BUREAU OF INDIAN AFFAIRS SILVICULTURE HANDBOOK

53 IAM 9-H

Bureau of Indian Affairs
Directorate, Environmental and Natural Resources
Division of Forestry
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FOREWORD

This handbook documents the procedures required to implement the Bureau of Indian Affairs' (BIA) Silviculture policy, as documented in Part 53 of the Indian Affairs Manual (IAM), specifically, 53 IAM 9. It supersedes all related content in 53 IAM 9-H: Silviculture, issued on 4/30/2012, and all policies and procedures related to silviculture on Indian lands that may have been created or distributed throughout IA previously.

This handbook is intended for use by BIA agency and regional forestry staff. It may also be useful for compacted/contracted Tribal staff.

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1. INTRODUCTION

Silviculture is the art and science of controlling the establishment, growth, composition, health, and quality of timberlands and woodlands to meet the diverse needs and values on Indian lands on a sustainable basis. Silviculture encompasses planning, evaluating, and investing in future resources by managing existing stands to meet future objectives. The use of sound silvicultural principles is required by 25 CFR 163.11.

Silviculture applies to all scales of forest management, from stand-level forest treatments to forest- level planning within Forest Management Plans. Silviculture prescriptions are developed at the stand- level and support the goals and objectives of the broader Forest Management Plan. More specifically, a silvicultural prescription outlines the planned series of activities that are designed to modify the existing structure and composition of the stand to meet desired future conditions. When combined across the forest, the silvicultural prescriptions provide a detailed course of action toward meeting the forest wide goals and objectives.

This handbook provides procedural guidance for implementing silvicultural practices to manage forest stands on lands held in trust or restricted status under the Bureau of Indian Affairs (BIA) jurisdiction. It outlines procedures, protocols, and best practices for developing, implementing, documenting, and evaluating forest management activities in alignment with the goals and objectives of the Forest Management Plan as detailed in 53 IAM Chapter 9, Silviculture. Additionally, the handbook addresses training opportunities, personnel requirements, and options for silviculturist certification based on BIA Regional standards. Notably, much of the content, particularly in Chapter 3, is adapted from the 10th edition of *The Practice of Silviculture: Applied Forest Ecology* by Mark S. Ashton and Matthew J. Kelty (2018). The terms ‘forester’ and ‘silviculturist’ are used interchangeably in the handbook.

This handbook can be used alongside other silviculture references, including textbooks, research journals, and technical reports. Referenced publications are listed in order of occurrence in the appendix and list of recommended reading is also provided. Use of proper terminology is necessary to avoid confusion when implementing silvicultural treatments. *The Dictionary of Forestry* edited by Dr. Robert Deal (2018) and published by the Society of American Foresters is the recommended reference source for terms.

2. SILVICULTURAL EXAMINATIONS

Prior to the preparation of a silvicultural prescription, it is necessary for the silviculturist to conduct an evaluation of site and stand-level conditions to identify the existing stand conditions, site capabilities and historical trends. A silvicultural examination includes two elements, an office review of available spatial and tabular data then a field examination to verify the existing stand condition.

2.1 Silvicultural Stand Examination

A review of historical forest management activities, whether conducted at the same site or adjacent areas with comparable forest cover types, is essential for understanding the treatment area of interest within the broader forested landscape. This review may utilize various forms of information, including spatial data, aerial imagery, regeneration surveys, soil type maps, monitoring reports, and other relevant documentation. Analyzing this historical data allows silviculturists to develop initial assessments of site productivity and to identify the forest metrics that need to be collected during the stand examination.

2.1.1 Silvicultural Examination Office Review

Spatial data, especially remote sensing information, plays a vital role in delineating existing stand boundaries, evaluating road access, classifying ecological sites, and assessing soil types. Additionally, it aids in identifying treatment constraints such as riparian management zones, wildlife habitat areas, and archaeological sites. Historical documentation, including previous prescriptions and Forest Officer Reports, is also essential for comprehensive assessments and effective forest management planning.

2.1.2 Silvicultural Examination Field Review

The field examination entails the collection and documentation of site and stand-level data to assess current stand conditions for diagnosis and prescription development (IAM 53, Chapter 9). By inventorying the immediate site and adjacent forested stands prior to treatment, forest managers can gather essential metrics that enhance understanding of the existing conditions and quantify the degree of deviation from the desired future condition.

2.2. Types of Stand Exams

There are two commonly utilized methods to collect data for stand diagnosis and prescription development. Formal stand/silvicultural exams use an unbiased sampling method, and walkthrough exams may use more observed sampling than measured sampling.

2.2.1 Formal Stand Exams

Formal stand exams involve collecting tree data using an unbiased sampling method, which may incorporate both variable radius and fixed radius plots. Data typically gathered includes species identification, diameter at breast height, total height, age, crown ratio, tree vigor, and information regarding insect and disease impacts. For accurate volume calculations, supplementary details such as taper and defects may also be required. It is essential to design the inventory to ensure that the sampling intensity sufficiently captures specific parameters to inform decision-making.

2.2.2 Walk-through Exam

A walk-through exam involves the collection of less extensive baseline data concerning the stand and trees than a formal stand exam and is often conducted prior to the development of a silvicultural prescription. This method is generally employed after a significant period has elapsed since the completion of a formal stand exam, allowing for verification that the forest conditions remain accurately represented by the previously collected data.

During a walk-through exam, the data may include key metrics such as species composition, quadratic mean diameter, basal area, and regeneration status. Unlike formal stand exams, plot locations in a walk-through exam are not established on a predetermined grid; instead, they are determined on-site during the visit. While some bias is anticipated in this approach, it is crucial that the selected locations are representative of the overall forest stand. The walk-through method does not adhere to true simple random sampling or systematic sampling techniques.

2.3 Forest Parameters

Forest parameters are essential for gathering fundamental data needed to understand forest ecosystems and are summarized to produce stand-level forest metrics such as basal area per acre. When selecting which forest parameters to collect, it is important to ensure that the data not only adheres to policy requirements but also provides specific insights into the characteristics of the forest stand. This information is crucial for evaluating whether the stated objectives and criteria for evaluation have been met. The following forest parameters are commonly collected during a silvicultural examination, although some can be determined during an office review. Other parameters should be collected as locally determined to meet silvicultural diagnosis needs.

A. Site-level Parameters
1) Elevation
2) Slope and aspect
3) Slope percent
4) Slope position
5) Soil type

B. Tree-level Parameters
1) Tree species
2) Stem count
3) DBH
4) Total height
5) Crown ratio
6) Age
7) Damage agents
8) Snag class

C. Regeneration-level Parameters

1) Tree species
2) Stem count
3) Diameter Class
4) Height Class
5) Damage agents

2.3.1 Other Factors for Consideration

In addition to forest parameters, other factors to consider include road access, compatibility of logging systems, topography, site productivity, habitat types or plant associations, and the physical properties of the forest soils within and adjacent to the stand. These factors can significantly influence management decisions and the overall health of the forest ecosystem.

A. Transportation Network

Transportation network analysis is required to plan management of forest resources, as it facilitates efficient monitoring, maintenance, and future timber harvesting activities. Though, road construction and maintenance can pose several environmental concerns that must be identified and documented. Key environmental issues to consider include:

- **Soil Erosion:** The creation and use of roads can lead to increased soil erosion, particularly on slopes where vegetation has been removed. It is essential to assess potential erosion sites and implement erosion control measures to mitigate impacts.

- **Wildlife Habitat Degradation**: Road access may fragment wildlife habitats, disrupt animal movement, and lead to habitat loss. Documenting the presence of critical wildlife habitats is necessary to evaluate the potential impacts of road construction and use.

- **Fisheries Habitat Degradation**: Roads that run adjacent to water bodies can contribute to sedimentation and pollution, negatively affecting fish habitats. Identifying proximity to fisheries habitats and potential runoff risks is important for conservation efforts.

B. Logging System Compatibility

Assessing logging system compatibility is essential for ensuring the efficient and sustainable harvesting of timber. This involves determining road access and evaluating whether the specific stand and adjacent forest areas require ground-based, cable-based, or helicopter logging systems.

- **Road Access Evaluation**: Analyze the existing road infrastructure to determine if it is suitable for supporting heavy logging equipment. Consider the condition of the roads, including width, stability, and potential maintenance needs.

- **Ground-based Logging Systems:** If road access is adequate, ground-based logging systems may be the most efficient option. This method utilizes equipment such as skidders and feller bunchers to harvest timber and transport it directly to the roadside.

- **Cable-based Logging Systems:** In areas where ground access is limited due to steep slopes or sensitive soils, cable-based logging systems may be necessary. This method employs cables and pulleys to transport logs to a landing area, minimizing soil disturbance and protecting the surrounding environment.

- **Helicopter Logging Systems:** For stands in remote locations or those with very poor access, helicopter logging may be the best solution. This system allows for transportation of logs without the need for extensive road networks, though it is generally more costly and requires careful planning to minimize environmental impacts.

C. Topography

When evaluating forest stands, it is crucial to consider how topographical features may impact site productivity. Various factors, including elevation, slope percent, and slope aspect, can significantly influence moisture gradients and, consequently, the overall health and growth potential of the forest ecosystem.

- **Elevation:** Changes in elevation can affect temperature and moisture availability. Higher elevations may experience cooler temperatures and increased precipitation, impacting soil moisture content and the types of vegetation that can thrive at different locations.

- **Slope Percent:** The steepness of slopes influences water runoff and infiltration. Steeper slopes may be more prone to erosion and rapid runoff, which can lead to reduced moisture retention in the soil. Conversely, gentler slopes may allow for better water absorption, enhancing site productivity.

