Strategy for Historical Forest Restoration using Uneven-aged Silviculture and Prescribed Fire at the Landscape Scale

Kings River Project
Sierra National Forest
High Sierra Ranger District

By
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CONTENTS

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INTRODUCTION

This landscape treatment plan is the result of an effort to identify silvicultural and research treatments (plantation maintenance, uneven-aged group selection, underburning, research plot treatments, and controls) that implement an uneven-aged strategy at the landscape level for the Kings River Project (KRP), Sierra National Forest (formerly Kings River Administrative Study) to restore historical forest conditions. The treatment plan supplements information found in the Kings River Landscape Analysis (KRASLA), 1995. The treatment plan disaggregates landscape level objectives that provide direction for stand level treatments for the 132,000 acre KRP landscape. The landscape incorporates three (3), sixth field hydrologic units (Dinkey Creek, two watersheds and Big Creek, one watershed). Elevations within KRP range from 800 feet to 9,800 feet. Vegetation types include all vegetation types along an elevation gradient from blue oak woodland to sub-alpine.

The landscape objectives include: uneven-aged with regeneration in groups and reintroduction of fire to mimic historic forest structures and landscape patterns, securing regeneration of shade intolerant plant species, providing opportunities for Pacific Southwest Experimental Station (PSW) research, and answering administrative questions (Inter-Agency Memorandum of Understanding 2002). The wildland urban interface (WUI), Defensible Fuel Profile Zones (DFPZ) and wildlife habitat needs are other landscape features that provide stand level objectives. Stands are the smallest units that contain homogenous vegetation types, slope, objectives, and access. Together the stand level objectives, ecological processes, and existing condition provide a pathway for management. Stands travel along these pathways to reach the historic forest condition (desired condition). The historic condition resulting from these pathways would be varied in structure, space, and through time. Dense stands and open stands would be found across the landscape. Time would result in shifting structures as a result of low intensity disturbance.

The inter-agency memorandum of understanding (MOU) signed by both the Pacific Southwest Research Station Director and the Pacific Southwest Regional Forester directs the High Sierra Ranger District to implement uneven-aged group selection with matrix uneven-aged silviculture individual tree selection across the Kings River Project and provide an opportunity for research to study the effects (USDA 2002). The Kings River Project has been implementing the uneven-aged strategy for the past 10 years. The uneven-aged stand level objectives of diameter distribution (Dq), maximum tree size, and the range (90 to 50 percent of normal basal area or 60 to 25 percent of maximum SDI) in tree removal intensity for the matrix (portions of stands not in reforestation groups) have been identified generally for stands (Smith and Exline 2003, KRASLA 1995). These stand level considerations describe the forest structure within a stand. However, the intensity of matrix tree removal or the variability in stand structure (canopy layering, canopy density) between stands requires a landscape perspective. This paper examines the variability of stand level objectives between stands and across the landscape.

The District Wildlife Biologist, District Fuels Management Officer, and District Silviculturist (landscape group) were charged with developing a landscape treatment map. The landscape treatment map is the continuation of a literature review recently completed on the ecological processes and historic stand structures that were represented by pre settlement forests of 1850 (see adjacent text boxes) and the KRASLA. The landscape group reviewed District files, historic photos (1870 to 1920), and descriptions of the Sierra National Forest and the Kings River Project Area by 19th century observers. In addition, the landscape group reviewed the scientific literature concerning the processes that resulted in the historic stand structure and variable landscape pattern. This examination of the historic condition on the Kings River Project in particular and the Sierra National Forest and Sierra Nevada Range in general resulted in six basic conclusions described in the adjacent text boxes. It was this examination of the historic 1850 forest that would drive the initial unconstrained view of how treatments would play out across the landscape.

Treatments and land allocations to achieve the historic forest condition were developed in two steps. The first step was to identify treatments that would achieve the historic forest condition with few or no constraints. This unconstrained landscape was assigned treatments based on assumptions that resulted in few forest land allocations or zones. This landscape is similar to alternatives described in the Sierra Nevada Ecosystem Project (1996) and the California Spotted Owl Technical Report (1992). The second step was to begin adding constraints based on meeting the needs of research studies or species protection.

HISTORICAL FOREST CONDITION

1) The historic forests of the Kings River Project were dominated by large trees.

Descriptions of the Sierra Nevada by observers in the late 1800's and early 1900's (Lieberg 1902, Sudworth 1900a, Sudworth 1900b, Flintham 1904, Show and Kotok 1924) indicate that the forest was dominated by trees greater than 24" in diameter at breast height. In addition, trees greater than 50 inches occurred commonly. While large trees dominated, trees less than 10 inches diameter at breast height were found infrequently (Taylor 2003, Bouldin 1999, McKelvey 1992). Examination of data collected by Sudworth in 1899 and Dunning in 1904 indicate that trees less than 11 inches occurred at a low frequency. Sudworth's data collected in 1899 within the Sierra National Forest indicate mean diameters in excess of 39" (Stephenson 1999).

Examinations of the VTM data collected in 1935 (Bouldin 1999) indicate that while large trees dominated, there was also great variability in tree size. This is consistent with other studies of presettelment forests that found a range in age and tree size (Bonickson and Stone 1982). This variability occurred within forest types and between forest types (Bouldin 1999, Taylor 2003, North et al 2004).

Reconstructions of historic forests in the Sierra Nevada support that trees greater than 24 inches at breast height dominated Sierra Nevada forests (Taylor 2003, North et al 2006). Reconstructions of ponderosa pine forests in the intermountain west (Arno 1995) support that large trees dominated forests. Recent reconstruction of forests in the Lake Tahoe Basin and the Teakettle Experimental Forest (adjacent to the KRP) also support the conclusion that forests were dominated by large trees and less than 100 trees per acre smaller than 15 inches were present. This literature is supported

ADAPTIVE MANAGEMENT

The memorandum of understanding between the Station Director and the Regional Forester directs that the KRP should incorporate the principles of adaptive management. Lessons learned from the first series of projects and research studies were presented at a symposium (USDA 2002). As a result of this symposium and subsequent meetings between Sierra National Forest staff and PSW researchers, several adaptations to the Kings River Project have been made. The adaptations to the project and research portions of the project include changes to the uneven-aged strategy, enlargement of the KRP boundary, and a landscape approach to treatment variability.

Adaptations to the uneven-aged strategy include maintaining -one-third of the growing space in large trees, maintaining larger trees within reforestation groups when present, and a reduction in the reforestation group size. Maintenance of large trees has been an important component of the KRP. While the uneven-aged strategy was developed as a a means of meeting wildlife habitat needs and reducing the risk of catastrophic fire, a new approach to large tree retention maintains one-third of the growing space in large trees. This is similar to strategies developed for the Southwest (Covington 1997) and the Sierra Nevada (Hollenstien 2001). Another adaptation for large tree retention was maintaining legacy trees in reforestation groups. Reforestation groups would keep all trees larger than 35 inches diameter at breast height (dbh) and where trees larger than 35 inches are not present, four trees larger than 24 inches inches. The maximum regeneration group size would be reduced from 5 acres to 3 acres. The maximum size was reduced because actual implementation resulted in a small percent of groups created in this size range and because the smaller size is more consistent with descriptions of the historic forest. A detailed description of the uneven-aged strategy including the rationale for the large tree retention approach can be found in Appendix C2.

As researchers began to plan the next series of designed research studies within the KRP, it became apparent that the boundaries would not provide sufficient space for replication of study treatments and controls. In addition, the smaller KRP boundary did not include entire sixth field watershed boundaries. The entire watersheds for Dinkey Creek and Big Creek would provide both the necessary space for research and a landscape large enough to include the full range of variability for a landscape perspective. A large landscape allows for the analysis of impacts on habitat connectivity, watershed impacts, and species variability (Franklin and Forman 1987). This resulted in an increase of the KRP from approximately 64,000 acres to 132,000 acres.

Prior applications of the uneven-aged prescriptions in the KRP allowed the desired residual basal area to drive the resulting canopy cover; that is a residual basal area was prescribed and the resulting crown canopy cover was measured. This post-treatment measurement of crown canopy determined that while treatment basal area targets were met, the resulting crown canopy was greatly affected by the method of measurement or determination. A resulting study determined that the “moosehorn” and photo-interpretation provided the most consistent measure of canopy cover. An adaptation was made to allow the canopy cover to drive the residual stand structure.

Maintaining stand structures that provide suitable habitat for the California spotted owl is an important desired condition for the KRP. An examination of stand structure following the implementation of the first two KRP tasks revealed that the prescriptions were not maintaining sufficient layering to meet California spotted owl needs (Verner pers conf). While the expectation is that layering will develop in these treated stands in time, an adaptation was made to encourage and maintain two or more vegetation layers in stands outside of the WUI

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UNCONSTRAINED TREATMENTS

by a review of the VTM data set that found 60 trees per acre smaller than 11inches in mixed conifer, 35 trees per acre were smaller than11 inches in Jeffrey pine and 54 trees per acre smaller than 11 inches in red fir dominated stands. A similar review of historical data on the San Bernardino National Forest 1935 (Minnich 1995) also supports that large trees dominated. Figure H5 compares the numbers of trees larger than 11" dbh for several data sets. Most of the data sets have fewer than 35 trees per acre. This is especially true for ponderosa pine in the relic ponderosa pine stands in the 1910 historical data set (Hasel 1931) and Oliver (2001)

An examination of the Sierra San Pedro Martir Forest in Baja California indicates that forests disturbed by frequent fire perpetuate stands dominated by large trees (Minnich 2000).

Finally, an examination of photos taken of undisturbed forests indicates that forests in the Sierra National Forest were dominated by trees > 20 inches at breast height. Photos show very few pole size or smaller trees. Photos taken in the early 1900s do indicate a dramatic increase in conifer regeneration following the removal of fire. This flush of in-growth is observed in other areas across the Sierras (Taylor 2003, Kilgore and Taylor 1979, Vankat and Major 1978, Gruell 2001) and in the Teakettle Experimental Forest (North et al 2004, North et al 2006).

Assumptions

The initial unconstrained assignment of treatments was based on the desire to implement treatments that were representative of the historic forest processes, create historic forest structure, and recognize modern realities. These modern realities included the need to protect homes from fire, the need to consume biomass growth, and the need to protect wilderness values. The need to protect homes from fire is part of the Cohesive Strategy and National Fire Plan. The process of growth (accumulation of biomass on existing trees), mortality, and regeneration are part of the dynamic nature of forests. This biomass will eventually find its way to the forest floor and become fuel. The processes to consume this biomass include decay, combustion (fire), and removal. While the process of decay occurs constantly, the present accumulation of forest fuels would indicate that this process alone would not meet objectives of the National Fire Plan or the desired condition for the KRP. The landscape group worked under the assumption that fire would re--enter the landscape and that growth must be consumed at a rate that limits the accumulation of fuel. In addition, the landscape group made the assumption that the KRP would be constrained by laws that mandated protection of wilderness, giant sequoia, and endangered species. As a result, no mechanical treatments would be proposed in the wilderness or move species closer to extinction. The landscape group assumed that the public would expect that treatments would need to reduce the threat of catastrophic crown fire to structures.

2) The historic yellow pine and mixed-conifer forests of the Kings River Project had relatively low tree densities.

Of the many descriptions of the historic 1850 mixed conifer stands of the Sierra Nevada the clearest and most succinct is by Duncun Dunning, silviculturist for California from 1910 to 1940:

> *"The situation confronting the forester was a very difficult one. As a result of early fires, insect attacks and grazing the forest were usually understocked with a preponderance of mature and decadent timber, a deficiency of intermediate classes from which to select thrifty reserves, younger trees poorly distributed or stagnating in groups and reproduction frequently absent or composed of undesirable species"(Dunning 1923).*

Other early observers noted the openness of the pine and mixed-conifer stands. Sudworth's field notes collected in 1898-1900 indicate the open nature of the pine and mixed conifer forests, noting several times that trees per acre ranged from 30 to 50 trees (Sudworth 1900a). This would agree with his representative ¼ acre plots in the Kings River drainage that range for 16 to 36 trees per acre. Flintham was charged with surveying the Sierra Reserve for the potential of regeneration of conifers in 1904. Flintham (1904) noted the open character of pine dominated stands:

> *"In this belt the forest presents a rather open stand in which the yellow pine occurs pure or predominant. The timber is often of large dimensions and very merchantable, but it stands rather* scattered, *reducing the*

The final assumption made was that sufficient value existed within stands or sufficient appropriated dollars would be available to accomplish the treatments.

The landscape treatments would also seek to meet criteria defined by the Kings River Project MOU. These criteria include:

- Implementation of a uneven-aged group selection management scheme
- Treatments should mimic historic forest processes, structures, and patterns
- Treatment intensity and schedules should provide habitat for all species
- Reintroduction of fire should be part of treatments
- Treatments should secure regeneration of shade intolerant species
- Smoke and wood fiber would be by-products of treatments
- Treatments should provide opportunities for PSW studies
- Treatments should seek to answer administrative questions

The uneven-aged strategy as defined by reforestation areas (groups) and inverse J-shaped curve (residual basal area, maximum tree diameter, and Delquuart's Q) would be applied to all conifer stands between the oak woodland and the sub-alpine vegetation zones (see Appendix C2). Regeneration of intolerant species would occur in reforestation groups. The landscape group assumed that mimicking processes and structures consistent with the historic forest would result in sufficient habitat for all species. Fire would be reintroduced consistent with the Districts work capacity.

Landscape features such as slope, roads, and site quality would limit prescribed fire treatments and mechanical equipment. These physical features limit the practicality of reintroducing fire on the landscape or achieving historic stand structures. While historically fire entered every stand in the landscape, it may not be possible to burn every stand because of lack of control lines and nearness of homes. Treatments would also be limited by the capabilities of harvest equipment. While it may be desirable to use cut-to-length systems or mechanical masticators, they are limited by slope and rock.

Armed with the basic landscape-wide assumptions and KRP criteria, the landscape group identified tasks to complete the landscape treatment plan:

- Identify stand boundaries to disaggregate landscape level objectives to individual stands.
- Identify treatment intensities to mimic landscape patterns.
- Identify a strategy to protect homes from catastrophic fire.
- Identify stand treatments to create uneven-aged structures and develop a treatment schedule.

Stand and landscape level outputs (smoke and fiber), as well as costs, would be analyzed following the description of the landscape treatments plans in a separate analysis. Reforestation groups would be identified at the time of implementation.

> *acreage cut."*
>
> Flintham noted the increase in density with more fir and sugar pine:
>
> "*This belt, marked by greater density, and by the presence of a heavier stand of merchantable pine timber, is the type in which the best timber in the Sierras is lumbered.*"
>
> Flintham also noted the increased density of fir dominated forest:
>
> "*The dense fir forests present the typical virgin condition, in which all ages and stages of development may be noted as younger growth pushes up to take a place in the forestcrown. (sic) The stand of red fir is generally very dense, ….*"
>
> Show and Kotok (1924) noted the open character of pine and mixed-confer stands as it related to frequent fire:
>
> *"The virgin forest is uneven-aged, or at best even-aged by small groups, and is patchy and broken; hence it is fairly immune from extensive devastating crown fire."*
>
> *"Local crown fires may extend over a few hundred acres, but stands in general are so uneven-aged and broken and have such a varied cover type that a*

