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An Evaluation of the Blue River Landscape Project:

How Well Does it Use Historical Fire Regimes as a Model?

FINAL REPORT

to the

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1. INTRODUCTION

The Blue River Landscape Project, which I will refer to in this report as the Landscape Plan, represents an ecosystem management strategy for an approximately 57,000 acre area in the Douglas-fir dominated forests of the central western Oregon Cascades. By basing forest management largely on historical disturbance regimes, the Plan attempts to "... sustain native habitats, species, and ecological processes while providing a sustained flow of wood fiber..." (Blue River Landscape Management and Monitoring Strategy (i.e., BRLMMS) 1997). Wildfire has been the most significant natural disturbance process in the region, with regard to altering forest structure and the landscape pattern of habitats upon which species depend (Agee 1993). Wildfire is also the type of natural disturbance whose history is most readily reconstructed, using tree-ring or lake sediment charcoal records. Therefore, an important feature of the Landscape Plan is to use silvicultural prescriptions to approximate key elements of the historical fire regime.

The original formulation of the Landscape Plan relied heavily on fire history studies that were available at the time (Teensma 1987, Morrison and Swanson 1990), and utilized the Weisberg (1996) report that integrated these studies with unpublished data available from Peter Morrison's field notebooks. These studies provided information about fire regimes for much of the Blue River Watershed, although certain areas (e.g., the Tidbits and Quartz Ck. watersheds) were less well represented. However, our knowledge of Blue River fire history has increased greatly since then, particularly with the completed dissertation of Weisberg (1998). Also, we know more about the effects of fire on forest stand structure in the region, and spatial variation in stand structures.

Obviously silvicultural manipulation is never the same as fire. Fire in mature stands typically removes a small proportion of forest biomass, while many silvicultural objectives require the removal of a large amount of forest biomass for use in wood products. Effects of wildfire and timber harvesting may also differ greatly for biogeochemical cycling. But silvicultural manipulation can emulate, in a general way, certain key aspects of fire regime influencing the mortality and regeneration of trees and associated understory species, and landscape structure. The Landscape Plan seeks to emulate the frequency, severity, and spatial pattern of fire with the harvest rate, green tree retention level, and patch size distribution of its silvicultural treatments (BRLMMS 1997). Additional prescriptions attempt to match the spatial pattern of retention trees, frequency of low-severity (i.e., prescribed) fire, and species composition of both retention and regeneration trees, to what has been reconstructed or observed for historical fires. In this report, I evaluate how well the Plan emulates these key aspects of historical fire regimes. Although many elements other than fire history were important parts of the Landscape Plan formulation, I limit my analysis to a comparison of the Landscape Plan with the historical fire regimes of the area, and with the stand structures and landscape patterns produced by the historical fire regimes. As a result, the analysis is somewhat one-dimensional. Some of my recommendations, while appropriate from the "historical fire regime approach" perspective, may be inappropriate for other reasons.

My general objective is to compare the silvicultural prescriptions in the Plan with the known fire history of the Blue River watershed. Most of the report is devoted to a comparison of the historical fire regime with the proposed silvicultural regime, treating both as disturbance processes and comparing the frequency, severity, size, and spatial pattern of disturbance. A second part of the report compares the landscape patterns and forest structures that are expected to result from the two disturbance regimes. Although recommendations for changes to the Plan are scattered throughout the report, I summarize these at the end, and provide suggestions for monitoring how well the Plan emulates past wildfire patterns in the future, as Plan implementation unfolds.

2. COMPARISON OF DISTURBANCE PROCESSES: *How well do forest disturbance processes resulting from silvicultural prescriptions of the Landscape Plan approximate past fire disturbance processes?*

The Blue River Landscape Plan uses past fire regimes as a model for current management activities by approximating certain fundamental fire regime components with silvicultural practices. Fire frequency (mean fire return interval) is matched to an appropriate silvicultural rotation and harvest frequency. Fire severity (level of fire-induced mortality) is matched to an appropriate green-tree retention level within harvested units. Fire spatial pattern is matched to an appropriate distribution of fire patch sizes at the landscape scale, and to patterns of green tree retention at the scale of the individual harvest unit. Since these three components are the primary means by which the Landscape Plan uses fire history information as a guide for ecosystem management, it is important to review each of these in some detail.

The Landscape Plan identifies three landscape areas that are intended to correspond to three different fire regimes, and are managed accordingly. Landscape Area One is intended to approximate key elements of a relatively frequent, moderate severity (40 - 60% mortality) stand-regeneration fire regime; Landscape Area Two to approximate key elements of a moderate frequency, moderate-to-high severity (60-80% mortality) stand-regeneration fire regime; and Landscape Area Three to approximate key elements of an infrequent, high-severity (>80% mortality) stand-regeneration fire regime. A recently completed fire history analysis for the Blue River study area (and some adjacent areas) also identified three fire regime areas (Weisberg 1998). It is instructive to compare prescription elements for the landscape areas with fire regime descriptors for the fire regime areas (Tables 1 - 3). Since the fire regime areas of Weisberg (1998) are not spatially coincident with the landscape areas, it is also useful to compare prescription elements with fire regime descriptors derived from field sites contained within each of the three landscape areas (Tables 1 - 3).

2.1. Rotation vs. Fire Frequency

Appropriate silvicultural rotations in the Landscape Plan should approximate reconstructed fire intervals for each landscape area. The mean fire interval (i.e., MFI) between fires that caused significant overstory mortality (i.e., regeneration fires) provides a more appropriate measure for deriving harvest rotation ages than does the MFI for all fires. Therefore, fires estimated to have been of low severity were excluded from the fire frequency calculation (Tables 1 - 3). The average MFIs of the high-and-moderate frequency fire regimes of Weisberg (1998) were 19 and 29 years higher than rotation ages of Landscape Areas One and Two, respectively (Tables 1, 2). Since it was the intent of the landscape plan to lengthen silvicultural rotations by 20 - 40 years relative to the relevant MFIs, to incorporate the inevitability of unplanned natural disturbance, there may be reason for lengthening the rotation ages of Areas One and Two. However, some of the low-severity fires not included in the MFI calculation would have resulted in as much as 30% overstory mortality (Weisberg 1998), and so should have been included as regeneration fires, resulting in slightly lower MFIs.

The rotation age of Area Three is 16 years greater than the MFI of the low-frequency fire regime of Weisberg (1998), but 38 years greater than the MFI of the Weisberg (1998) fire history sites that actually lie within this landscape area (Table 3). The low-frequency fire regime of Weisberg (1998) includes a greater proportion of high-elevation, true fir forest than lies within Area Three, and so may overestimate MFI. Therefore, the existing rotation age for Area Three seems appropriate.

The Landscape Plan includes areas, designated as late-successional reserves, aquatic reserves, and special interest areas, where no timber harvesting will occur. A meaningful measure of disturbance frequency for the Blue River watershed as a whole would include the area in reserves. This area occupies 12290 acres, or approximately 21% of the watershed. Including the H.J. Andrews Experimental Forest, occupying 15,731 acres, reserves occupy approximately 48% of the watershed. By including these areas of no planned disturbance, a disturbance rotation can be calculated for the study area as a

Table 1. Comparison of prescription elements for Landscape Area One with fire regime descriptors for the "high-frequency fire regime" (Weisberg 1998), and for the 9 fire history site locations from Weisberg (1998) within Landscape Area One. Fire frequency is the average of Mean Fire Intervals for sites within the fire regime area. The % overstory surviving fire is estimated by weighting the estimated proportion of overstory trees surviving for high and moderate fire severity classes (i.e., high - 15%, moderate - 50%) by the mean proportion of fires occurring within each of these fire severity classes in Weisberg (1998). This calculation is considered a gross approximation. Low-severity fires are not considered here because they are approximated by thinning and prescribed fire in the landscape plan, and not by regeneration timber harvests.