- **Slope Aspect:** The direction a slope faces (slope aspect) determines the amount of sunlight it receives, which influences temperature and moisture levels. South-facing slopes generally receive more sunlight and are warmer, which can promote faster growth and different vegetation types compared to north-facing slopes, which are typically cooler and may retain more moisture.

D. Site Index

Field measurements of site index, utilizing tools such as hypsometers and increment borers, are critical for assessing the productivity of forest stands. The site index represents the potential growth capacity of specific tree species based on height and age.

E. Habitat Type/Plant Association

Habitat types and plant associations are valuable tools for assessing site productivity and understanding successional pathways within a forest stand. These classification systems describe the growth potential of different forest cover types and outline how stands may naturally develop in the absence of disturbances at either the stand or landscape level. Typically, most systems utilize late-successional plant communities as the primary unit for measuring site productivity.

These communities are characterized by their associated overstory and understory species, along with relevant physiographic factors that influence growth conditions. Classification guides for these systems often include a taxonomic key that uses specific understory indicator plants observed within the stand to help identify the community type.

While habitat types and plant associations provide useful insights for informing silvicultural prescriptions, they should not serve as the sole basis for management decisions. Additionally, it is important to note that not all geographic regions have established plant association data, which can limit their applicability in certain areas.

F. Forest Soils

Soil survey maps that offer detailed descriptions of topographical, physical, chemical, and biological properties of soils are essential for evaluating site and stand productivity in forest management.

- **Physical Properties:** These include soil texture, structure, porosity, density, drainage, and hydrology. Understanding these properties is crucial, as they directly influence the chemical and biological properties of the soil, which affect the overall site productivity.

- **Chemical Properties:** These encompass the soil's nutrient status, rates of nutrient cycling, and pH levels. Assessing these chemical characteristics is vital for determining the availability of nutrients necessary for tree growth and overall forest health.

- **Biological Properties:** This category refers to the various soil organisms that play a significant role in tree growth, such as mycorrhizal fungi, nitrogen-fixing bacteria, and a diverse array of invertebrates. These organisms contribute to nutrient cycling and soil structure, thereby enhancing site productivity.

3. DIAGNOSIS OF TREATMENT NEEDS

Following a comprehensive silvicultural examination, the process of stand diagnosis involves assessing the current conditions at both the site and stand-level by analyzing the collected data. This diagnosis specifically evaluates each forest stand's site capability and identifies how the current stand conditions may not align with the desired future stand conditions, considering a broader landscape perspective.

3.1 Analysis and Summarization of Forest Metrics

The diagnosis of treatment needs entails establishing desired future conditions that align with the goals, objectives, and criteria outlined in the Forest Management Plan. In this context, various forest metrics, such as species composition and structural characteristics, are analyzed throughout the stand's lifecycle, from initiation to regeneration harvest.

The diagnosis process begins by determining whether the forest stand meets the desired condition. If the stand is found to align with desired conditions, treatment can be deferred. Conversely, if the current stand condition does not meet the desired condition, the stand may be evaluated for treatment such as stand replacement through a regeneration harvest.

Forest metrics data is analyzed to produce summaries of the stand’s species composition, diameter distribution, density, regeneration, issues with insects and diseases, basal area, and volume. It is recommended that summary data be displayed using stock and stand tables that illustrate the stand composition by tree species and diameter class distribution. This includes calculations for average volume (stock table) and trees or basal area per acre (stand table), providing a comprehensive tabular overview of the stand which aid in the development of prescription alternatives.

3.1.1 Growth and Yield Models

Growth and yield models can also be employed to project the stand's future conditions and assist in formulating silvicultural prescription alternatives. The Forest Vegetation Simulator (FVS) serves as a nationally supported framework for forest growth and yield modeling, offering several geographically based variants that are implemented throughout the United States.

Effectively analyzing and modeling stand examination data is vital for diagnosing treatment needs and selecting appropriate silvicultural systems that encourage stand growth toward the desired future conditions specified in the Forest Management Plan.

3.1.2 Choice of a Silvicultural System

Forest management requires addressing complex biological, physical, social, and economic factors (Ashton & Kelty 2018). Furthermore, these factors must be considered over long-time horizons. Working under a systematic program is needed to ensure silvicultural treatments maintain ecological function and benefit tribes.

The choice of a silvicultural system must consider several key factors:

- Alignment with Tribal Goals and Objectives: The selected system should support the overarching goals and objectives set forth by the tribal management plan.

- Timely Regeneration of Desired Species: It is essential that the system facilitates the prompt regeneration of species that are desirable for the ecosystem and management goals.

- Efficient Use of Growing Space and Site Productivity: The silvicultural system should optimize the use of available growing space.

- Management of Forest Pathogens and Damaging Agents: The approach must include strategies to manage forest pathogens and damaging agents within acceptable limits to safeguard forest health.

- Conservation of Soil and Water Resources: The system must prioritize the conservation of vital soil and water resources to maintain ecological balance and support forest health.

- Long-term Harvest Volume Predictability: It should aim to produce a predictable amount of harvest volume over the long term, ensuring sustained yield while balancing ecological and economic concerns.

3.1.3 Characteristics of Even-aged and Uneven-aged Stands

Another factor to consider prior to developing silvicultural treatment alternatives, is whether the stand in question is even-aged or uneven-aged. Stands can be easily misidentified as uneven-aged since diameter distribution can be a poor indicator of age in many forest types. An overview of common characteristics of even-aged and uneven-aged stands is listed below for reference (Nyland, et al 2016):

A. Even-Aged

1) Diameters usually vary widely when a stand has shade-tolerant species.

2) Only old stands have sawtimber-sized trees.

3) Small trees have a short live-crown length compared to the total height (live-crown ratio), even as small as 10-15 percent.

4) The largest trees often have 20-30 percent live-crown ratios, depending on stand density and tree age.

5) The crown canopy (live foliage) is generally limited to a single layer and elevated well above the ground.

B. Uneven-Aged

1) Diameters range from seedling-sapling to sawtimber sizes, regardless of the species present.

2) Trees of all diameters have a high live-crown ratio, often 40-60 percent in managed stands.

3) Tree heights vary with tree diameters, with short ones having small diameters and tall trees having large diameters.

4) The crown canopy generally has multiple layers and commonly extends close to the ground.

3.2. Overview of Silvicultural Systems

“A silvicultural system is a planned program of silvicultural treatments extending through the life of the stand” (Ashton and Kelty, 2018). A silvicultural system is developed from stand-specific analyses that result in a prescriptive course of treatments to manipulate forest vegetation within select stands throughout the forest. Treatments control the establishment, composition, and growth of the stand to meet desired future conditions. Silvicultural systems include regeneration methods, may include tending operations, protective treatments, or intermediate cuttings that follow, and culminate in the removal of trees for purposes of initiating the regeneration. Proper timing of treatments is critical to successfully implementing a silvicultural system to achieve desired future conditions.

3.2.1 Components of Silvicultural Systems

All silvicultural systems include three basic components:

- **Timely Regeneration**: Treatments that establish a new cohort within a stand by natural or artificial methods. Timing of the implementation is a critical element in the success of the regeneration treatment.

- **Tending or Intermediate Treatments**: Actions that are intended to enhance growth, quality, vigor, and composition of the stand after establishment or regeneration and prior to final harvest.

- **Harvest**: An intermediate or final cutting that removes commercial forest products from trees.

3.3 Even-aged Systems

Even-aged systems produce stands that consist of trees of the same or nearly same age class. A stand is considered even-aged if the range in tree ages does not exceed 20% of the rotation age. Methods that produce even-aged stand structures include clearcutting, seed tree, shelterwood, and coppice.

A. Even-aged Regeneration Methods

B. Clearcut (CC) is a method of regenerating a stand in which a cohort, or new age class of seedlings, develops in a fully-exposed microenvironment after removal, in a single cutting of all trees in the previous stand. Regeneration is from natural seeding, direct seeding, planted seedlings, and/or advance regeneration. Cutting may be done in groups or patches (group or patch clearcutting), or in strips (strip clearcutting). In the clearcutting system, the management unit in which regeneration, growth, and yield are regulated consists of the individual clearcut stand. When the primary source of reproduction is advance regeneration, the preferred term is "overstory removal".

C. Seed-tree method (ST) is an even-aged regeneration method in which a new age class develops from seeds that germinate in virtually a fully-exposed microenvironment after removal of the entire stand except for a small number of widely dispersed trees retained for seed production. Seed trees may be removed after regeneration is established.

D. Shelterwood (SW) is a method of regenerating an even-aged stand in which a new cohort, or age class of seedlings, develops in a moderated microenvironment beneath the residual trees. The sequence of treatments can include three distinct types of cuttings:

1) An optional **preparatory cut** for regeneration and accomplish one or more of the following:

   a) Enhance conditions for seed production by releasing future seed trees.

   b) Develop wind-firmness of future seed and shelter trees.

   c) Provide for the removal of merchantable suppressed and intermediate trees thereby reducing breakage during the establishment cut.

   Care should be taken to keep crown closure high enough to discourage expansion of grass, shrub or forb competition.

2) An **establishment cut or shelterwood seed cut** to prepare the seed bed and to create the new stand; and

3) The final **removal cut** to release the established regeneration from competition with the seed and shelter trees.

Cutting may be done uniformly throughout the stand (uniform shelterwood); in groups or patches (group shelterwood); or in strips (strip shelterwood). Alternately, the final removal cut may be deferred, creating an irregular shelterwood, where regeneration occurs over a considerably longer period than a traditional shelterwood. Irregular shelterwoods are described in detail later in Section 3.9.