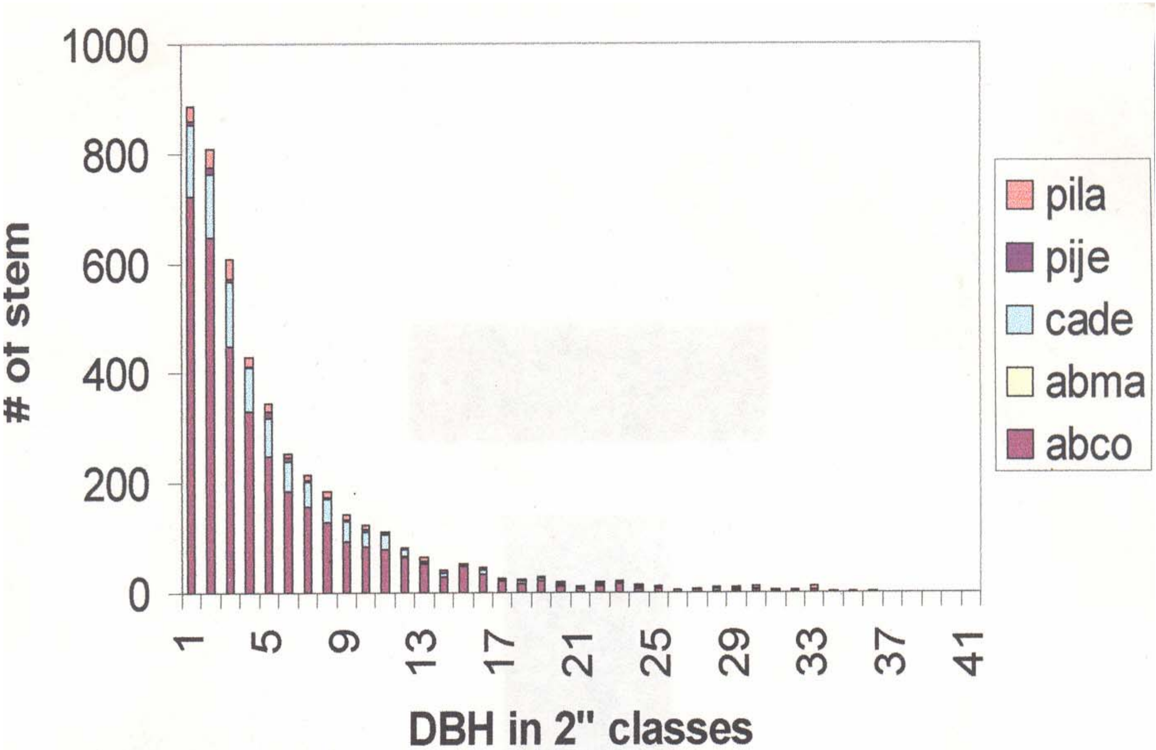
Uneven-Aged Prescription

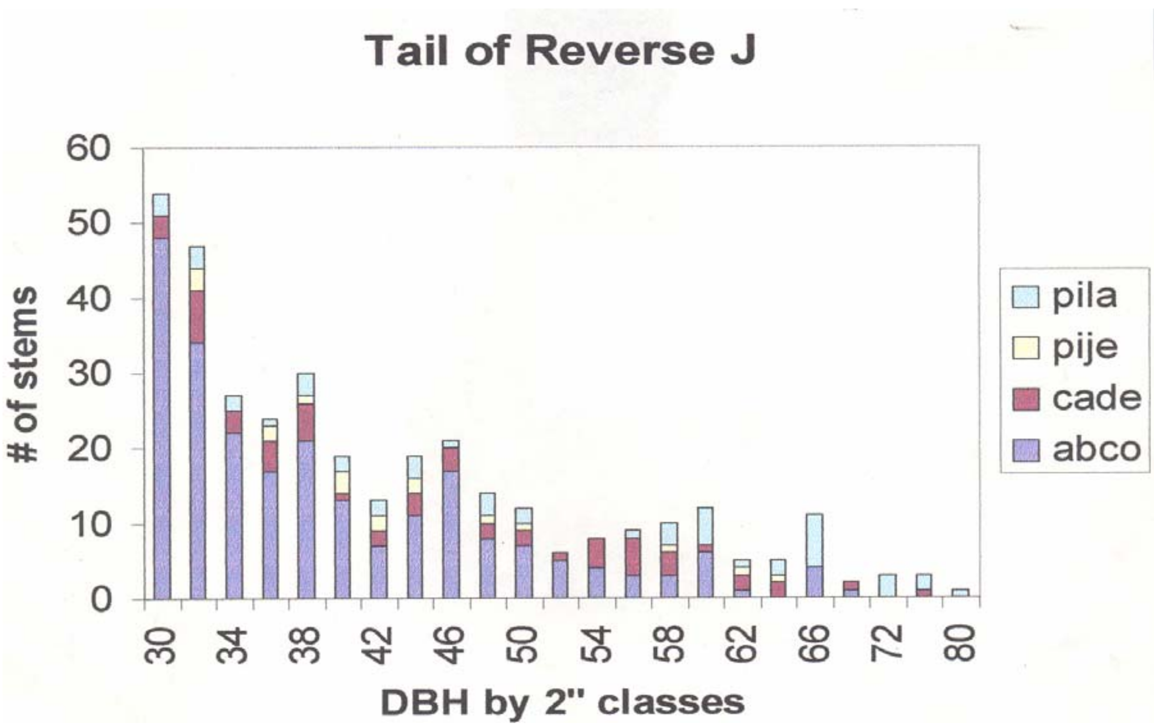
Uneven-aged silvicultural strategy is used in the KRP to move stands closer to the desired historic condition described in the Kings River Landscape Analysis and supplemented by this document. The uneven-aged strategy is applied at the stand level. There are existing groups of different sizes, ages, and vertical layering resulting from past disturbance. The inverse J-shape curve diameter distribution of trees would be created by tree removal to accentuate the existing distribution of groups of different ages, adding young reforestation groups and retaining groups of large trees (35 inches dbh and larger). As stands are thinned, the existing species distribution would be adjusted to one more closely reflecting the historic forest.

When the objective is to have a balanced or regulated uneven-aged stand, a histogram depicting the diameter distribution of trees in the stand (trees per acre vs. diameter class) approximates a smooth, inverse, J-shaped curve, described in some detail by Alexander and Edminster (1978). It has three key parameters. First is slope, which results from the diminution quotient (Dq—a value that, when divided into the number of trees in one size class, gives the number of trees expected in the next smaller size class). Second is the largest size tree that defines the right tail of the J-shaped curve. And third is the stocking level (basal area of trees per acre), represented by the area under the curve. The Dq value for the KRP is 1.2. The largest tree size varies by forest type and site quality. It is 49 inches for low site quality and 58 inches for high site quality. Residual stocking levels are determined for each stand based on landscape processes described in this document. A detailed description of the uneven-aged silvicultural strategy in the KRP is found in Appendix C2.

While the traditional J-shaped curve has been observed both in managed and unmanaged stands for centuries (O'Hara 1998), other distributions have been observed in unmanaged stands and have been suggested to represent the historic forest. The "reverse sigmoid" has been suggested to represent old growth stands. The graph of this distribution can be described as having one or more humps in the mid diameters that represent fewer trees in adjacent age classes. The distribution, however, represents a generally declining number of trees with increasing tree size. This distribution is mathematically more complex and is a variation of the traditional J-shaped curve. Stand distribution data from unmanaged mixed-conifer stands in the Teakettle Experimental Forest (North 2000), historical data sets from the Southern Sierra Nevada (Hasel 1931), relic ponderosa pine forests (Oliver 2002), and analogous forests in Baja California (Stephens and Gill 2005), and historical observations (Dunning 1923. Meyers 1934, Sudworth 1900) would tend to support both the use of the J-shaped curve and the uneven condition of the historic forests (North 2000, Bonnickson and Stone 1982). The distribution data for 20 acres of unmanaged forest shows a smooth J-curve for all diameter classes in the Teakettle Experimental Forest. A blowup of the larger and older trees on these 20 acres would indicate that the distribution is not as smooth, but still declining with increased diameter. Reconstructions of historical conditions in the Teakettle forest show a flat tree, distribution with roughly equal numbers of trees in each diameter class (North et al 2006).

The uneven-aged prescription is applied across a stand. Both the reforestation groups and the matrix (areas between groups) are part of the regulated stand. The groups insure conditions for growing seedlings and the matrix provides growing space for trees of all sizes. Treatments within the matrix are similar to thinning. Treatments in the groups are similar to plantation management. Matrix trees are provided growing spacing through removing trees across all diameters. Reforestation areas are less than 3 acres. Reforestation areas focus on finding under-stocked areas within a stand that have resulted from past harvest, fires, and insect-caused mortality.

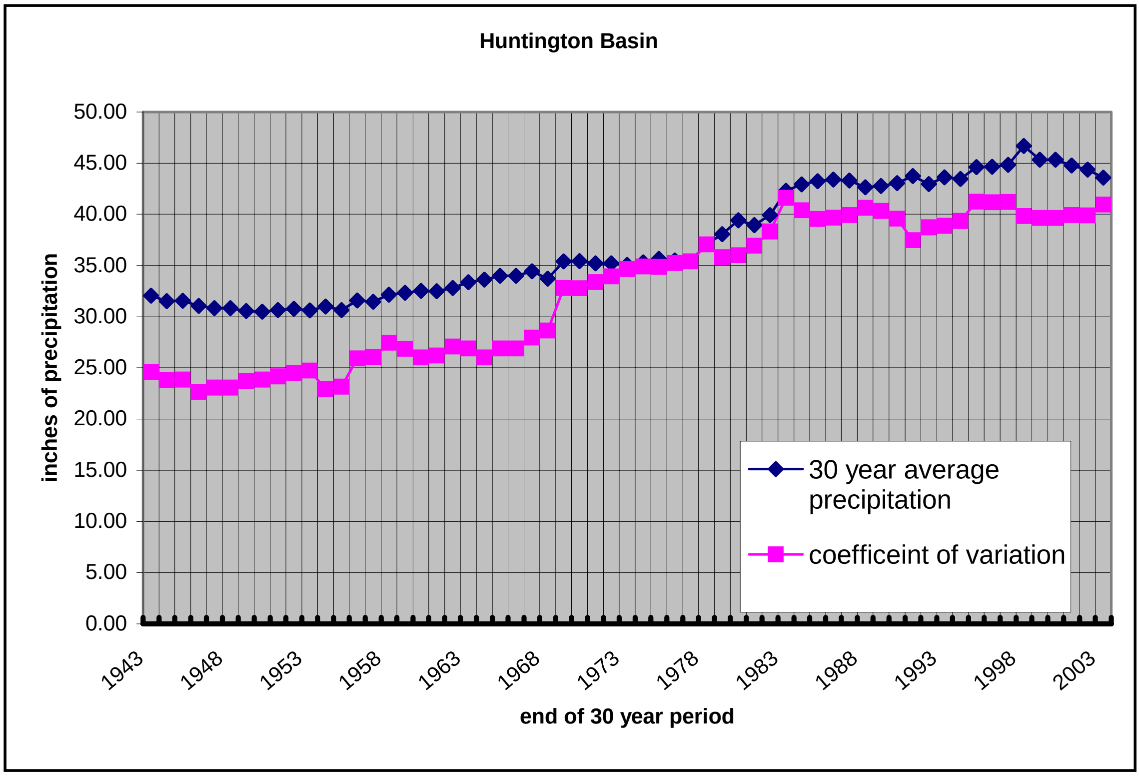




The figures above display the diameter distribution of 20 acres of unmanaged mixed conifer forest in the Teakettle Experimental Forest. The lower graph represents the tail of the reverse J in the upper graph.

Historic Forest Climate

Climate influences the processes of growth and disturbance in which the historic forest developed (Keeley and Stephenson 2000). While climate cannot be influenced by landscape level manipulation, it can and has changed over the last 4000 years. The climate affecting fire return intervals and plant growth for the 500 years prior to 1900 was dominated by the little ice age (Millar and Woolfenden 1999). Fire return intervals and the resulting forest structure were the result of a wet and warm period prior to 1550 (medieval warm period) followed by a dry and cold period (little ice age) from 1550 to



1900. The change in climate lead to shifts in vegetation zones and fire return intervals (Swetnam 1993, Miller and Urban 1999, Brunell and Anderson 2002). The species composition changed while the presence of plant species remained constant (Millar and Woolfenden 1999). The little ice age resulted in the historic forest that is the desired condition for the KRP. This past climate may not represent future climate changes. Current temperatures are rising within a short-term cycle (100 years) while temperatures are declining on a longer cycle (1,000 years) (Millar and Woolfenden 1999). It is unclear what the future will mean for climate change. Maintaining the current mosaic of forest structures may not insure ecosystem stability (Millar and Woolfenden 1999, Schoennagel and Veblen 2004). Maintaining functioning processes and a wide range of age and class structures may be the most realistic landscape approach in the face of uncertainty or changing climate.

continuous crown fire is practically impossible."

Sudworth collected six ¼ plots within the Sierra National Forest that can be considered mixed-conifer. In addition, Sudworth collected notes and photographs of the areas he visited. The plots are subjective plots collected with bias and likely expanded to the full acre narrowly represent only the sampled areas (Stephens and Fiske 1998, Bouldin 1999). Sudworth indicated that plots were representative of entire drainages or large areas (Sudworth 1900b). That is to say that the ¼ acre plots represented the average condition and were not statistical samples. Used as representative or subjective samples these plots reflect the descriptions and photos (Figure H1). The comparison in figure H5 with other data sets of the historical forest clearly show that at the full acre the plots were not representative of average conditions. The plots indicate a range in basal area in square feet from 152 to 358 at the ¼ acre. This range indicates open to moderately dense forest. These basal area ranges are consistent with his descriptions and photographs. Sudworth's photos of the Kings River Project are consistent with open to moderately dense mixed conifer forest and open and scattered pine type (see photos H5 and H6).

Another data set that depicts historic condition of the Sierra National forest is from a six acre plot collected by Dunning and Show in 1914 and re-measured by Hasel in 1930. Trees per acre across the six acres averaged 45. Basal area was determined using the mid point and the upper limit of each diameter class. The basal area of the plot calculated using the mid point of the stand table was 148 square feet per acre and 208 square feet per acre using the upper limit of each diameter class. This would indicate a rather open mixed-conifer forest. This data set can also be compared with other ponderosa pine and mixed conifer forest data and yields similar results as relic stands in the Beaver creek pinery.

Decade long temperature changes govern long term fire cycles and precipitation governs yearly fire occurrence (Swetnam 1993). Climate and fuels play different roles depending on forest type (Schoennagel and Veblen 2004). Short-term changes in precipitation may result in increased fire severity above historic levels for ponderosa pine and mixed-conifer types (Brunell and Anderson 2002). The 30-year average precipitation and coefficient of variation is in graph number for the last 90 years at Huntington Basin. The Huntington rain gage is located 9 miles from the KRP area at 7100 feet in elevation. It is the longest continuously measured rain gage in the southern Sierra Nevada (California Department of Water Resources). The figure indicates that annual rainfall has increased and become more variable over the last 45 years. This trend in increased precipitation over the last 50 years has been observed elsewhere. More biomass accumulating during the high precipitation cycle could result in greater risk to catastrophic insect attack or fire during the drought cycle. This precipitation pattern would indicate a short term (50 years) desired condition should be resilient enough to account for this trend. Growth should be directed at maintaining low tree densities at or near full site occupancy with a high proportion of large trees. Low stand densities (stand density index or basal area) reduce insect mortality (Oliver 1998) and large trees are more resistant to fire. This structure is consistent with the historic forest. The landscape group assumed that maintaining a range of forest structures and patterns would provide a forest that was resilient enough to withstand potential short term weather patterns that create conditions for catastrophic fire and long term changes in climate.

Historic Canopy Cover

Some PSW researchers and Sierra National Forest staff have indicated that the Kings River Landscape Analysis did not incorporate variability. Variability within stands and among stands was an important feature of the historic forest condition (see historic forest discussion). A spatial context for the landscape variability would provide a reference. The desired condition for the KRP landscape is one where the processes that shaped the historic mixed-conifer and

Figure H1: The rendering on the left displays data collect by Sudworth in 1899. The photo on the right is located generally were the data used for the rendering was taken. A man is at the base of the large sugar pine in the center of the photo. A large 75" sugar pine is part of the rendering on the left.

ponderosa pine forest types and the Sierra National Forest Land and Resource Management Plan (LRMP) objectives dictate pathways for each stand. Pathways are composed of ecological processes and treatments. Treatments direct ecological processes to meet the desired condition.

PLOT	*TREES PER ACRE*	*PERCENT SDI*	*QMD*	*BA*	**CANOPY COVER*	*CROWN BULK DENSITY*
10	36	*52*	*42.7*	*358*	*57*	*0.047*
20	25	*35*	*42.6*	*247*	*45*	*0.037*
22	34	*48*	*39.8*	*293*	*51*	*0.038*
23	27	*34*	*40.6*	*242*	*41*	*0.033*
26	16	*22*	*41.8*	*152*	*35*	*0.018*
27	21	*40*	*47.1*	*254*	*47*	*0.027*

Table H1: Sudworth notes of the Sierra Reserve. Canopy cover is from forest vegetation simulator assuming each tree had at least 20 to 30 feet of the tree clear of limbs. Live crown ratio is based on Sudworth's notes and photos.

These pathways lead to the desired condition for each stand and result in the variability of stand structures across the landscape and within each stand. The variability of the historic forest is expressed in changing forest structures through time and across the landscape. The ecological processes play themselves out in a dynamic forest. Stands move along pathways in response to processes and treatments within certain ranges of variability and from different starting points. These pathways do not all lead to the same structure. For example, stands within the ponderosa pine versus within the white fir Potential Natural Vegetation (PNV) will respond to disturbance (thinning, fire, insect attack, etc.) differently. Each change in PNV and site quality will determine the rate of change for the process of growth and fuel accumulation, while aspect and slope will help determine the fire behavior. Treatments such as planting and uneven-aged silvicultural system will shape forest structure and composition along with the ecological processes. Fire is viewed as both an ecological process and treatment that achieves historic structure. Treatments and processes need a landscape component to describe how the pathways for each stand would play out across the landscape. The landscape group adopted an approach to mimic the landscape pattern of the historic forest by describing the landscape variability for canopy cover.

Frequent low-intensity fire was a major disturbance process in the historic mixed-conifer and ponderosa pine forest (Show and Kotok 1924, Bonicksen and Stone 1981, North 2004, others). While frequent fire may have been a part of the true fir as well as the mix-conifer and pine forest types, the effect resulted in different patterns of regeneration and mortality for each forest type (Taylor 1993, North 2004). Fire return intervals within the KRP were lower than neighboring forests (Drum 1998) and may have varied by forest type (North 2004). The factors that influenced the disturbance pattern and the resulting forest structure are well documented in the literature: slope, aspect, site quality, vegetation type, landscape position (ridge or drainage bottom), and climate are often cited as important factors in the fire return interval (FRI) and the resulting forest structure (Skinner and Chang 1996, Skinner 1996, Agee 1996, others). The first four factors influencing the landscape are available for display and analysis in the Ranger District files. Slope and aspect polygons can be developed from Digital Elevation Models (DEMs). Vegetation types can be developed from order 3 Ecological Unit Inventory (EUI) maps and soil maps. These EUI maps display the PNV. In addition, EUI maps display the Forest Service Site Class (cubic foot volume growth potential) based on the soil type.

