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FOR543
Final Project

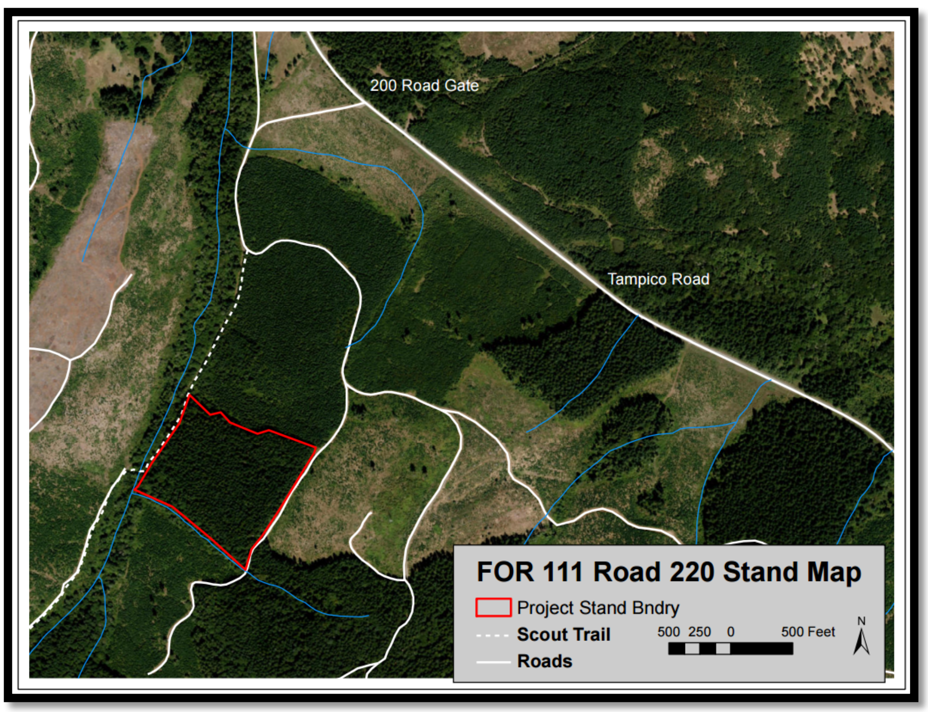
# Silviculture Prescriptions

## I. SITE DESCRIPTION

Location and Ownership Structure

The stand of interest is hypothetically privately-owned by a family who want to maximize economic returns via growing commercially important timber species on the land.

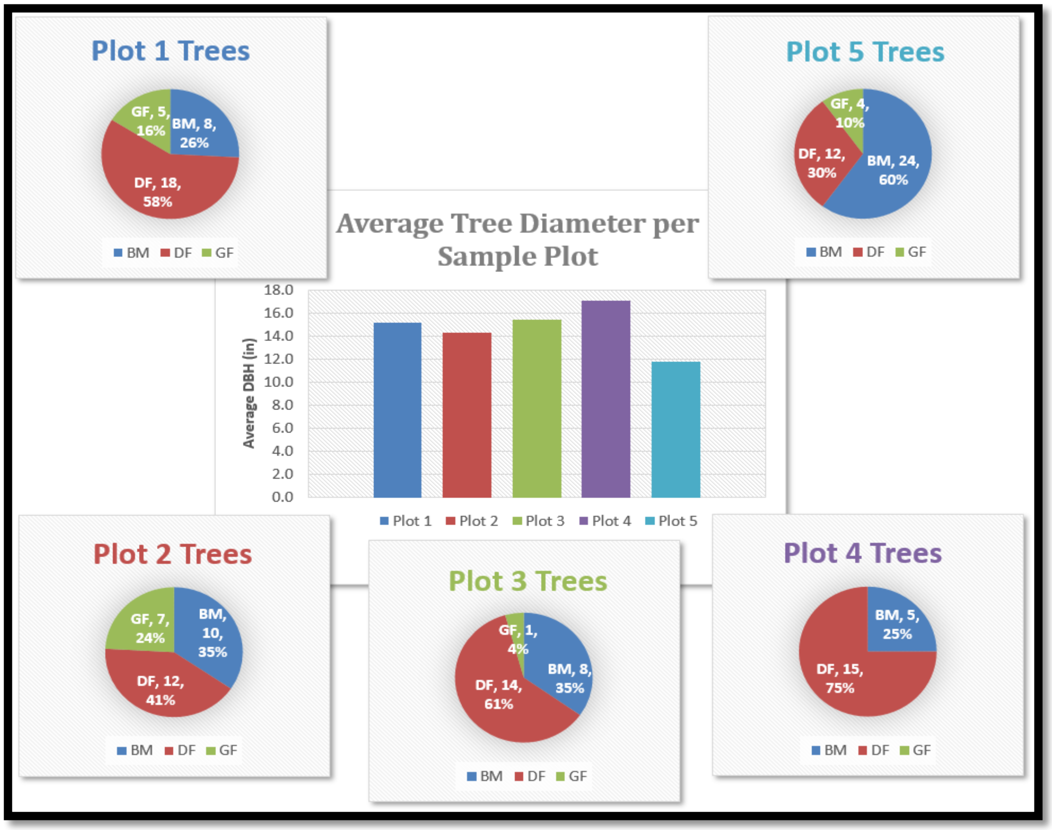
The stand is roughly square in shape, with its western-most corner located at 44°42'00.4"N, -123°18'01.8"W, in Benton County, Oregon. The stand covers a total area of 16.7 acres (6.8 hectares, 727,452ft$^2$), spanning the side of a hill from its lower slope (approx. elev. 506ft) to upper slope (approx. elev. 650ft). There is a moderate incline ranging from 10-25%. The face of the hill follows a slight curve that gives a range in aspect from 296º-320º NW.




*Stand location and boundary.*

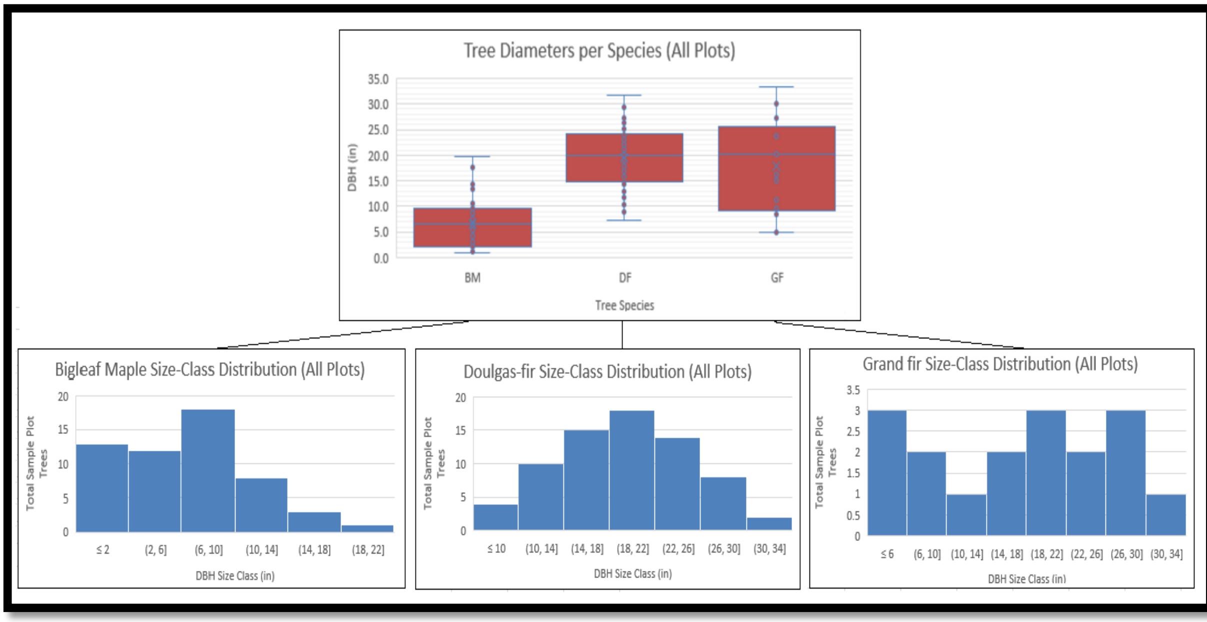
Species Composition

The 16.7-acre stand has previously been surveyed using a grid of five 1/8-acre plots. The plots reveal three primary tree species present throughout the entire stand: Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and bigleaf maple (*Acer macrophyllum*). Distributions of tree species are not uniform across the five plots: Douglas-fir is the majority tree in all plots but one (plot 5), where it is bigleaf maple found in highest proportion. This finding might infer a history of severe disturbances (e.g. wind exposure) or harsher growing conditions (e.g. sunlight, temperature, slope) in plot 5 that cater to hardwood preferences.