E. Coppice is a method of regenerating a stand in which all trees in the previous stand are cut, knocked over, or injured at the root and the majority of regeneration is from stump sprouts or root suckers. This is primarily used in hardwood stands; however, coastal redwoods may also be regenerated using this method.

3.4 Policy Requirements for Regeneration

Regeneration is a critical and often costly phase of the prescriptive cycle. The Code of Federal Regulations, 25 CFR § 163.12 (a) states:

"Harvesting timber on commercial forest land will not be permitted unless provisions for natural and/or artificial reforestation of acceptable tree species is included in harvest plans."

Choosing the right regeneration method is the first step toward assuring adequate, timely regeneration of a target species.

3.4.1 Considerations for Choice of Regeneration Method

The choice of regeneration method is dependent upon a potential host of silvical, ecological, societal and administrative factors. Natural regeneration should be the first choice if it can meet stocking objectives for desired species efficiently and cost-effectively. This method ensures the establishment of native genetic stock and site-adapted seedlings.

- Investment analysis indicates that the net present value (NPV) (or other measure) of planting or seeding is significantly greater than the natural regeneration option. This might occur due to site severity factors infrequent cone crops, stiff vegetative competition to seedlings, or the development of vegetative competition in stands where site preparation will likely be administratively delayed (e.g., while waiting for burning windows, etc.)

- The need to improve genetic potential of the new stand.

- The vigor, health or age of the existing stand may not afford natural regeneration of the desired species

- The need to restore species diversity or ensure full stocking of desired species.

- Consider the size and shape of the harvest unit in relation to the effective seed dispersal distance of desired species, along with the topographic position and prevailing wind direction's effect on seed dispersal and windthrow risks.

- Assess site improvement needs for hot, dry, or frost pocket areas, utilizing residual trees in conjunction with planting or as a supplement to natural regeneration.

- Evaluate slope steepness, site preparation methods, and associated costs, including protection for reserve trees from fire and the economic viability of removing seed or shelter trees, as well as the impact of aspect on burning windows and timely site preparation.

3.4.2 Components of a Successful Regeneration System

For a detailed discussion of reforestation and site preparation techniques, refer to 53 IAM 5-H, Forest Development. The goal of the prescription is to regenerate a fully-stocked stand with established seedlings of the desired species, however, a prescription should not be implemented without careful consideration of these important items:

- Species selection: Consider genetics along with existing insect or disease potential in the area such as root rot or mistletoe to determine appropriate planting schemes.

- Long-term site protection: Consider large woody debris retention, long- term nutrient capital, soil compaction and displacement issues, and cultural resource protection.

- Site preparation: Consider cost effectiveness; silvical needs of target tree species; protection of seed or shelter trees; response of the tree, shrub, and grass community; and consistency with historical disturbance patterns.

- Hazardous fuel disposal or treatment: This is generally accomplished during the site preparation process and those same items listed above should be considered.

- Harvesting: Felling, skidding, and processing methods should be consistent with all the above listed items.

3.5 Intermediate Treatments

Intermediate treatments include all silvicultural treatments occurring in stands that are between regeneration periods. Intermediate treatments are performed to ensure the desired species composition; improve stem quality; or adjust stand density (spacing) to regulate growth in a developing stand. These treatments have the primary emphasis of correcting stand defects and increasing the volume and value of usable forest products. There is no intention of establishing regeneration through the application of an intermediate cut. Consideration for the protection of the residual stand is necessary during this entry.

Common classifications of intermediate treatments are as follows:

3.5.1 Release Cuttings

These treatments are designed to free young, target trees from undesirable, usually overtopping, competing vegetation. The emphasis is upon stand improvement and species composition, rather than growth effects, although increased growth rates are an advantageous outcome.

The types of release treatments include:

Cleaning - A release treatment made in an age class not past the sapling stage which frees the favored trees from less desirable tree species of comparable age. A cleaning treatment might be applied to ease young ponderosa pine stands from competing juniper trees or oak sprouts in the southwest; or to free white pine from overtopping by hardwoods such as aspen, in eastern regions.

Weeding - A release treatment made in stands not past the sapling stage that eliminates or suppresses any undesirable vegetation regardless of crown position and may include grass, vines, or shrubs. Undesirable competing vegetation in the southwest includes oak, grass, or locust; and in the northwest may include mountain and vine maple. This term is typically used to describe a more thorough removal of all plants competing with the crop species regardless of whether their crowns are above, beside or below the desired trees.

Liberation - A release treatment used to open up overtopping growing space to young stands that are below the seedling, sapling, or pole stage by removing older and larger trees. This treatment differs from a cleaning treatment in that the trees removed are from a much older age class. This method may resemble the final removal cuttings of the seed-tree or shelterwood regeneration methods. The difference however is that generally undesirable trees are removed, rather than ones left intentionally for seed and or additional growth.

Liberation cuttings often yield low harvest volumes per acre and may be passed over within a treatment area for that reason. However, they may be one of the highest priorities for treatment if the understory will not only be liberated but protected from pathogens such as dwarf mistletoes.

3.6 Thinning

Thinning occurs between regeneration and final harvest to reduce stand density for the purpose of stimulating the growth of remaining trees to increase the yield of desired products, enhance forest health, or recover potential mortality. Its primary focus is on the re-distribution of resources to selected leave trees to enhance growth potential.

3.6.1 Methods of Thinning

Low Thinning: trees are removed from lower crown classes to reallocate resource utilization from these crown classes to the codominant and dominate crown classes. The method emulates natural stand development as stem exclusion occurs. Removing smaller trees from lower crown classes can be important for fuels reduction or aesthetic objectives.

Crown Thinning: trees are removed from the middle and upper canopy classes to release vigorous trees in the same classes. The favored crop trees reserved from cutting are healthy dominants and codominants with excellent form. When applied, these crop trees generally have a set spacing distance from each other, and it is applied uniformly across the stand. Intermediate or suppressed trees that do not interfere with the growth of crop trees are not harvested. This maintains some vertical structure in the stand which can be important to prevent epicormic branching or provide wildlife habitat.

Dominant Thinning: trees in the dominant crown class are removed to facilitate growth of trees in the lower crown classes. This method can lead to high grading if applied incorrectly. Dominant thinning has three applications:

1) Removal of Poor-Quality Dominants – Some stands may develop large, branchy crowns which are undesirable or poor form due to disease, insects, and damage from weather. This one-time thinning treatment can remove these trees and reallocate resources to better formed trees in lower crown classes.

2) Species Conversion – dominant trees can be removed to create an even-aged, mixed species condition. Often the objective is to remove shade intolerant species in an upper crown class to promote shade tolerant species in lower classes. An example from the Northeast US is removing birch to promote the growth of maple and beech.

3) Allocate Growing Space to the Understory – dominant thinning can be used to promote the cultivation of non-timber forest products (NTFPs). Removing larger trees in even or uneven-aged stands can provide more sunlight into the sub-canopy layers to grow tree or herbaceous species important for NTFPs.

Free Thinning: this method combines low, crown, and dominant methods to spatially explicit areas of the stand. Generally, these stands are mixed species with a variable spatial arrangement. A combination of thinning methods can create a more uniform stand condition to meet objectives. For example, one area of the stand may require a dominant thinning due to ice-storm damage while the remainder of the stand receives a crown thinning.

Variable-Density Thinning: trees are removed to create a more complex forest structure. Often, the previous methods are implemented using uniform spacing requirements in even-aged stands which can conflict with other management objectives. This method can be viewed as the opposite to free thinning where uniform stands are driven to an irregular structure. A larger variety of ecological conditions exist in the stand as a result. Variable-density thinning has been used in the Pacific Northwest to meet wildlife habitat objectives through thinning stands with a series of canopy gaps and un-thinned patches in stands.

Geometric Thinning: also known as a mechanical thinning, trees are removed based on a geometric spacing pattern only. This method is usually applied in young plantations where minimal crown differentiation has occurred. Thinning using a rigid geometric spacing is the least efficient method in distributing growing space across the stand, however its simplicity makes it easy to implement. Another advantage is the spacings created allow the stand to be readily accessed by harvesting equipment during future entries.

3.6.2 Understanding the Quantitative Applications of Thinning

Objectives for thinning treatments can range from forest health, aesthetics, and watershed quality, however, thinning is often implemented to produce dimensional wood products (Ashton and Kelty 2018). Numerous indices and theories exist on thinning to guide foresters on maximizing yield in stands. It is important to have a strong understanding of how stands develop in time with and in the absence of thinning treatments to apply these guidelines appropriately.

In even-aged systems where thinning is typically applied, growth in can be measured using the following volume metrics:

- **Mean Annual Increment (MAI):** the total increment of a tree or stand (standing crop plus thinnings) up to a given age divided by that age.

- **Periodic Annual Increment (PAI):** the growth of a tree or stand observed over a specific time period divided by the length of the period.

- **Current Annual Increment (CAI):** the growth observed in a tree or stand in a specific one-year period.

Volume increases rapidly in young stands as stem exclusion occurs where tree crowns compete for photosynthetic capacity (Nyland et al 2016). Over time, height and diameter growth slow once crown positions stabilize and some trees die which reduces PAI. The reduction in the trend of PAI will theoretically at some point cause it always to intersect with the peak of MAI. This point is referred to as the culmination of mean annual increment (CMAI) or biological rotation age where stand growth has reached its maximum. Here, the stand is harvested if the objective is to maximize long-term yield (Ashton and Kelty 2018). Harvest would generally occur at a slightly earlier age than CMAI if the objective is to manage for net present value of commercial forest products.