Wind and topography are important factors that contribute to the pattern of fire spread and intensity. The prevailing wind blows from the southwest in the KRP. Many slopes within the KRP, especially in the Big Creek drainage, have southwest aspects. These southwest aspects are often steep (greater than 45 percent). This alignment of aspect, slope, and wind pattern results in more intense fire (Rothemel 1983). District personnel have observed this higher fire intensity during both prescribed fire and wildfire for more than 60 years. This wind pattern across the landscape certainly influenced fire in the historic forest of 1850. Research (Caprio et al 2000) in Sequoia/Kings National Park indicates a significant difference in Fire Return Interfal (FRI) based on aspect and elevation. The Sequoia/Kings National Park study site is approximately 25 miles south of the KRP. The National Park also has experienced similar climate and contains similar vegetation types. Other studies of landscape level FRI have found similar patterns (Heyerdahl et al 2000, Skinner and Taylor 2003**).** It appears reasonable to assume that aspect would have affected FRI similarly in the KRP area. Skinner and Chang (1996) indicate that fire patterns and FRI affected stand structure. Skinner and Taylor (2003) found that FRI in the Klamath Mountains and stand structures were related. More

Location	Fire return interval (years)	Elevation (feet)	Author
Teakettle	11.5	7000	North et al
Dinkey	3 to 12 (8)	6000	Drum
Big Creek	2.6 to 20 (11.2)	4200	Taylor (preliminary)
Big Creek	2.2 to 3.8	3800	Philips (unpublished)

Fire return intervals at different locations in KRP. Note the variability in return intervals at different elevations.

frequent fires on southwest slopes would result in greater consumption of fuels and vegetation than on northeast slopes. The resulting stand structures on southwest slopes would have had less canopy cover and larger gap size than northeast slopes.

The landscape factors of slope, aspect, site quality, and PNV remain largely unchanged from the historic landscape in KRP area. As a result it is possible to create a map of polygons with these four factors as attribute labels that are representative of the historic forest. The resulting map is one that describes the landscape pattern relative to the process of growth (site quality), topography (slope, aspect), and vegetation (PNV). If, as the literature suggests, these factors influenced the disturbance agent of fire and resulting forest structure, then the "base" polygons created describe the landscape pattern. The polygons lack attributes that link these four landscape factors to forest structure parameters such as canopy cover, stand density, and tree size.

The California Wildlife Habitat Relationship (CWHR) model is used in the KRASLA landscape to describe stand structure. The CWHR is composed of a vegetation type, an attribute for tree size class (quadratic mean diameter), and an attribute for canopy cover class (as seen from aerial photos). The overwhelming body of literature indicates that the historic stand structures were uneven-aged (McKelvy 1992, Bouldin 1999, Dunning 1933, Show and Kotok 1924, Bonickson and Stone 1981, others). While it is tempting to assign a CWHR size and canopy cover class to each stand, it would fail to capture the dynamic and ephemeral nature of structure within any PNV type. Thus, it is difficult to assign a stand one historic canopy number. No matter what number is chosen it is certainly wrong for that stand depending on how ecological process have affected a stand and when it is measured. It is more appropriate to assign a stand a range in canopy cover than to give an exact number. In addition, an average diameter would also provide little additional information. Since stands tended to be uneven-aged, or at best multi-aged, a measure of central tendency is of little value. Large trees dominated the stands, but many sizes were present. Measures of central tendency in these uneven-aged structures offer a poor description of the stand. Stand density based on canopy cover by PNV should be the focus of describing the landscape pattern.

A map of polygons with the four factors as attribute labels that are representative of the historic forest was produced for conifer dominated PNV and adjacent types in the KRP landscape. A historic density range was assigned to each combination of factors (site quality, slope, and aspect). The assignments were made on the bases of literature, early 1900 descriptions of that forest type, and local judgment. This process was inherently subjective. A set of criteria was created in order to assign canopy cover classes to each combination of landscape factors. These criteria were based on descriptions of the KRP by Sudworth (1900a), and Flintham (1904), historical photos of the Sierra National Forest taken between 1880 to 1930, a review of the literature describing the historic forest structure and process, 1914 cruise data from the KRP area, 1926 cruise data from the KRP area, mixed-conifer data collected by Sudworth (1900a) on the Sierra Forest Reserve, and aerial photographs from 1940 and 1944. Using the criteria, a subjective assignment of canopy cover class was made to each combination of forest type (PNV), site quality, slope, and aspect. Landscape position was only taken into account after these initial assignments.

Historic Landscape Variability

While descriptions of the historic forest often describe it as open, the density of the forest varied by forest type and within forest types (Vankat and Major 1979). This is similar to what has been found in the intermountain west, southwest, and the Sierra Nevada (Schoennagel and Velden 2004, Covington and Moore 1994, Caprio and Swetnam 1995). A more complete description of the variable forest condition is found in the adjacent text panels.

While many researchers have found a positive correlation between slope position and fire return interval, Drum (1998) found no such relationship for sampled watersheds in the KRP and fire return interval. Drum proposed that this was due to fires starting low in the landscape and spreading uphill. The position of the fire start made it likely that fires would have spread across all slopes. Other researchers have found a relationship between aspect and fire return interval (Caprio and Swetnam 1995, Caprio and Graber 2000). North (2004) found a strong relationship between regeneration patterns and species relative to riparian areas and ridge tops. The difference in findings is likely due to the scale of each study. Drum and North gathered data from a small geographic area, while the examinations in the

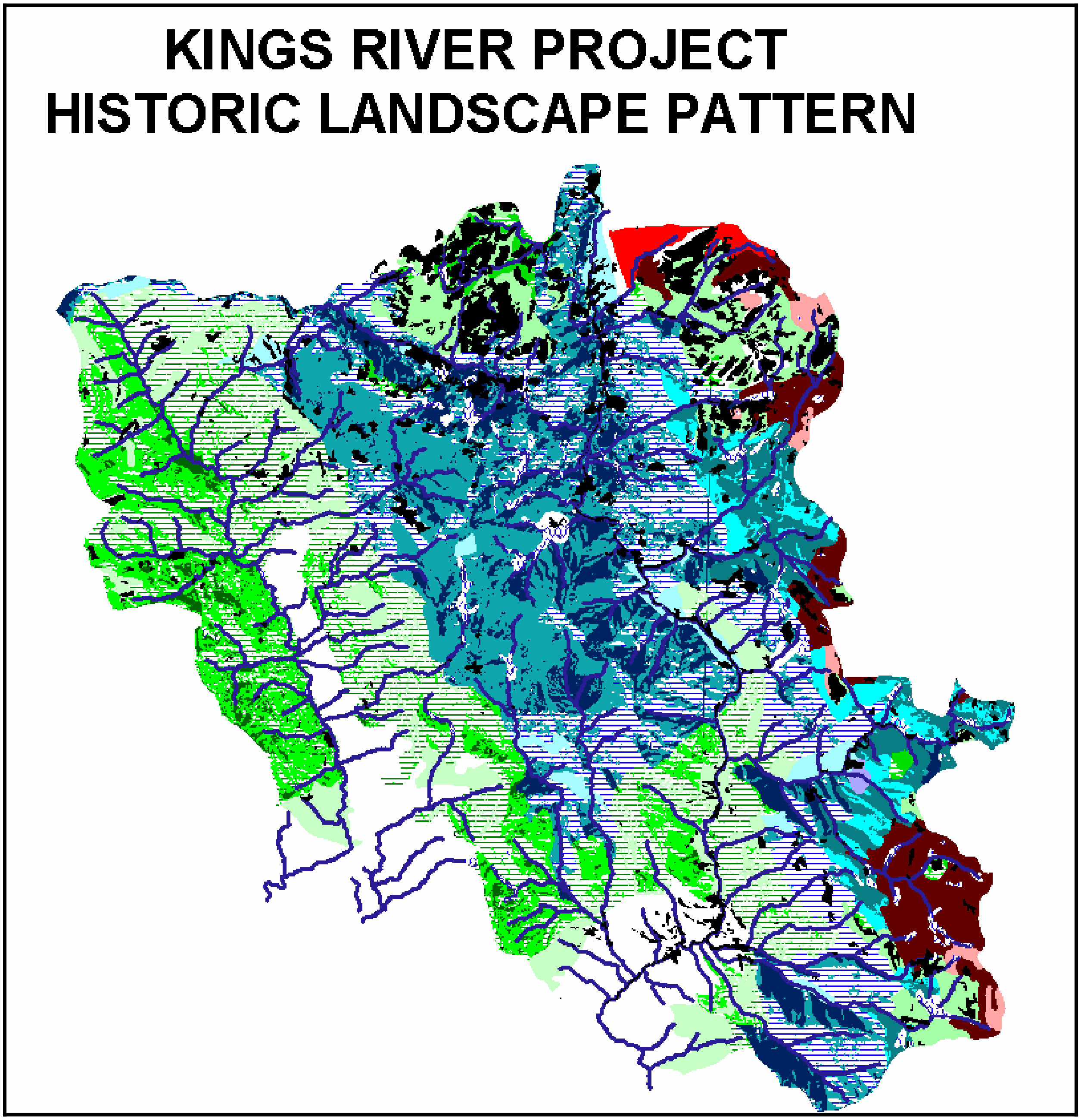
Addition illustrations of the nature of pre-settlement stand densities are contained in Sudworth's 1898-1900 plots. A rendering of Sudworth's data and a photo of mix-conifer forest on the Sierra National Forest are shown side by side to display similarities (*Figure H1*). The rendering and the photo both represent the same mixed conifer stand. The plot in *Figure H1* had several conifers that exceeded 75" in diameter at breast height. It contained 358 ft2/acre of basal area and represented 52 percent of maximum stand density index. A stand density less than 35 percent of maximum is consider below full site occupancy, while a stand density above 60 is considered at risk of density induced mortality (Long 1985, Drew and Fleweling 1979). The following table (H1) shows several plots had relative stand densities below or near full site occupancy.

Reconstructed forests across the Sierra Nevada display a similar range in basal area per acre. At Lake Tahoe reconstruction showed a range that varied by forest type (Taylor 2003). Jeffrey pine-white fir type ranged in density from 12 to 46 trees per acre and 48 to 166 square feet of basal area with a mean of 111 square feet per acre for trees over 11 inches in diameter. Red fir-western white pine stands contained 48 to 84 trees per acre and 129 to 398 square feet per acre and a mean of 243 square feet per acre. This is similar to reconstructed forests at the Teakettle Experimental Forest measured by North et al 2006. However, North et al (2006) measured more basal area in the Teakettle forests (224 square feet) with a similar number of trees per acre (27 trees per acre)

Bouldin's review of the 1935 VTM data set indicated that basal area varied between forest types and gave the following: mixed conifer 368, Jeffrey pine 223 and red fir 384 square feet of basal area per acre. The VTM

Sequoia and Kings Canyon National Park studies by Caprio and others were at larger geographic scales. Comparing the work of North et al and Drum with other data collected for the KRP would indicate a relationship with elevation and FRI.

Using the available information, criteria were developed to assign a range of canopy cover to each base polygon (combination of aspect, slope, site quality, PNV).



The figure above shows the historic landscape pattern in the Big Creek and Dinkey Creek watersheds. Darker colors indicate denser canopy cover. (Green = ponderosa pine, Dark blue = mix conifer, Red = red fir, Light blue = white fir, Black = rock, and White = non conifer. Streams appear in blue)

Appendix C3 contains the range of canopy cover assignments for each combination of physical attributes and PNV. The canopy cover range was assigned based on the criteria listed below.

1) North aspects are twice as dense as southwest aspects
2) Low site quality limited stands to sparse.
3) Steep slopes are one canopy class lower than gentle slopes.
4) Drainage bottoms not limited by site are dense.
5) Ponderosa pine and Jeffrey pine types are open unless on north to east aspects on moderate to high sites.
6) Mixed-conifer and white fir stands are dense unless on south to southwest aspects.
7) Red fir type is dense unless limited by site.

Ponderosa pine PNV is found in the lower elevations of Rush Creek, Big Creek, and Dinkey Creek. The maximum canopy cover for this PNV is set by site. Dense stands ranged from 50 percent canopy cover for low sites to 85 percent for the highest sites. The latter would have been found in perennial drainage bottoms and would have been narrowly confined due to the influence of increased moisture and site quality. Denser stands would have also been found on north to northeast slopes. This is a result of less frequent fire, more soil moisture longer in the growing season, and perhaps better site quality. Most other ponderosa pine stands would have been open to sparse and less than 40 percent cover. These open stands would have been found on the south and west facing slopes in Rush Creek, Big Creek, and Dinkey Creek drainages. The moderate density stands (40 to 50 percent) would have been on better sites, gentle slopes, aspects with lower fire frequencies, and less intense fire. These would have also been areas that had a higher frequency of sugar pine and white fir.

> trees per acre data would also generally agree with the Tahoe data in terms of trees per acre large than 11 inches in diameter: 62 in mixed conifer, 37 in Jeffrey pine and 76 red fir.
>
> Examinations of change in forest structure in Sequoia National Park indicate that tree densities in yellow pine stands and mixed-confer stands have generally increased (Vankat and Major 1978). The increase in density is attributed to changes in fire return intervals and grazing (Vankat and Major 1978).
>
> The open and moderately dense character of historic mixed conifer and pine tree densities would also account for the high frequency of very large diameter trees (Poage and Tappiener 2002). They concluded that rapid and sustained diameter growth in the first fifty years was significantly correlated with large old growth trees in western Oregon. Large diameter trees may require a period early in life were tree growth is not limited by stand density. Since diameter growth

Mixed-conifer PNV is found on north and east facing aspects in the Rush Creek and Big Creek drainages and most aspects of the Dinkey Creek drainage. The mixed conifer PNV would have been moderately dense up to the limits for the site and species mix. This dense mixed conifer would have ranged from 60 percent on low sites to 95 percent on very high sites dominated by white fir. These dense areas would have been found in drainage bottoms tributary to Dinkey Creek and aspects with less frequent fire. Moderately dense stands ranged from 40 to 60 percent and were limited by species, fire return interval, and site quality. Moderately dense mixed conifer would have been found on the south to west facing slopes of Dinkey Creek and the north to east aspects in the lower elevation of Rush Creek. Open stands (less than 40 percent) would have been found on steep slopes on south to west aspects or on low quality sites. Deeper soils on Dinkey Mountain would have supported moderately dense canopy cover. These deeper soils are found in areas with greater snow pack, better site quality, and that are not adjacent to chaparral with more intense fire.

Red fir and white fir PNV would have been moderately dense to dense. These areas would have had greater than 60 percent canopy cover. Moderately dense fir would have been found on lower sites or dry sites near Jeffrey pine ridges. Open and sparse fir (less than 50 percent) would have been found on very low quality site. Gaps in fir-dominated forest types may have been similar in frequency to lower elevation mixed-conifer types; however, the range in gap size would have been larger. Larger gaps would have resulted from more destructive fire effects on overstory fir trees. Jeffrey pine PNV would have been open and sparse. This would have been a result of both site limitations and species potential.

The variability of canopy cover for the historical forest based on PNV types indicates that dense and moderate canopy cover dominated 33 percent of ponderosa pine forests and 65% of mixed-conifer forest and the remainder of each type in open or sparse conditions. Information from mixed conifer forests analyzed by Bonickson and Stone (1982) indicates that approximately 30 percent was dominated by grass, bare ground and brush (sparse and open) and 70 percent in moderate to dense tree cover. The KRP values for mixed conifer pine dominated types are similar to that measured by Bonickson and Stone (1982).

Ponderosa pine and mixed-conifer types along the lower elevations adjacent to the chaparral were assigned a lower canopy cover range than similar stands away from the chaparral. This stemmed from the frequency and intensity of fires that move from chaparral into adjacent forest types. Examples include stands at the lower end of the conifer zone in the Big Creek watershed or in the Rush Creek drainage. The same was true of stands in areas where wind intensifies fire behavior, such as in the headwaters of the Big Creek drainage.

Potential Natural Vegetation (PNV)	Dense	Moderate	Open	Sparse
Ponderosa pine	5%	27%	45%	23%
Mixed conifer - pine	22%	41%	31%	6%
Mixed conifer - white fir	60%	39%	0%	1%
Jeffrey pine	0%	10%	6%	84%
Red fir	75%	12%	0%	13%

Displays the proportion of conifer dominated PNV type in each canopy cover class in the historical KRP landscape.

The historical canopy cover ranges in the table below provide a relative means of displaying the variability in canopy cover across the historical landscape. The range is base on developmental potential and canopy occupancy rather than on canopy occupancy alone. CWHR stand and density classification identifies canopy cover in terms of area occupancy. CWHR does not reflect the potential of a forest type to reach a particular density. The historical canopy cover range reflects the cover occupancy relative to the site potential. A dense stand is one that has reach approximately 90% of normal basal area. Normal basal area is that density when mortality would begin to occur. Thus a pine type on medium quality site would reach 90% of normal basal area and contain 50% canopy cover. A mixed conifer type on medium quality site would reach 90% of normal and contain 60% canopy cover.

	Mixed-Conifer	Ponderosa Pine	Hardwoods
Sparse	S = 10-25% Canopy closure	S = 10-25% Canopy closure	None identified
Open	P = 25-45% Canopy closure	P = 25-35% Canopy closure	None identified
Moderate	M = 45-65% Canopy closure	M = 35-55% Canopy closure	HM = 40-60% Canopy closure
Dense	D = >65 (max depends on species and site)	D = >55 (max depends on species and site)	HD = >60% (max depends on species and site)

Unconstrained historical density ranges: Canopy cover density ranges are based on developmental differences by forest type, linear regressions of photo interpreted canopy closure, and basal area

The historical canopy cover range is intended to provide a relative means of displaying the variability in canopy density across the historic landscape. The historic canopy cover range must be combined with other stand objectives to assign the final intensity of tree removal or fire prescription. The presence of homes, spotted owls, fire control areas, research plots, or low live crown ratio will constrain the tree removal intensity and the use of prescribed fire. It is also important to point out that the historic density does not replace the range in tree removal density between full site occupancy and the onset of self-thinning (50 to 90 percent of normal basal area or 35 to 60 percent of maximum stand density index) described in the uneven-aged silvicultural strategy. This range is generally between 40 and 75 percent canopy cover. A more detailed review of the relationship between stand density and canopy cover is found in Appendix C1.