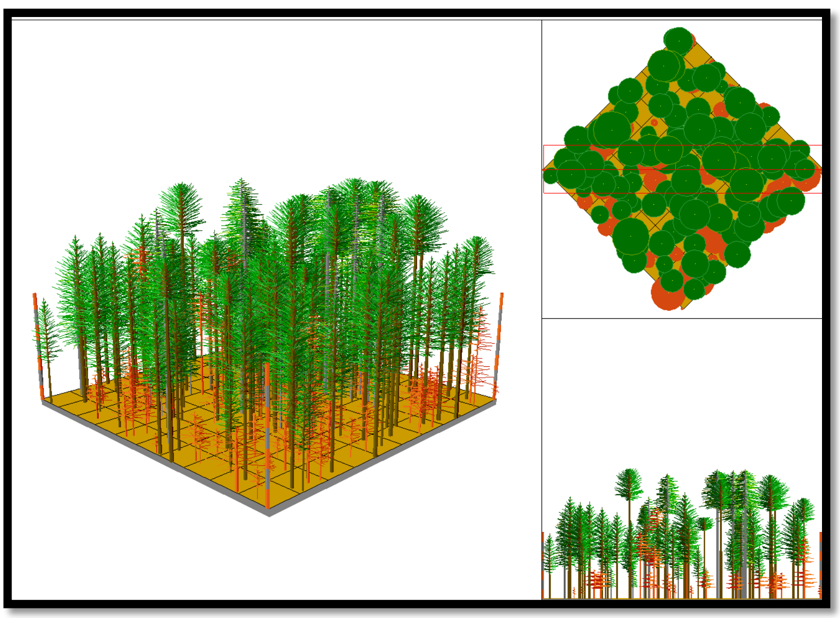



*Sample-plot average tree diameters (column, center), and tree proportions per plot (pies, surrounding).*

The current stand is 74 years old (in 2017). Sample plot DBH (diameter at breast height) distributions of Douglas-fir and grand fir imply a generally even-aged structure, although it could be argued the stand is transitioning into an uneven-aged structure; mature, large-diameter trees from the original mixed-conifer (Douglas-fir and grand fir) cohort form a mostly closed canopy, while sword fern, ocean spray, hazel, false bellwort, gallium, trillium, and other herbaceous vegetation are spread non-uniformly about the forest floor. Sporadic canopy gaps created by downed logs and snags have encouraged gap-phase succession of bigleaf maple, in high proportion along the trail- and road-side boundaries and towards the southern-most portions. Grand fir have also begun to establish a younger cohort. The prominence of openings in an otherwise continuous single-strata canopy resulting from many snags and downed logs suggests the stand has reached – and is beginning to pass – competitive stem exclusion, and is entering into a state of understory re-initiation. Supporting this assumption is the abundance of grand fir found throughout the stand here, which is often considered a seral or climax species when competing for dominant overstory with Douglas-fir (Foiles et. al *"Grand fir")*. Overall, the stand has mediocre diversity, average growing space occupancy, and above-average biomass.




*Diameter measurements of three tree species (top) and species-specific size class distributions (bottom) totaled from five 1/8-acre sample plots.*

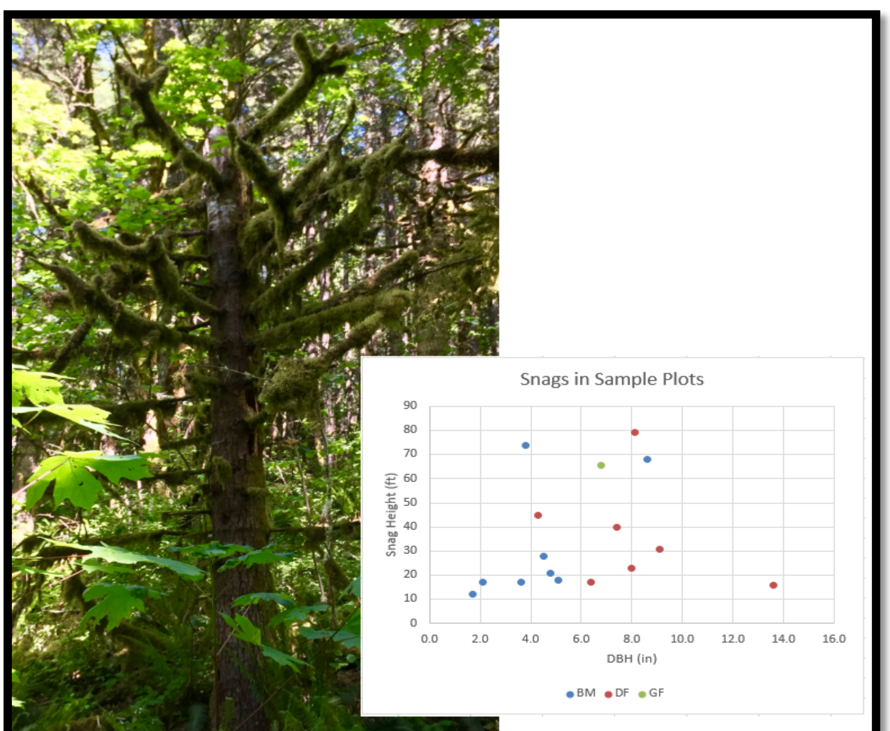


*Stand structure from LMS simulation, showing dense overstory connectivity, with understory starting to emerge in gaps.*

The stand's Relative Density Index (RDI, Drew and Flewelling 1979) is 0.587, and that is only of Douglas-fir; there is an additional 115 TPA (extrapolated) of other tree species sharing growing space and resources. As Douglas-fir usually self-thins at around 0.55 - 0.60 RDI, this is evidence supporting the idea that the stand is at the point of self-thinning from competition-induced mortality.

*Small canopy gaps in an otherwise single-strata closed canopy (left, center). Many gaps have been recolonized by bigleaf maple (right).*

The five representative 1/8-acre plots hold sixteen standing dead snags in total, with over half of those snags observed in sample plots 1 and 2 (from the northern-most section). The average snag measures 6.1 inches in DBH (st.dev. of 3.0 inches). Several snags were observed having broken tops, suggesting forgone episodes of wind, wet snow, and/or ice damage. The tallied number of snags per sample-plot can be extrapolated to equal roughly 25 snags per acre across the 16.7-acre stand, a proportion of approx. 1:9 to the extrapolated 229 living TPA.




*Snag (left), and scatterplot of snag Height vs. Diameter per tree species (right).*

### Biotic and Abiotic Features

The family's land contains soils of the Jory-Gelderman complex (63% to 22% ratio), commonly found on 12-30% slopes with basalt bedrock. This soil is categorized as being well drained. Mean annual precipitation for this soil region is 45-60 inches, and mean annual air temperature is 50-54ºF (10-12ºC) with a frost-free period of 160-120 days/year. There is a low potential for fire on lands with this soil type, partly associated with (among other complex factors) the vegetation commonly found growing on it. Jory-Gelderman soils are well-suited for supporting Douglas-fir with a site index (average height, in feet, of the dominant tree species over a specific number of years) of 122ft since 1966 (51 years). This soil type is moderately-suited for harvest equipment operability (USDA Web Soil Survey).

Alongside the southeastern edge of the stand is a restricted-access forest road. Running parallel to the stand's approx. 850ft-long northwestern edge is a public-access hiking, biking, and equestrian trail. Another 20-100ft further west of the trail runs South Fork Berry Creek, a medium-sized (4-20ft width) fish-bearing stream (Type F). New updates to the Oregon Forest Practices Act will require a buffer distance of 80ft from timber operations. In order to adhere to this rule with no risk of infraction, 0.7 acres (30,492ft$^2$) of the stand's lower slope area parallel to the stream will be dedicated as a riparian buffer zone. All calculations in the following silviculture alternatives will accordingly be adjusted to use 16.0 acres as the total area of manageable land.