Prescription Elements/Fire Regime Descriptor	Landscape Area One	Fire History Sites Overlaid on Landscape Area One	High-Frequency Fire Regime
Rotation Age/Fire Frequency (Mean Fire Interval, excluding low-severity fires) (years)	100	128 (95% CI: 92 - 165)	119 (95% CI: 99 - 139)
Retention Level/% Overstory Surviving Fire	50% (except 70% within 75' of Class III stream)	38%	26%
Retention Mixture	Shade Intolerant: 65% Shade Tolerant: 35%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 19%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 18%
Reforestation Mixture	Shade Intolerant: 40% Shade Tolerant: 60%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 19%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 18%
Low-severity Fire	Not planned	On average, one low-severity fire occurs every 182 years (95% CI: 149 to 232 years)	On average, one low-severity fire occurs every 204 years (95% CI: 175 to 244 years)

Table 2. Comparison of prescription elements for Landscape Area Two with fire regime descriptors for the "moderate-frequency fire regime" (Weisberg 1998), and for the 12 fire history site locations from Weisberg (1998) within Landscape Area Two. Fire frequency is the average of Mean Fire Intervals for sites within the fire regime area. The % overstory surviving fire is estimated by weighting the estimated proportion of overstory trees surviving for high and moderate fire severity classes (i.e., high - 15%, moderate - 50%) by the mean proportion of fires occurring within each of these fire severity classes in Weisberg (1998). This calculation is considered a gross approximation. Low-severity fires are not considered here because they are approximated by thinning and prescribed fire in the landscape plan, and not by regeneration timber harvests.

Prescription Elements/Fire Regime Descriptor	**Landscape Area Two**	**Fire History Sites Overlaid on Landscape Area Two**	**Moderate-Frequency Fire Regime**
Rotation Age/Fire Frequency (Mean Fire Interval, excluding low-severity fires) (years)	180	197 (95% CI: 116 - 279)	209 (95% CI: 163 - 255)
Retention Level/% Overstory Surviving Fire	30% (except 50% within 75' of Class III stream)	21%	36%
Retention Mixture	Shade Intolerant: 80% Shade Tolerant: 20%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 18%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 29%
Reforestation Mixture	Shade Intolerant: 60% Shade Tolerant: 40%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 18%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 29%
Low-severity Fire	Once between year 100 and year 180	On average, one low-severity fire occurs every 218 years (95% CI: 143 to 455 years)	On average, one low-severity fire occurs every 161 years (95% CI: 125 to 227 years)

Table 3. Comparison of prescription elements for Landscape Area Three with fire regime descriptors for the "low-frequency fire regime" (Weisberg 1998), and for the 17 fire history site locations from Weisberg (1998) within Landscape Area Three. Fire frequency is the average of Mean Fire Intervals for sites within the fire regime area. The % overstory surviving fire is estimated by weighting the estimated proportion of overstory trees surviving for high and moderate fire severity classes (i.e., high - 15%, moderate - 50%) by the mean proportion of fires occurring within each of these fire severity classes in Weisberg (1998). This calculation is considered a gross approximation. Low-severity fires are not considered here because they are approximated by thinning and prescribed fire in the landscape plan, and not by regeneration timber harvests.

Prescription Elements/Fire Regime Descriptor	**Landscape Area Three**	**Fire History Sites Overlaid on Landscape Area Three**	**Low-Frequency Fire Regime**
Rotation Age/Fire Frequency (Mean Fire Interval, excluding low-severity fires) (years)	260	222 (95% CI: 171 - 273)	244 (95% CI: 204 - 284)
Retention Level/% Overstory Surviving Fire	15% (except 30% within 75' of Class III stream)	30%	24%
Retention Mixture	Shade Intolerant: 95% Shade Tolerant: 5%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 31%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 35%
Reforestation Mixture	Shade Intolerant: 75% Shade Tolerant: 25%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 31%	Mean Proportion of Stand Basal Area in Shade Tolerant Species: 35%
Low-severity Fire	Twice between year 100 and year 260	On average, one low-severity fire occurs every 137 years (95% CI: 103 to 213 years)	On average, one low-severity fire occurs every 179 years (95% CI: 147 to 227 years)

whole by summing the area to be harvested within the three landscape areas over a specified time interval, and dividing the total harvested area by the area of the Blue River watershed (including reserves) to obtain a proportion of harvested area. The time interval used in the above calculation is then divided by the proportion of harvested area to obtain a disturbance rotation.

Considering the watershed as a whole, but not including the HJA, disturbance rotation is 246 years. This disturbance interval is a 25% increase from the study-area-wide MFI (not including low-severity fires) of 197 years (Weisberg 1998), and is a 29% increase from the MFI of 191 years for only those fire history sites within the planning area.

Given that some unplanned disturbances will occur, it is arguable that the disturbance frequency of the managed watershed as a whole will be comparable to (or even less than) the frequency of the natural disturbance regime over the past several hundred years. Whether rotation ages of Landscape Areas One and Two need to be lengthened depends upon the rationale behind intended forest management. If it is intended that the harvest rotation **of each landscape area** be greater than the historic mean fire interval, then rotations for Areas One and Two need to be lengthened by about 20 years, to 120 and 200 years, respectively. If it is intended that the disturbance regime **integrated over the entire watershed** approximates that of the natural fire regime, then existing prescriptions for rotation ages may be appropriate, depending upon how much of a harvest rotation buffer against unplanned disturbances is considered necessary. Of importance to consider are the relevant spatial scales at which species require habitat that is being disturbed, or is produced by disturbance occurring, at a given rate relative to the range of natural variability within which the species has survived over millennia (sensu Swanson et al. 1993). Reserves are scattered throughout the Watershed, particularly as 100 acre late-successional reserves or aquatic reserves along all fish-bearing streams, and so most mobile organisms should have access to areas of extremely low disturbance.

2.2. Retention vs. Fire Severity: Landscape Areas

Existing fire history studies do not accurately characterize fire severity, defined here as the level of tree overstory mortality caused by fire, and which is especially difficult to reconstruct for earlier fires where multiple fires have burned in a stand. The Weisberg (1998) fire history study attempts to characterize fires as low, moderate, or high severity using a dichotomous key (Weisberg 1998: Table 4.2). By weighting the estimated midpoint proportion of overstory trees surviving for high and moderate severity fire classes (i.e., high - 15%, moderate - 50%) by the relative proportion of fires occurring within each of these two classes, a crude estimate of the % overstory surviving "typical" moderate and high severity fire was obtained for each fire regime area. This estimate is less than the retention level prescription for Landscape Area One (Table 1), is similar to the retention level prescription for Landscape Area Two (Table 2), and is greater than the retention level prescription for Landscape Area Three (Table 3). There seems to be little difference in fire severity between the three fire regime areas, although Weisberg (1998; Table 4.12) found the low-frequency fire regime to have a greater proportion of low-severity fires, not included in the above calculation. For the 1991 Warner Creek Burn, approximately 31% of the 3669 ha area retained at least 76% of its pre-fire canopy cover (Kushla 1996: Fig. 2.1), suggesting similar "fire retention" levels as calculated in Tables 1 - 3.

A similar calculation based on fire severity patch data for the 1893 fire episode in the Cook-Quentin study area (Morrison and Swanson 1990; Table 8) resulted in an estimate of 54% overstory survival. The same calculation for the Cook-Quentin study area for all fires from 1800-1900 resulted in an estimate of 51% overstory survival. The Cook-Quentin study area currently lies in Landscape Area Two, although I recommend that much of it be moved to Landscape Area One (Section 2.8), suggesting that the current retention level (50%) for Landscape Area One may be appropriate. However, the 1800-1900 period does not include the higher-severity fires that occurred in earlier centuries, and so may not provide an adequate record for comparison.