Achievement of the historic canopy density will be limited by several factors. While low density stands can be maintained through frequent stand disturbance, frequent disturbance can be impractical or lead to undesirable outcomes. Open and sparse stands provide unused growing space that can be occupied by brush or trees if left undisturbed. Keeping these very open stands below full site occupancy may be impractical. The same is true for high-density stands. Maintaining historically dense stands adjacent to structures could prove catastrophic to both property and forest structure. High canopy density will result in stand attributes that may not meet landscape objectives. These include less crown depth and volume, less canopy layering, low light levels at the forest floor, higher fuels accumulations, death rates higher than decomposition rates, and increased susceptibility to fire and insects.

Stand Boundaries

Stand boundaries were created based on factors listed below, not in order of priority:

- Historic crown canopy range
- Logging systems
- Existing stand structure
- Plantations
- Identifiable land features (roads, streams, ridges)
- Spotted Owl protected activity centers (PACs)
- Deer holding areas
- Goshawk and Great Grey Owl territories
- Visual quality objectives
- Fire barriers and existing burn projects
- Research study needs
- Wildland Urban Interface
- Average size of 100 acres

and density are highly correlated (Oliver and Larson 1996), large trees would need to grow during a period when stands were near or below full site occupancy. The open stand character and low tree density is consistent between data from reconstructed presettelment stands and densities of stands in existing mixed-conifer forests with frequent fire return intervals (Minnich 2000). White fir-Jeffrey pine forests currently subject to frequent fire without fire suppression in Baja California exhibit similar stand densities (Minnich 2000). Open forests conditions are also found in relic west-side ponderosa pine stands at the Beaver Creek Pinery on the Lassen National Forest (approximately 25 greater than 11" dbh) (Oliver 2001).

3) The historic forest had high variability within forest types and between forest types.

Descriptions by Sudworth in his "Notes on Regions in the Sierra Forest Reserve" in 1900 describe the density and nature of the timber in the Sierra Reserve. He often described the change in density from north aspects to south aspects and on the basis of site quality:

> "*The north slope of this canyon bears a generally heavier stand of timber than the south slope. The commercial stand of timber on the latter slope is of a less valuable type, ranging from 2,000 to 5.000 feet, and very inaccessible on account of the rocky nature of the slope."*
>
> "*Passing from the head of Stevenson Creek, which is heavily timbered with Sugar Pine, Jeffrey and Yellow Pines, White Fir and Incense Cedar, the same heavy stand of timber prevails on the head of Dinky Creek*"

Sudworth often described the density of stands in terms of board feet:

> *"The canyon of Dinky Creek, below Dinky Meadow, is narrow and slopes to the rocky channel, but is timbered throughout. The prevailing timber is Sugar Pine and White Fir. The estimated yield is 4 to 7 million feet per 160 acres (estimate of mill cutting)."*

In addition, Sudworth's notes and photos supplement his ¼ acre plots. In his published paper covering the Stanislaus Forest Reserve he describes his ¼ acre plots as representative and displays the data unexpanded to the full acre (Sudworth 1900b). Reviews of Sudworth's 1898-1900 notes have concluded that his ¼ acre plots are problematic when expanded to the full acre (Stephens and Fiske 1998, McKelvey 1992, and Bouldin 199). His method of representative plots is similar to the subjective sampling scheme described by Lund and Thomas (1989). Using Sudworth's ¼ acre plots as representative of the average condition it becomes reasonable to examine the mixed-conifer forest structure. Two of these plots fall in the Kings River Project area. In addition to plot data, Sudworth took photographs and notes of each plot or area. The notes describe the general character of stands and watersheds. His notes include descriptions on the variability of volume and stand density. Even though Sudworth's plots seem uncharacteristically high for the KRP a review reveals some information on stand structure for mixed conifer stands. Data displayed in Table H1 indicates that even though mixed-conifer stands had high volume per acre, plots are hovering near the lower limit of full site occupancy based on stand density index (Long 1985). The lower limit of full site occupancy would indicate open to moderately dense stands.

Sudworth's descriptions of volume and density for the Dinkey watershed covers land later cruised by the Forest Service in 1914 and 1926. Volumes per acre described in the Forest Service cruise of 1914 seem to agree with Sudworth's descriptions. This cruise data was gathered by section for each township and range. Only those sections with little or no harvest activity were examined. It indicates a range in volume from 13,000 board feet to 41,000 board feet per acre across the Dinkey watershed. This is consistent with Gowen's 1922 cruise of the same watershed and the Pine Logging cruise of 1926. Gowen measured volume ranges from 11 MBF to 35 MBF. The 1926 data is by section. Sections dominated by fir have higher densities than those dominated by pine and sections on north aspects have higher volumes than those on southwest aspects.

A comparison of the PNV polygons developed from an ecological unit inventory of the Kings River Project and the 1926 Pine Logging cruise data indicates volume varied greatly by PNV. This cruise volume indicated that sections dominated by ponderosa pine PNV had stand volumes less than 11,000 board feet. Sections dominated by mixed conifer PNV had volumes as much as 3 times that of the ponderosa pine PNV.

Another data set that describes stand structures on the Sierra National Forest prior to logging was collected by Show and Dunning in 1914 and later examined by Hasel in 1931in the" methods of cut study" (Table H2). The data

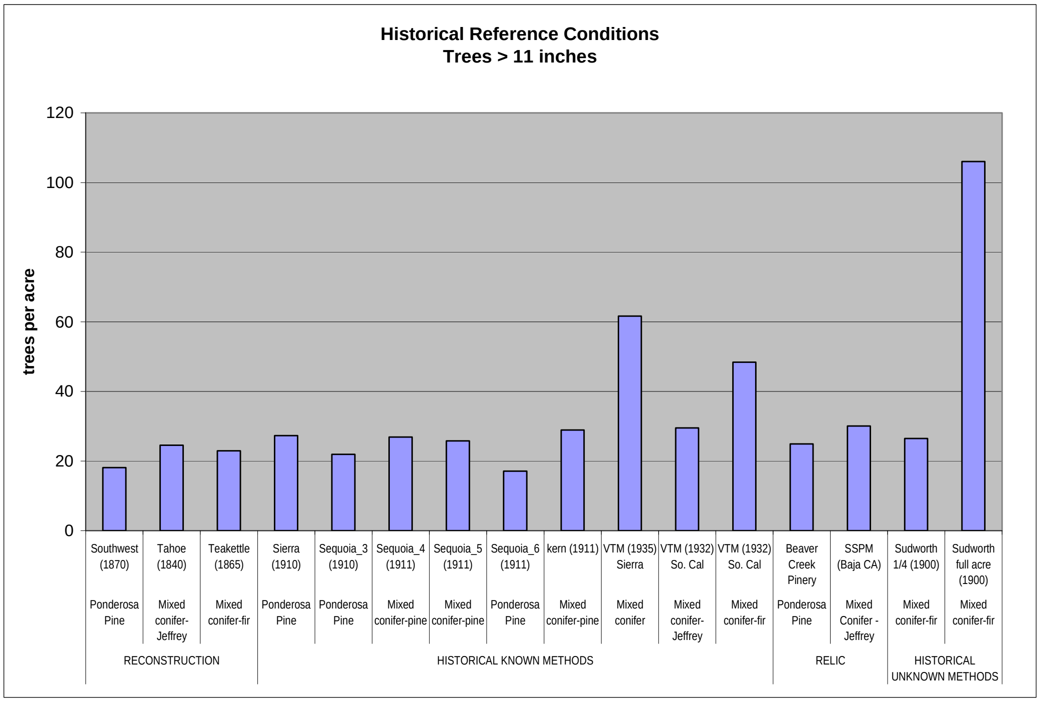
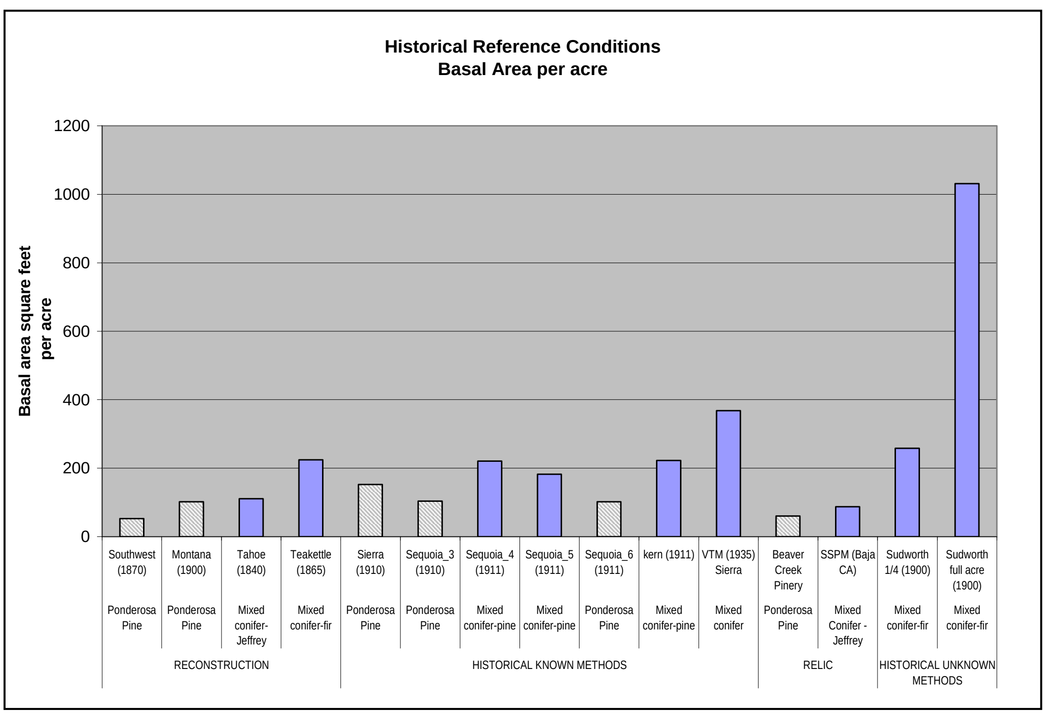
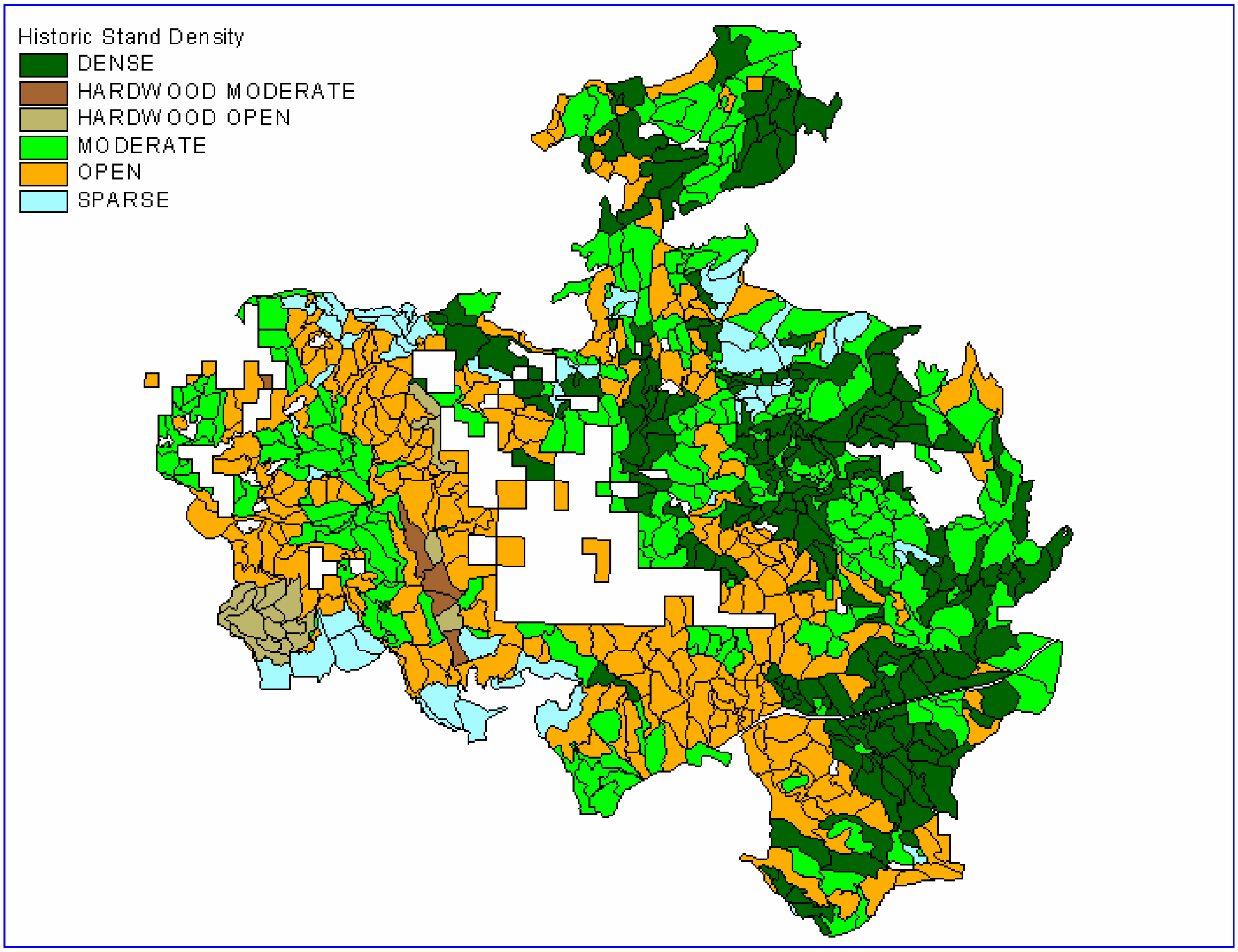


Figure H5 displays the number of trees per acre greater than 11" for reconstructed forests, relic forests in the Sierra Nevada and Baja California, and historical data sets with known and unknown collection methods. These data sets indicate that historical forest structures had relatively few trees. In addition they compare Sudworth's ¼ acre plots collected in 1900 to other data sets representing the historical condition. The comparison clearly shows that Sudworth's plots expanded to the full acre are not representative of the average historical condition. Figure H5 b below displays the basal area per acre of a subset of those in figure H5 a. Data shows the relative open nature of stands.





The figure above shows the canopy cover density range assigned to each uneven-aged stand. While several base polygons could occupy one stand, the canopy density with the greatest area was assigned.

These criteria were used by the landscape group to develop stand boundaries across the 132,000 acre watersheds of the KRP using an iterative process. Adjustments to stand boundaries were made as more information about each stand was accumulated. Stand boundaries were made to conform to logical treatment areas based on Forest Land and Resource Management Plan direction and stand relationships to the key stand factors listed above. A great deal of time was spent adjusting boundaries to maintain homogeneous stand objectives and eliminating small portions of stands split by multiple factors. Stands were configured so that California spotted owl PACs and home range core areas (HRCAs), maintenance underburns, DFPZs and similar land management direction could be contained within logical boundaries. This often resulted in stands becoming larger in size. The result was an average stand size of 105 acres (variation).

represents conditions in 1910 and 1911. Data for stand density in Table H2 were developed assuming all trees were at the upper limit in each diameter class. Even using this assumption that is sure to exaggerate stand density, the data describes an open stand below full site occupancy. The data is also consistent with other data sets in describing stands dominated by large trees with few trees below 11 inches DBH (Sudworth 1900a, McKelvey and Johnston 1992, Lieberg 1902). The stand has 50 percent of the site occupied by trees larger than 35 inches DBH. Photos of the sites following logging indicate that trees were clumped. Hasel describes the arrangement within the stand as "grouped or clumped". Again looking at figure H5 indicates that these plots are similar in tree number to several of the other data sets shown. However, ponderosa pine data has a lower range of trees per acre than mixed conifer data.

The VTM data set from 1935 is the most descriptive of the Sierra Nevada at a landscape scale. The VTM data would indicate a wide range of stand structure and density (Bouldin 1999). Bouldin's review of this extensive data set indicates that stands varied greatly within forest types and between forest types. While mixed-conifer pine averaged 368 square feet per acre across the Sierras with 3 percent of the plots exceeding 1000 square feet per acre, the mean and the range changed depending on the location. The average mixed conifer stand was dense, while the average Jeffrey pine stand was relatively open. Bouldin identified two areas on the Stanislaus that were remote and not likely to have been logged prior to the VTM data collection. He suggests that these areas are representative of presettlement Sierran forests. An examination of Bouldin's Figure 71a (Figure H2) indicates that plots for these two remote areas on the Stanislaus Forest Reserve showed 54 percent of the plots located in open to moderately dense stands (0 to 500 square feet per acre). The VTM data set has more trees greater than 11" than any of the other data sets with known collection methods.

Stand Prescriptions

Each stand or group of stands across the watersheds was evaluated for the potential to implement the uneven-aged silvicultural strategy. Stands dominated by chaparral, oak woodland, rock, and private land, or sub-alpine vegetation was eliminated from further consideration for the uneven-aged strategy. Treatments were not planned on private land. This evaluation resulted in identifying 72,000 acres and 771 stands for inclusion in the uneven-aged strategy.

The 771 stands were evaluated for a range of treatments to achieve an uneven-aged structure. Each stand was assigned a stand level suite of treatments. The potential treatments included a mechanical uneven-aged single tree removal intensity based upon the historic canopy cover, a potential logging system, a fuels prescription to reduce fuels accumulations and reintroduce fire, a site preparation treatment for reforestation groups, and a release treatment to achieve seedling/sapling survival and growth.