The competition induced mortality as stands age suggests a relationship between the maximum number of trees that can occupy a site and the average basal area. Reineke (1933) notably defined this as stand density index by plotting the logarithm of number of trees per acre against the logarithm of average diameter of fully stocked stands which showed a straight-line relationship (Avery and Burkhart 2002).

The slope of the straight-line in almost all forest types approximates -3/2, leading to the name “3/2 Law of Self-Thinning” where competition induced mortality occurs (Avery and Burkhart 2002). Shade tolerant species have higher upper limits of stocking and can retain more trees per acre before self-thinning begins. Applicability of the 3/2 law does not hold well in uneven-aged stands and likely most mixed species stands (Ashton and Kelty 2018).

3.6.3 Stand Density Index and Relative Density

Stand density index is the basis of many indices and graphical tools used to quantitatively guide thinning decisions. It is calculated using the stand’s quadratic mean diameter and trees per acre:

SDI = TPA * (stand QMD / 10)^1.605
This equation calculates stand density with any combination of size and density and re- expresses it as if the stand had an average diameter of 10 inches.

The highest possible relative density for a given species is termed Maximum SDI (SDImax). Since the maximum SDI has been determined for numerous species, one can calculate the current relative density (actual SDI / SDImax). Relative density can be used to estimate how much the stand will grow in average diameter and basal area in a fixed time period. Researchers suggest specific “zones” of density which implicates the need for treatment. These zones are not strict rules but rather tend to be thought of as ranges that allow for approximations of treatment schedules.

Relative Density values indicate the following zones of stand development:

- 0.15-0.25 is crown closure/onset of competition
- 0.35 is the lower limit of full site occupancy
- 0.55-0.60 is the lower limit of self-thinning, where competition-based mortality begins

Density Management Diagrams (DMD) are simple graphical models of even-aged stand dynamics (Long and Shaw, 2005) developed for mostly western species that can also be used for designing a density management regime. The most common application of DMDs is in determining what post-thinning density will result in the type of stand desired at the next entry (Long and Shaw, 2005).

There are multiple measures of relative density and one should be familiar with what is most used in their area. For example, Drew and Flewelling (1979) have included height as a way of incorporating the relationship between tree volume and numbers of trees per unit at maximum density for Douglas-fir in the Pacific Northwest. Numerous other indices are available such as crown competition factor.

3.6.4 Responses to Thinning

Thinning is essentially the reallocation of growing resources in a stand. Residual trees after a thinning have less competition and increased vigor. The result generally creates greater stand health and yield of dimensional wood products. The ratio of sawtimber to pulp is substantially larger in thinned stands than stands without thinning. Sawtimber gains can exceed 25-40% of gross growth (Nyland 2016). For stand development of overtime, periodic thinning treatments temporarily reduce stand volume with the residual trees capitalizing on the opened growing space. The trend of stand volume over time will have a saw-toothed appearance marking each thinning entry along a positive slope. Thinning treatments timed and applied to maximize use of growing space in the stand will delay when PAI peaks. DMDs can be used to achieve a positive slope and increasing volume production over the length of a rotation.

Yields of sawtimber are increased by thinning, however overall stand volume is usually diminished. The vacancies in growing space left by harvesting account for a loss in total biomass at the end of a rotation. Research has produced many widely used relationships to describe the interactions of thinning, stand density, and stand volume. Though foresters should exercise caution in assuming such relationships will always predict thinning treatment outcomes. "Langsaeter's Curve" published in 1941 was considered a central rule of silviculture and taught extensively. The curve proposed that total stand growth plateaus after a low level of stand stocking is attained and therefore foresters had considerable flexibility in thinning intensity to create larger individual trees without any substantial loss in total stand volume production (Dean et al 2020). Several studies have demonstrated continued volume growth with increasing stand density including a long-term study examining coastal Douglas-fir (Curtis et al 1997).

High site productivity appears to be key in this continuation of growth. Faults with Langsaeter's curve are now well documented with a considerable body of evidence showing a tradeoff exists between individual tree growth and stand growth.

3.6.5 Caution on Thinning

Thinning response studies in recent decades have challenged many of the standard assumptions around thinning. In certain outcomes, thinning treatments have shown to increase tree mortality by wind damage or water stress and create growth stagnation across the stand (Bose et al 2018). Other studies emphasize timing is critical, with low to mid-shade tolerant species requiring thinning early in stand development for positive growth responses while certain tolerant spruce-fir forest types can respond to thinning even after 70 years of age (Bose et al 2018). Thinning treatments are to be developed with a detailed consideration of species silvics with site factors like soil type and climate.

3.7 Pruning

Artificial forest pruning is a silvicultural treatment, performed to improve wood quality or to remove dead or diseased limbs. It is labor intensive, costly, and requires an understanding of the treatment objectives.

3.8 Irregular or Two-Aged Systems and Reserve Trees

Modifications to traditional systems such as the shelterwood or clearcut method where some trees remain in the stand for extended periods can be an effective way to meet ecosystem management goals. These are known as two-aged or irregular systems and are often viewed to emulate natural disturbances. Stands contain two or more age classes where regulation through balancing the classes is not a concern. Typically, most of the area is occupied by a younger cohort of trees regenerating after a harvest with a small portion of stand containing mature trees kept for meeting specific objectives.

The term 'irregular' has multiple definitions in silviculture literature and is most associated with shelterwoods. Definitions are centered on how retention age classes are spatially distributed or the timeframe for harvest entries. In both cases, the reasoning for these prescription decisions differs from traditional systems. Though the functions for securing regeneration remain the same as traditional systems regardless of the irregular or two-aged system chosen. Irregular systems can include more than two age classes and the term will be used hereafter, however the silvicultural principles described are entirely applicable to two-aged systems or stands. Key reasons for selecting an irregular shelterwood or other method include (Ashton and Kelty 2018):

- To retain the habitat structure of a mature forest. Many wildlife, plants, fungi, etc. are uniquely adapted to these environments.

- Maintaining a portion of mature forest may be necessary for aesthetic, religious, or cultural value.

- Exceptional timber quality. Some large or slow-growing trees may need to be kept for twice the normal rotation length or longer.

- Successful establishment of difficult-to-regenerate tolerant and mid-tolerant species.

3.8.1 Reserve Trees and Considerations for Irregular Methods

The selection of trees designated to be reserved and the timing of harvest entries are key components when using irregular methods. These decisions are largely based on the silvicultural system being adapted also the concepts on reserve trees discussed have applicability to regular even-aged methods. Shelterwoods are perhaps the most complex to implement as reserve trees provide a seed source and must be distributed spatially to create a favorable shading environment for the desired crop trees. One example of an irregular shelterwood method gaining use is the 'Femelschlag' or expanding- gap shelterwood for the regeneration of oak species in the eastern US. Here, gaps are made during the initial entry where cohorts of regenerating oak are shaded on the sides of the gap. The timing of the next entry to expand the gap only occurs when the oak seedlings have reached sufficient height to become advanced regeneration and can respond favorably to release. Timing decisions for any irregular method are usually made to ensure the desired regenerating species is established, but could be based so reserve trees can obtain the quality needed for a certain forest product.

When using a seed-tree method, the seed trees may be retained in stand indefinitely to meet certain habitat requirements. The clearcut method is often prescribed with reserve trees. A single regeneration cut still occurs, however the reserve trees are only left for habitat or aesthetic reasons. These trees do not have any function for regenerating the next cohort.

Reserve trees need to meet certain criteria for achieving the prescription objective. Habitat-based objectives may favor trees with cavities or partial decay, uncommon species, tree species that provide an important food source for wildlife, etc (Ashton and Kelty 2018). These differ from timber-based objectives which may include, excellent stem form, be windfirm, and have crowns of sufficient size to produce a stem-growth response to the larger growing space (Ashton and Kelty 2018).

Two methods exist for the spatial distribution of reserve trees in the stand: dispersed distribution and aggregated distribution. In dispersed distribution, the trees are scattered throughout the stand and generally at a certain density. Basal area, trees per acre or canopy cover percent can be used as prescription guidelines when the stand is marked. Aggregated distribution clusters patches of trees in certain areas of the stand. This may be needed to protect wetlands, rock outcrops, and other areas of ecological importance (Ashton and Kelty 2018). The shape of the patch can be made to meet objectives such as a teardrop oriented to prevailing winds to prevent windthrow or a linear shape for wildlife corridors (Ashton and Kelty 2018).

3.8.2 Growth Considerations with Irregular Methods

In any use of irregular methods, foresters need to consider how reserve trees will affect the growth of the regenerating crop tree cohort. The density of reserve trees may significantly impede the growth of seedlings. This is especially true of aggregated regeneration. Residual basal areas can be quite low and still decrease growth. In Douglas fir stands of the Pacific Northwest, regeneration growth was reduced by 20% with an overstory basal area of only 15-20ft^2 (Birch and Johnston 1992).

3.9 Uneven-aged Methods using Selection Systems

Selection systems use treatments to maintain growth in three or more distinct age classes. The stand is never fully rotated as is the case with even-aged silvicultural systems. Periodic harvests create enough disturbance to trigger regeneration each time the stand is entered. This period between entries is called a cutting cycle (Ashton and Kelty 2018). A prescription under the selection system strives for targeted reductions of trees throughout age classes, coupled with regeneration to create a stand where each age class occupies the same amount of area. These are referred to as 'balanced' stands.

Balanced stands or ones approximating the condition, produce sustained yields of forest products at regular intervals. The stand should provide high-quality sawtimber trees, regular replacement of mature trees with vigorous growth from a younger age class, and a stable condition of forest structure.