Based on the Morrison and Swanson (1990; Table 10) 1800 - 1900 fire patch data for the Deer Creek study area, representing Landscape Area Three, the % overstory surviving fire is estimated as 56%, greater than the 24% estimated for the Weisberg (1998) low-frequency fire regime, and much greater than the prescribed 15% retention level (Table 3). Again, the 1800-1900 period is not representative of Blue River fire patterns for the past several centuries. However, these data support the Weisberg (1998) conclusion that there may be little overall difference in fire severity at the scale of landscape or fire regime "areas", and that differences in fire severity may be more apparent at finer scales such as hillslope position or slope aspect. Also, patterns of fire severity for the 1991 Warner Creek fire, in Douglas-fir forest south of the study area, show mean ranges of surviving crown cover from 45% to 73% for four different landscape areas (Kushla 1996). These numbers are similar to the Morrison and Swanson (1990) estimates given above. Kushla (1996) was better able to explain fire mortality patterns using fine-scale topographic predictor variables in separate regression models for each of the four landscape areas than by including landscape area as a predictor variable in a single regression model for the entire burn. The landscape area variable explained only 4% of the variation in fire mortality for the Warner Creek burn.

These results suggest there may be little basis for the assumed inverse relationship between fire frequency and severity implied in the Landscape Plan, at least at the scale of the landscape areas considered. Reasons for why there may be a direct relationship between fire frequency and severity at this scale are discussed in Weisberg (1998). If low-severity fires are not included, since they do not correspond to timber harvests in the Plan for which rotation and retention need be specified, then there appears to have been little difference in fire severity between fire regime areas (Tables 1 - 3).

Nevertheless, I have too little confidence in extant calculations of past fire severity for the Blue River Watershed to recommend any changes in silvicultural prescriptions for retention level. Also, observations of decreasing numbers of age cohorts of shade-intolerant tree species along the gradient from high-frequency to low-frequency fire regime (Weisberg 1998; Table 4.12; Figs. 4.27, 4.28) suggest that fires in Area One cannot have been primarily stand-replacing, and that fires in Area Three cannot have been primarily low or moderate severity. It would be interesting to employ simulation modeling to test whether observed fire frequency differences between the landscape areas were sufficient to have produced the observed differences in stand structure (i.e., age cohort numbers and rates of cohort establishment), given various levels of fire severity that were held constant. In the absence of such information, I can only stress that such limited and questionable information as is available does not support current prescriptions for green tree retention levels, and that further research on fire severity patterns is necessary to either support current prescriptions, or provide guidance for modifications.

Meanwhile, there are at least two options available: (1) Continue with the current prescriptions for 50%, 30% and 15% retention for Areas One, Two, and Three, respectively; and (2) Given that there is little empirical basis for the current severity/retention prescriptions, vary only frequency between landscape areas, and have a constant retention level of approximately 30%. The observed landscape-level pattern of shade-intolerant age cohorts supports the first option, while the observed pattern of reconstructed fire severities supports the second. Until more is known about landscape-level fire severity patterns in the region, I recommend the first option, since the second would decrease variability in forest structure, possibly resulting in further deviations from the range of natural variability.

2.3. Retention vs. Fire Severity: Distribution Within Stands

The Landscape Plan provides guidelines for the spatial pattern of retention trees (BRLMMS: pp. 13-14). I shall evaluate these guidelines individually with regard to how well they serve to emulate observed patterns of post-fire overstory mortality.

(1) *Retention trees should be both clumped and scattered individuals (with guidelines in BRLMMS Appendix A for the relative proportions of trees and canopy area in clumps and scattered trees).*

This guideline ensures variability of spatial pattern in post-harvest stand structures, which should serve to create a more heterogeneous managed landscape. Specifying that larger landscape blocks have larger clumps is consistent with the observation, for the boreal forest in Alberta, that larger fires have larger patches of unburned trees (Eberhart and Woodard 1987). For the subalpine forests of British Columbia, Stuart-Smith and Hendry (1997) found that the number of surviving trees and patches increased with fire size, but that the average size of surviving patches did not change.

Landscape mosaics resulting from moderate and variable severity fire regimes are typically quite heterogeneous (Pitcher 1987, Morrison and Swanson 1990, Chappell and Agee 1996), and the differences between such landscape mosaics and the more uniform patterns that result from many clearcutting regimes have been discussed in depth elsewhere (Franklin and Forman 1987, Spies and Franklin 1988). Guideline 1 should help to create a forest pattern more similar to that of the natural fire regime.

(2) *Variable retention levels should be provided adjacent to streams (with at least 25% in clumps adjacent to intermittent streams in Area 3, and an additional 25% of total retention trees provided as clumps within the higher retention zone along perennial streams).*

In the Blue River Watershed, Douglas-fir trees in lower slope positions tend to be older than Douglas-fir trees in upper slope positions, where there is a difference in age (Weisberg 1998: Fig. 4.17). Average ages for Douglas-fir trees were about the same between slope positions for 18%, older for lower slope positions for 56%, and older for upper slope positions for 26%, of 85 sampled sites. Further, sites at lower slope positions had, on average, a 16% greater percentage of their fires be of low severity than had middle slope positions, after the effect of site elevation was accounted for (Weisberg 1998: Table 4.8). Fire severity was also less for lower slope positions in the Oregon Coast Range (Impara 1997), and was less with increasing proximity to streams during the Warner Creek fire (Kushla 1996). Since there is some evidence for lower-severity fire and greater likelihood of survival of Douglas-fir trees at lower slope positions in this area, Guideline 2 should lead to management that better emulates post-fire mortality patterns.

(3) Scattered retention trees should generally be left in the larger tree size classes...

There is overwhelming evidence that the critical time for cambial kill during fire increases with increasing tree diameter, for a variety of western conifers (Agee 1993: Fig. 5.6). It is widely observed that larger trees have a greater likelihood of surviving wildfire than smaller ones, due to thicker bark, taller crowns, and greater reserves of photosynthate. Guideline 3 is thus appropriate from the perspective of emulating natural fire patterns.

(4) Retention trees should include the largest, oldest live trees, decadent or leaning trees, wolf trees, and hard snags.

This guideline resembles Guideline 3, and my analysis is similar. Hard snags, in particular, would have been likely to remain standing following wildfire. I observed many snags that were charred by fires which post-dated the original cause of tree mortality.

(5) Higher levels of retention should generally be located near streams and lower slope positions, and lower levels on upper slope areas.

See analysis for Guideline 2.

(6) Retention trees shall be placed on sites of potentially unstable ground, and on localized areas adjacent to streams prone to streamside slides, to the degree needed to minimize mass movement risks.

This guideline will not serve to emulate past fire patterns, nor is it intended to. Fire is unlikely to discriminate between places of different risks for erosion, mass movement, and sedimentation. Where such areas occupy steeper slopes, fires may have typically burned there with greater severity, making green tree retention less appropriate from a fire regime perspective. However, the vegetation in such areas may also have been sparser and less productive, resulting in reduced fire severity from fuel limitations.

(7) No trees should be cut on any floodplain or streambank, nor should trees directly contributing to streambank stability be cut.

While past wildfires were less likely to kill trees on the floodplain, they certainly did on occasion. However, the intention of this guideline is not to emulate past fire patterns, but to preserve streambank stability.

(8) Rock outcrops, wet areas, or other special or unique habitats could be used to anchor retention clumps.

Both rock outcrops and wet areas may have provided fire breaks for adjacent trees, and so may well have anchored "retention clumps" resulting from past wildfires. This guideline is appropriate from a fire regime perspective.

Guidelines 9 and 10 (BRLMMS 1997: p. 14) are not intended to emulate past fire patterns, and are not addressed here.