### Social Considerations

The stand owners do not possess ownership of the land belonging to the trail or stream, and therefore may be subject to pubic judgement of their management decisions. For safety reasons, the trail may need to be closed to the public during harvest operations, inconveniencing community members. However, this trail is over five miles drive from the nearest community (Adair Village), and plenty of closer, more popular trails would likely remain accessible for community members during a temporary closure of this trail. Conifer tree plantations are located to at least one side of the stand, and more are within close vicinity to the southeast.

# II. MANAGEMENT ALTERNATIVES

## A) EVEN-AGED

### Treatment Objectives and Timeframes

The desired future condition for this stand is an even-aged plantation, with an initial objective of producing a high volume of Douglas-fir conifers for high-prized poles, and subsequently for dimension lumber. In this prescription, ecosystem processes such as diverse habitat promotion take a backseat to bottom-line wood production for economic gain. Pole-size trees will be removed at year 33, with the final harvest removal of all trees at 50 years. As with other plantations, minimal environmental disturbance is critical to meet the long-term goals of the stand, and treatments (discussed below) will manage for expected factors such as early competing vegetation, windthrow, and extreme temperatures.

### Desired Condition

An initial clear-cut of the entire stand will be followed by a single cohort of densely spaced Douglas-fir (thereby keeping with the current prevailing species). The high density conditions will promote low live-crown-ratio (LCR) for a knot-free lower stem with minimal taper – ideal characteristics for conforming to the highest quality pole requirements (Wolfe and Moody "*Standard Specifications for Wood Poles*").

Once crop trees attain 80ft and 10-inch DBH – coinciding with the start of self-thinning at 400 TPA – the stand will be commercially thinned for the highest quality pole-sized trees (producing two 40ft poles), while leaving other vigorous trees more widely spaced in the stand. The reduction of inter-tree competition will allow the remaining trees to expand in diameter, ending up at year 50 with large diameter trees to harvest for high quality dimension lumber. Throughout the duration of the rotation, vegetation competing with Douglas-fir should be actively managed against to limit the loss of growing space and resource allocation for crop trees.


*Example of an even-aged Douglas-fir plantation.*

<u>Proposed Treatments and Implementation Guidelines</u>

*YEAR 1 - FALL*

- By foot, measure and mark all present-day commercially viable Douglas fir for sale as dimension lumber or C- and D-class veneer (min. DBH 12 inches; min. height 12ft (Oester and Bowers 2009). Extrapolating sample plot data, that should average 102 TPA.
- Mark commercially viable grand fir (min. DBH 16in; min height 17ft) for later harvest for "special mill" dimension lumber or C- and D-class veneer.

*YEAR 1 - WINTER*

- Using ground-based equipment, harvest all marked Douglas-fir and grand fir and send to closest accepting lumber mill.
- Harvest any qualifying softwoods (>2 inches DBH; <50% defects by volume) for sale as pulp chips (market dependent, see Culbertson "*Chip & Pulpwood*").
- Clear-cut all other standing vegetation.
- Leave all slash on site, and distribute evenly if necessary (particularly into minor depressions where ephemeral streams from precipitation could evolve).
- Site prep:
    - Broadcast-spray herbicide to limit recolonization from herbaceous plants (ocean spray, hazel, sword fern, false bellwort, gallium, trillium, etc.).

  - Bigleaf maple of all sizes should be cut as close to the ground as possible, and the stump treated with a lethal herbicidal injection to prevent re-sprouting ("cut-stump treatment," Tappeiner et. al 216).

*YEAR 1 – SPRING*

- Purchase and plant 6,400 nursery-grown Douglas-fir saplings in 10x11ft spacing (400 TPA).
- Complete OFPA "free-to-grow" regeneration exam within six years.

*YEAR 33 – FALL*

- Well after canopy closure, and upon entry into competition-induced mortality (RDI=0.60, SDI=360), measure all Douglas-fir crop trees and mark up to 270 TPA (4,320 total) high-quality pole trees having suitable pole dimensions (10 inch DBH, 80ft height, minimal taper).
  - Trees should be selected foremost based on dimensions and quality; however, if possible, secondary attention should be given to leaving residual tree spacing close to 18x19ft. This will result in 130 TPA left in the stand after harvesting poles.
- In the case that there are not 270 Douglas-fir TPA that meet acceptable pole size and quality standards: calculate the difference (i.e. 270TPAtarget – 220TPAmerchantable = 50TPAcull) and mark (using a different color) that number of trees which are deemed to have the lowest vigor, poorest quality, most defected, etc. for later removal.

*YEAR 33 – WINTER*

- Commercially thin all marked pole-size trees using ground-based equipment; send to mill or buyer.
- If applicable, pre-commercially thin-from-below those poorest-quality trees needed to reduce stand density to 130 TPA. These cull trees may be left on-site, unless infected with disease or pests.

*YEAR 33 – SPRING (with occasional repeat until final harvest)*

- Maintain and support continued growth of remaining trees through post-thin fertilization.
- Prune lower branches.
- Manage for gap-phase successional species sprouting in created openings, using mechanical treatments or herbicides, until residual crop trees have re-closed canopy. This includes curtailing natural regeneration of a new Douglas-fir cohort.

*YEAR 50*

- Final harvest. Remove all Douglas-fir crop trees from the original cohort using ground-based machinery.
- Assess the stand and evaluate further silviculture treatments according to management objectives at that time.
-

<u>Analysis of Long-Term Development</u>

*YEAR 1 - WINTER*

The heaviest operations (lumber harvesting and clear-cutting) should be done during winter because this is when soils are least susceptible to compaction. Ground-based machinery is feasible, considering the gradual slope, stable soils, and cheaper cost.

Leaving slash on-site after clear-cutting will greatly reduce sediment runoff into the stream downhill. Although it will be more difficult to manually plant saplings through a layer of slash, the cover may help provide some initial minor temperature reduction to the regenerating Douglas-fir and reduce light levels for shade-intolerant colonizing species. Allowing the slash debris to dry in the sun will limit the risk of bark beetle outbreaks (Tappeiner et. al 205). Eventually the slash will decompose and help return some nitrogen to the soil. Risk of fire coming through this stand is low, due to several environmental factors. (Piling and burning the slash would eliminate longterm nutrient recycling, increase runoff of soil and ash thereby degrading fish stream quality, risk smoking out downwind communities, and increase labor costs.)

Herbicides, when used properly, can control competing vegetation in a dependable, economical, and potentially harmless manner (Tappeiner et. al 219). Herbicide should be applied during the first and second winters (Maguire et. al 2009), during which active shrubs will be affected by herbicides in contrast to dormant conifers (Tappeiner et. al 214). Herbicide treatments should aim to keep out early seral shrubs at an aim of 25% or less of site occupancy, for exponential growth results (Tappeiner et. al 212). Bigleaf maple is currently present in the stand (especially in gaps and at edges), which can outgrow and out-shade Douglas-fir (Tappeiner et. al 208, 211, Minore and Zasada *"Bigleaf Maple").* Diligent mechanical and herbicidal combination treatments such as cut-and-spray can be effective in desiccating this particular vegetation (Tappeiner et. al 214, 216).

*YEAR 1 – SPRING*

With the decision to artificially regenerate the site using nursery-grown saplings, there is no need to intentionally scarify the soil during the previous season's operations. Planting saplings instead of relying on seedlings will minimize damage and increase the likelihood of survival against frost and animal foraging, as well as allow the landowners to more easily meet "free-to-grow" Oregon Forest Practices regulations. Artificial regeneration increases upfront costs, but allows for more control over preferred genetic traits, density and spacing distribution, and regenerating species composition (particularly important with the current site occupancy of bigleaf maple) (Tappeiner et. al 192-193).

To meet the broader management objectives, the initial cohort of Douglas-fir should be planted at the relatively high density of 400 TPA. This easily meets Oregon Forest Practices minimum restocking requirements of "free-to-grow" trees: 400 saplings-per-acre $\div$ 0.6 $\geq$ 200 seedlings-per-acre equivalent.