Ecosystem services such as wildlife habitat, hydrologic conditions, and visual qualities also remain fairly stable throughout time (Nyland 2016). Using uneven-aged systems to create perfectly balanced stands is not necessary. Generally, the objective is to manage stands for multiple age classes to maintain appropriate growth and regeneration while meeting tribal goals.

The selection system is not appropriate for all forest cover types. It can be successfully implemented in certain shade-intolerant cover types such as ponderosa pine and longleaf pine, however it is best used for cover types with the following characteristics (Nyland 2016):

- Shade-tolerant species
- Long-lived species that will grow well even at advanced ages, and produce regular seed crops
- Species with seed that germinate in undisturbed litter and a partly shaded environment

3.9.1 Types of Selection Systems

Single Tree Selection

The single tree selection method creates regeneration openings equivalent to the crown spread of a single mature tree. These small discontinuous openings provide enough light and moisture for regeneration by seed or vegetatively while serving a thinning function for trees in the various age classes present. As the cutting cycle ends, lateral growth by adjacent older trees will suppress the regenerating cohort which need release during the next entry. Single tree selection is often viewed as simulating the stand dynamics seen in gap-phase disturbances such as wind or the death of single mature trees. It should be cautioned that repeated cutting cycles of this treatment over multiple decades may drive mixed-species stands to become comprised purely of one shade tolerant species.

Group or Patch Selection

The group selection method removes trees grouped together generally in areas the size of two mature tree heights or smaller. This method can accommodate species with wider shade tolerances as the environmental gradient shifts from the edge of the gap to the center where light and moisture conditions may approach that of a true clearcut. Essentially the harvested groups become even-aged aggregations within the larger stand (Ashton and Kelty 2018).

Any opening larger than two tree heights can be considered a patch. Patches can create a level of disturbance similar to a one-cut shelterwood and use scarification to meet species regeneration needs (Ashton and Kelty 2018). Patches are often used in a hybrid system with single tree selection to release areas of advanced regeneration and diversify species composition.

3.9.2 Methods for Implementing Selection Systems

Numerous methods have been proposed to create balanced stands using mathematical relationships or guides derived from long-term research studies focused on regional forest cover types. Long held views of silviculture in the 20th century saw balanced stands as perfect sustained-yield units resembling old- growth forests which were thought to be in a state of self-maintaining equilibrium (Ashton and Kelty 2018). This concept of a balanced stand has no basis in natural forest development, however the methods presented here can be useful tools to regulate growth across age classes and maintain or create uneven-aged stands.

A tight relationship exists between the cutting cycle, residual stocking, and site quality. Cutting cycle lengths in many selection system applications are short ranging from 5-20 years. Several factors influence determining a regular interval length for a cutting cycle. Two key factors include: 1) what is the residual stocking needed to achieve regeneration requirements 2) what is the volume amount needed to make the harvest entry financially and logistically viable (Dickinson 2020). While balancing these factors is critical, foresters can also incorporate growth into cutting cycle determinations.

A common mathematical approach to regulating growth using diameter class is called BDq. The stand structure is moved to a negative exponential also known as a reverse- J diameter distribution using a ‘q- factor’ which is the ratio of trees in a diameter class to the number of trees in the next larger class (O’Hara and Gersonde 2004). ‘B’ is the target stand basal area, and the ‘D’ represents the maximum diameter class allowed. These factors are used together with the q-factor being the guiding value providing the slope of the line cutting across all diameter classes. A stand with a q-factor of 2.0 would have twice as many trees as the next larger diameter class with 2.0 representing a steeper slope than a factor of 1.5. The higher the q-factor, the more trees are being harvested in the larger diameter classes with the reverse being true for lower factors.

BDq is based on the concept that any stand with a q-factor structure has arrived at a stable equilibrium which would continue if the cutting cycle or disturbances kept returning the diameter distribution to the same q-factor (Ashton and Kelty 2018). Some examples of natural stands exist with a q-factor-like diameter structures which informed the creation of the method (Meyer 1952). Again, it should be noted no evidence exists that a stand with a true reverse-J diameter distribution containing multiple age classes occurs naturally (Ashton and Kelty 2018). Studies on natural occurring uneven aged stands over different regional cover types often show diameter/age distributions with a horizontal 'S' shape or lacking any smooth curve. Foresters should recognize BDq is a human construct created by foresters to regulate growth and meet sustained-yield objectives (O'Hara 2015).

The sustainability of the BDq method is centered on removing the excess trees that exceed the target diameter distribution. A balanced stand is theoretically created by the q-factor producing a structure where volume cut equals volume growth, and each size class occupies equal growing space (O'Hara and Gersonde 2004). Though realistic application of the method will certainly require adjustments over multiple cutting cycles. For example, some have proposed assigning different q-factors to sapling, pole, and sawtimber sizes classes to address issues with growth rates or regeneration (Nyland 2016). Another flexibility could be increasing the target basal area to allow for more stocking in each size class.

Further caution needs to be exercised when implementing BDq as it assumes the necessary amount of regeneration will occur at the correct time to backfill trees as growth moves existing trees into new diameter classes (Ashton and Kelty 2018). Also, mistakenly assuming different diameter classes sizes are indictive of age could lead to high grading (O'Hara and Gersonde 2004). BDq provides clearly calculated metrics to inform prescriptions and can be sustainable, however close monitoring of the stand structure over cutting cycles is needed to determine if adjustments are necessary.

Other quantitative methods for implementing selection systems are centered on the ecological factors driving natural stand dynamics. Stand density index allocation takes concepts from relative density calculations for even-age stands and instead applies SDI at the diameter class level in uneven-aged stands. SDI values for each diameter class in reference to a combined target SDI value become the
means for determining growing space allocation. A detailed explanation of this method using conifer stands in the southwest is given by Long (1998) as well as Long and Daniel (1990).

A more recent method using leaf area index (LAI) instead of diameter class to regulate growth across age classes has been developed by O'Hara (1996) and others. It works by dividing the stand into canopy strata or age classes with LAI as the metric for each unit's growing space occupancy. Growing space can be allocated over cutting cycles based on LAI to balance the stand or create a desired structure. Elements for success with this method include determining the amount of LAI to be maintained which is closely tied to site quality and how this value will be allocated by canopy strata or age class (Ashton and Kelty 2018). An overview of the LAI method or commonly known as the Multi-aged Stocking Assessment Model is provided by O'Hara, Valappil, and Nagel (2003). This method has been applied in ponderosa pine cover types.

3.9.3 Operational Considerations for Selection Systems

Successful implementation of the selection systems generally requires more fieldwork than other silvicultural treatments during the planning stage. Stand exams must be of a large enough sample size to provide accurate metrics on age, size class, stocking, and species present. Skilled timber marking is also critical to avoid common errors such as confusing tree size with age.

Careful sale design for logging systems is needed during planning. The high residual basal area in many treatments make efficient use of harvesting equipment difficult and valuable sawtimber trees can be easily damaged by moving equipment. Skid trails should be designated prior to harvest to offset this and prevent unnecessary soil compaction.

3.10 Treatments to Control Damage

Opportunities occasionally exist to apply treatments to reduce or eliminate the impacts of anticipated disturbances. These treatments are generally variations of the clearcut method and are used on stands vulnerable to fungi, insects or in some instances abiotic disturbances. Treatment implementation occurs on a rapid timeline to prevent impacts from forest pests or capture value from recent mortality. Use of the following treatments requires a thorough understanding of the forest disease being anticipated or the impacts of a certain abiotic disturbance.

3.10.1 Pre-Salvage Cuttings

Pre-salvage cuttings are targeted harvesting of individual tree or stands where mortality is anticipated soon. With abiotic disturbances such as ice or wind, trees with asymmetrical crowns already damaged from ice can be harvested to prevent windthrow. Stands with species susceptible to pests like bark beetles are more commonly treated than abiotic disturbances. Some species such as ponderosa pine have visual guides to determine tree vigor and select trees more vulnerable to beetle outbreaks. Widespread use of this practice is discouraged as it may eliminate resistant genotypes to pathogens.

3.10.2 Sanitation Cuttings

Sanitation cuttings generally blend objectives of pre-salvage and cutting affected trees. Stands or trees are harvested which are the source of an insect or disease infection. Surrounding trees that are likely to be susceptible are also included. A sanitation harvest must disrupt the outbreak cycle of the disease or insect to be effective, as many pathogens can spread rapidly and over long distances where any harvesting would provide no control. Sanitation is often applied to for bark beetle outbreaks in western conifer forests.

3.10.3 Salvage Cuttings

After a disturbance such as a fire or bark beetle outbreak, a salvage harvest can occur to recapture some value of the standing timber. A salvage is not meant to control the spread of diseases. Factors to consider are if the merchantability of the dead trees can justify the cost of harvesting operations and the importance of snag creation for wildlife. Timing of harvesting is critical especially with burned stands where subsequent insect outbreaks can further degrade the timber value. The health of the trees damaged by the disturbance should be judged to determine its vigor post disturbance. With severe fires, some species such as red pine can make a full recovery with 10% or less of live foliage left. Guides for many conifers are available to determine burn severity and potential recovery for individual trees.

3.11 Traditional Ecological Knowledge and Silviculture

Foresters are encouraged to work with tribal governments and find ways to bring Traditional Ecological Knowledge (TEK) into silvicultural treatments when opportunities exist. The use of TEK practices can increase the likelihood of treatments meeting tribal goals and objectives. Implementation of TEK practices requires the permission of tribal community members who hold such knowledge. In most instances TEK is considered sensitive information and ownership of the knowledge will need to remain with the tribe after implementation.