2.5. Landscape Block Size vs. Fire Pattern

Landscape blocks represent management units for scheduling future silvicultural activities, and are specified in the Plan as ranging from tens to hundreds of acres, with the largest blocks being 400 acres (BRLMMS: p. 24, Table 2). The sizes of landscape blocks are intended to resemble those of mortality patches from past fires. The prescriptions for block sizes are designed so that landscape blocks (and hence, harvest units) will be largest for Landscape Area Three and smallest for Landscape Area One. This relationship between block size distribution and landscape area was derived from photo-interpreted fire patch distributions for two areas of different fire regime within the Blue River watershed, reported in Morrison and Swanson (1990). The Cook-Quentin area had a relatively high-frequency, low-severity fire regime, while the Deer Creek area had a relatively low-frequency, high-severity fire regime. The Cook-Quentin area had more of its burned area in smaller patches than the Deer Creek Area, and so data for the two areas were used as models for Landscape Areas One and Three, respectively. It is expected that fires that burn with higher severity would create larger mortality patches, since fuel breaks would be less effective in controlling fire behavior, and rate of fire spread is positively associated with fireline intensity (Rothermel 1983).

The Weisberg (1998) study did not report fire patch size distributions because such data are extremely imprecise when obtained from tree-ring-based fire history studies. Therefore, no new information on historical fire patch sizes for the Blue River watershed is available. Although it is unclear whether Landscape Area Three burned with greater severity than Landscape Area One, one would still expect fire sizes (and sizes of patches within fires) to have been greater for the higher elevations in the study area because the lower elevations (Landscape Areas One and Two) are characterized by dissected topography, while much of Landscape Area Three contains earthflow-dominated terrain associated with gentle slopes and little topographic dissection. More dissected topography is associated with a greater density of ridgetops and riparian areas that might act as firebreaks, and so limit the sizes of fire patches. In the absence of new empirical information, the current prescriptions for differences in landscape block size distributions between landscape areas seem appropriate.

While the trend toward larger patches at the higher elevations may emulate the effects of historical fires, the actual magnitudes of patch sizes created by timber harvesting may not, particularly at the upper end of the size spectrum. Certain very large fires of the 1400s and 1500s likely created very large patches (10^3 to 10^5 acres) of mortality, that afterwards developed into some of the large patches of old-growth which dominated much of the region prior to logging (Teensma 1987, Weisberg 1998). However, it would not be feasible to recreate such large patches of disturbance for a variety of reasons (BRLMMS 1987).

2.6. Landscape Region Size vs. Fire Extent

The Landscape Plan uses six landscape regions to cluster harvests in space and time. Harvest blocks are grouped within one or two landscape regions in a given 20-year period (BRLMMS p. 25). These landscape regions are intended to correspond in size with the outer perimeters of past wildfires. The six regions range in size from 3748 to 11656 acres (BRLMMS: Table 3).

It is very difficult and imprecise to define fire boundaries from tree-ring-based fire history studies, and few data are available for fire sizes in the Blue River Watershed. Perhaps the best data for sizes of relatively recent fires come from the research of Rasmussen and Ripple (1998), who used a 1936 map to reconstruct pre-logging landscape patterns of western Oregon. For the central Oregon Cascades, they found that the range of sizes for fire patches mapped in the 1930s was from 121 to 8985 acres, with a mean of 840 acres. These numbers suggest that the landscape regions of the Landscape Plan are larger than typical wildfires of the 1800s and early 1900s. However, there is tree-ring-based, fire history evidence from the Blue River watershed suggesting fires of the 1400s and 1500s were larger than those that followed (Teensma 1987, Weisberg 1998). For example, the 1482 fire episode was estimated by Teensma (1987) to have burned over 25,000 acres, while the four fires that followed in the 1500s burned from 3705 to 16,333 acres. Thus, the sizes of the six landscape regions roughly approximate the sizes of the large fires that burned in the 1400s and 1500s, that initiated most of the old-growth forests we see in the Pacific Northwest today.

2.7. Prescribed Fire

Prescribed, low-severity fire (0 - 30% overstory tree mortality) is included in the Landscape Plan to simulate some of the "process roles" of fire, including soil heating, biogeochemical effects, regeneration of some fire-adapted plant species, creation of fine-scale habitat heterogeneity, and fuels reduction. Two types of low-severity fire are present in the Plan: post-harvesting slash fires in harvested blocks, and prescribed fires later in the rotation in nonharvested forests. The first type is likely to burn with greater intensity than historical low-severity fires, due to higher fuel loadings at ground level, while the second type is more likely to resemble natural low-severity fires. It is recommended that the timing of post-harvesting slash fires be used to mitigate fire intensity, soil heating, and fuel consumption levels. Low-severity prescribed fires in mature stands will likely represent the lower end of the low-severity spectrum, since fire management policy would be conservative so as to prevent fires getting out of control and resulting in widespread tree mortality.

Landscape Plan prescriptions for low-severity fire would best emulate natural fire regimes if the frequency and timing of such fires were similar to that observed in fire history studies. This comparison is made in Tables 1 - 3. For the high-frequency fire regime (Weisberg 1998), one low-severity fire occurred about every 180 or 200 years. Since the rotation age of Landscape Area One is only 100 years, it is understandable that no low-severity fires are scheduled. Low-severity fires too early in the rotation may not be possible, since low fireline intensities may still result in lethal cambium temperatures and crown scorch for short, thin-barked young conifers. Low-severity fires late in the rotation would not result in many of the desired effects for vegetation structure, since many of these effects require time for post-fire recovery and stand development, but would still produce some of the desired soil effects. However, such soil effects would also be produced by the slash fire following harvest every 100 years or so. I recommend that low-severity fires occur at least every 200 years in Landscape Area One, whether by post-harvest slash fires, or by prescribed fires late (e.g., at 80 years) in the rotation.

The frequency of low-severity fires between Landscape Area Two and the Moderate-Frequency Fire Regime (Weisberg 1998) compares well. Under the natural fire regime, low-severity fire occurred about once every 160 years; under the Landscape Plan, low-severity fire will occur about once every 180 years (Table 2). For Landscape Area Three, low-severity fire will occur about once every 130 years, not too dissimilar from the once every 180 years observed for the Low-Frequency Fire Regime (Table 3). Using the value for fire history sites overlaid on Landscape Area Three (i.e., fire history sites in the Low-Frequency Fire Regime of Weisberg (1998) but not in Landscape Area Three), the average low-severity fire frequency was about once every 140 years, which is only slightly greater than the frequency prescribed in the Landscape Plan.

2.8. Retention and Reforestation of Shade-Tolerant Tree Species

Prescriptions for species composition mixtures (i.e., relative proportion of shade-tolerant tree species) for retention and reforestation will likely result in patterns of shade-tolerant species distribution opposite to what was observed to have resulted from the natural fire regime (Tables 1-3; Weisberg 1998: Table 5.10, Fig. 5.5). Mature stands at higher elevations, corresponding to Landscape Area Three, generally had greater relative basal areas of shade-tolerant tree species even when stand age was included as a covariate (Weisberg 1998: Table 5.5). While it is true that the reforestation mixtures specified in the Landscape Plan (Tables 1-3) are at "time 0" of stand development, and so are not directly comparable to empirical observations of relative shade-tolerant dominance in mature stands, it is probable that current prescriptions will result in more shade-tolerant dominance for Landscape Area One, and less for Landscape Area Three. Prescriptions should be adjusted so that more hemlock and redcedar are allowed to establish and grow in Landscape Area Three relative to Landscape Area One. Probably adjustments should be greater for the reforestation mixture relative to the retention mixture, since it makes sense that a lesser proportion of shade-tolerant trees should survive where fire severity is greater, since shade-tolerant species in the study area are less fire-resistant. However, there may have been little difference in fire severity between landscape areas (see Section 2.2). Adjusted prescriptions that would produce the desired altitudinal gradient in relative dominance of shade-tolerant species (Weisberg 1998) might resemble:

Landscape Area	**Retention**		**Reforestation**	
	Intolerant	**Tolerant**	**Intolerant**	**Tolerant**
One	90%	10%	70%	30%
Two	85%	15%	60%	40%
Three	75%	25%	50%	50%

A potential problem with these prescriptions is that shade-intolerant species, such as Douglas-fir, may not survive and/or grow well in stands with 50% canopy retention (Landscape Area One). However, Douglas-fir regeneration in stands following partial stand-replacing wildfire is likely to be more concentrated in localized areas where overstory mortality is greater. Since the spatial pattern of retention trees will resemble the heterogeneous pattern of overstory survival following wildfire (Section

2.3), it is possible that Douglas-fir may regenerate well in such stands if Douglas-fir seedlings are planted in larger canopy gaps, and seedlings of shade-tolerant species planted in smaller ones. It would be useful to simulate stand development under different scenarios for the retention and reforestation of shade-tolerant tree species, and determine under which sets of guidelines the observed relative dominance of these species is likely to be obtained for mature stands.