Two other District activities were considered when assigning treatments to stands: 1) the current underburning program and 2) existing even-aged plantations. The KRP contains approximately 17,300 acres currently prescribed for underburning. In addition, it contains approximately 3,500 acres in plantations. Both the continuation of the underburning and the maintenance of plantations were considered when treatments were assigned to stands.

The mechanical treatments would focus on tree removal in the matrix between reforestation groups. The uneven-aged silvicultural system would conform to the diameter distribution as defined by the residual basal area, the diameter limits, and Deliquourt's Q (Smith and Exline 2002). These parameters are used to define the shape of the inverse J-shape curve. The intensity of tree removal would be initially "unconstrained" and would be carried out as described earlier on pages 7 and 8. Mechanical treatments also had the objective of preparing stands for the reintroduction of fire. The uneven-aged treatments in the matrix would reduce ladder fuels and disrupt crown continuity sufficiently to reintroduce fire into the stand and create or maintain uneven-aged structures.

Upper dbh class	Trees per acre	Stand Density Index (sdi)	Volume weighted max sdi	Percent of max sdi
11	18.2	21.20		
17	7.5	17.53		
23	3.9	14.79		
29	4	21.97		
35	4	29.69		
50	7.9	103.75		
Total	45.5	208.92	618	33.80

Species	Board ft volume	Trees per acre	Volume per tree
PP	27510	14	1965.00
SP	8820	2.5	3528.00
WF	4500	2.7	1666.67
IC	4680	8.1	577.78
Total	Volume	per acre =	45510

Table H2: 1914 data from the Sierra N.F. The data represents a ponderosa pine stand on high site. Slopes are less than 20 percent. Stand densities are below full site occupancy assuming all trees fall at the upper range of the diameter class. Hasel 1931 (original sample by Show and Dunning 1904)

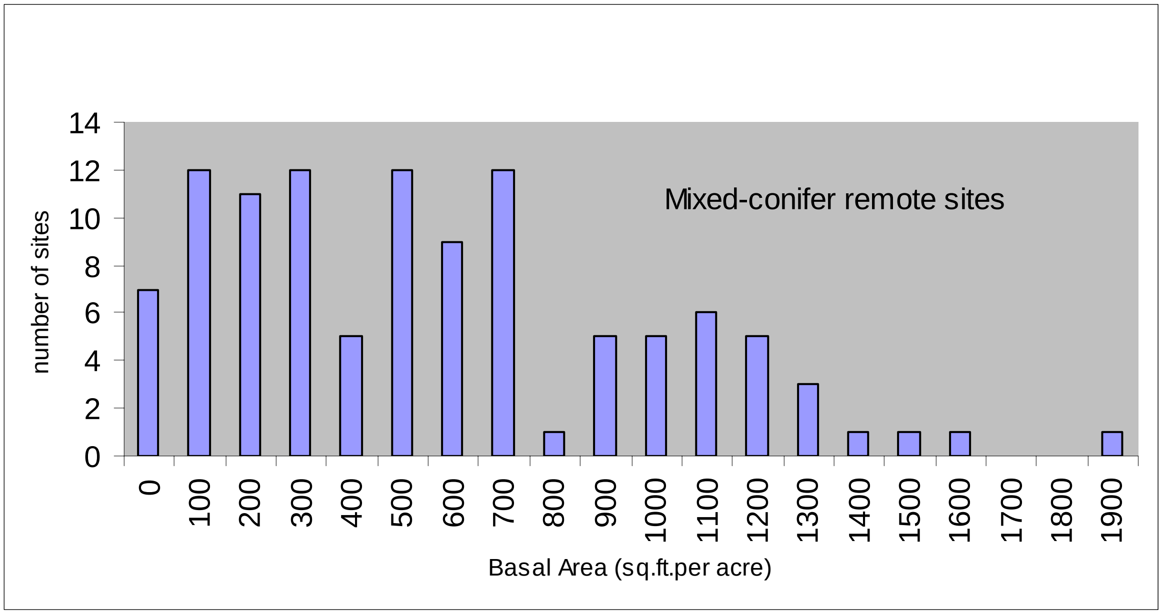


Figure H2: Bouldin (1999) displays the range in variability for two unlogged mixed-conifer areas with 1935 VTM plots.

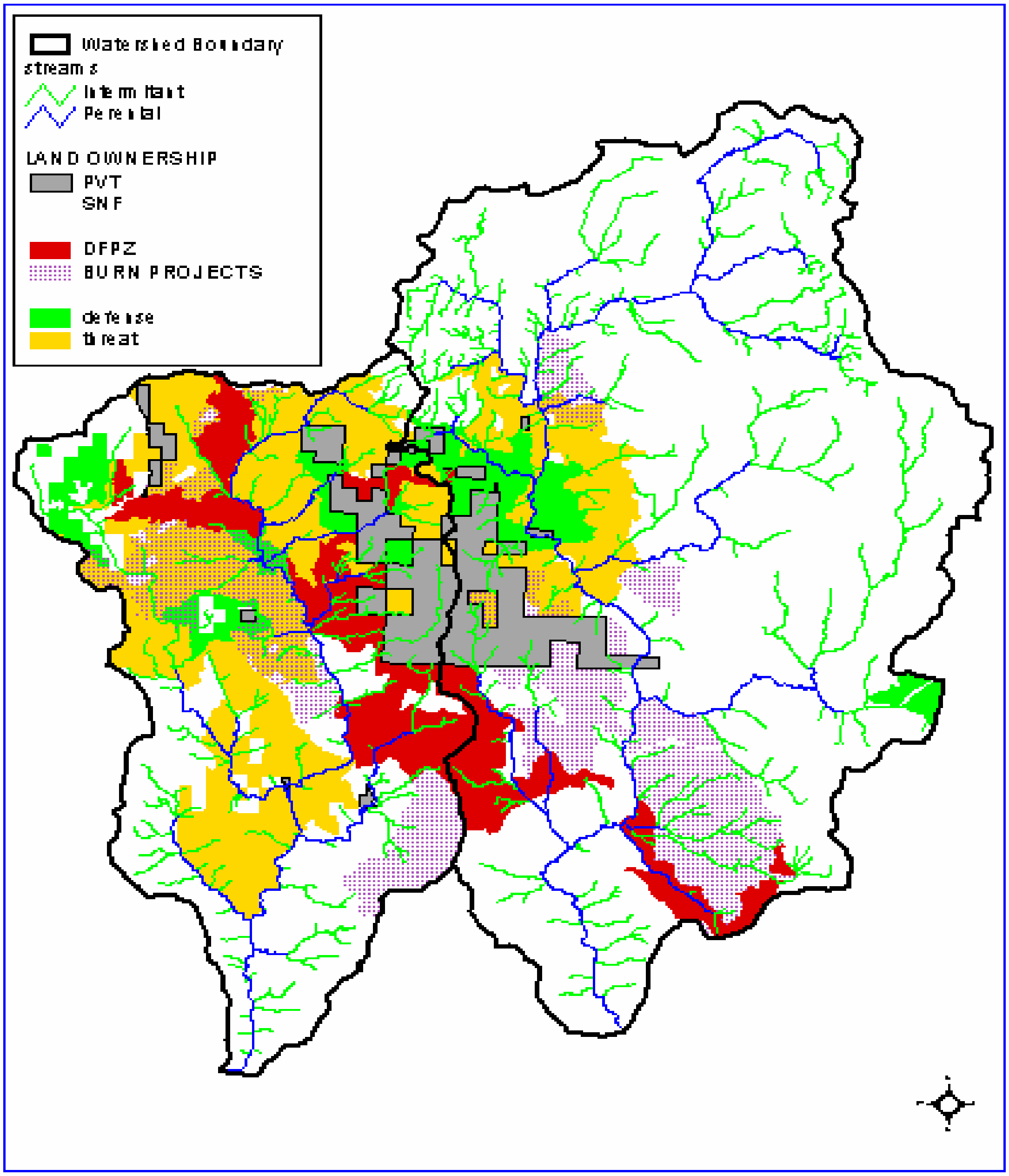
Mechanical treatments could be accomplished using ground based skidding systems (tractor/skidder or forwarder/harvester), skyline, or helicopter. Logging systems were based upon an initial logging plan completed for the KRP (Durston 1995). This initial plan was recently refined based on the ground information and local knowledge. Slope was the major criteria for determination between stands identified for tractor/skidder and forwarder/harvester. Designation of a stand as potentially suitable for forwarder/harvester was not intended to preclude the use of other equipment and did not consider the presence of other limitations such as rock. Stands labeled as skyline assumed that sufficient road access was available or would be made available to accommodate skyline systems. Helicopter logging systems assumed that landings of sufficient size could be made or currently exist.

Reconstruction of historic forests at landscape scale indicate that stands were generally open and patchy (Bonickson and Stone 1982). This patchy nature was made of groups that were either homogenous in age (Bonickson and Stone 1981) or heterogeneous in age (North et al 2004). These patches were not uniformly distributed. This general description of the variability within mixed-conifer stands is supported by descriptions of the McKinely Grove of giant sequoias within the Kings River Project (Gutherie 1906). Gutherie's description of Mckinely Grove indicates it was affected by low intensity fire. Clumps of trees are interspersed with small openings created from higher severity fire. Gutherie (1906) describes one opening formed by the mortality of a dozen understory fir 100 feet tall. Research based on limited data indicates that group sizes within mixed-conifer forests ranged from .08 acres to 100s of acres (Keeley and Stephenson 2000). The highest frequency group size was those less than .49 acres (Keeley and Stephenson 2000). While 2/3 of mixed conifer presettlement groups were less than .49 acres they accounted for only one-third of the area. These ranges in gap size

Fuels treatments included underburning, tractor pile and underburn, hand pile and burn, gross yard, mastication and burn, or tractor pile and no underburn. Underburning could occur without mechanical treatment or in combination with mechanical treatments. All other fuels treatments would occur in combination with mechanical treatments to treat fuels created by the activity. Criteria used to decide on the type of fuels treatment included the presence of fire control points, slope, and the size of treatment material. Fire control points such as roads or wet drainages would provide an opportunity to underburn. Underburning could be used to both consume activity fuels and alter stand structure. Without control points other means to consume activity fuels are necessary. On steep slopes (greater than 35 percent) dominated by poles and saplings hand piling was preferred.

Stand structures are also identified as single-story or multi-story. Very little information on canopy layering exists for the historic forest. Canopy layering was assigned based on subjective criteria by forest type, tree silvics, and canopy density.

Following the evaluation of stands based upon the broad treatment categories (logging systems, uneven-aged strategy) specific sequences of treatments were selected for each stand. Representative stands were initially selected to assign treatments. These representative stands were selected on the bases of slope, aspect, location of WUI, and the presence of fire control points. Decisions made from these stands were used to make treatment assignments to the remaining stands.



The figure above displays the land allocations and fuels treatments in the KRP.

On steep slopes dominated by larger material, either existing or created by treatments, gross yarding could be used to reduce fuels. Gross yarding is the process by which the harvesting equipment is used to remove the tops of trees along with the boles to the landing site. In stands with steep slopes adjacent to homes gross yarding and hand piling would be used to reduce the fuels hazard. On gentle slopes (less than 35 percent) with fire control points underburning would be used to consume fuels. On gentle slopes among campgrounds or structures (such as the Dinkey Ranger Station) hand piling would be used. Mastication would be used on gentle slopes where brush dominates the have been suggested for restoration of mixed conifer (Piirto and Rogers 2002). Within the Teakettle experiment forest, in contrast to Bonickson and Stones reconstruction of Redwood Creek, presettlement groups were not composed of even-aged trees but rather of many cohorts (North et al 2004). Within Teakettle trees were also clumped and that the clumped arrangement was dependent upon the soil depth and rock. Both studies would indicate that mixed conifer forests were composed of a randomly arranged widely variable distribution of tree ages and sizes. This distribution occurred at a very fine scale. This fine grained mosaic of age/size class has been noted in the reconstruction of presettlement pine forests of the interior-west with a frequent fire interval similar to the Sierra Nevada (Arno 1995). The structure on moist sites in the interior-west tended towards even-aged as a result of the catastrophic intensity of fires and tended towards coarse grained. Reconstruction of the Teakettle Forest by North et al (2004) indicates that the clustered pattern occurred at a very fine scale with the clustering pattern *occurring within a 160 foot circle.*

Flintham surveyed the Sierra Reserve in 1904. His descriptions of density by forest type, aspect and landscape position are consistent with other observation of the time (Sudworth 1900b, Lieberg 1902). In addition he describes a change in density relative to a stands position on the landscape. Pine stands adjacent to chaparral were more scattered in canopy density than those higher in elevation. In addition, fir dominated stands adjacent to pine stands or above steeper slopes were more prone to fire mortality and fragmentation. Using descriptors such as “scattered”, “open”, “dense”, and heavy Flintham described the range of variability across the Sierra Reserve.

Other descriptions of the early 1900 Sierra are also helpful in setting limits on canopy density. Descriptions by many observers indicate that trees in the yellow pine and mixed conifer were spaced so far apart that a sustained crown fire was unlikely (Show and Kotok 1924). Flintham noted that he observed no sign of crown fire in the ponderosa pine and sugar pine stands. Flintham made special note of the mortality from fire in the dense fir stands. These descriptions while broad provides some insight

understory and fire control points exist. In addition, mastication in combination with herbicides would be used to release plantations with large ceanothus plants. Tractor piling could occur alone or in combination with underburning. Underburning would be used to maintain the fuels condition following tractor piling, hand piling, or mastication, where fire control points exist.

Currently maintenance underburns are scheduled to occur every 5 to 20 years and to be repeated for the foreseeable future. Each stand that contains a maintenance burn (part of the current district program) was identified. The timing of the maintenance burns is dependent on burning windows. Based on the Districts current underburn program of 2,000 to 3,000 acres per year and estimates of the potential for future days available for underburning, an estimate of 30,000 acres underburned per decade for the project is feasible. Approximately one-third of the acres would be second treatment or maintenance burns. The landscape group identified 28,000 acres of underburn across the KRP landscape. These 28,000 acres included the existing burning program plus new burning identified with the uneven-aged strategy.

Plantations are scattered across the KRP landscape. Plantations are contained within stands. Plantations were rarely broken out to stand on their own. Each uneven-aged management stand has a set of mechanical, hand, or chemical treatments to achieve a desired stand structure. Each plantation also has a suite of treatments to provide for survival and growth of planted seedlings. This suite of treatments for maintenance is often in addition to the mechanical treatments identified for the balance of the stand. An uneven-aged stand that has high-intensity tree removal (low residual canopy crown cover or low residual basal area per acre) accomplished with conventional tractor logging may also have a mastication treatment within the plantation. Plantation treatments include hand thinning, herbicide release, mastication, mechanical thinning, underburning, and tractor piling.

Thus the full suite of treatments for any particular stand could only be understood from looking at the plantation maintenance treatments, underburning maintenance treatments, and uneven-aged treatments.

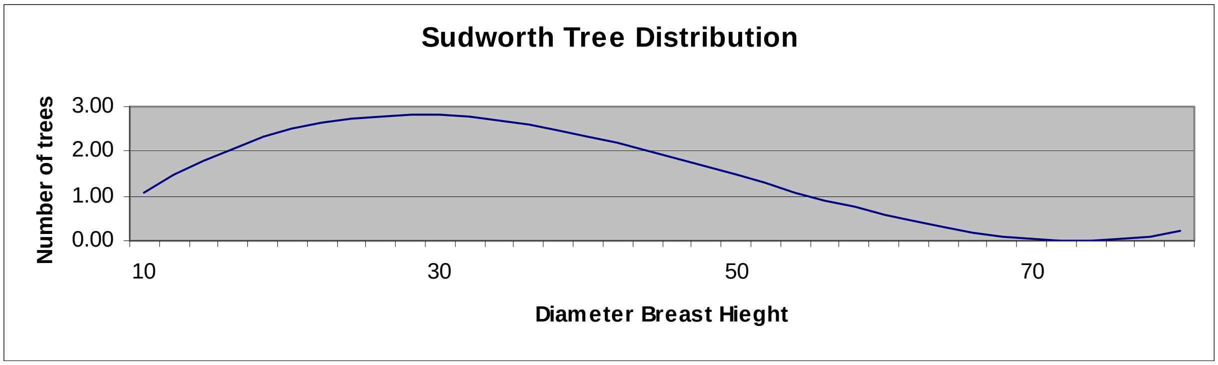


Figure H3: Mckelvy's 1992 polynomial equation and graph that depicts the distribution of diameter measured by Sudworth in the Southern Sierra Nevada.

Figure H4: Ponderosa pine stand in 1900, San Joaquin River drainage.

Fire Strategy

The landscape group adopted the Sierra Nevada Forest Plan Amendment strategy of defense and threat zones associated with the WUI in conjunction with Defensible Fuel DFPZ. A DFPZ and Top Tier strategy for the KRP was developed in 1995 and described in the Landscape Analysis Plan. The philosophy at the time was to pick strategic roads and ridge tops that could serve as control points for fire suppression activities in the event of a wildland fire and implement a heavy thinning in the top tier (upper third of the slope). The top tier concept was never implemented and has been dropped from the fire strategy. Five DFPZs were identified within the KRP. Two of these DFPZs have been completed since the initiation of the KRP, 10S18 (approximately 2,000 acres) and Indian Rock (approximately 1,000 acres). A combination of treatments mainly timber harvest, hand thinning, tractor piling, mastication, herbicide, and underburning were used in creating a total of 5.5 miles of DFPZ through these projects and underburn treatments.