4. SILVICULTURAL PRESCRIPTION

A silvicultural prescription is a detailed written document outlining the specific treatments required to guide forest growth toward a desired future condition. These prescriptions are written for individual stands and provide a comprehensive overview of the necessary treatments at present to achieve management objectives within a selected silvicultural system. For instance, a stand managed under a shelterwood system may currently require an establishment cut to prepare the seedbed, with a final removal cut scheduled several years later. Each of these treatments receives separate prescriptions when the stand is ready.

4.1 Guidance from FMP

The objectives and silvicultural systems outlined in the prescriptions must align with the tribal Forest Management Plan. According to the Minimum Content Standards for Forest Management Plans outlined in 53 IAM 2, essential components include "Landowner Goals and Objectives" and "Silvicultural Guidelines." Understanding these content standards is critical in preparing an effective prescription. Treatments described in the prescription must also meet NEPA criteria.

4.1.1 Elements of a Silvicultural Prescription

The following listed elements are the minimum content standards required in the prescription. Economic analysis can sometimes be disregarded depending on the treatment. Prescriptions with cost intensive treatments such as site preparation, artificial regeneration, and precommercial thinning are recommended for economic analysis. A prescription example is included in the chapter appendix.

A. **Site Description.** The site description consists of the following items:
   1) Location on the Landscape
   2) Landform or Classification
   3) Acres, Soils, Water, Geology
   4) Slope, Aspect, Elevation
   5) Special or Unique Considerations
   6) Threatened, Endangered, and Sensitive Species
   7) Previous Disturbances
   8) Previous Management History

B. **Stand Description.** The stand description consists of the following items:
   1) Stocking, Density, Basal Area
   2) Stand Structure
   3) Species Composition and Forest Type
   4) Number of Cohorts and their Age Classification
   5) Stage of Stand Development
   6) Present Condition
   7) Regeneration Potential
   8) Site Productivity
   9) Fuels and Coarse Woody Debris

10) Habitat Considerations

C. Goal, Objectives and Evaluation Criteria

This section provides a clearly defined statement that reflects the current condition of the stand, outlines the desired future condition, and describes the pathways to achieve that condition using quantifiable assessment methods.

Objectives serve as specific, measurable interpretations of the overarching goals, which are typically more general and qualitative in nature.

Evaluation Criteria act as quantitative indicators to determine whether an objective is achievable through a given silvicultural treatment alternative. Generally, one to three evaluation criteria should be developed for each objective statement. When formulating an evaluation criterion, it is advisable to avoid terms such as “reduce” or “increase.” Instead, utilize precise quantitative phrases like “greater than…,” “less than…,” or “within [a specified] range of…”

An example for a given forest stand is provided below:

GOAL:

Minimize fire hazards for forest users and landowners while enhancing the probability of successful fire suppression.

OBJECTIVE:

Establish and maintain fuel profiles and loadings to reduce the risk of crown fire during periods of severe fire weather (95th percentile Energy Release Component).

EVALUATION CRITERIA:

a) Crowning index greater than the critical wind speed (23 mph).

b) Torching index greater than the critical wind speed (23 mph).

c) Surface flame length less than 4 feet.

D. Treatments to be Prescribed

This section provides a comprehensive overview of the proposed treatments, including the selected silvicultural system, regeneration methods, and intermediate operations. Additionally, it discusses whether reforestation will be conducted through natural or artificial means, as well as the necessary site preparation methods, if applicable. It is essential to include sufficient detail to facilitate the implementation of treatment activities, along with measurable criteria for quantification. Furthermore, the sequence and timetable for these treatment activities should be clearly outlined.

E. Landscape Considerations

This section describes how the proposed treatments will enhance or mitigate impacts on other resource areas, including cultural resources, watersheds, and wildlife and fisheries habitats.

F. Economics

This section includes an economic analysis for the purpose of justifying the costs associated with any management treatments. This analysis is particularly essential for treatments such as pre-commercial thinning, site preparation, and artificial regeneration projects. Common analytical techniques used in silviculture include Net Present Value (NPV) and Soil Expectation Value (SEV).

G. Monitoring

This section provides guidelines for the ongoing assessment of the implementation and effectiveness of the prescribed treatments. Detailed descriptions of monitoring protocols will be provided in the following chapter.

5. MONITORING AND EVALUATION OF SILVICULTURAL TREATMENTS

Monitoring and evaluation are essential following silvicultural treatments to ascertain whether the objectives and evaluation criteria outlined in the silvicultural prescription have been achieved. It is imperative that silvicultural prescriptions incorporate a comprehensive monitoring plan that includes specific objectives and quantifiable evaluation criteria for assessing the success of the treatments implemented.

The results of monitoring not only confirm whether the silvicultural treatment aligns with the desired future condition but also provide critical insights for necessary adjustments to current or future prescriptions and identify any remedial actions needed if the stated objectives are not met. Regional Offices and Agencies/Tribes are tasked with developing monitoring procedures and quantifiable evaluation criteria tailored to meet the specific objectives established in the corresponding Forest Management Plan.

5.1 Monitoring Objectives and Evaluation Criteria

Monitoring objectives are based on the goals and objectives articulated in the Forest Management Plan. While the goals of the Forest Management Plan are generally broad and often qualitative, the objectives represent a more specific interpretation of these goals, typically framed in quantitative terms regarding time and specific conditions.

Evaluation criteria function as indicators to determine whether the outlined objectives are likely to be met through the prescribed silvicultural treatments. For each stated objective, it is recommended to develop one to three quantifiable evaluation criteria based on relevant stand attributes.

Common quantitative evaluation criteria may include expressions such as “greater than...,” “less than...,” or “within [specified] range of...,” which often relate to key aspects such as residual basal area, stand density, average diameter, species composition, and stand structure (including diameter distribution).

Additionally, a timetable outlining future monitoring requirements should be included to assess whether suitable regeneration or other desired conditions have been achieved. If the desired outcomes are not realized within the specified timeframe, a contingency plan outlining potential remedial treatments may be necessary to meet the stated objectives.

5.1.1 Monitoring and Evaluation Documentation

In addition to the prepared silvicultural prescription, it is recommended to maintain a comprehensive summary of the monitoring data, including both analyzed findings and raw data. This documentation should consist of a narrative that details the successes and failures of the treatments in relation to achieving the desired future conditions. Additionally, any recommendations for future forest management treatments should be included to guide ongoing and adaptive management strategies. This documentation serves as an essential resource for assessing the effectiveness of silvicultural practices and informing future decision-making in forest management.

6. TRAINING AND CERTIFICATION OF SILVICULTURISTS

Adequate training and continuing education are a critical component to the successful application of silvicultural practices and principles on Indian forestlands. Although national Bureau of Indian Affairs (BIA) policy does not mandate silviculturist certification, it encourages technical training to achieve and maintain such certification. Regional Offices have the discretion to determine whether certification is required and to decide on participation in certification programs. This flexibility allows for approaches to professional development that meet the specific needs of individual regions and their forest management objectives.

6.1 Technical Training – National Advanced Silviculture Program (NASP)

Tuition assistance for the National Advanced Silviculture Program (NASP) will be provided by Central Office to forestry staff, contingent upon budget availability. Each region will be responsible for covering employee time and travel-related expenses. The number of participants from the Bureau of Indian Affairs (BIA) in NASP is limited and depends on nominations, which may vary annually. BIA participation in NASP occurs in cooperation with the U.S. Forest Service and is not guaranteed.

Additionally, regional-specific training may be offered as a supplement to the NASP curriculum and will be available at the discretion and expense of the individual region. The responsibility for coordinating and funding attendance at region-specific training lies with the respective region.

6.1.1 Silviculturist Certification

The Certification program for silviculturists is designed to ensure that practicing silviculturists possess the necessary knowledge, skills, and abilities to prepare effective silvicultural prescriptions for Indian forestlands.

As a form of peer review and evaluation, the certification process requires aspiring silviculturists to comprehensively demonstrate and defend their understanding of land management issues and technologies. The certification involves three distinct phases that collectively verify a candidate's qualifications: work experience, formal education, and the successful completion of a Certified Silviculturist Position Task Book (PTB).

Individual mentoring by an experienced silviculturist can be an effective strategy to guide candidates through identifying and fulfilling the certification requirements. Upon the successful completion of all three phases, candidates are "certified" to prepare and approve silvicultural prescriptions for various forest vegetation treatments. These treatments may include, but are not limited to, reforestation, timber stand improvement, prescribed burning, hazardous fuels reduction, habitat and resource enhancement, and timber harvest activities.

6.1.2 Work Experience

Practical forestry-related work experience is essential for initiating professional development as a silviculturist, with a minimum of one year of field-level experience recommended. Ideally, seasoned forestry professionals should mentor entry-level foresters during this phase to enhance their learning and skills.

Silviculture certification candidates are advised to possess at least 36 months of recent experience as a professional forester (GS-0460 series) in silviculture, forest management, or a closely related field.
The following list outlines the minimum required professional forester experience and the expected duration for each area:

Stand Examination: 1 field season (approximately 3 months)
Timber Sale Layout: 2 field seasons (approximately 6 months)
Timber Sale Administration: 1 field season or more (approximately 3 to 6 months)
Reforestation / Site Rehabilitation: 2 field seasons (approximately 6 months)
Timber Stand Improvement: 1 field season (approximately 3 months)
Forest or Project Level Planning / NEPA: 1 field season (approximately 3 months)
Silvicultural Prescription Preparation: 1 field season (approximately 3 months)

6.1.3 Formal Education

A comprehensive understanding of silvicultural concepts and application techniques is essential for preparing effective silvicultural prescriptions and for certification as a silviculturist. This knowledge is typically acquired through undergraduate education, supplemented by continuing education courses such as the National Advanced Silviculture Program (NASP) or equivalent graduate-level training, subject to Regional Director approval. These educational opportunities provide aspiring silviculturists with the theoretical foundation and practical skills necessary to succeed in the field, ensuring they are well-equipped to contribute to sustainable forest management practices.