It might prove easier to manage for greater dominance of shade-tolerant tree species at higher elevations by using the complex prescriptions for rotation and retention discussed in Section 6.2. A greater proportion of shade-tolerant trees might be planted following the higher-retention harvests, allowing more shade-intolerant trees to be planted following the lower-retention harvests. This would also more closely emulate observed patterns of forest succession following wildfire.

2.9. Responses to Unplanned Disturbances

Unplanned disturbances due to fire, wind, insects, and other sources will undoubtedly occur. The guidelines for responding to such disturbances stress the positive aspects of forest disturbance for creating additional variability, while allowing salvage logging after large fires to recover timber volumes approximating those that would have been harvested in the absence of fire (BRLMMS: pp. 18-19). Of particular importance is the role of fire in creating large patches of snags, which will not be generated by the Landscape Plan in the absence of unplanned wildfire.

These guidelines seem highly appropriate for helping unplanned disturbances bring the system back to something more closely resembling its fire-driven state. It might be interesting to use unplanned fire and blowdown events as opportunities for experimentation using a replicated treatment design, where different levels of salvage (including no salvage) are implemented, and the effects of these treatments measured over a period of decades.

2.10. Landscape Areas vs. Fire Regime classes: geographic zoning

It is not straightforward to compare the fire regime characterization in Weisberg (1998) with the landscape area delineation of the Landscape Plan (Fig. 1). The Weisberg (1998) characterization employed a finer spatial resolution than the Landscape Plan delineation. In the Weisberg (1998) characterization, the Moderate-Frequency Fire Regime Area was modeled as an intermediate fire regime along the continuum between the Low-Frequency Fire Regime Area at higher elevations, and the High-Frequency Fire Regime Area at lower elevations. It also emerged as a delineator of riparian and valley bottom areas, which burned less frequently than uplands, within the High-Frequency Fire Regime Area.

Figure 1. A comparison of landscape areas in the Blue River Landscape Plan with fire regime areas of the Weisberg (1998) fire history study.

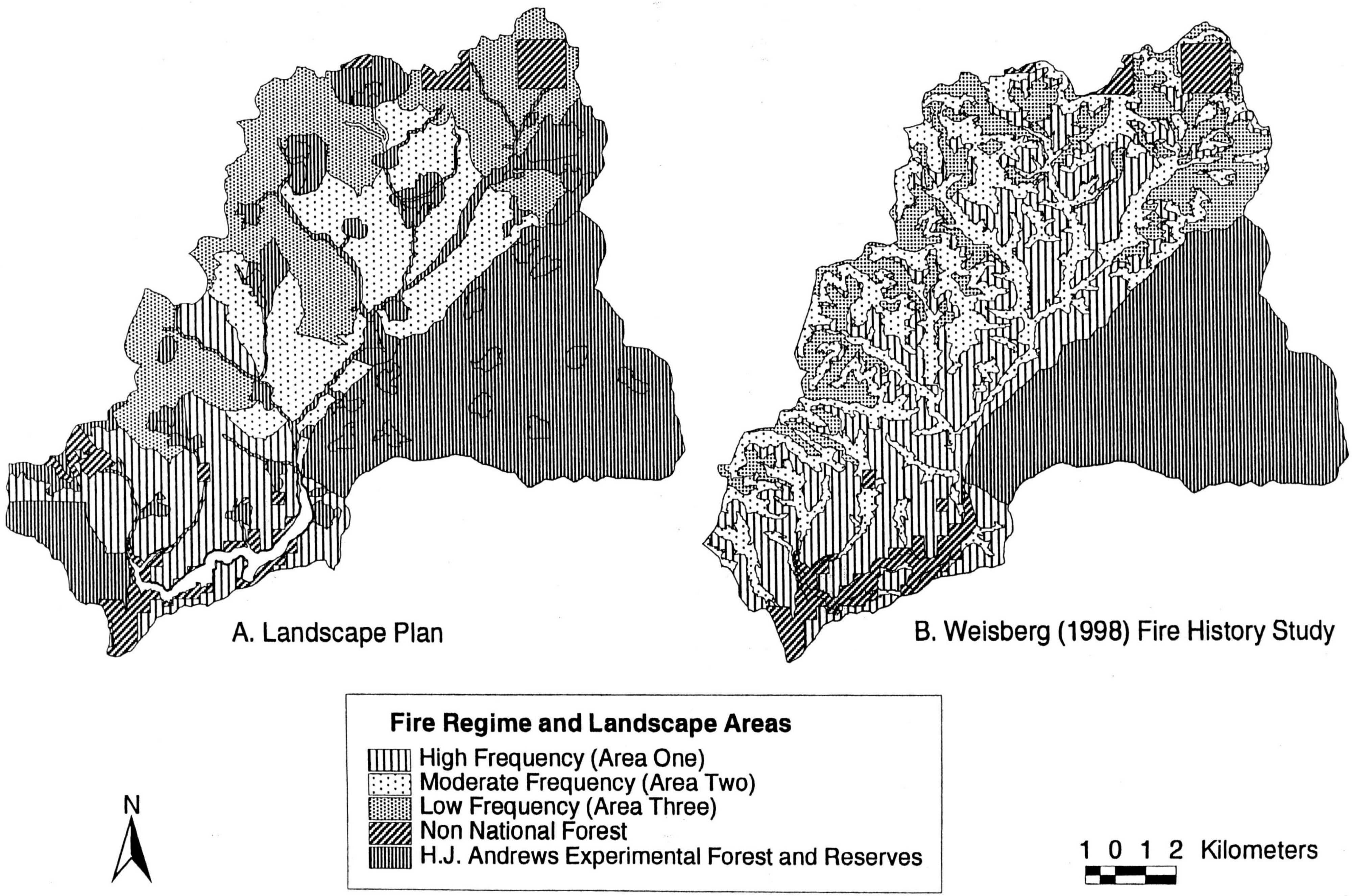
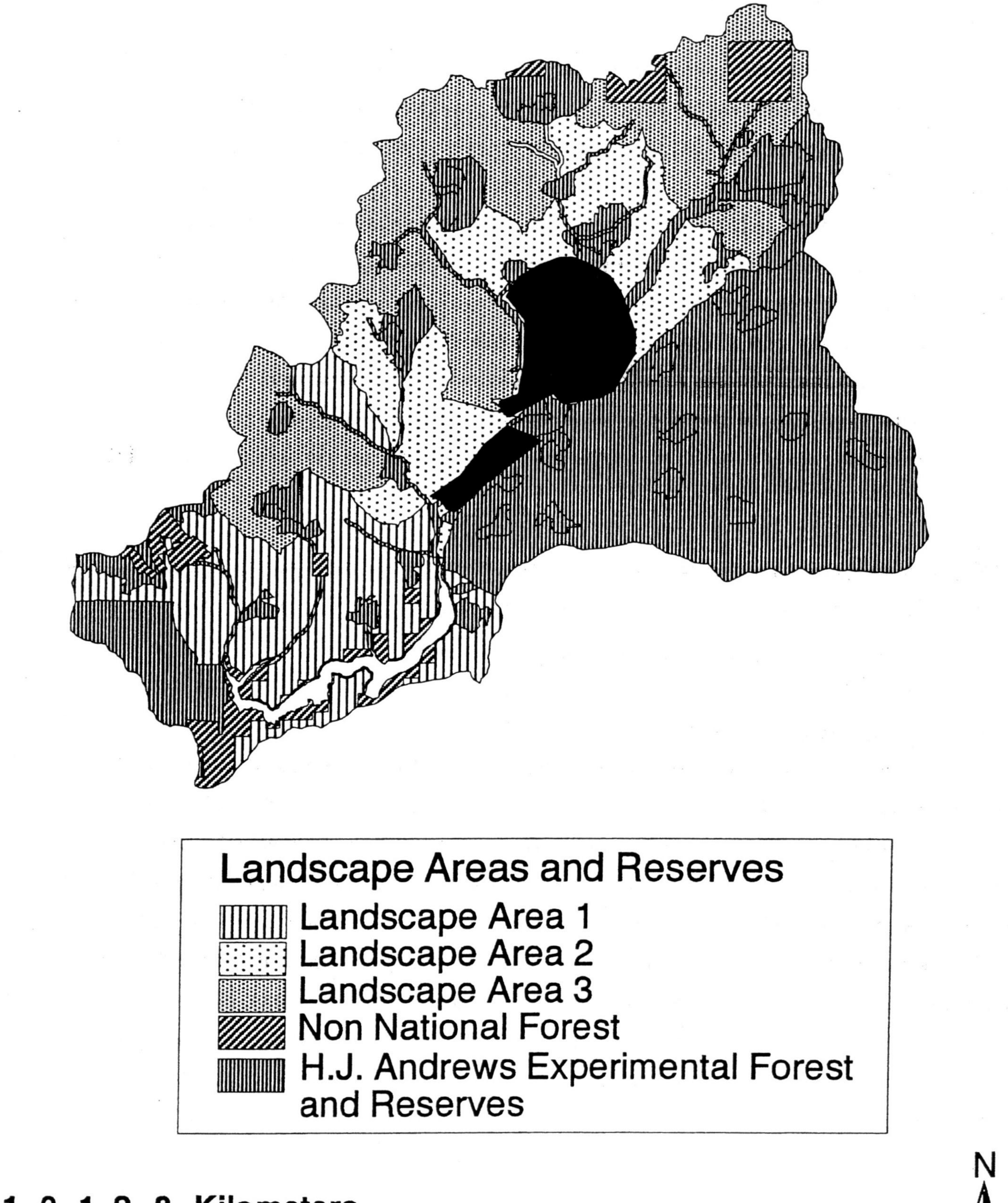