Planting at a high density has several tradeoffs. Denser stands generally produce a higher volume of wood over early stages of tree growth (Tappeiner et. al 239), and moreover produce a less amount of low-specific-gravity juvenile wood that is undesirable for structural uses (e.g. poles and beams) (Tappeiner et. al 255-256). The trees will reach canopy closure and a much younger age, and a high height:diameter (H:D) ratio associated with dense stands – where little sunlight reaches lower parts of the stem – means that trees should not produce many lower branches that would become knots (a requirement for high quality poles) (Wolfe and Moody "*Standard Specifications for Wood Poles*", Oester and Bowers 2009). Conifer trees produce their greatest stem growth within or at the bottom of their crowns; therefore, keeping a high density of trees with small, short crowns will allow the trees to grow taller with minimal taper, and ensure maximization of the length of the stem that can be used for merchantable volume (Tappeiner et. al 140). In keeping the density well below the 500 TPA threshold, crown-to-stem ratios should stay above 25% and therefore respond well to thinning (Tappeiner et. al 251).

On the reverse, the high H:D ratio may also subject trees to increased swaying in the wind, which would cause the trees to have reduced xylem permeability due to vascular tissue damage, and may decrease the value (Tappeiner et. al 253).

*YEAR 33 – WINTER*

After growing for 33 years at a density of 400 TPA, the average Douglas-fir is projected to be around 80ft tall and 10 inches DBH (Babiker 1967, Flewelling et. al 2001). Assuming an optimistic RDI of 0.60 as the imminent point of competition-induced mortality between Douglas-fir trees, the stand should be commercially thinned at this point for harvesting high-value poles.

The thinning should be a moderate-severity thinning, based foremost on tree quality (as pertaining to pole-dimension requirements and leaving vigorous trees for continued growth). This particular severity of thinning is intended to limit epicormic branching from buds under the bark, prevent remaining trees from drastically increasing taper, and not severely limit continued height growth from "thinning shock" (Tappeiner et. al 238). A moderate thin will also save operational costs (in comparison to a heavy thin). In all, the thinning aims to switch over stand volume production from rapidly growing young trees to faster growth in fewer, sparsely distributed, older trees (Tappeiner et. al 248). The trees that are left to continue growing should be those with the lowest H:D ratio, as they will be the most stable against the elements, and taper-minimalization is not as high a priority for these trees. In fact, since board feet per cubic foot increases with increasing tree diameter, the lower stand density will be more desirable for growing larger trees with higher merchantable volume at final harvest in year 50 (Tappeiner et. al 241). Finally, some attention to spatial homogeneity should be considered for the spacing of residual trees, to avoid leaving clumped patches (Tappeiner et. al 245). An inter-tree distance of 18x19ft is ideal, but can be flexible to prioritize selecting quality poles for harvest.

Thinning at year 33 – a relatively young age in the life of Douglas-fir – helps reduce risks of pathogens, insects, and fire, which tend to become more common when stands are left at high density for too long. Trees selected for sale as poles should be between 60-120ft tall, have minimal taper, and no knots in the lowest 10ft of the bole (American Tree Farm System "*Utility Poles*", Wolfe and Moody "*Standard Specifications for Wood Poles*", Oester and Bowers 2009).

Thinning can occasionally cause adverse consequences for stand health, which must be evaluated. Sunscald from increased sunlight penetration (Tappeiner et. al 236) should not be too severe, because the stand does not have a southern aspect. Log-removal operators can sometimes damage soils and residual trees, so only reputable professionals should be contracted. A post-thinning increase in soil moisture will be beneficial for the stand's well drained soils, leading to increased rates of photosynthesis due to higher leaf water potential (Tappeiner et. al 236). Residual trees will be more prone to damage from environmental factors such as wind, ice storms, and accumulated snow, but the trees left in the stand are expected to be among the largest and most robust, and therefore have the greatest chance at withstanding the elements during the first 10 years after thinning. Lastly, thinning will open small canopy gaps and encourage the growth of shrubs, sages, grasses, and shade-intolerant vegetation. While this understory vegetation may compete for resources in the short run, they should eventually subside after overstory crown expansion and no additional thinning (Tappeiner et. al 258-259).

If there are not enough pole-quality trees to harvest to arrive at 130 remaining TPA, then non-merchantable trees of the smallest size should be felled or girdled (to remove competition of resources) and left onsite to provide additional ecological benefit. The low risk of fire in this stand justifies this decision, which would otherwise be reconsidered in the aim of reducing floor fuel loads.

Oregon Forest Practices minimum stocking standards will be again met after this harvest: the residual 130 TPA of 1-10-inch trees exceeds the required 200 seedlings-per-acre equivalent.

*YEAR 33 – SPRING*

After the commercial thinning, additional release treatments should be applied to encourage the remaining trees to continue growing for sale as high-quality dimension lumber at year 50. Fertilization is the recommended method for getting this stand back up to periodic annual increment in shorter time. Although Helms (1964) found no measurable difference in photosynthetic rate in Douglas-fir as a result of fertilization, the direct effects of increased stem volume growth and total biomass increment are likely due to some level of increased efficiency in photosynthetic rates (Tappeiner et. al 279), correlated with increased needle size, abundance of shoots, and longevity of total leaf area (Brix and Ebell 1969, Brix 1981). In keeping with these findings, the stand owner should arrange a springtime nitrogen fertilizer application to achieve direct effects of increased stem growth (a.k.a. cubic volume) through improved nutrition, as well as the indirect effects of increased growing stock (Tappeiner et. al 278). Fertilization after thinning will additionally limit the acceleration of competition-induced mortality of remaining crop trees. Holding off fertilization treatments until year 33 also limits the total interest time of this financial investment.

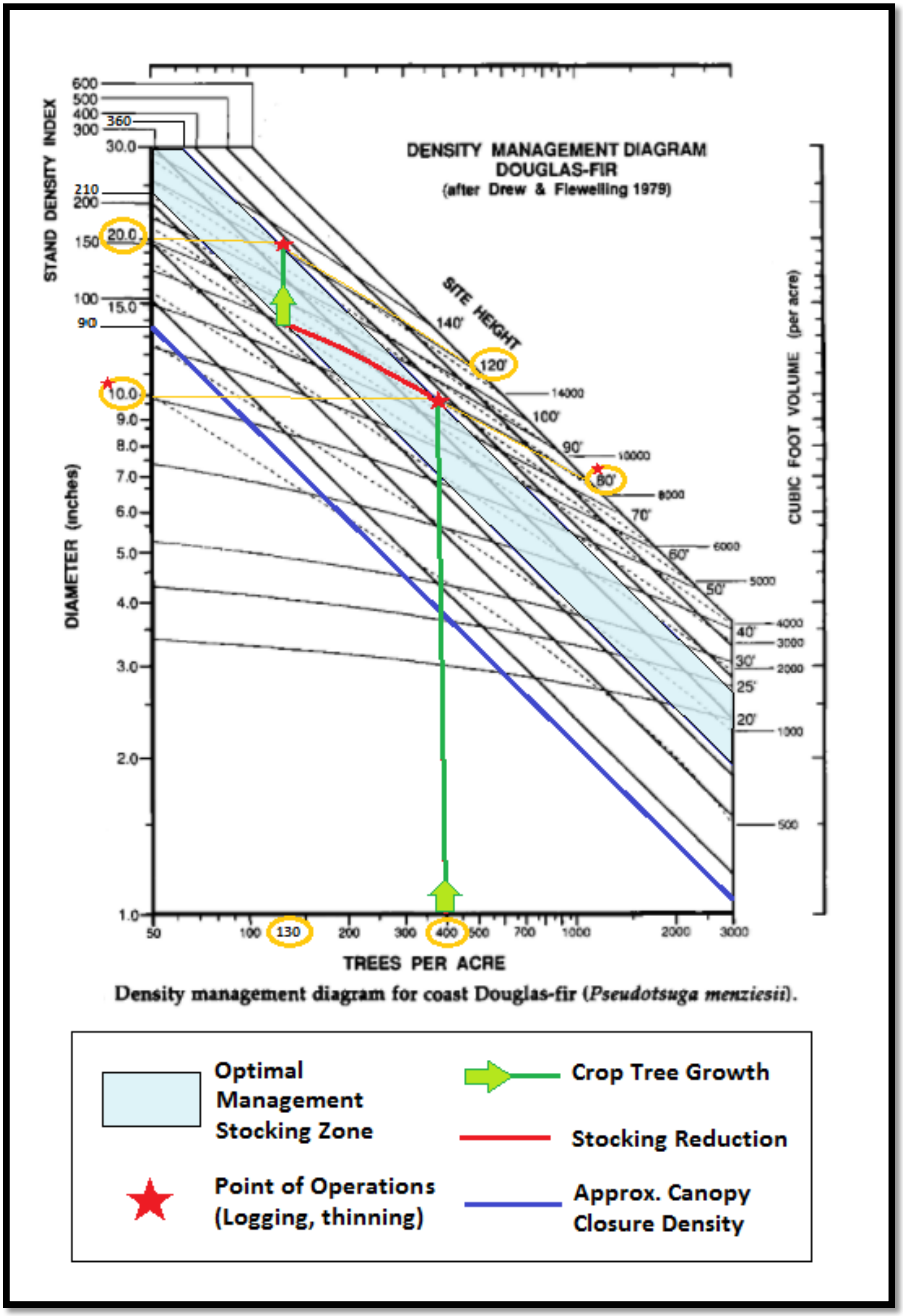
Pruning can be a worthwhile investment in wood quality, and thus in the value of timber (American Tree Farm System "*Utility Poles*"). This prescription suggests carrying out light pruning some time after the commercial thinning, and periodically through to the final harvest, in order to keep crowns at around 40% of stem heights. Pruning should remove 25% or less of the live crown to avoid reducing growth, and only target dominant and codominant trees (Tappeiner et. al 255). This will balance continued height growth with diameter growth while allowing trees to retain canopy dominance or codominance. (While an expensive labor cost if employing outside contractors, the family could look to employ inhouse laborers (their children) to manage this occasional task.)

