forestry. 19(8): 877-885. doi:10.1093/jof/19.8.877

Weidman, R.H.; Silcox, F.A. 1936. Timber growing and logging practice in ponderosa pine in the Northwest. Tech. Bull. No. 511. Washington, DC: U.S. Department of Agriculture. 91 p. https://naldc.nal.usda.gov/download/CAT86200506/PDF

Willms, J.; Bartuszevige, A.; Schwilk, D.W.; Kennedy, P.L. 2017. The effects of thinning and burning on understory vegetation in North America: A meta-analysis. Forest Ecology and Management. 392: 184-194. doi:10.1016/j.foreco.2017.03.010

Wilson, E.R.; McIver, H.W.; Malcolm, D.C. 1999. Transformation to irregular structure of an upland conifer forest. Forestry Chronicle. 75(3): 407-412. doi:10.5558/tfc75407-3

Woodall, C.W.; Fiedler, C.E.; Milner, K.S. 2003a. Intertree competition in uneven-aged ponderosa pine stands. Canadian Journal of Forest Research. 33(9): 1719-1726. doi:10.1139/x03-096

Woodall, C.W.; Fiedler, C.E.; Milner, K.S. 2003b. Stand density index in uneven-aged ponderosa pine stands. Canadian Journal of Forest Research. 33(1): 96-100. doi:10.1139/x02-168

Woodall, C.W.; Miles, P.D.; Vissage, J.S. 2005. Determining maximum stand density index in mixed species stands for strategic-scale stocking assessments. Forest Ecology and Management. 216(1-3): 367-377. doi:10.1016/j.foreco.2005.05.050

Yang, T.-R.; Lam, T.Y.; Kershaw, J.A. 2018. Developing relative stand density index for structurally complex mixed species cypress and pine forests. Forest Ecology and Management. 409: 425-433. doi:10.1016/j.foreco.2017.11.043

York, R.A.; Battles, J.J.; Heald, R.C. 2003. Edge effects in mixed conifer group selection openings: tree height response to resource gradients. Forest Ecology and Management. 179(1-3): 107-121. doi:10.1016/S0378-1127(02)00487-5

York, R.A.; Heald, R.C.; Battles, J.J.; York, J.D. 2004. Group selection management in conifer forests: relationships between opening size and tree growth. Canadian Journal of Forest Research. 34(3): 630-641. doi:10.1139/x03-222

York, R.A.; Battles, J.J.; Wenk, R.C.; Saah, D. 2012. A gap-based approach for regenerating pine species and reducing surface fuels in multi-aged mixed conifer stands in the Sierra Nevada, California. Forestry. 85(2): 203-213. doi:10.1093/forestry/cpr058

Yoshida, T.; Naito, S.; Nagumo, M.; Hyodo, N.; Inoue, T.; Umegane, H.; Yamazaki, H.; Miya, H.; Nakamura, F. 2017. Structural complexity and ecosystem functions in a natural mixed forest under a single-tree selection silviculture. Sustainability. 9(11): 2093 (15 p). doi:10.3390/su9112093

APPENDIX 5: SILVICULTURE WHITE PAPERS

White papers are internal reports, and they are produced with a consistent formatting and numbering scheme – all papers dealing with Silviculture, for example, are placed in a silviculture series (Silv) and numbered sequentially. Generally, white papers receive only limited review and, in some instances pertaining to highly technical or narrowly focused topics, the papers may receive no technical peer review at all. For papers that receive no review, the viewpoints and perspectives expressed in the paper are those of the author only, and do not necessarily represent agency positions of the Umatilla National Forest or the USDA Forest Service.

Large or important papers, such as two papers discussing active management considerations for dry and moist forests (white papers Silv-4 and Silv-7, respectively), receive extensive review comparable to what would occur for a research station general technical report (but they don't receive blind peer review, a process often used for journal articles).

White papers are designed to address a variety of objectives:

(1) They guide how a methodology, model, or procedure is used by practitioners on the Umatilla National Forest (to ensure consistency from one unit, or project, to another).

(2) Papers are often prepared to address ongoing and recurring needs; some papers have existed for more than 20 years and still receive high use, indicating that the need (or issue) has long standing – an example is white paper #1 describing the Forest's big-tree program, which has operated continuously for 25 years.

(3) Papers are sometimes prepared to address emerging or controversial issues, such as management of moist forests, elk thermal cover, or aspen forest in the Blue Mountains. These papers help establish a foundation of relevant literature, concepts, and principles that continuously evolve as an issue matures, and hence they may experience many iterations through time. [But also note that some papers have not changed since their initial development, in which case they reflect historical concepts or procedures.]

(4) Papers synthesize science viewed as particularly relevant to geographical and management contexts for the Umatilla National Forest. This is considered to be the Forest's self-selected 'best available science' (BAS), realizing that non-agency commenters would generally have a different conception of what constitutes BAS – like beauty, BAS is in the eye of the beholder.

(5) The objective of some papers is to locate and summarize the science germane to a particular topic or issue, including obscure sources such as master's theses or Ph.D. dissertations. In other instances, a paper may be designed to wade through an overwhelming amount of published science (dry-forest management), and then synthesize sources viewed as being most relevant to a local context.