Figure 2. Suggested changes to the landscape area delineations. The blackened polygons might be changed from Landscape Area Two to Landscape Area One.



Weisberg (1998) reports that, while the Low-and-High-Frequency Fire Regime Areas are truly distinct with regard to fire history variables, the Moderate-Frequency Fire Regime Area represents a transitional zone (Weisberg 1998: Table 4.12).

However, the two maps (Fig. 1) allow a useful comparison for Landscape Areas One and Three with the boundaries of the High-and-Low-Frequency Fire Regime Areas, respectively. The boundary of Landscape Area Three corresponds quite nicely with that of the Low-Frequency Fire Regime Area. The boundaries of Landscape Area One and the High-Frequency Fire Regime Area correspond less closely. Based on the results of Weisberg (1998) and my knowledge of fire history throughout the Blue River Watershed, I see no fire regime distinction between the Quartz Creek drainage and the lower portions of the Cook and Quentin Creek small watersheds. I recommend extending Landscape Area One up Blue River into the lower portions of the east Cook Creek and Quentin Creek watersheds, as illustrated in Figure 2. I do not recommend extending Landscape Area One into the Tidbits and Ore Creek watersheds, which are relatively protected from east wind influences on fire spread and fuel desiccation, and have burned less frequently than the Cook and Quentin Creek watersheds (Weisberg 1998: Fig. 4.6).

3. COMPARISON OF FOREST PATTERNS AND STRUCTURES: *How well do landscape patterns and forest stand structures resulting from the silvicultural manipulations of the Landscape Plan compare with those that would be expected to result from a natural fire regime?*

<u>3.1. Patterns of Within-Stand and Between-Stand Structure</u>

One might think of within-stand patterns as applying to a single hillslope, although some stands may be a great deal larger. At this scale, the results of the Weisberg (1998) fire history study suggest that the natural fire regime often produced a pattern of higher densities of larger, older Douglas-fir trees in lower hillslope positions. However, this pattern was weak and variable, with Douglas-fir ages often not differing between upper and lower slope positions (Section 2.3, Guideline 2; Weisberg 1998: Fig. 4.17). The Landscape Plan is likely to produce a similar pattern as a result of riparian buffers along fish-bearing streams, and green tree retention guidelines that require leaving more trees on lower slopes and floodplains (Section 2.3). The spatial pattern of tree sizes and ages in the Landscape Plan is likely to be less variable, and more strongly associated with hillslope position, then such patterns as produced by the natural fire regime.

Within-stand patterns of overstory tree species composition may also have been influenced by topographic heterogeneity. Due to a gradient of increasing fire frequency and severity with increasing hillslope position, the natural fire regime would have been expected to result in more trees of shade-tolerant species along stream corridors, and on lower slopes. The ecological affinity of species such as western hemlock and western redcedar for wetter, cooler environments should also contribute to such a pattern. Although this result did not emerge from Weisberg (1998), I often observed such a pattern in the field. Western redcedar, in particular, seems closely linked to stream corridors and wet, north-facing slopes over much of the study area. Slope aspect appears to be a very important factor for the distribution of shade-tolerant tree species within the study area, with stands on more mesic slope aspects having greater relative dominance of shade-tolerant species, after accounting for variation in stand age and fire history (Weisberg 1998: pp. 215-220). Such within-stand patterns of shade-tolerant tree species distribution are unlikely to be maintained beyond a few rotations by the Landscape Plan, as there are no criteria for green tree retention that address this (see Section 2.8). Perhaps an additional criterion might be specified that would call for more reforestation of shade-tolerant trees (e.g., western hemlock, western redcedar) on lower slopes and north aspects within a harvested landscape block. Such a criterion would allow more of the shade-intolerant trees (e.g., Douglas-fir, noble fir at higher elevations) to be planted at upper slope positions where they should establish and grow more successfully due to lower green tree retention levels.

Weisberg (1998) also found differences between fire regime areas in the number of age cohorts of shade-intolerant tree species within stands. More age cohorts were present, and the rate of age cohort formation was greater, for stands within the High-Frequency Fire Regime Area (Weisberg 1998: Table 4.12, Fig. 4.28). These relative differences are likely to be maintained by the criteria for rotation ages and retention levels of the three landscape areas. More age cohorts of Douglas-fir will be created and maintained in Landscape Area One, with higher harvesting frequency and green tree retention, than in Landscape Area Three, with lower harvesting frequency and green tree retention.

3.2. Landscape Patterns

Landscape patterns likely to be produced by the Landscape Plan have already been projected into the future, evaluated, and compared with those predicted to result from the Northwest Forest Plan (BRLMMS 1997: pp. 27-29; Cissel et al. in press). The Landscape Plan should increase patch size, reduce forest fragmentation, and decrease edge density relative to the present landscape. While quantitative information on pre-logging, wildfire-driven landscape patterns in the Oregon Cascades is lacking, it is obvious that timber harvesting on National Forest lands in the region has generally decreased patch size, increased forest fragmentation, and increased edge density. Over the coming decades, the Landscape Plan should bring the Blue River watershed further within the range of variability of landscape patterns produced by the natural fire regime.