If the owner is favorable to the practice of pruning, it may also be implemented periodically during the rapid growth period of the early dense stand (up to the point of commercial thinning for poles); this investment can increase wood value by at least 10% (Tappeiner et. al 255, Woodland "*Timber Market Update*").

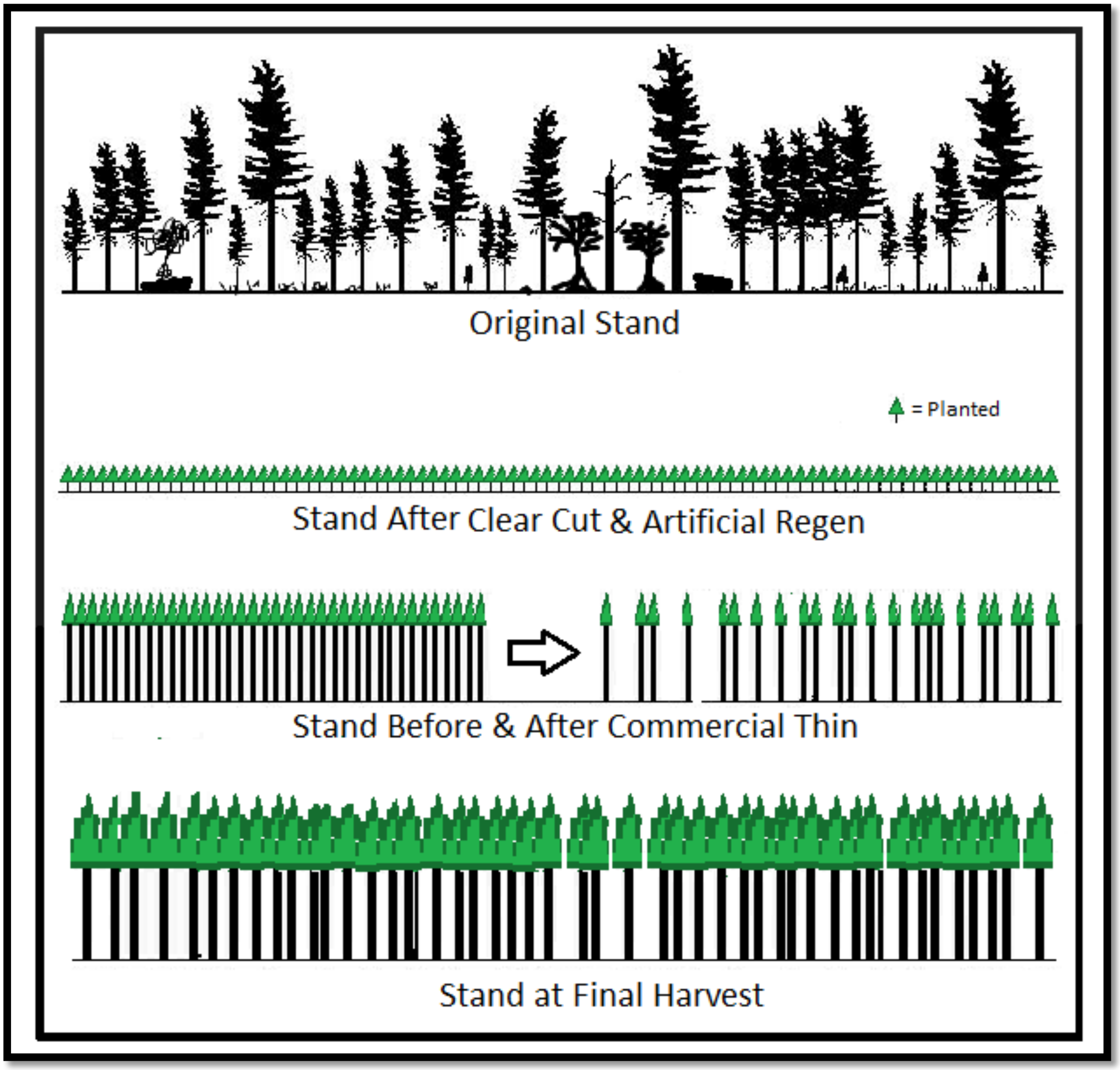
*YEAR 50*

The stand should be harvested at year 50 for all remaining trees. At this density, the stand will begin to reenter overstocking and competition-induced mortality; however, with a diameter of 20 inches at 120ft tall (Babiker 1967, Flewelling et. al 2001), the trees will meet specifications for high quality dimension lumber (American Tree Farm System "*Utility Poles*", Oester and Bowers 2009).

Upon reflection of the previous rotation's goal efficiencies, trends in wood markets, site health, and assessment of environmental and political climates, the stand should be reevaluated and a new silviculture plan should be devised for management after year 50.




*Density management diagram for Douglas-fir. Crop Tree Growth line recedes slightly with upward recruitment, accounting for minor early-stage mortality.*




*Plantation prescription conceptual diagram.*

Mitigation Measures

A primary concern with this stand is its potential to face damage from strong winds, snow, and/or ice storms, influenced by its aspect and elevation. Even if such events do not kill crop trees, the trees might build up compression wood (reaction wood) in defense of these stresses (Tappeiner et. al 120). As a mitigation measure, the high tree density can reduce the force of wind blowing through the stand, as well as lead to smaller crown widths and heights for branches to collect snow and ice buildup.

Of the three prescriptions proposed, this treatment might be considered the least aesthetically pleasing to the public, with a clear-cut and little regard for promoting biological diversity. Due to the adjacent proximity of a public trail bordering the stand, and considering the stand's ascent from the trail, a visual buffer strip might do little to block the view of the stand from the trail. Still, the 0.7 acres consigned along the trail edge will help mitigate just that.

Some of the practices proposed in this prescription might otherwise be considered a risk for fire; however, fire is most likely to spread uphill from below, and this stand's lower portion neighbors a stream that provides a cooler and moister environment not very conducive to fire. Fires in moist conifer forests of the Western Cascades have been historically infrequent (100 years or more) (Tappeiner et. al 329).

Because this stand is less than 25 acres, it does not qualify for requiring two snags per acre after a clear cut.