DFPZs were placed both to provide protection to homes and structures and to alter fire behavior associated with fires moving from the chaparral into the conifer stands. These DFPZ structures were placed in locations where past wildfire had moved at high burning intensity and where suppression forces would have a high probability of successful attack. The placement and size of the DFPZs were developed based on the history of fire since 1910. Because of the potential of high intensity fire from chaparral vegetation DFPZs were expanded from narrow linear features and now more closely represent wider area treatments. Their function is to provide less fuel continuity and anchor points for suppression forces.

on canopy density resulting from frequent low intensity fire and the less frequent higher intensity or variable intensity fire. Research by Van Wagner (1978) and modeling by Van Wagtendonk (1996) and Hollenstien (2001) indicate that crown canopies below a range of 40% offer little opportunity for active crown fire. In addition, crown bulk density figures less than 0.1 Kg/m^3 cannot support active crown fire (Scott 2003, Scott and Rienhardt 2001). One-quarter acre plots gathered by Sudworth in the Sierra National Forest all have crown bulk densities below .1 kg/m^3. Thus the historic descriptions by Show and Kotok and Flintham provide limits as described by contemporary research. The limited data also would support the low crown bulk density. The majority of the stands dominated by ponderosa pine or Jeffrey pine must have been near or below 40% canopy cover. In addition, the descriptions by Flintham of dense stands dominated by fir indicate that canopy covers often exceeded 40 % canopy cover for fir stands. Otherwise mortality as described by him would not have been observed in the fir. This is consistent with Sudworth's 1900 data set shown in Table H1.

The historic fire pattern and forest structure was the result of climate, topography, fuel load and fire frequency (Heyerdahl, Brubaker and Agee 2001, Caprio and Swetnam 1995, Arno 1995, North et al 2004, others). Reconstruction of the historic forest pattern done in the Sequoia/Kings National Park found a pattern of fire return interval strongly related to the aspect and elevation (Caprio and Swetnam 1995). Reconstruction of the presettlement Teakettle Forest indicates a strong influence in age structure, micro-site conditions and soil depth. This same variability in forest structure and pattern for presettlement forest has been documented in other parts of the Sierra Nevada and western coniferous forests (Heyerdahl et al 2001). These findings are consistent with the descriptions by early observers and would indicate that forest structure in Kings River Project would also have had a high degree of variability dependent upon climate, topography, fuel load, and fire frequency.

Surveys of mixed conifer forest types which have sustained frequent fire show mean canopy cover for all trees less than 50%. The highest tree canopy density measured was 60% (Minnich1995).

4) Historic forest stand structures were uneven-aged.

Late 19th century and early 20th century descriptions of the pre-settlement mixed conifer and pine stands in the Sierra Nevada indicate that structures were dominated by uneven-aged tree distribution (Dunning 1923, Show and Kotok 1924) . Dunning (1933) concluded succinctly "The virgin stands are not even-aged". He also states the nature of the mixed conifer forest type:

> *"In relatively few sections of this large region are the stands uniform in age. All age classes are not present, as they would be in a true selection forest. Stands are usually made up of small even-aged groups, the ages of the groups differing by periods of 10 to 20 years."*

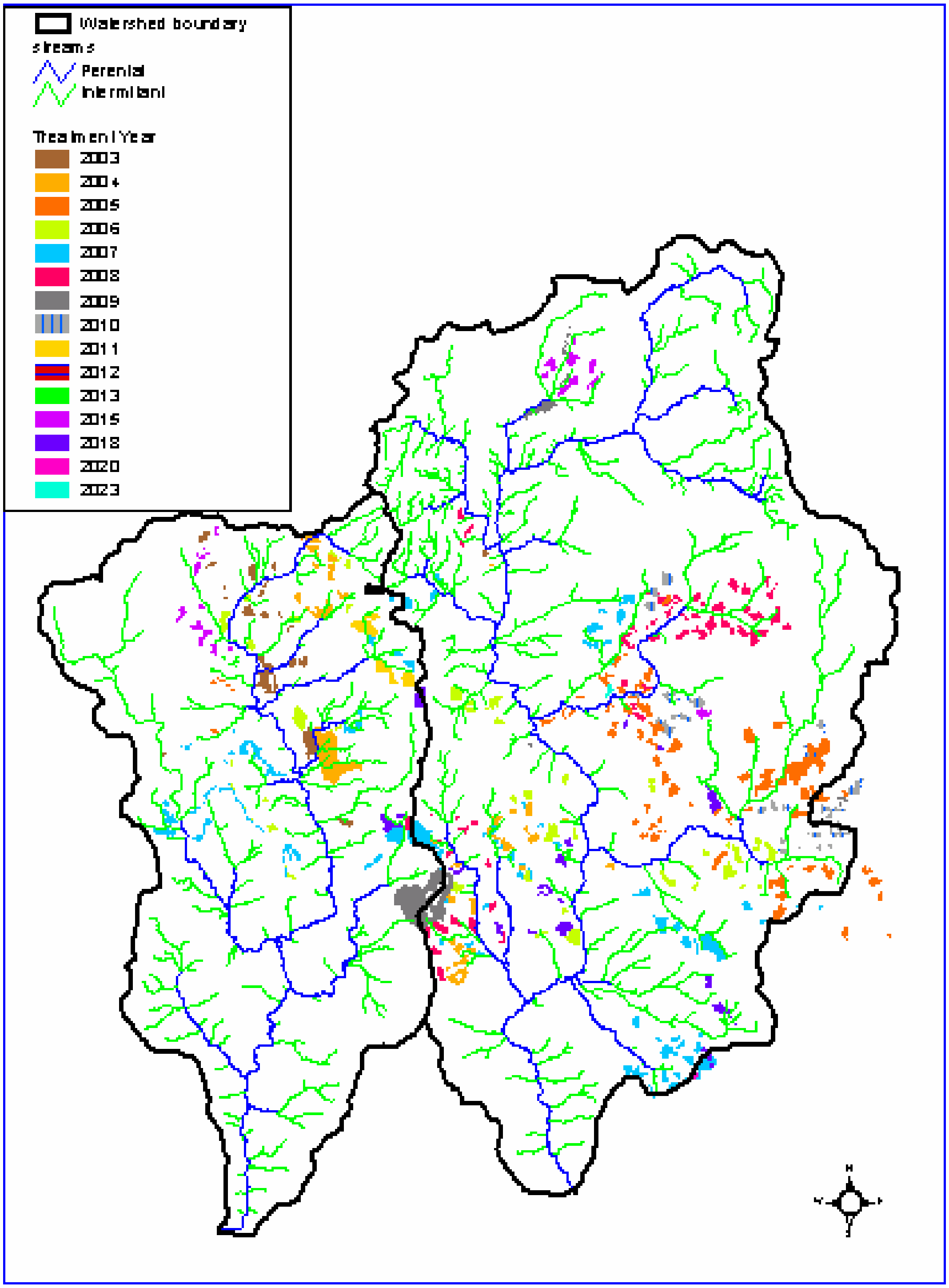
Observations of the early 1900s of the Sierra National Forest and the Kings River Project area in general would also indicate that the uneven-aged structure was dominant (Flintham 1904, Sudworth 1900a). Meyers (1934) in his description of ponderosa pine forests of the west coast including California noted the uneven-aged character and the general more open nature of the Sierra Nevada. Little data on presettlement forests was collected. What little data exists would indicate that the structure was uneven-aged but many tree distributions were present.

Several tree distributions have been suggested as representative of this historical condition. North (2005) has suggested the rotated sigmoid. Reconstruction of 1865 forest structures in the Teakettle Experimental Forest (adjacent to KREW-bull management unit) indicates that a relatively flat tree distribution existed after the last major fire (North et al 2006). Mckelvey and Johnston (1992) display data collect by Sudworth in 1900 showing a highly skewed distribution with more small trees than larger trees. Bouldin's (1999) review of the earliest sierra wide data set (VTM 1935) suggests that distributions with decreasing numbers with increasing size were dominant. Minnich's (1999) review of similar VTM data in Southern California mixed conifer forest showed flat and inverse J-shaped distributions. Data from un-harvested mixed conifer and ponderosa pine stands on the Sierra Forest Reserve measured by Dunning and Show (circa 1910) indicate an inverse-j shape was prevalent. Data from relic forest in Baja California Sierra San Pedro Martir (Stephans and Gill 2004) indicate that the dominant tree distribution was inverse-j shaped. Relic ponderosa pine forest in the Sierra Nevada structures had a flat distribution following high intensity fire (Oliver 2000), but had an inverse-j distribution prior to high intensity fire (Knapp 2006, presentation R5 fuels vegetation conference). Ponderosa pine stands across the western United States also show this variability (Arno et al 1995, Covington et al 1997). Figures H6 and H7 display the

Key to the success of reducing the risk of large-scale wildfire was the tactic of applying an uneven-aged silvicultural system in the existing matrix of trees in between reforestation groups. Matrix uneven-aged tree removal, group selection, and underburning resulted in reducing stand densities from 500-700 trees per acre to approximately 135 trees per acre. These treated stands provide areas of reduced fuel continuity and lower potential for crown fire.

Concurrently with the uneven-aged treatments the KRP has implemented an underburning program. Continuous blocks of forest have been underburned with low intensity fire in an attempt to reduce future wildfire intensity, fuels hazard, and reintroduce fire to the ecosystem. To date, approximately 15,000 acres have had a first entry of fire. Approximately 3,000 acres have had two entries of fire. These underburns lie adjacent to the DFPZ stands and serve to strengthen the effectiveness of planned and existing DFPZs. They were located in areas previously identified as strategic control points for fire suppression. Repetitive burning, mechanical treatments, and herbicide use in these areas will create and maintain adequate DFPZs over time.

The fire strategy incorporates the concept that once the landscape begins to function through processes and structures that are similar to the historic forest, then the fire strategy will become less dependent upon the WUI and DFPZs and rely upon maintenance of stand structures that contribute to low-intensity fire. Each stand was labeled with a fire strategy component; WUI (defense and threat), underburn, DFPZ (roads and ridges), or none.



The figure above displays the schedule for plantation maintenance within the Kings River Project.

Treatment Schedule and Treatment Areas

The timing of treatments across the landscape was arranged to emphasize the treatment of the WUI and DFPZ first, and then treat stands at highest risk to catastrophic insect attack.

Management units were identified that grouped stands based on treatment objectives, research, road systems, existing data, and the typical uneven-aged re-entry period of 20 years. Research projects are on a time table that had to be coordinated with the uneven-aged strategy. (For an explanation of the 20 year re-entry cycle, see Appendix C2.)

Road systems that are disconnected or feed into different arterial roads would increase treatment costs and make the removal of timber products impractical. Stands were grouped together so that they had road systems in common.

The emphasis on treatment of the WUI and DFPZs first and the fact that stands in these areas tended to be larger allowed for treatments to be maximized near homes. The treatment schedule clumped stand treatments near the WUI. The result was 36 management units which ranged in size from 375 acres to 5,243 acres. Implementation was scheduled to occur each year for 20 years until all 771 stands had received an uneven-aged treatment. The cycle would then repeat until all acres that were amenable to the creation of reforestation groups was treated. Stand areas amenable to reforestation groups are those with soil water holding capacity suitable for conifer and oak seedlings (approximately 20 inches of water holding capacity), or areas with objectives that do not preclude reforestation groups (nest trees, den sites). Matrix uneven-aged silviculture using the J-curve or plantation thinning, fuels reduction and release treatments would occur between groups.

Unconstrained Treatment Maps

The stand coverage (map) produced for the unconstrained treatment strategy contained several data attributes for each stand.

Field name	Attribute description	Attributes
Manage	This field identified the stand as part of the uneven-aged strategy or not part of it.	Uneven-aged, private property, other
Logsys	Range of logging systems available for mechanical treatment	Helicopter, helicopter or cable, skyline, tractor, tractor or cut-to-length
Fuels1	Fuels treatments	Gross yard and underburn, gross yard, hand pile, tractor pile and underburn, tractor pile alone, mastication and underburn
Hist_dens	This field is the canopy cover code used to label base landscape polygons	S = 10-25% CC P = 25-40% CC (species dependent) M = 40-60% CC(species dependent) D = >60%(species dependent) HM = 40-60% Mostly Hardwoods HD = >60% Mostly Hardwoods

Priority_1	LRMP allocation for stand. (A high priority indicates a higher constraint, i.e. Priority_1 takes precedence over Priority_2.)	McKinley Giant Sequoia Grove and wilderness
Priority_2	“ “	Critical aquatic refuge
Priority_3	“ “	Protected activity centers and spotted owl home range core areas
Priority_4	“ “	Deer holding areas, and WMT, visual quality objectives
DFPZ	Stands that contain DFPZ along road or ridge	Yes or No
Urban	Wildland urban interface as defined by SNFPA ROD	Threat or defense
Burn_current	Stands currently part of the Districts underburn program	Name of the underburn project
Acomp	Timber stand compartment number	
Current_proj	Management area or project name under the unconstrained treatments	Name of the project area
Plan_id	Unique identifier for each stand	
Mech_year	Year of stand treatment or implementation under the unconstrained treatments	Year

CONSTRAINED TREATMENTS

After the assignment of unconstrained treatments the landscape group presented the resulting maps and treatments to KRP researchers from PSW and Sierra National Forest staff. The PSW researchers and Forest staff made recommendations based upon the desire to limit disturbance to sensitive wildlife habitat, coordination of activities with PSW studies, and LRMP land allocations.

The constrained treatment map was the result of constraining the intensity of treatments, timing of treatments, and the arrangement of treatments across the landscape. The intensity of treatments was reduced to maintain habitat for fisher and spotted owls. The timing of treatments was dispersed to reduce disturbance to wildlife. The management areas were dispersed across the landscape to distribute impacts on wildlife habitat.

Landscape recommendations by PSW researchers focused on limiting treatments based on three criteria:

1) The need to provide habitat connectivity for the old forest dependent species.
2) The need to protect nesting and foraging stands for spotted owls by limiting treatment intensity in protected activity centers.
3) The need to provide specific treatments and controls for PSW research.

tree distribution of several reconstructed forests, historical data sets with known data collection methods and historical data with unknown methods. eleven of the fifteen data sets have an inverse-j shaped curve or a highly skewed distribution.

An important factor in creating the uneven-aged distribution was the episodic nature of regeneration in mixed-conifer and true fir forests (Taylor 1991, Taylor 2003, North et al 2004, Battles 2000). This is similar to the episodic regeneration patterns in ponderosa pine forests of the Southwest (White 1985). Regeneration occurred after disturbances and when conditions were suitable for establishment. Regeneration patterns differed by species and between ridge tops and riparian areas (North et al 2004). Seedling survival was dependent on fire free intervals (Vankat and Major 1978, Kilgore and Taylor 1979). However, there is some evidence that in red fir dominated stands regeneration occurred independent of fire and was dependent on sufficient moisture (Taylor 1991, Taylor 1993, North et al 2004).

5) The historic mixed-conifer and pine forest had a lower frequency of shade intolerant individuals.

Several studies comment on the increased density and increased abundance and frequency of shade tolerant species in California conifer forests (Vankat and Major 1978, Minnich 1995, Bouldin 1999, others). The higher frequency of shade tolerant species is attributed by several authors to the decreased fire return interval (Skinner and Chang 1996). With the removal of fire from the landscape, white fir and incense cedar, present in drainages and on cooler aspects, seeded the open forest floor. North et al (2004) indicates that initiation of shade tolerant cohorts coincided with cessation of fire in 1865 in the Teakettle Forest. This increased establishment of shade tolerant incense cedar and white fir coincided with an increased logging of pine species and the removal of fire as a landscape process. North et al (2006) found that reconstructed mixed conifer forests at 7000 feet in elevation had a nearly 50/50 split between shade intolerant pine and shade tolerant fir and incense cedar. Measured data from the 1910's (Hasel 1931) indicates slightly higher amounts of pine. These shade tolerant incense cedar and white fir now occur at a higher frequency and at higher densities than presettlement forests(North et al 2006, Taylor 2003, Vankat and Major 1978).

6) The historic forest was greatly affected by frequent low intensity fire.

Habitat Connectivity

The Sierra Nevada Forest Plan Amendment (2001) contained Forest-wide standards and guidelines that apply to all land allocations (other than wilderness areas and wild and scenic river areas). One of these standards and guidelines pertained to "Vegetation Management Related to Habitat Connectivity for Old Forest Associated Species" (SNFPA ROD, 2001, pg. A-27). The following information was compiled for use in the assessment of habitat connectivity for old forest associated species (California spotted owl, northern goshawk, great gray owl, Pacific fisher, and American marten) in the KRP.

- Consider forested linkages (with canopy cover greater than 40 percent) that are interconnected via riparian areas and ridge-top saddles during landscape and project-level analysis (SNFPA ROD, 2001, pg. A-27).
- Forested linkages are addressed in the LRMP with standard and guideline #62, "*For connectivity, manage a minimum of 600 foot wide travel ways, identified and mapped as part of the planning record, to provide linkage between marten and fisher habitat areas. Continue existing Forest uses in and adjacent to travel ways. Allow new management activities in travel ways when they will not directly or indirectly preclude use by marten and fisher as determined by a biological evaluation.*"
- Fishers prefer continuous or nearly continuous forests (SNFPA FEIS, 2001, Vol. 3, Ch.

3, part 4.4, pg. 5). Habitat connectivity is key to maintaining fisher within a landscape. Conservation of fishers in the Sierra Nevada will require the retention or restoration of sufficient habitat and habitat connectivity throughout the planning area (SNFPA FEIS, 2001, Vol. 3, Ch. 3, part 4.4, pg. 5).