One major difference between future landscapes produced by the Landscape Plan and those produced in the past by the natural fire regime is the tremendous amount of variability present under the natural fire regime, only a small part of which is expected to be mirrored by the silvicultural manipulations of the Landscape Plan. For example, it is likely that the Blue River watershed was mostly occupied by younger forests in the late 1500s and early 1600s, but was predominately occupied by mature/old forests in the late 1700s and early 1800s (Weisberg 1998). Such radical, widespread shifts in forest age class pattern are not permissible under the current sociopolitical environment influencing forest management, nor will they occur (barring unintended fire) under the Landscape Plan. It can be argued that the Landscape Plan seeks to emulate landscape patterns under a natural fire regime, but at a finer scale, with smaller patches and less variability.

3.3. Role of Aquatic Reserves

Aquatic reserves, occupying nearly 10% of the Blue River watershed (BRLMMS 1997: Table 3), were established to ensure protection of aquatic habitats and processes. In a region where late-successional habitats have been greatly depleted by timber harvesting over a short time period, such reserves may be important as refugia for late-successional species. At first glance, such reserves seem at odds with the underlying philosophy behind the Landscape Plan: that native habitats, species and processes will best be sustained by a disturbance regime approximating the historical disturbance regime to which these species have adapted (BRLMMS 1997: p. 5). What is the rationale behind protecting such a large portion of the area from all disturbances, when disturbances are considered necessary to produce the variability of habitat and resources upon which all aspects of the natural system depend? However, a closer analysis suggests that, given the other prescriptions within the Landscape Plan, such reserves are indeed appropriate, even from the narrow perspective of how well they emulate the natural fire regime.

Under the natural fire regime, certain stands were free of severe disturbance for 400 - 500 years. It is likely that these "fire refugia" areas were important for maintaining metapopulations of late-seral species within the planning area. Such species may have retreated to these areas following periods of widespread, high-severity disturbance, persisted there in reduced numbers for centuries, and then dispersed outwards to colonize other areas as key features of late-successional habitat reappeared in the surrounding forest over time. The Landscape Plan uses the average fire frequency, over all sampled stands, to guide harvest rotation. As a result, all stands (within the three landscape areas) are harvested under the Landscape Plan within 260 years. It is therefore important to maintain some stands free from disturbance for longer time periods of at least 400 - 800 years, through the mechanism of aquatic and special area reserves.

Without aquatic and special area reserves, rotation ages of Landscape Areas One and Two would need to be increased by 20 or more years in order to approximate the past (i.e., 1475 - 1996) fire frequency (Section 2.1). With such reserves, the planned harvest rotation of the Blue River watershed as a whole exceeds the historical fire rotation by about 25 - 30 %.

4. RECOMMENDATIONS FOR FURTHER FIRE HISTORY RESEARCH

I have four recommendations for further fire history research for the Blue River area, listed in order of importance to the Blue River Landscape Project:

A. Fire severity patterns of past wildfires are poorly known, and are difficult to reconstruct from the dendrochronological record. Unfortunately, knowledge of past fire severity patterns is very important as a guide for green tree retention. Fire severity needs to be studied further on several levels, using evidence from both field and remote sensing studies of relatively recent fires. Field studies might examine spatial patterns of residual trees (i.e., ones that survived the last fire) along riparian-upslope gradients, or on different slope aspects. Remote sensing and aerial photo-interpretation of recent and future wildfires would be useful to assess fire severity patterns over larger spatial scales, such as that of landscape areas.

B. The Blue River Landscape Plan relies heavily on information from fire history studies that employed non-cross-dated tree-ring counts in the field, even though errors inherent in such studies may be significant (see Weisberg 1998: Chapter 3 for an analysis of the error associated with not cross-dating). In fact, nearly all of the tree-ring-based fire history information available for the westside Cascades comes from such studies. More cross-dated studies are needed, to test the veracity of important results from the non-cross-dated studies, and to develop more precise fire chronologies for locations carefully selected to represent different positions along the complex environmental gradient.

C. Little is known about how past disturbances, including fire, interacted with successional processes over time to create the mosaic of forest structures observed prior to widespread logging. A major premise of the Blue River Landscape Plan is that emulation of past disturbances will produce forest stuctures and landscape patterns that resemble those produced by the natural disturbance regime of the past several hundred years. While this premise seems intuitive, it has not been tested. For example, the same disturbance regime under a different climate might well produce different landscape patterns. Also, a highly variable, stochastic disturbance regime may be capable of generating an extremely broad range of landscape patterns. It would be interesting to use simulation modeling of the landscape-level interactions between fire, climate, and vegetation to explore some of these questions.

D. No paleoecological fire history studies are readily available for the immediate area of the Blue River watershed. It would be interesting to use information from such studies to compare with the tree-ring-based record, and to determine the temporal extent (and associated climatic conditions) over which the "natural fire regime" reconstructed using tree-ring evidence is representative.

5. RECOMMENDATIONS FOR FUTURE MONITORING

Monitoring of how well the Landscape Plan emulates the Blue River watershed natural fire regime (1475 - 1996) might focus on how well the Plan results in forest stand structures and landscape vegetation patterns that resemble those present in unharvested forests, formed under the natural disturbance regime. This need for forests that will remain unharvested under the Plan provides another motivation for maintaining some of the watershed in reserves (Section 3.3). The aquatic reserves, special area reserves, and the H.J. Andrews Experimental Forest are all available for this purpose, although their resemblance to ecosystems dominated solely by the natural disturbance regime will decline with time, as fire suppression continues to be a focal management activity. Such comparisons should be made over both stand and landscape scales. Stand structure, including variables describing horizontal and vertical structure, diameter distributions, densities of large trees and snags, large woody debris, wood biomass, and tree species composition, might be compared between managed stands and "reference" stands in similar environments, and of similar developmental stage. Spatial pattern analyses might be employed to determine if the spatial patterns of individual trees in managed areas are outside the range of variability found for such patterns in reserve areas. Also, spatial analyses of the mosaic of Blue River Landscape Plan stand structures, as they emerge over time under active management, might be compared to similar analyses of hypothetical landscape mosaics that were simulated to have emerged from natural disturbance regimes (Section 4, part C).

Other forest structure variables should be monitored that might then be compared between landscape areas and topographic settings of the harvested forest within the Blue River watershed, to ascertain whether differences present in pre-logged forest structure are maintained following management under the Landscape Plan. For example, fewer Douglas-fir cohorts and a greater relative dominance of shade-tolerant tree species should be present at higher elevations (i.e., Landscape Area Three) and more mesic aspects (Weisberg 1998).

This discussion has focused on variables involving overstory tree species because many other important variables have already been targeted for monitoring under the Blue River Landscape Plan, including northern spotted owls, stream discharge, social acceptability, stream-dependent amphibians, fish populations, stream temperature, wood input, erosion, forest regeneration, and nonvascular plants (BRLMMS: pp. 66-72). Soil biogeochemistry is conspicuously absent from the list of things to be monitored, although the effects of different plant species composition and levels of large woody debris on soil carbon and nutrient cycling are being studied in nearby forests as part of the Long-Term Ecosystem Productivity (LTEP) project. Since the Landscape Plan is more likely to be successful at emulating the mortality effects of fire on overstory tree species than it is at emulating the process effects of wildfire on nutrient dynamics, it seems important that biogeochemical cycling be monitored and compared to that of relatively unmanaged forest ecosystems.

6. POTENTIAL MODIFICATIONS TO THE LANDSCAPE PLAN

The section presents an evaluation of two potential modifications that are not currently part of the BRLMMS.