6.1.4 National Advanced Silviculture Program (NASP)

The National Advanced Silviculture Program (NASP) comprises four national course modules delivered over four separate two-week modules. This program offers graduate-level instruction designed to enhance the knowledge, skills, and abilities of professional foresters in the field of silviculture. Each course module focuses on distinct topics and is hosted at a different university:

Ecological Systems: This module covers topics such as forest ecology, geology, hydrology, tree physiology, basic silvics, genetics, and fire ecology and behavior.

Inventory and Decision Support: Students will explore subjects including growth and yield, site quality and productivity, inventory statistics, economic principles, forest regulation, forest planning, legal requirements, and monitoring.

Landscape Ecology: This module focuses on landscape ecology, concepts of scale, landscape characterization, landscape processes, disturbance ecology, fire ecology, ecological implications, landscape dynamics, landscape modeling, and management applications.

Advanced Silviculture Topics: Participants will study various aspects such as silvicultural systems, regeneration, stand and forest dynamics, woodland and savanna management, range management, prescribed fire, fish, wildlife, and management of threatened and endangered species, invasive species management, timber market utilization, harvest systems, the diagnosis process, and prescription preparation.

6.2 Certified Silviculturist Position Task Book (PTB)

The final phase of certification as a silviculturist involves the completion and evaluation of the Certified Silviculturist Position Task Book (PTB). The PTB describes the candidate's qualifications for the role of certified silviculturist by a portfolio that documents the candidate's training, evaluation records, and work experiences required to demonstrate the achievement of the standards described within the Core Competencies.

Experience gained within and external to the agency will be reviewed and documented in this PTB, where appropriate.

To request the PTB, the Line Officer (i.e. Agency Superintendent or Forestry Program Manager) on behalf of the candidate, will send the candidate's resume and letter of interest to the Regional Forester, who will review the resume, sign off on task completion through previous work, and initiate the PTB for the candidate. Candidates will work with persons listed in Appendix 1. Roles in Certification Process throughout the certification process. Candidates may also work with related resource specialists within their program, and research scientists or professors. Regional Foresters may recommend mentors to candidates, as necessary.

The successful completion of all requirements identified in the PTB, as determined by qualified evaluators, will be the basis for recommending the candidate for final review by the Regional Forester. Qualified evaluators are subject matter experts (refer to Appendix 1. Roles in Certification Process). The Line Officer will verify that the candidate has successfully completed all minimum training and performance competencies and signs the PTB as a final evaluator prior to being sent to the Regional Office for review. Sample work products (such as prescriptions and other documents) and consultations with evaluators may also be used in the review process that leads to the decision to recommend certification.

Finalization of the certification process for official designation as a Certified Silviculturist requires the recommendation of the Regional Forester and final approval by the Regional Director through their signature. Central office candidates will coordinate with the Branch of Forest Inventory and Planning (FIP) for appropriate approval signatures designating certification. Candidates should be aware that certification through the Bureau of Indian Affairs does not automatically mean certification will be recognized by the USDA Forest Service or other federal agencies.

6.2.1 Recertification

Recertification is at the discretion of the BIA Regional Office. However, it is recommended that the certified silviculturist retains their skills through continuing education. Certified silviculturists can remain current in their knowledge of silviculture and forest ecology by reviewing technical and professional literature, conference attendance, and continuing education.

ATTACHMENT 1 – PRESCRIPTION EXAMPLE

Stand and Site Description

Location: W ½ SE 1/4 of Section 30, T49N R33W, Baraga County, MI
Acres: 59
Tract #: 12
Compartment: 24 **Stand:** 8
Forest Type: SAF cover type is Sugar Maple (27). Stand is comprised primarily of sugar maple and eastern hemlock. Hemlock is discontinuous in distribution and occurs in small patches. Associate species include yellow birch, black cherry, American hophornbeam and red maple. Northern-white cedar and balsam fir are also present, but are a very minor component of the stand.
Size Class Distribution: distribution follows a reverse "J"- shaped curve typical of most hemlock-hardwood stands in the Lake States. Sapling and pole-size stems comprise the majority of the stand density. Basal area is concentrated between the 12-20" size classes (Figure 1). Trees larger than 24" DBH are largely absent from the stand. Quadratic mean diameter is 12.8 inches.

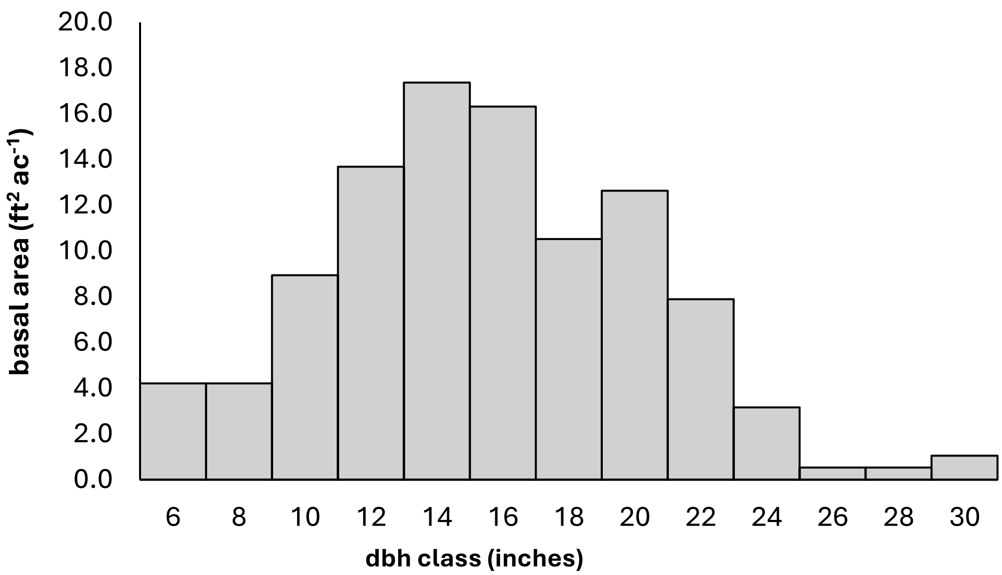

Figure 1. Current basal area distribution by diameter class.
Stand Density: Stand is well stocked at 113 > 5" trees per acre. Regeneration is also well stocked with saplings at 1215 trees per acre and seedlings at 6450 trees per acre.
Basal Area: 101 ft^2 ac^{-1}
Total Stand Volume: 542 MBF, 383 cords
Soil Type(s): Soils are Champion cobbly silt loam and Champion-net complex. These soils belong to the soil order Spodosols.
Habitat Type: ATD (*Acer saccharum-Tsuga/Dryopteris*).

Stand Age: Stand is likely uneven-aged. Three or more distinct canopy layers are present throughout the stand. Layers generally have well-developed crowns with the smallest layer extending to the forest floor. These characteristics are indictive of multiple age classes.
Current Stand Conditions: Stand is at a late successional state as evidenced by the overstory of sugar maple and hemlock. Aside from hemlock patches, sugar maple is dominating all size classes and forming nearly a pure stand. This stand has likely been managed using single-tree selection for several decades. Two other overstory species, black cherry and red maple have regeneration present but are largely unable to recruit into upper size classes. No yellow birch regeneration was recorded or observed in the stand. Hemlock regeneration was observed but was not found in substantial amounts. Deer browse is likely affecting recruitment. Low-level canopy disturbances have favored sugar maple. These conditions have created large amounts of sugar maple advanced regeneration that are able to respond to any gap size and outcompete mid-tolerants.

A wide diameter distribution is present. Some areas of the stand contain sugar maple sawtimber of high quality. Crowns of dominant and intermediate trees show strong vigor. Epicormic branching is not widespread.

Sugar maple dominance may leave the stand vulnerable to potential invasive pests such as the Asian Longhorned Beetle. Sugar maple could see declines due to compounding factors relating to climate rather than its silvics. Proliferation of invasive earthworms could reduce regeneration and make sugar maple more susceptible to drought. Precipitation events and temperature fluctuations are expected to become more extreme. These weather changes could create increases in freeze-thaw cycles and soil frost on a litter layer already altered by earthworms. Root damage can be extensive to sugar maples under these conditions causing crown dieback.

Several wildlife species of concern may be using larger diameter trees as habitat. These include: cerulean warbler and northern long-eared bat. Other ecological considerations include the lack of old-growth structure typical of northern hardwoods or hemlock hardwood stands. Features such as tip-up mounds and large amounts of downed woody material are only found in hemlock patches. The widespread absence of these features could have negative implications for many wildlife and make the stand less resilient to impacts such as drought.

Goal, Objectives and Evaluation Criteria

Goal: Improve forest resiliency to future impacts of forest health issues while continuing to provide forest products for local economies. A stand condition meeting the goal should be achieved by 50 years.
Objectives

- **1:** Improve diversity of hardwood species comprising dominant overstory trees

  Evaluation Criteria: Mid-tolerant species such as yellow birch, black cherry and basswood each respectively comprise 10-20 basal area ft^2 ac^{-1} of the stand within 50 years

- **2:** Promote biological legacies such as large downed dead wood, snags and understory plant communities

Evaluation Criteria: Increase snags per acre and large downed dead wood by 25%, no measurable loss in herbaceous plant diversity

- **3:** Create sawtimber quality trees

  Evaluation Criteria: 90% of sawtimber size trees have grade 1 or 2 quality in 50 years.