- Key habitats for fisher are structurally complex late-successional coniferous forests (Freel 1991, Buskirk and Powell 1994 in SNFPA FEIS, 2001, Vol. 3, Ch. 3, part 4.4, pg. 5) and generally CWHR types 6, 4D, 4M, 5D, 5M in stands of at least 80 acres in size (Freel 1991 in SNFPA FEIS, 2001, Vol. 3, Ch. 3, part 4.4, pg. 5).
- Fisher rest sites in the KRP were significantly closer than random sites to a permanent stream at 374 feet, and temporary streams at 138 feet (Mazzoni 2002).
- The elevation range of the Southern Sierra Fisher Conservation Area (SSFCA) is 3,500 feet to 8,000 feet on the Sierra and Sequoia National Forests (SNFPA ROD, 2001, pg. A-45). If fishers are detected outside the SSFCA, evaluate habitat conditions and implement appropriate mitigation measures to retain suitable habitat within the estimated home range.
- The presence of large conifers and hardwoods is a

Flintham in his survey of the regeneration potential of the Sierra Reserve in 1904 wrote several sections on the influence of fire on different forest types. His conclusions were that fire varied by forest type in intensity and severity of effects. His observations were that frequent fire in the ponderosa pine and mixed-conifer types resulted in more open stands and that damage was largely confined to individual tree scaring and the mortality of seedlings and saplings. This last observation was also generally described by Show and Kotok for the Sierra Nevadas. Sudworth 1899 notes on the Sierra Reserve make mention of the ubiquitous nature of fire in all forest types. Flintham, however, makes special notes on the catastrophic nature of fire in the dense fir stands. He noted in particular the greater injury and introduction of stem rots from frequent ground fires as well as more extensive damage that resulted in the creation of brush fields.

The frequency of fire in the historic forest has often been attributed to native Indian burning (Weaver 1974). Interviews by historians with local native people also indicate that native people burned on a regular basis (Anderson 1992). In addition, cattlemen and sheepherders were responsible for lighting fires on the Sierra Reserve (Rose 1993).

Fire return intervals are generally shorter with decreasing elevation (Kilgore and Taylor 1979). Increasing amounts of white fir are found in areas with longer fire return intervals (North et al 2004). Examinations of fire return intervals within the Kings River Project have found some variation among mixed-conifer forest types with differences in the abundance of white fir and red fir. A study by Drum (1996) in the Kings River Project mixed-conifer–white fir type determined a mean pre-1900 fire return interval of less than 8 years on all sites prior to fire removal. Four of the six sites measured by Drum had mean fire return intervals less than 5 years.

Recent studies of fire return intervals in the mixed-confer forest in the Teakettle Experimental Forest in the mixed-conifer-red fir type indicate a fire return interval of 11.4 years (North et al 2004). The Teakettle Experimental Forest are located at higher elevations than the mixed-conifer forests in Drum's study. Widespread fire ceased after 1865 in the Teakettle experimental forest (North et al 2004). This lack of wide spread fire could be the result of increased grazing. Both Drum (1996) and North et al (2004) would indicate a fire return interval with in the range observed by others for the Southern Sierra Nevada (Wagner 1961, Kilgore and Taylor 1979, Skinner and Chang 1996). However, others have found an increase in fire return interval with changing aspect and elevation (Caprio and Swetnam 1995, Kilgore and Taylor 1979).

A fire return study in the ponderosa pine forest type in the Big Creek drainage found a mean fire return interval that ranged from 3.8 years to 2.2 years from 1770 to 1850 (Phillips 1998 highly significant predictor of fisher occurrence (Carroll et al. 1999 in SNFP FEIS, 2001, Vol. 3, Ch. 3, part 4.4, pg. 4). Identify stands larger than 1 acre classified as CWHR 5M, 5D, and 6 (SNFPA ROD, 2001, pg. A-26).

- Density of overhead cover is another predictor of fisher occurrence (Carroll et al. 1999 in SNFP FEIS, 2001, Vol. 3, Ch. 3, part 4.4, pg. 4). Landscapes with high levels of overhead cover may protect fishers from predation, reduce the amount of energy fishers expend when traveling between foraging sites, provide more favorable microclimates, and increase prey numbers or prey vulnerability (Buskirk and Powell 1994, Powell and Zielinski 1994 in SNFP FEIS, 2001, Vol. 3, Ch. 3, part 4.4, pg. 4).
- The core elevation range for marten is 5,500 to 10,000 (SNFP FEIS, 2001, Vol. 3, Ch. 3, part 4.4, pg. 20).
- Martens selected stands with 40 to 60 percent canopy closure for both resting and foraging and avoided stands with less than 30 percent canopy closure (Spencer et al. 1983 in SNFP FEIS, 2001, Vol. 3, Ch. 3, pg. 19).
- Various studies in the Sierra indicate that martens have a strong preference for forest-meadow edges, and riparian forests appear to be important foraging habitat (Hargis et al. 1994 in SNFP FEIS, 2001, Vol. 3, Ch. 3, pg. 19).
- Riparian conservation area standards and guidelines apply to: 1) den site buffers (or portions of den site buffers), and 2) great gray owl PACs (or portions of PACs) in riparian areas and critical aquatic refuges except where the standards and guidelines for den site buffers and great gray owl PACs place greater restriction on management activities (SNFPA ROD, 2001, pg. A-39).
    - There are no known locations of den sites in the Sierra NF; however, evidence of reproduction has been determined from physical examination of female fishers captured within the KRP area (Boroski 1999, Mazzoni 2001).

unpublished results)

While fire scar evidence without stand structure reconstruction, such as Drum (1996) or Wagner (1961), may over estimate the fire return interval (Baker and Ehle 2001). Short fire return intervals and stand reconstruction measured by Taylor (1991, 2003) and North et al (2004), would support both descriptions of frequent fire by native people, early observers and other fire history reconstructions for the Sierras and the Kings River Project (Skinner and Chang 1996). Some evidence of longer more intense fire return intervals does exist in dry forest types in the Southwest similar to forest types found in the Sierra (Baker and Ehle 2001).

The result of this frequent low intensity fire on the Kings River landscape was variable on stand structure and species composition. Within the stands dominated by ponderosa pine the effect was to maintain a seral pine type that was composed of irregularly spaced individuals at low density. While at higher elevations along main ridges or on north aspects the frequent fire produced vegetation that was a fine mosaic of small irregularly spaced groups. The fine scale mosaic of groups was determined by both soil depth, fuel bed and landscape location (North et al 2004). The frequent low intensity fire maintained the uneven-aged distribution. Areas of rock, lingering snow pack and low ground fuels provide barriers to fire that affected the coarse large scale pattern of vegetation. The effects of frequent fire and site conditions produce a vegetation mosaic that can be explained at the coarse scale by the Potential Natural Vegetation.

- No great gray owl PACs have been delineated within the KRP area, but presence and reproduction of great gray owls has been documented at the northern boundary of the KRP area.

- Evaluate locations of new landings, staging areas, and recreational developments, including trails and other disturbances (SNFPA ROD pg. A-27).
- Identify areas for acquisition, exchange, or conservation easements to enhance connectivity of habitat for old forest associated species. Assign a priority order for these species (SNFPA ROD pg. A-28).

The following table shows the CWHR classes for old forest associated species, which are defined in the SNFPA (2001).

CWHR[1]	**6**	**5D**	**5M**	**4D**	**4M**	**Other Criteria**
SPOW PAC/HRCA	x	x	x	x	x	≥ 50% canopy cover (CC)
NOGH Nesting[2]	x	x	x	x	x	≥ 40% CC
GGOW PAC	x	x	x			Meadow/Meadow Complex
Marten Den Sites	x	x	x	x	x	≥ 70% CC ≥ 9 trees/acre ≥ 24” dbh
Marten Travel/Forage	x	x	x	x	x	≥ 6 trees/acre ≥ 24” dbh
Fisher Den Sites	x	x		x		≥ 60% CC
SSFCA[3]	x	x		x		≥ 60% CC

The Kings River Project area is situated at the narrowest part of the Southern Sierra Fisher Conservation Area (SSFCA). This is also an area where there is the largest concentration of private land within the boundaries of the Sierra National Forest. The Forest Service cannot rely on private land to be managed in a way that is favorable for the fisher and other species associated with old forests. Thus, the National Forest land base could prove important for the maintenance of habitat linkages for old forest species.

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[1] CWHR Classes:

6 Multi-layered, tree size class 5 (dbh > 24”) over a distinct layer of size class 4 (11-24”) or 3 (6-11”) trees, total tree canopy exceeds 60% closure.
5D Dbh > 24” and canopy cover 60-100%
5M Dbh > 24” and canopy cover 40-59%
4D Dbh 11” – 24” and canopy cover 60-100%
4M Dbh 11” – 24” and canopy cover 40-59%

[2] The best available forested stands for Northern Goshawk PACs have the following characteristics: 1) trees in the dominant and co-dominant crown classes average 24” dbh or greater; 2) Westside conifer stands have at least 70 percent tree canopy cover (SNFPA ROD, 2001, pg. A-36).

[3] Southern Sierra Fisher Conservation Area outside the urban wildland intermix zone. Manage each planning watershed to support fisher. Retain 60 percent of each 5,000- to 10,000-acre watershed in CWHR size class 4 or greater and canopy cover greater than or equal to 60 percent.

This and the information above were taken into consideration in the designation of the old forest linkage (OFL) within the KRP area. The process used to designate the OFL for the KRP is described below.

Vegetation data, owl locations, and stand boundaries were examined as the first step to identify the OFL areas within the KRP. The objective was to identify areas that should be managed to maintain connectivity of old forest habitat areas within the KRP area as well as the rest of the Sierra National Forest to the north, east, and south. Some of the OFLs follow roughly the same path as those identified in the LRMP. The majority of these OFLs are within the SSFCA. The OFLs outside the SSFCA are intended to maintain habitat connectivity for marten and spotted owls. The process used to create the OFL GIS coverage is described below.

An initial linkage map was created from the unconstrained stand map. A new field "OF Link" was added to the table for the map. The locations of perennial and intermittent streams were determined from the stream maps. Any stand in the initial linkage map that touched a perennial or intermittent stream was coded with a "Y" in the "OF Link" field. Ridge top saddles were used when needed to link the stream corridors together.

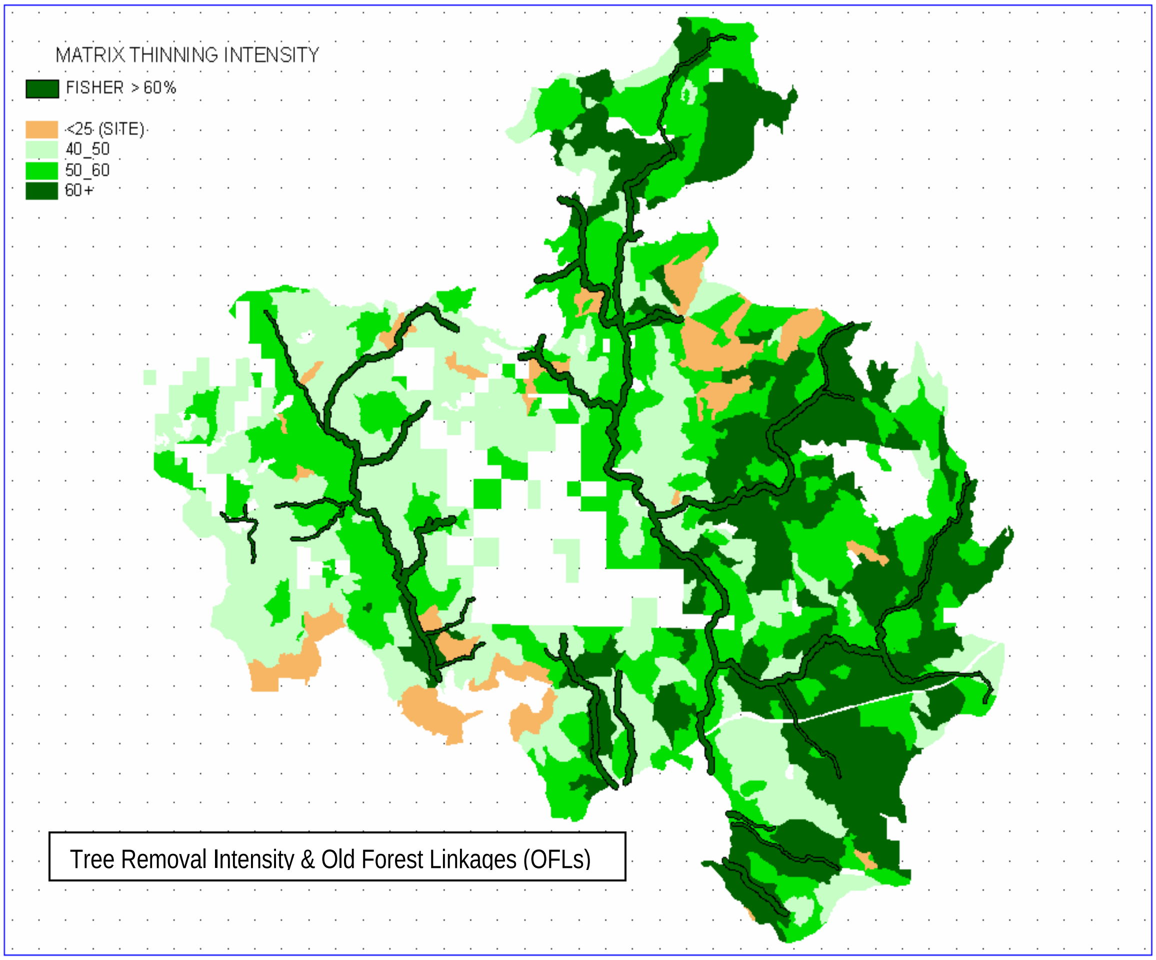
Several habitat linkages are needed to ensure habitat connectivity in the event that a linkage is lost to a catastrophic event, such as wildfire. Habitat on private land was not considered as a contribution to the OFL, for the reasons stated above. Therefore, OFLs were only designated on Forest Service land around blocks of private land. OFLs would be maintained through retaining greater than 50 percent (pine type) or greater than 60 percent canopy cover, and at least 40 percent crown canopy cover in stands in between. There are two major OFLs extending north to south along Big Creek and Dinkey Creek. They are linked together from east to west at the northern and southern portions of the KRP area. The OFLs that were designated and the supporting rationale are described below.

> **Big Creek and Dinkey Creek –** Track plate surveys and radio telemetry studies have verified that fisher occupy the KRP area. Radio telemetry work shows concentrations of fisher rest sites in two areas. Spotted owl PACs are also concentrated in these two areas. The OFLs designated along Big Creek and Dinkey Creek are intended to provide a north south linkage of fisher and spotted owl habitat for these two areas. The Dinkey Creek OFL extends up into the Dinkey Lakes Wilderness. The Dinkey Creek OFL is intended to link with the upper reaches of Tamarack Creek outside the KRP, and to provide habitat connectivity for marten and spotted owls.
>
> **Nutmeg Creek –** This is the area just outside the southwest corner of Southern California Edison's (SCE) Dinkey Lands, and it is at the lower elevations of the Southern Sierra Fisher Conservation Area. The ridge top saddle west of the upper reaches of Nutmeg Creek was designated as OFL to ensure connectivity between Big Creek and Dinkey Creek at the southern portion of the KRP area. This OFL includes Bear Meadow Creek and Big Creek.

Bear Meadow Creek and Oak Flat Creek – This is the area directly south of SCE's Dinkey Lands, between Big Creek and Dinkey Creek. This OFL was designated because the area is within the home ranges of one or more fishers. Several spotted owl PACs and a goshawk PAC are in this area.

Summit Creek and Grand Bluff – This is the area northwest of SCE's Dinkey Lands and south of SCE land around Shaver Lake. Two linkages were designated; one is along Summit Creek, and the other is along an unnamed tributary to Big Creek that is south of Summit Creek and north of Providence Creek. These two linkages straddle a block of private land that is situated northeast of Grand Bluff, and link Big Creek and Dinkey Creek at the northern portion of the KRP area. The OFL along Summit Creek overlaps an area where several fisher rest sites were found. There are also several spotted owl PACs in this area.

Although both of these OFLs are within the WUI, they may be critical to maintain connectivity with habitat outside of the KRP east of Shaver Lake. Maintaining a linkage east of Shaver Lake is critical for fisher because the quality of habitat west of Shaver Lake is compromised by the extensive development on private land, the community of Shaver Lake, and Highway 168. Fisher are known to occur on the private land and may be able to travel over approximately 3 miles of private land to access the San Joaquin River drainage. However, this private land area is within the WUI where the vegetation treatments to be implemented would reduce the canopy cover. The reduction of canopy cover may reduce the quality of habitat for fisher and expand the extent of low-quality habitat to approximately 4.5 miles.



Bald Mountain and Rock Creek - This is where the Summit Creek and Grand Bluff OFL join together to form a link between the upper reaches of Big Creek and Rock Creek, which is a tributary to Dinkey Creek. This OFL leads to the Tamarack Meadow area outside of the KRP, and is at the upper elevation limit for the fisher. The Rock Creek OFL also provides habitat connectivity for marten and spotted owls.

Cow Creek – This OFL extends northwest from the Dinkey Creek OFL up to the higher elevations and outside the elevation range for the fisher. The Cow Creek OFL is intended to maintain connectivity of habitat for marten and spotted owl.

Bear Creek and Deer Creek – These OFLs extend northeast and link with the Dinkey Creek OFL. They provide habitat connectivity for fisher, marten, and spotted owl. They are intended to link with habitat outside the northeast boundary of the KRP.