## II. MANAGEMENT ALTERNATIVES

### B) UNEVEN-AGED

Treatment Objectives and Timeframes

Commodity wood production remains a priority in this silviculture prescription, but with increased attention to maintaining certain ecological functions such as providing diverse habitat for native fauna. The land owners can strike a balance between the prior prescription's industrial-style monoculture plantation and the final prescription's free-for-all nature. In keeping with the main commercially-valuable species naturally found on the site presently, Douglas-fir will be the primary crop harvested, while grand fir be allowed to grow as a secondary crop species.

Objectives focus on the continual removal of valuable timber species on relatively shorter cutting cycles, allowing patches of the forest to develop between cycles. This prescription encourages a healthier balance of ecosystem benefits, more positive anticipated public reactions due to improved aesthetics and hunting opportunities, and more frequent, steady cashflow alongside reduced investment-period payouts. Public attitudes may not be easily quantifiable, so an analysis of estimated profits via stand growth simulations could assist the owner's consideration of this prescription.

Desired Condition

The stand will be managed as uneven-aged to produce a continual sustainable supply of timber. Uneven-aged structure supports continuous site occupancy of large trees, seeds and saplings (Tappeiner et. al 133). Larger trees provide an ideal microclimate of moisture and shade for younger confiner regeneration, until they are harvested, at which point mid- and understory trees can recruit upwards due to the release from crowding and shade. There will be a gradient of reduced TPA from the smallest size classes to the largest. Lastly, the high amount of vertical heterogeneity encourages increased diversity of natural biota in the stand.


*Example of single-tree selection in an uneven-aged system.*

<u>Proposed Treatments and Implementation Guidelines</u>

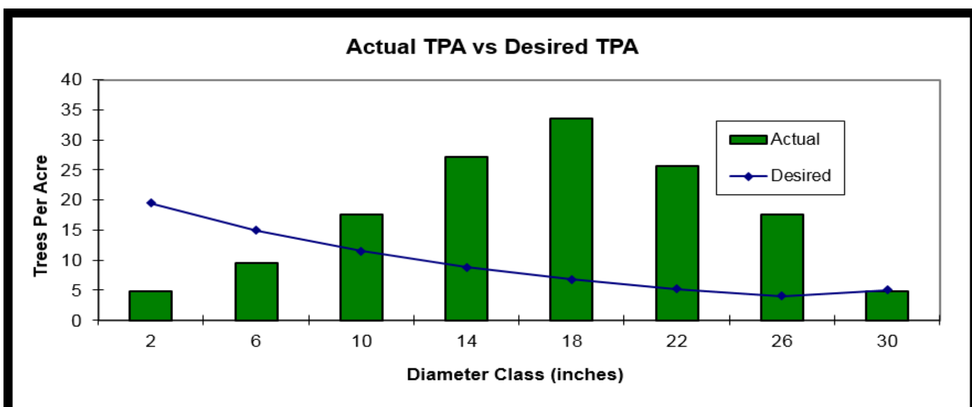
*YEAR 1 – FALL*

- According to the "Basal area - maximum Diameter - diminution Quotient" (BDq) marking guide (below), measure all trees, and mark the appropriate number of trees from each size class and status to be referenced during logging operations.
    - The BDq chart is for influencing a Douglas-fir / grand fir mixed composition. Markers should use their best judgement on the proportion of each species to mark for removal, based on tree vigor, health, and to promote non-variable spacing.
        - A higher proportion of Douglas-fir removed in the initial harvest will reap higher profits in year 1 to help offset startup costs, but could advance too much grand fir that reduces potential long-term profitability.
- For Douglas-fir and grand fir marked for removal between 10- and 26-inch DBH, mark in one color indicating commercial value, to be later removed from the stand and sent to the mill. This should be approximately 85 TPA.
- For any non-merchantable conifers to be culled: if the tree is found to be diseased, it should be marked in a second color for removal from the stand; otherwise, it should be marked in a third color to be either cut down or girdled and left on site as a snag or log for wildlife habitat or regen-seedling microclimate benefits.
    - In the case of bigleaf maple, all trees should be marked in a fourth color to indicate special treatment needed (see Year 1 - Winter).

**BDq Guide for Uneven-Aged Distribution of Douglas-Fir / Grand Fir**

B= 75 D= 30 Q= 1.3

| | | | TARGET | | | | Current | | | | # TPA to | % TPA | MARKING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| d-class | arbTPA | arbBA | TPA | BA | SDI | %BA | TPA* | BA | SDI | %BA | Mark | to Mark | GUIDE |
| 2 | 12.5 | 0.27 | **19.4** | 0.4 | 1.5 | 1% | 4.8 | 0.1 | 0.4 | 0% | -14.6 | -305.0% | none |
| 6 | 9.7 | 1.90 | **15.0** | 2.9 | 6.6 | 4% | 9.6 | 1.9 | 4.2 | 1% | -5.4 | -55.8% | none |
| 10 | 7.4 | 4.05 | **11.5** | 6.3 | 11.5 | 8% | 17.6 | 9.6 | 17.6 | 4% | 6.1 | 34.6% | 1 of 3 |
| 14 | 5.7 | 6.11 | **8.8** | 9.5 | 15.2 | 13% | 27.2 | 29.1 | 46.7 | 11% | 18.4 | 67.5% | 2 of 3 |
| 18 | 4.4 | 7.76 | **6.8** | 12.0 | 17.5 | 16% | 33.6 | 59.4 | 86.3 | 23% | 26.8 | 79.7% | 8 of 10 |
| 22 | 3.4 | 8.92 | **5.2** | 13.8 | 18.6 | 18% | 25.6 | 67.6 | 90.7 | 26% | 20.4 | 79.5% | 8 of 10 |
| 26 | 2.6 | 9.59 | **4.0** | 14.7 | 18.5 | 20% | 17.6 | 64.9 | 81.6 | 25% | 13.6 | 77.3% | 3 of 4 |
| 30 | 2 | 9.82 | **5.0** | 24.5 | 29.2 | 33% | 4.8 | 23.6 | 28.0 | 9% | -0.2 | -4.2% | none |
| | arb BA sum: | 48.42 | | **Stand SDI:** | 118.5 | | 140.8 | 256.1 | 355.5 | | | | |
| | TPA Corr Factor: | 1.549 | | **Total TPA:** | 75.8 | | *Current TPA extrapolated from 5/8 acre sample data | | | | | | |
| | BA Check | 84.2 | | **Stand RDI:** | 0.20 | | | | | | | | |




*Basal area - maximum Diameter - diminution Quotient (BDq) marking guide for desired uneven-aged stand.*

*YEAR 1 - WINTER*

- Logging operations per BDq guide specifications:
    - Carefully harvest and remove (via single-tree-selection) those trees in merchantable size classes marked for timber sale;
    - Fell (and leave on site) or girdle non-merchantable conifer trees marked for removal per BDq chart;
    - Cut and remove any trees marked as diseased (if applicable);
    - Mechanically and chemically treat (e.g. hack-and-squirt or cut-and-spray) bigleaf maple – and any other hardwoods, if found – to favor conifer composition and prevent vigorous natural regeneration of the site (Tappeiner et. al 235);
    - Establish skid-trails for future harvest operations.

*YEAR 1 – SPRING*

- Artificial regeneration via planting nursery-grown Douglas-fir saplings at 15 TPA.
- Plant at wide inter-tree spacing, favoring the shady south sides of large gaps (1 acre (.4-ha) or less) created by the prior season's tree removal, to promote seedling survival (Tappeiner et. al 181). Evenly-spaced (e.g. grid pattern) planting is not desired.

*EVERY 15-25 YEARS*

- Cutting cycle of every 15-25 years to harvest Douglas-fir and grand fir for sale.
    - Remove trees according to the above operational guidelines and to meet BDq chart's desired TPA.
- In light of the current abundance of bigleaf maple, and considering the stand's adjacency to surrounding woodlands and plantations, mechanical and chemical treatments should be applied as needed.
- With year 1's artificial regeneration having endowed the inadequately-stocked lower size-classes of the BDq chart, natural regeneration from seed-trees will be relied on after the first year.
- If cutting the five 30-inch trees is not financially supported, they may be left as reserves indefinitely.
    - However, trees of the original 26-inch DBH size class and smaller should always be harvested for timber before having a chance to grow out of the 30-inch DBH size class.