6.1. Specific Rules for Distribution of Retention Trees Within a Harvest Unit

It has been suggested that the prescriptions for distribution of retention trees within a harvest unit be made more specific, so as to more precisely emulate past natural fire patterns (John Cissel, USFS Blue River R.D., pers. comm.). We know little about the magnitude of within-stand, or within-burn, influences of topography on fire severity. The results of Weisberg (1998) suggest a weakly significant effect of hillslope position such that fires burned with lower severity in lower slope positions (Section 2.3, Guideline 2). Slope position explained but a small proportion of the variance in low-severity fire occurrence; a regression model including the effects of both elevation and slope position explained only 14% of the variance (Weisberg 1998: Table 4.8). Influences of slope aspect were weaker and more variable. The Blue River fire history study (Weisberg 1998) finds lower severity on north slopes, while a fire history study in the nearby Bear-Marten watershed (Weisberg 1997) reports greater fire severity on north slopes. In the Wenatchee Mts. of north-central Washington, late-successional fire refugia were most likely to occur on northerly aspects, particularly in stream confluences, valley bottoms, on benches, or in the middle to upper headwall (Camp et al. 1997). In subalpine forests of the Canadian Rocky Mts., trees and patches of trees that were skipped by fire were slightly more likely to have occurred on cooler slopes, islands of trees that had experienced underburning were more likely to have occurred on warmer slopes, and small clumps of unburned trees were about equally likely on both types of slopes (Stuart-Smith and Hendry 1997).

The guidelines for spatial pattern of retention trees (BRLMMS 1997: pp. 13-14) already include provisions for leaving more trees near streams and lower slope positions. Influences of slope aspect on fire severity appear to be weak and variable. In the central western Cascades, steeper slopes were observed to have burned with greater severity (Weisberg 1997, 1998), likely due to more intense burning from preheating of upslope fuels, convective winds, and greater exposure to solar radiation for drier aspects (Swanson 1981). But while leaving fewer retention trees on steeper slopes may serve to better emulate past fire patterns, this practice might lead to increased risk of landslides, earthflows, and stream sedimentation following harvesting. Therefore, I recommend that more specific prescriptions for the distribution of retention trees within harvest units be limited to relationships with hillslope position. In particular, a greater number of retention trees might be left on flat, broad riparian terraces. Where valleys are deeply incised, retention trees might be distributed along more of a gradient from stream to ridgetop. Broad, flat ridgetops, where they exist in the study area, might also have a relatively high proportion of retention trees.

6.2. Complex Prescriptions for Rotation/Retention

Although fire frequencies given in Tables 1 - 3 represent mean fire intervals, fires seldom burned at such intervals. It was more typical for fires in the Blue River Watershed to have burned over either short or long intervals, such that multiple fires occurred within 50 or 60 years of each other, followed by a long fire-free period of 200 to 400 years. Such long fire-free intervals may have been very important for species associated with late-seral stages, and for allowing fire-susceptible, shade-tolerant species like western hemlock, western redcedar, and Pacific silver fir to become widely established. Also, low-severity and partial stand-replacing fires occurred more frequently than stand-replacing fires, suggesting that different harvest rotation ages would be appropriate for harvests of different intensities, within a landscape area. The Blue River Plan might better emulate past fire patterns by incorporating complex prescriptions for rotation and retention, where high-severity (i.e., low-retention) harvests were planned over longer intervals, while low-severity harvests occurred more frequently. For example, a Landscape Area Three stand might be harvested with 15% retention at year 1, with 40% retention at year 100, with 40% retention at year 400, with 15% retention at year 600, with 40% retention at year 700, with 40% retention at year 1000, with 15% retention at year 1200, and so on. Certainly these ideas need a great deal of thought and development, and must be linked to silvicultural objectives for stand growth and development, before they can be applied.

7. SUMMARY OF RECOMMENDED CHANGES

Recommended changes to the Blue River Landscape Plan are listed below:

A. Sufficient area is maintained in reserves to offset the slightly higher disturbance frequencies in the Plan for Landscape Areas One and Two (Section 2.1). Planned disturbance frequency for the Blue River Watershed as a whole (including reserves) will be nearly 30% less than the historic fire frequency, with a disturbance rotation of about 55 years more. There are at least three reasonable options: (1) No Change, if the 55 year difference in overall disturbance rotation is considered a reasonable buffer against unplanned disturbances; (2) a slight reduction in the area of reserves, to increase overall disturbance frequency; or, (3) a transfer of some areas from Landscape Area Two to Landscape Area One (Recommendation F; Fig. 2). For example, decreasing the overall disturbance rotation to 229 years, or 20% greater than the historic fire frequency of 191 years, could be accomplished by transferring 535 and 1316 acres of reserves to Areas One and Two, respectively. The same change could be accomplished by transferring about 2500 acres from Area Two to Area One.

I recommend leaving harvest rotations and reserve boundaries as they are, but following Recommendation F. After several more decades of management, the frequency of unplanned disturbances may be better known, and the overall disturbance rotation might then be re-evaluated.

B. It may not be necessary to develop more specific prescriptions for the distribution of retention trees within harvest units. If such prescriptions are developed, I recommend that specific guidelines be limited to relationships with hillslope position as described in Section 6.1.

C. Specific guidelines should lead to more reforestation of shade-tolerant trees (e.g., western hemlock, western redcedar) on lower slopes and north aspects within a harvested landscape block (Section 3.1).

D. I recommend that low-severity fires occur at least once every 200 years in Landscape Area One (Section 2.7).

E. Prescriptions for tree species composition mixtures for retention and reforestation should be modified so that a greater density of large, shade-tolerant trees are typically present in Landscape Area Three, and fewer in Landscape Area One (Section 2.8).

F. I recommend extending Landscape Area One up Blue River into the lower portions of the east Cook Creek and Quentin Creek watersheds, as illustrated in Figure 2.

8. OVERALL EVALUATION

No combination of silvicultural activities can come very close to emulating all of the effects of wildfire, or of any other natural disturbance process. Any forest management plan in the westside Pacific Northwest that uses the historic range of variability as a guide can only include a subset of that range (Swanson et al. 1993), since some wildfires in the past created larger areas of widespread tree mortality than society would now tolerate (Teensma 1987, Morrison and Swanson 1990, Weisberg 1998). Further, the timing of fires under the natural fire regime varied greatly according to changes in climate. During hot, dry periods, multiple large fires occurred in the same century; during cool, wet periods, long periods of time passed with very little fire (Weisberg 1998). In the Landscape Plan, disturbance intervals will be much more regular, will be largely deterministic, and will likely not track changing climate.

Despite these limitations, the Blue River Landscape Plan should produce anthropogenic disturbance regimes that more closely resemble natural disturbance regimes than have previous timber harvesting systems in the region. Further, it represents an attempt to fit management activities to the landscape by using the spatial heterogeneity of past fire patterns as a template for future silvicultural disturbances. In general, the Landscape Plan does a good job of representing past fire regimes with regard to disturbance frequency, spatial heterogeneity of disturbance regimes (i..e., geographic zoning of landscape areas), and spatial pattern of retention trees. The Landscape Plan may not do as well with regard to disturbance severity, although this is not critical nor certain because our knowledge of historical fire severity is nebulous. The Landscape Plan also seems to misrepresent the spatial pattern of retention and reforestation of shade-tolerant tree species.

It is important to stress the limitations of the fire history data upon which this analysis is based. The Weisberg (1998) fire history study was not cross-dated, and it therefore was likely to have dated fires more recently than they actually occurred, and to have misrepresented fire frequency slightly at some of the sites (Weisberg 1998: Chapter 3). There are limitations inherent in any fire regime characterization based on tree-ring reconstructions of fire history (Weisberg 1998: Chapter 2). Studies such as that described in Weisberg (1998) provide an imperfect glimpse into the past, and it behooves forest managers to use such information more as general indicators of variability and spatiotemporal trends under natural fire regimes, than as precise quantitative descriptions to be strictly adhered to as targets for forest management. Further research may be necessary to better understand how forest ecosystems within the watershed functioned under natural disturbance regimes in the past, and how closely ecosystem processes in the near future, as the Landscape Plan unfolds, approximate those of the past.

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