Desired Future Condition
Mid-tolerant species comprise one-third of the overstory. These trees should be of strong vigor and dominant crown class. Sugar maple will continue to comprise the majority of species present. Hemlock will remain in isolated patches. Snags and downed dead wood should occur throughout the stand. Understory plant communities will continue to have characteristic species such as trillium and blue-bead lily. Moist and cool conditions in hemlock patches may be favorable to rarer plants such as orchids.

Treatments to be Prescribed

Even-aged system using a two-cut shelterwood. The two cuts will be an establishment and a final removal. The removal cut should occur 5-10 years after the first harvest. Adequate advanced regeneration of mid-tolerant species will signal time for the removal of the overstory.

Specific Silvicultural Recommendations

Before the establishment cut, 50% of the stand is to be scarified with a bulldozer mounted with a salmon-blade. This site-preparation treatment will create favorable seedbed conditions for yellow birch and reduce sugar maple saplings. Scarification needs to be concentrated in areas with pure sugar maple advanced regeneration, black cherry saplings are to be avoided. Any American hop-hornbeam encountered is to be uprooted and chopped by the dozer.
Current canopy cover in the stand is approximately 105%. The establishment cut will reduce crown cover to 60% across the stand. A 60% residual canopy cover has been suggested to be the optimal amount for yellow birch regeneration for a two-cut shelterwood. Canopy cover at lower amounts can greatly increase the presence of competing herbaceous plants such as raspberries and blackberries. Residual basal area will be approximately 55-75 ft^2 ac^{-1} (Figure 3). Basal area is a poor indicator of canopy cover and will be variable across the stand to meet the 60% canopy cover target. Increases in sunlight and changes in microclimate conditions should favor sapling growth of black cherry and yellow birch over sugar maple.

Residual overwood (leave trees) trees need to have full crown, excellent form and be in a dominant or codominant crown position. These trees will be of the sawtimber size classes (preferably 14-20”) and should be able to add volume through strong growth before the removal cut. Trees in the 22” class and above should be cut if allows for the target canopy closure to be met and so economic value can be captured. All overstory species can be cut except hemlock and black cherry. No harvesting is to occur in hemlock patches. All overstory yellow birch should be cut except trees present in hemlock patches. Overstory yellow birch experiences numerous forest health issues when exposed to shelterwood cuttings such as sapsucker attack. Yellow birch seed source will be from trees in the hemlock patches as seed can travel up to 5 chains from parent trees.

The removal cut will occur once stocking objectives are met. Harvesting needs to occur during the winter with deep snowpack to prevent damage to advanced regeneration. During both cuts, mature cull trees are to be girdled or felled to ground and left. These techniques are to accelerate snag and downed dead wood production.

Table 1. Marking guide for establishment cut.

<table>
<tr><th>Marking Guide</th><th>Silvicultural System: two-cut shelterwood</th><th>Marking Method: leave tree</th></tr>
<tr><td colspan="3">Spacing between Overwood Trees: 26ft – 33ft

Species Priority
• Sugar maple and black cherry

Tree Priority
• 12-20 dbh classes
• Favor trees of larger size class and higher canopy position
• Dominant or codominant
• Full crown
• Straight form
• No forks or major defects if possible</td></tr>
</table>

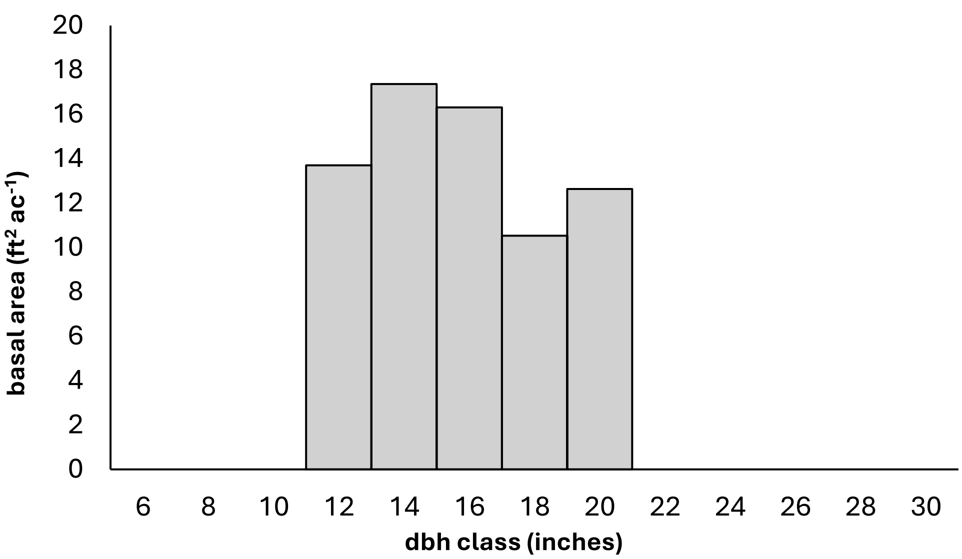

Figure 2. Approximate target residual basal area after establishment cut (70 BA for this example and excluding hemlock patches).

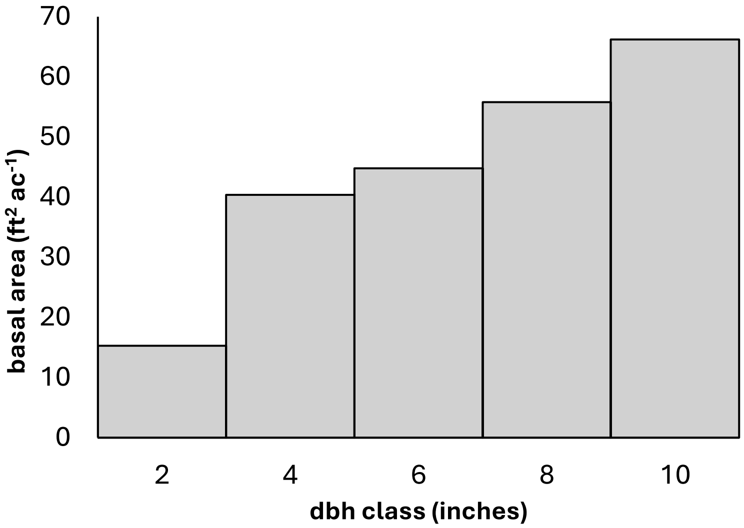

Figure 3. Basal area distribution at year 2070, stand average of 144 basal per acre[2] (Forest Vegetation Simulator Lake States Variant projection).

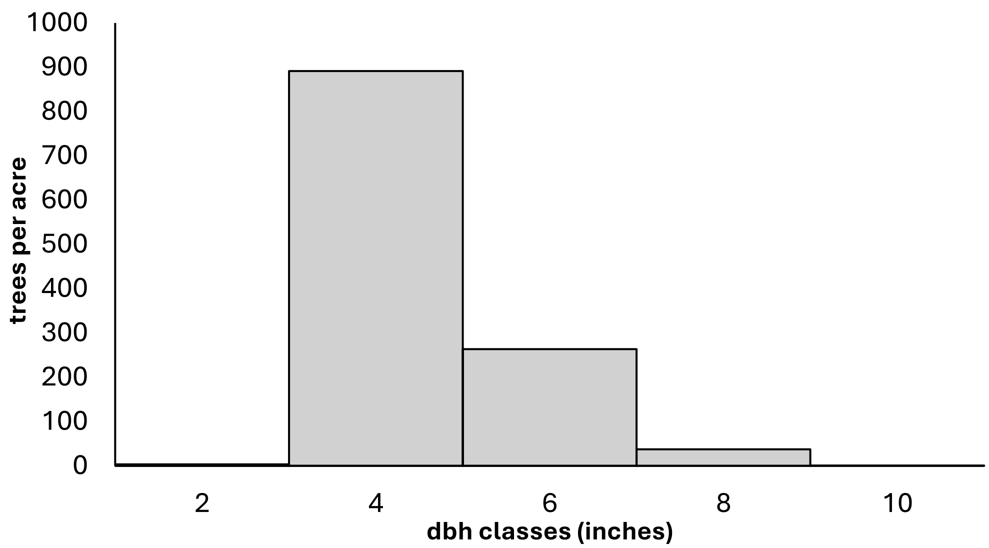

Figure 4. Trees per acre distribution at year 2070, stand average of 1196 trees per acre (Forest Vegetation Simulator Lake States Variant projection).

Even-aged systems such as shelterwoods are often met with trepidation in Lakes States northern hardwood stands, but studies have shown these silvicultural methods to be effective and sustainable. Shelterwoods used on the Argonne Experimental Forest in Northern Wisconsin were effective at promoting yellow birch. This site is similar to the current stand with well-drained silt loam soils.

Timeline of Activities

- Scarification fall 2021

- Establishment cut during winter 2022
- Removal cut during the winter occurring 5-10 years after first cut

Landscape Considerations

Vernal pools exist in the stand and harvesting should be completed in the winter to avoid impacting these areas. Logging operations need to be carefully planned and implemented during the establishment cut. Basal injuries during this harvest can allow the fungal pathogen that causes sap streak to affect sawlog quality of overwood trees.

Monitoring

- Inspection determining scarification has been applied to 50% of stand
- Ensure adequate advanced regeneration of mid-tolerant species before removal cut (1000 – 2000 trees per acre, combination of black cherry, basswood and yellow birch)
- Mid-tolerant species such as yellow birch, black cherry and basswood each respectively comprise a basal area of 10-20 ft^2 ac^{-1} of the stand within 50 years

<u>**ATTACHMENT 2 – WORKS CITED**</u>

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<u>ATTACHMENT 3 – RECOMMENDED READING</u>

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