## Analysis of Long-Term Development

BDq charts are advantageous in their simplicity of accomplishing multiple-species management objectives (Tappeiner et. al 302). The chart for this stand employs a somewhat low q-factor (given 4-inch diameter classes) of 1.3 that emphasizes growth of larger merchantable trees, and, combined with a low basal area ($B=75ft^3$) and high maximum diameter class (D=30), will lead to a sustainable, relatively open stand (Tappeiner et. al 303). The low density (Total SDI=118.5) promotes the natural continuation of grand fir in the stand (a species otherwise intolerant of high overstory density (Tappeiner et. al 226)); meanwhile, harvesting trees via a gradient of large-to-small diameter size classes will allow the relatively shade tolerant Douglas-fir to continually be released to recruit into larger size classes.

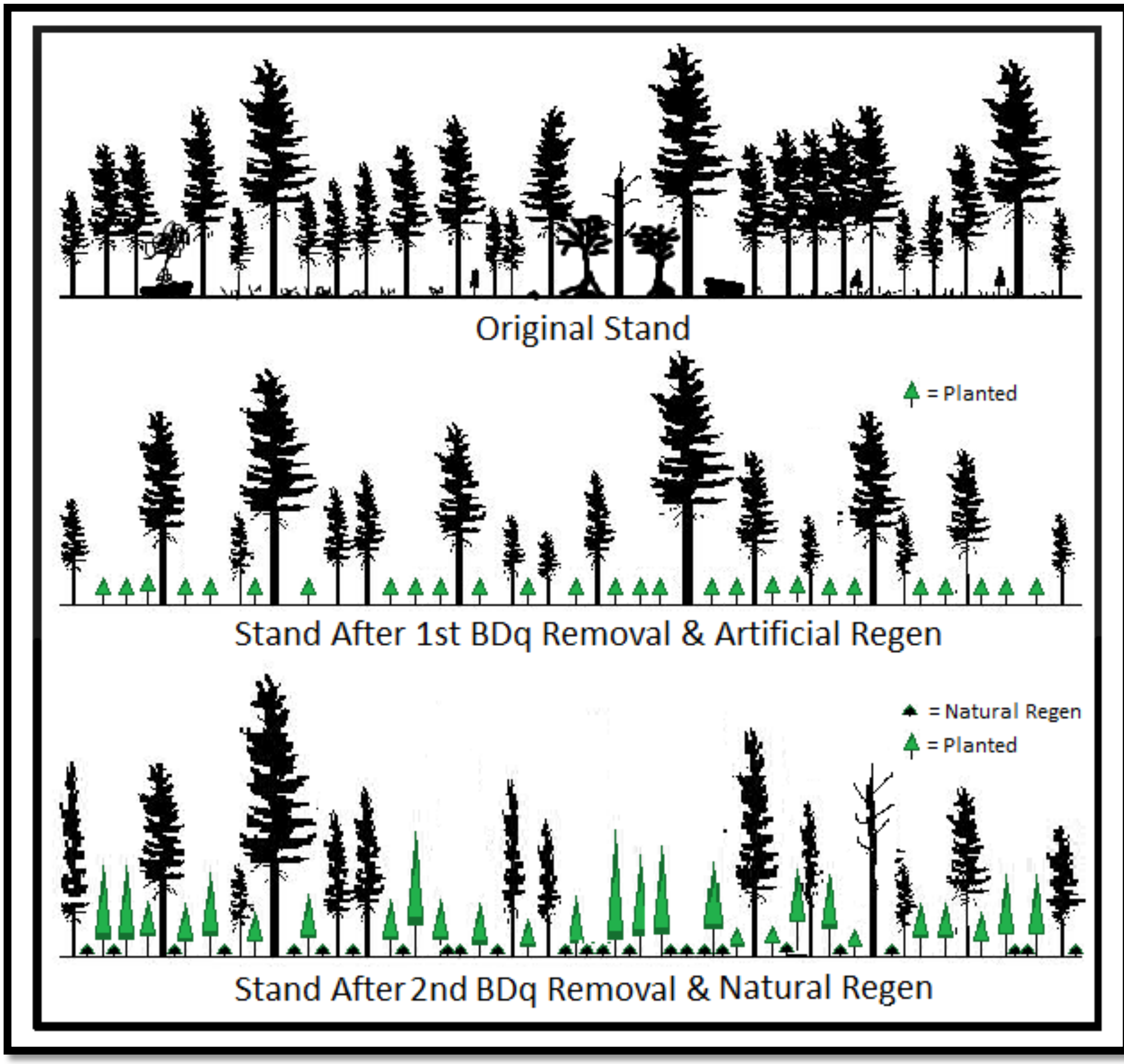
The BDq chart has been adjusted for the retainment of "leave trees" in the highest diameter class (30-34 inches). These largest leave trees, which are too large to log and send to the mill, will function as seed-trees for natural regeneration (if they have good form and are healthy), as well as to champion habitat diversity, vertical heterogeneity, and understory microclimate protection against extreme temperatures. They may even serve as a barrier against the rapid invasion of grasses, sedges, and other gap-dependent re-colonizers. However, even these largest trees are relatively young in their potential life cycle, so to minimize negative influence on understory crop tree growth due to increasingly expanding crown widths, these seed-trees will be left few and far between (only 5 TPA).

The stand's current distribution of Douglas-fir and grand fir is centered around 18-inch diameter class trees, and therefore the stand must undergo an age distribution shift to lower age classes. However, upon the first removal of trees, there will be a large deficit of trees in the lowest diameter classes: 15 TPA short in the 2- to 6-inch class, and 5 TPA short in 6- to 10-inch. Artificial regeneration from nursery-grown saplings will be the chosen method of reforestation for the first cycle, which will help get the stand started in the right direction. Artificial regeneration offers better promise of high establishment and survival (80%+) because of a height advantage over faster-growing shrubs (Tappeiner et. al 191), not to mention added control over density and species composition (in a suddenly opened stand). In uneven-aged stands, seedlings are already at a growth-rate disadvantage compared to even-aged systems (Tappeiner et. al 226), so waiting several years for upward recruitment of naturally regenerating seedlings would be an inadvisable handicap in the first cycle.

Beyond the first growing cycle, reliance on successful natural regeneration can easily surpass Oregon Forest Practices "free-to-grow" requirements within six years of harvest:
200RS - [("x"TPAseed) + (34TPAsap ÷ 0.6) + (81ft$^3$BA ÷ 0.4)] = 60 TPA seedlings over the requirement (assuming all original 10-inch trees add at least 1 inch DBH over six years to be counted in the ≥11-inch category). In fact, OFPA requirements would be met after the initial harvest even without any artificial planting (since the harvested stand would only be 20 TPA seedlings short of target, yet has 60 TPA surplus of the mandate); nevertheless, it remains advisable to manually manipulate regeneration at the start, to set up the stand for future uneven-aged management of valuable timber species. Compared to the densely-stocked plantation prescription, labor and capital costs of planting will be light (15 TPA vs. 400 TPA). Natural regeneration (at no cost) can then be exclusively depended on, after first fitting TPA targets to the BQq size class distribution using artificial regeneration. Partial thinning of the overstory through single-tree-selection harvests can continually perpetuate natural regeneration with minimal vegetation control (Dodson et. al 2014).

The harvests will serve as a density reduction treatment at same time, thereby reducing competition, risks of fire, insects and disease, and ensuring continuation of desired crop species. Lower density also has the added bonus of growing sturdier trees more resistant to wind, wet snow, ice storms, fire (due to thicker bark development and farther spaced fuels), and insect pests associated with high tree density (Tappeiner et. al 288-289). On the other hand, widely spaced conifers might encourage other shade-tolerant trees to recruit into the understory, stealing soil and moisture resources and slowing growth rates. Competition from bigleaf maple is often a management challenge on productive, uneven-aged Douglas-fir stands (Tappeiner et. al 225), so active, continual control would be a necessary investment. This is a large reason why single-tree-selection is preferential to group selection for this stand.

Uneven-aged mixed conifer Douglas-fir stands can be sustainably harvested every 15-25 years depending on productivity, which for this stand equates to two or three cutting cycles by year 50.