(6) White papers function as a citable literature source for methodologies, models, and procedures used during environmental analysis – by citing a white paper, specialist reports can include less verbiage describing analytical databases, techniques, and so forth, some of which change little (if at all) from one planning effort to another.

(7) White papers are often used to describe how a map, database, or other product was developed. In this situation, the white paper functions as a 'user's guide' for the new product. Examples include papers dealing with historical products: (a) historical fire extents for the

Tucannon watershed (WP Silv-21); (b) an 1880s map developed from General Land Office survey notes (WP Silv-41); and (c) a description of historical mapping sources (24 separate items) available from the Forest's history website (WP Silv-23).

The following papers are available from the Forest's website: Silviculture White Papers

Paper #	Title
1	Big tree program
2	Description of composite vegetation database
3	Range of variation recommendations for dry, moist, and cold forests
4	Active management of Blue Mountains dry forests: Silvicultural considerations
5	Site productivity estimates for upland forest plant associations of Blue and Ochoco Mountains
6	Blue Mountains fire regimes
7	Active management of Blue Mountains moist forests: Silvicultural considerations
8	Keys for identifying forest series and plant associations of Blue and Ochoco Mountains
9	Is elk thermal cover ecologically sustainable?
10	A stage is a stage is a stage…or is it? Successional stages, structural stages, seral stages
11	Blue Mountains vegetation chronology
12	Calculated values of basal area and board-foot timber volume for existing (known) values of canopy cover
13	Created opening, minimum stocking, and reforestation standards from Umatilla National Forest Land and Resource Management Plan
14	Description of EVG-PI database
15	Determining green-tree replacements for snags: A process paper
16	Douglas-fir tussock moth: A briefing paper
17	Fact sheet: Forest Service trust funds
18	Fire regime condition class queries
19	Forest health notes for an Interior Columbia Basin Ecosystem Management Project field trip on July 30, 1998 (handout)
20	Height-diameter equations for tree species of Blue and Wallowa Mountains
21	Historical fires in headwaters portion of Tucannon River watershed
22	Range of variation recommendations for insect and disease susceptibility
23	Historical vegetation mapping
24	How to measure a big tree
25	Important Blue Mountains insects and diseases
26	Is this stand overstocked? An environmental education activity
27	Mechanized timber harvest: Some ecosystem management considerations
28	Common plants of south-central Blue Mountains (Malheur National Forest)
29	Potential natural vegetation of Umatilla National Forest
30	Potential vegetation mapping chronology
31	Probability of tree mortality as related to fire-caused crown scorch

Paper #	Title
32	Review of "Integrated scientific assessment for ecosystem management in the interior Columbia basin, and portions of the Klamath and Great basins" – Forest vegetation
33	Silviculture facts
34	Silvicultural activities: Description and terminology
35	Site potential tree height estimates for Pomeroy and Walla Walla Ranger Districts
36	Stand density protocol for mid-scale assessments
37	Stand density thresholds related to crown-fire susceptibility
38	Umatilla National Forest Land and Resource Management Plan: Forestry direction
39	Updates of maximum stand density index and site index for Blue Mountains variant of Forest Vegetation Simulator
40	Competing vegetation analysis for southern portion of Tower Fire area
41	Using General Land Office survey notes to characterize historical vegetation conditions for Umatilla National Forest
42	Life history traits for common Blue Mountains conifer trees
43	Timber volume reductions associated with green-tree snag replacements
44	Density management field exercise
45	Climate change and carbon sequestration: Vegetation management considerations
46	Knutson-Vandenberg (K-V) program
47	Active management of quaking aspen plant communities in northern Blue Mountains: Regeneration ecology and silvicultural considerations
48	Tower Fire…then and now. Using camera points to monitor postfire recovery
49	How to prepare a silvicultural prescription for uneven-aged management
50	Stand density conditions for Umatilla National Forest: A range of variation analysis
51	Restoration opportunities for upland forest environments of Umatilla National Forest
52	New perspectives in riparian management: Why might we want to consider active management for certain portions of riparian habitat conservation areas?
53	Eastside Screens chronology
54	Using mathematics in forestry: An environmental education activity
55	Silviculture certification: Tips, tools, and trip-ups
56	Vegetation polygon mapping and classification standards: Malheur, Umatilla, and Wallowa-Whitman National Forests
57	State of vegetation databases for Malheur, Umatilla, and Wallowa-Whitman National Forests
58	Seral status for tree species of Blue and Ochoco Mountains

REVISION HISTORY

October 1983: information in this white paper was originally compiled as an uneven-aged management training guide, with the same title, when the author was Forest Silviculturist for Pike and San Isabel National Forests in USFS Region 2 (south-central Colorado).

September 1987: material from the October 1983 training guide was reformatted and edited during this revision.

October 2018: substantial formatting and editing changes were made throughout the document, including adding a white-paper header and assigning a white-paper number. Appendix 5 was added describing a silviculture white paper system, including a list of available white papers. Many additional references, and several new introductory sections, were added. New and updated graphics were prepared, and many new figures and tables were added.