*Uneven-aged management prescription, conceptual diagram.*

## II. MANAGEMENT ALTERNATIVES
### C) NO ACTION

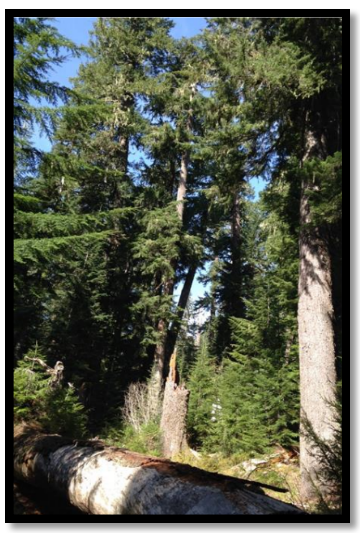
Treatment Objectives and Timeframes

This final silviculture prescription is a hands-off alternative, forecasting the stand at 50 years if no management actions are undertaken. In the absence of human intervention, normal ecosystem functions can play out. With proper simulation, the stand could be evaluated at 50 years against the same ownership objective of growing valuable wood for economic gain.

## Desired Condition

The present day stand's establishment age is 74 years, and it currently has a mostly closed canopy. The stand may be starting to transition to understory re-initiation (Oliver 1981, Oliver and Larson 1990) or maturation (Franklin et. al 2002), evidenced by the high amount of tall snags, downed logs, and few sporadic, smaller gaps. If the stand is allowed to continue growing without human intervention for the next 50 years, it will bring the oldest surviving trees to 124 years.

Assuming that disturbances are infrequent and non-stand-replacing, gap-phase species (e.g. bigleaf maple) will continue to occupy open gaps. As the stand ages, and fine disturbances from windthrow, disease, or old-age happen, mature trees will die and fall, creating increasingly larger gaps and boosting horizontal heterogeneity. Native shrubs establishing gaps on the forest floor, as well as the upward recruitment of shade-tolerant vegetation into the midstory, will contribute to vertical heterogeneity as they create additional strata (Tappeiner et. al 312). A demographic transition will be slowly underway, as a higher percentage of the stand's growing space continually shifts to new trees, and establishes an uneven-aged, complex structure. The death of large trees also frees up more sunlight, moisture, and nutrient resources for other canopy trees, and trees from the original 1943 cohort will be found at increasingly lower densities, though at much larger sizes. At 124 years after stand establishment, the stand will most likely exhibit signs of old-growth forest; diversity and biomass will have increased overall from the present day stand due to the high structural complexity such as large fallen trees (Tappeiner et. al 312). Douglas-fir may also be expected to begin being outgrown by shade-tolerant grand fir around 120 years (Hermann and Lavender *"Douglas-Fir*").



*Example of an old-growth stand in the Pacific Northwest. (Credit: Dr. Matt Powers)*

## Proposed Treatments and Implementation Guidelines

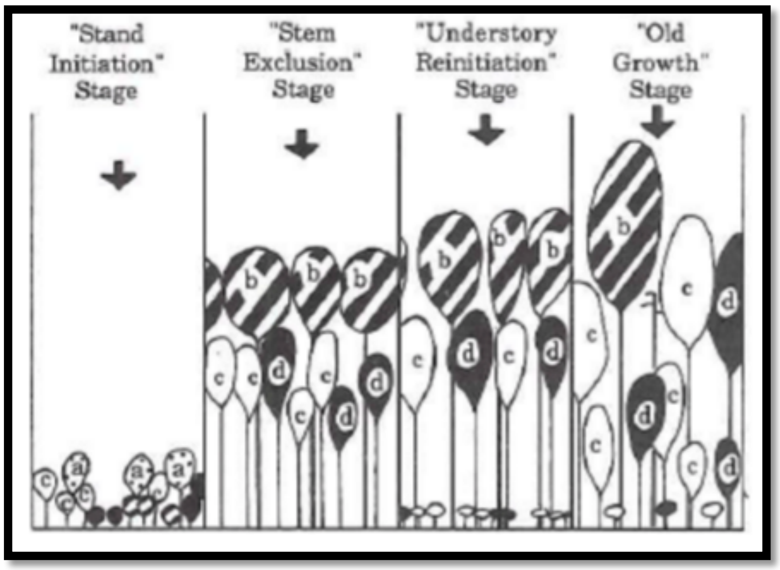
This prescription does not consider the implementation of any silvicultural strategies.

## Analysis of Long-Term Development

Nothing would be prescribed for stand development in this scenario. In weighing the future stand's (50 year) contribution to the landowner's broader management objectives, the stand will likely not have much wood that can be harvested and sold. The original cohort of Douglas-fir trees – the oldest having grown to 124 years – will likely be too large to send to most mills. It may also become illegal to cut very large trees even on private land (depending on forest practices in 2067).

Trees that had established in new gaps would have faced competition from a diversity of other vegetation that also tried to establish in it. Without the manual removal of larger trees, gaps may have been short lived due to overstory canopy expansion, returning any successfully-establishing conifers to a suppressed status with stunted growth.

With comparably less to reap from timber sales off this late-stage stand, a potentially better way to profit off the landholding may be to sell access rights to hunters, considering the high fauna biodiversity usually associated with older, structurally complex stands.




*Stages of stand development (Oliver 1981). The current stand has at least attained stem exclusion, and the next stage will be understory reinitiation.*

<u>Mitigation Measures</u>

With the stand positioned upslope from a public hiking trail, there could be increased risk of large trees falling downhill onto the path. The owners might then be responsible for maintenance costs of clearing the trail, or even face lawsuits in the case of injuries to the public.

## III. RECOMMENDED MANAGEMENT ALTERNATIVE

### A) EVEN-AGED

In light of the land owner's goals for maximizing timber sales, the silviculture prescription for an even-aged plantation is the best fit. This plan will see to the highest amount of commercial wood production, calls for a thinning that doubles as a commercial harvest for high-value poles to achieve an early partial return on investment, and otherwise requires only one major planting and one final harvest over 50 years. Although waiting until year 50 to perform the final harvest increases the chance of timber losses through death and disturbance, extends the interest period, and tests long-term market demands, the payouts can be much higher.

### B) UNEVEN-AGED

Microclimate gaps created in the un-even aged prescription provide good shade and moisture conditions for young Douglas-fir cohorts, and could help limit advanced regeneration of bigleaf maple because of lower light levels. Despite this, managing for such benefits may be unnecessarily excessive, since the stand is not on a dry exposed southern aspect.

The uneven-aged prescription encourages a mixed-species stand due to wider spacing between crop trees; however, this will add unwanted competition for merchantable crops that might reduce growth rate if not removed. Due to overstory shading, the more profitable Douglas-fir crop tree would not be expected to experience rapid growth rates until being released. Of the three prescriptions, this one requires the highest level of attention due to its dependence on continual harvest-release and vegetation-control operations; nevertheless, the benefits from keeping undesired species in check plus quickly weeding out low-vigor or diseased trees would be tangible in the long run.

Uneven-aged stand conditions favor natural regeneration from seed-trees (after the first cycle in this case), so this management strategy can yield sustainable low-investment returns. More frequent returns from the timber supply, combined with better forest health through higher biodiversity, make this prescription a middle-of-the-road safe bet.

## C) NO ACTION

The no-action option would be the least advisable management alternative to meet this landowner's objectives of producing merchantable wood. The 50 year untouched stand would result in few, widely spaced, large-diameter trees that would likely be too large to harvest and/or send to a local mill, while understory trees would face stunted growth until the death of overstory trees – a process which could take decades or centuries longer to occur. While the valuable, somewhat shade-intolerant Douglas-fir could naturally regenerate in this type of stand (Hermann and Lavender *"Douglas-Fir*"), the overall increase in floral biodiversity means that a larger portion of growing space would be occupied by non-commercially-viable species. Instead, land resources would be better used for growing species with market value -- a concept which is more directly addressed in the other prescription plans.

## Final Considerations

*Some of the management alternatives offered for this private family-owned land are geared towards meeting profit-minded objectives of growing commercially valuable timber. To encourage favorable forecasts, the above silviculture prescriptions assume little disturbance or interference from either infrequent fire or the public – criteria of which are provided honest substantiation above – though in actuality might not be met either now or in the future. The supplier of the silviculture management alternatives assumes no liability for any adverse consequences that may occur in conjunction with the implementation of the above hypothetical recommendations.*

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