East Deer Creek and House Meadow Creek – These OFLs are along the East Fork of Deer Creek and House Meadow Creek. They are intended to provide an east west linkage of habitat extending east from Dinkey Creek to habitats at both higher and lower elevations beyond the KRP.

Bull Creek – This OFL extends south and east from House Meadow Creek linking to habitats outside the KRP. This OFL is intended to link to the Teakettle Experimental Forest and beyond to lower elevations of habitat for fisher and spotted owl.

Turtle Creek and Ross Creek – This OFL extends south and east from Dinkey Creek and is intended to link to lower elevation habitats beyond the KRP boundary. This OFL is intended primarily for fisher and spotted owls.

Taking the old forest linkages, the wildland urban intermix, defensible fuel profile zones, historic density, slope, and aspect into consideration, stand canopy cover targets were developed. The OFLs within stands would be maintained along the identified perennial and intermittent creeks. The table below displays stand-wide tree removal intensity for the uneven-aged silvicultural system in terms of canopy cover constraints.

	WUI Land Allocation	Other Land Allocation	Aspect	Range of Canopy Cover	Pine Cover	Mix-conifer Cover	True Fir Cover
Outside WUI	None	Hrca	All aspects	The higher of historic density or 40 %			
Outside WUI	None	Hrca + Fisher Old forest linkage	All aspects	50-60	50	60	60
Outside WUI	None	PAC	North to East	60	60	60	60
Outside WUI	None	PAC	South to West	40-50	40	50	50
Outside WUI	None	PAC + Fisher Old forest linkage	All aspects	60	60	60	60
Outside WUI	None	Fisher Old forest linkage	North to East	50-60	50	60	60
Outside WUI	None	Fisher Old forest linkage	South to West	50-60	50	60	60
WUI	None	Low site	All aspects	<40	<40	<40	<40
Outside WUI	None	Other	All aspects	The higher of historic density or 40 %			
Inside WUI	Defense	PAC	All aspects	40-50	50	50	50
	Threat	PAC	North to East	50-60	50	50	60
	Threat	PAC	South to West	40-50	40	40	50
	Defense/threat	Fisher Old forest linkage	All aspects	40-50	40	40	50
	Defense/threat	Hrca	All aspects	40-50	40	40	50
	Defense/threat	Low site	All aspects	<40	<40	<40	<40
	Defense/threat	Other	All aspects	The higher of historic density or 40 %			

Stands were coded with new density codes based on the new canopy cover constraints. The dominant topographic aspect for a stand was used to assign the tree removal intensity. This resulted in OFLs dominated by tree removal intensity generally retaining greater than 50 percent canopy cover outside WUI and DFPZs. Major perennial and intermittent streams were designated with canopy cover retention greater than 60 percent. (See map above of Tree Removal Intensity & Old Forest Linkages.)

The majority of the spotted owl PACs and HRCAs within the KRP are in or adjacent to the OFLs. Most California spotted owl PACs and HRCAs that are outside of OFLs are at the lower portion of the Big Creek watershed. All but one of the nine northern goshawk PACs that are within the KRP are in or adjacent to the OFLs. As surveys for goshawks are completed it is likely that additional goshawk PACs will be designated, and additional OFLs may be needed. The OFL areas are not intended to represent all the areas that need to be managed for old forest associated species.

Spotted Owl PACs and HRCAs

Researchers indicated that some consideration for the protection of PACs in particular would be necessary. The landscape group developed a strategy that maintains the structural elements important for spotted owl foraging and nesting habitat (Verner 1992), but still treats the WUI. PSW researchers identified treatment areas for research including some in spotted owl PACs. Treatments proposed in PACs include those for Kings River Experimental Watershed study and the California spotted owl study. PACs involved in the spotted owl research would be treated as described for PACs in the defense zone of the WUI under the 2001 SNFPA. PACS not included in research studies would receive either underburning only or the SNFPA 2004 prescription. This would be the management strategy for at least the first five years, or until the Forest Service can demonstrate through the study that the Forest Service can treat PACs and maintain owl productivity across the landscape.

Canopy layering, less pine species, and more fir and incense cedar would be emphasized in the PACs, except in the WUI where single story stands would be emphasized to reduce the ladder fuels. Stands outside of the WUI would emphasize multi-story stands. HRCAs would be treated with the uneven-aged strategy.

Treatment Scheduling and Intensity

Treatment schedules were constrained by the need to disperse treatments across the landscape and through time. Recent work with fishers within the KRP indicates that female fisher home ranges average approximately 1200 acres and tend to overlap significantly (Mazzoni 2002). In an effort to reduce the potential to affect more than a third of a female fisher home range at one time, management units were constrained by a limit on the size to average 1200 acres. This average size is roughly 1/3 of a female fisher home range. In an effort to further limit the impact of a project or group of projects on a fisher home range, treatment of management units would be dispersed by a minimum of five years. Thus management units would have an adjacency rule that would limit when neighboring management units could be implemented. This would have the effect of dispersing impacts rather than concentrating impacts. However, treatment of the WUI would still take precedence over dispersion, if necessary.

The landscape group redefined management units into areas that conformed to the 1200 acre project size objective. Management units identified during the unconstrained proposal were divided into smaller management units. The size would be approximately 1.3 of a fisher home range. Management units in the constrained proposal now average 900 acres. Eighty management units were identified for the constrained uneven-aged strategy.

The five year dispersal rule was assigned across the entire landscape. One area within the WUI could not be dispersed. This area coincided with the Providence Experimental Watershed and WUI. This resulted in no dispersion of treatments for areas adjacent to the Providence Experimental Watershed.

The landscape group also incorporated NEPA and project planning and implementation into the project schedule. Two years of planning would be followed by three years of implementation. This would allow the KRP team to learn from the previous round of implementation, then to complete the needed NEPA work for the next set of projects.

Research Constraints

Research proposals constrain treatments by limiting the range of treatments and reducing the variability among treatment intensity. Current research projects include a forest bird study (Purcel), experimental watershed study (Hunsaker), spotted owl study (Keene), and fisher population study (Purcel). Proposed studies include uneven-aged management research, spotted owl response to treatment, fisher response to treatment, and fire modeling research. Research control plots require no planned activity. Manipulated plots often overlap different research studies. This overlap requires coordination between researchers to agree upon appropriate treatments for study. Ultimately stands involved in research are labeled with the necessary constraint on activities. Some stands could be burned but not mechanically treated. Other stands could be mechanically treated and not burned. Some require that both burning and mechanical treatment occur. Research needs often require the same intensity of treatments. Coordination between district specialists and staff are required to coordinate all activities. Research activities that require burning have to meet the same criteria for fire control points and safety as in the unconstrained treatments.

Constrained Treatment Maps

The stand coverage produced for the constrained treatment contained several additional data attributes for each stand.

Field name	Attribute description	Attributes
Manage_cnst	These are constraints on the ability to implement the uneven-aged strategy	
Logsys_cnst	Constraints that require or exclude a logging system	Control, mechanical, no-mechanical
Fuel_cnst	Constraints that require or exclude a fuels prescription	Control, burn, no burn
Matrix_int	The residual basal area used to describe the J-shaped curve for the matrix tree removal expressed in terms of a canopy cover range	S = <40%CC P = 40-50% CC M = 50-60% CC D = >60% CC
Fisher_cor	Stands that include old forest linkages	Yes or no
Proj_name	Names of projects under the constrained treatment plan	
Proj_year	Project year of the constrained treatment	

Figure H6: Picture of mixed conifer stand in the Kings River Project area in 1900 taken by George Sudworth. The photo is close to the KREW_Prov1 management unit. Sudworth's caption follows: *"Yellow pine forest on north side of Big Creek toward south slope - top of ridges. Timber similar to measurements taken on Little Kern River at Shot Gun Creek camp. Chiefly yellow pine, white fir and incense cedar. Shows the bare forest floor subject to frequent surface fires which have scarred tree trunks, see blackoned portions. Very little reproduction except in occasional small patches in open spaces."*

Figure H7: Photo of ponderosa pine forest at lower elevations of Big Creek, *"Interior of yellow pine forest on so. Slope of Big Creek. Incense cedar mixed 5 to 10%."* Quotation and photo by George Sudworth, 1900.

APPENDIX C1

Canopy Cover and Residual Stand Density

How do we relate a desire to maintain canopy cover at a particular level with the J-shaped curve used to thin the matrix between groups or regeneration areas. Canopy cover expressed in leaf area and stand density represented by stem number or relative measures such as percent of normal or stand density index (Assmann 1970, Dean and Baldwin 1996, Rieneke 1933) are related. The stem supports the crown and the larger the crown the bigger the stem needed to support it. This relationship between crown and stem has also been explained by cantilever beam analysis (Dean and Long 1986) and analyses that have found a strong relationship between the specific gravity of species and Rieneke's stand density index (Dean and Baldwin 1996). Dean and Baldwin (1996) have directly related stand density index to foliage density and live crown ratio.

An acre will support limited amounts of canopy cover. Research in Europe related simple geometric shapes of crowns to potential maximum canopy cover at full site occupancy (Assmann 1970). Crowns arranged in squares have a maximum cover of 70 percent, while crowns arranged along equilateral triangles have a maximum cover of 96 percent. That is, the area not covered by crowns is greater when trees are arranged in squares. Both arrangements express the potential canopy cover at full site occupancy. Now forests with few exceptions are rarely found in either squares or triangles but tend toward some arrangement in between. The point is that crown canopy cover will reach a maximum. This maximum cover can be explained by how crowns are arranged on an acre.

Tree species and shade tolerance appear to move stands toward the most efficient canopy cover for that species. Evidence of the relative efficiency of shade tolerant species to occupy more space can be seen in the comparison of maximum stand density index for ponderosa pine and white fir. Maximum SDI for ponderosa pine is 571, while white fir is 759 (Crookston 1979). A similar comparison of normal basal area reveals that at any given stage of development fir is relatively more efficient at occupying more stem area and thus more canopy. This higher efficiency is obvious. While an acre remains the same size, packing more stems, and thus more canopy cover onto the acre requires a more efficient use of growing space.

Crown closure occurs rather soon in a stands life. Crown closure occurs in even-aged stands at full site occupancy (Oliver and Larson 1996). However trees are arranged, crowns close and then change little when there is no mortality. As trees age they grow taller. Crowns expand until crowns begin to abrade. (Oliver and Larson 1996). After crown closure tree crowns lift as lower limbs die. Further height growth only results in shortening of the crown. No more canopy cover or foliage area is captured. This is especially true for conifers with strong epinastic control (Oliver and Larson 1996); that is crowns that maintain a single leader. As mentioned earlier when trees reach crown closure or full site occupancy these trees will cover 70 to 96 percent of an acre.

Trees are rarely distributed evenly. This is due to the variability of available growing space across a stand. Rock, low site quality, and roads affect the ability to occupy an acre with crown. Some reduction for these limiting factors is necessary to determine the actual canopy cover potential. An approximation would indicate that 10 percent would likely cover the reduction due to rock and low site on the average. Thus the true maximum canopy cover for any arrangement is likely 60 percent (squares) to 86 percent (triangles). Any unoccupied growing space will result in less than maximum canopy cover.

Full site occupancy and crown closure occur between 25 percent and 35 percent maximum SDI (McCarter and Long 1986, Drew and Flewelling 1979, Dean and Baldwin 1993). This is a zone, not a line, due to the variability in genetic potential. Nevertheless, the zone is relatively narrow and predictable for any species regardless of site quality. Mixtures of species will tend to occupy growing space somewhere between the maximum for each species. Typically a weighted average relative maximum is used to identify the relative use of growing space. The relationship between canopy cover and stand density makes it possible to define a density management scheme to achieve a canopy cover objective. Using these relationships between stem and crown, it is also possible to assess the potential for reaching a canopy cover objective.

The ability of stands to occupy growing space and provide canopy cover at full site occupancy has consequences for meeting stand objectives. In a ponderosa pine stand that tends to have lower relative stand density, and thus provide less leaf area index, a canopy target of 70 percent may be largely unattainable in single story stands. Additional canopy cover would occur through encroachment of shade tolerant species in the understory or not at all. This same objective for true fir stands is easily achieved in single storied stands because of the higher relative density. Multi–storied stands in true fir tend to be a result of disturbance to the upper canopy that allows unoccupied growing space. Otherwise fir stands tend to have canopy densities that do not allow for the second or third understory layer (Taylor 2001, Battles 2000).

Both PSW researchers and Forest management staff have spent a considerable amount of time evaluating different crown canopy measurement tools in the Kings River Project. The result of these field investigations has been that different measurement devices will provide different results for canopy cover for the same area. See the following table that was developed by Landram (2002) and represents unpublished results comparing different crown canopy measurement methods within the Kings River Project Area. They also related the canopy cover measurement from photo-interpretation to basal area. The sample of 32 polygons (300 plots) for basal area, densiometer, site tube, moose horn and photo interpreted canopy cover indicate a strong correlation. The relationship between basal area and canopy cover indicates about 78 percent of the variation in cover could be explained by the variation in basal area. A similar analysis of pine was done using Steger's photo-interpreted canopy cover and plots collect by the District; about 70 percent of the variation in cover could be explained by the variation in basal area for ponderosa pine.

The following table displays canopy density for different instruments, photo interpretation and calculated using the R5 Forest Inventory Analysis equations.(Landram 2002)

	CANOPY COVER							
	Photo Interpretation						R-5 FIA	R-5 FIA
Polygon ID	1997	2001	Densiometer	Moosehorn	SitingTube	Funnel	Overlapping	Non-overlapping
1863	25%	25%	41%	20%	20%	26%	28%	24%
2108	25%	30%	46%	31%	30%	37%	37%	31%
1912	30%	30%	65%	29%	29%	38%	48%	38%
2591	30%	25%	41%	27%	28%	29%	25%	22%
1546	35%	40%	46%	19%	20%	26%	37%	31%
2091	35%	25%	33%	13%	13%	22%	25%	22%
2253	35%	40%	61%	40%	40%	50%	45%	36%
3776	40%	40%	49%	34%	35%	37%	36%	30%
1231	45%	45%	82%	66%	67%	72%	95%	61%
2120	45%	40%	59%	39%	38%	49%	57%	43%
3187	45%	35%	69%	46%	46%	58%	62%	46%
1455	50%	55%	59%	38%	41%	45%	50%	40%
1990	55%	65%	86%	63%	62%	78%	108%	66%
2332	55%	60%	76%	54%	54%	64%	62%	46%
3559	55%	55%	72%	41%	42%	55%	51%	40%
1890	60%	55%	69%	41%	42%	51%	75%	53%
672	65%	60%	78%	59%	59%	68%	63%	47%
872	65%	55%	72%	45%	43%	55%	88%	58%
956	70%	65%	73%	50%	49%	62%	73%	52%
2640	70%	70%	91%	80%	80%	86%	111%	67%
55	75%	75%	83%	65%	66%	75%	80%	55%
851	75%	75%	88%	71%	73%	80%	97%	62%
2595	75%	80%	85%	72%	69%	77%	108%	66%
3476	75%	70%	89%	72%	76%	79%	98%	63%
1366	85%	80%	76%	51%	54%	58%	93%	61%
1645	85%	90%	95%	86%	88%	93%	111%	67%
1989	85%	80%	91%	78%	82%	87%	121%	70%
2564	90%	85%	87%	73%	74%	83%	141%	76%
1357	92%	90%	89%	66%	69%	76%	101%	64%
2742	95%	90%	94%	82%	84%	89%	97%	62%
3852	95%	95%	96%	92%	92%	94%	104%	65%
3973	95%	90%	97%	92%	92%	96%	144%	76%
average	61%	60%	73%	54%	55%	62%	77%	51%
r squared	1.00	0.95	0.77	0.76	0.78	0.77	0.75	0.77
std dev	23%	22%	18%	22%	23%	22%	34%	16%
intercept	0%	2%	-18%	13%	13%	5%	16%	-2%
slope	1.00	0.99	1.08	0.89	0.88	0.91	0.58	1.23

The following two tables display and compare the canopy cover and basal area relationship. This relationship between basal area and canopy cover was used to assign basal area targets from the landscape canopy cover objectives assigned to each stand.

The following tables display desired canopy cover for mixed conifer and ponderosa pine and the basal area (ft2) needed to achieve the canopy cover. Adjacent columns display the percent of normal basal area by Dunning and Rieneke and Meyers site class, respectively. Greater than 90 percent of normal basal area is the zone of eminent density induced mortality and loss by insects.

Mixed Conifer based on Equations by Landram & Steger

Dunning and Rieneke Index

Desired canopy cover	Desired basal area/acre	Rx canopy cover	Rx % normal SI 80	Rx % MCnormal SI 60	Rx % MCnormal MC SI 50	Rx % normal MC SI 40
70	333	68	95	107	113	119
65	300	65	86	96	102	108
60	267	62	76	85	91	96
55	233	56	67	75	79	84
50	200	50	57	64	68	72
45	167	44	48	53	57	60
40	133	41	38	43	45	48
35	100	35	29	32	34	36
30			sparse or younger than 30 years			

Ponderosa pine based on Equations developed in Kings River

Meyers Index

Desired canopy cover	Desired basal area/acre	Rx canopy cover	Rx % normal PP SI 120	Rx % normal PP SI 100	Rx % normal PP SI 80	Rx % normal PP SI 60
70	287	69	111	126	146	170
65	260	65	101	114	132	154
60	234	61	91	103	119	138
55	207	54	80	91	105	123
50	181	50	70	79	92	107
45	154	46	60	68	78	91
40	128	40	49	56	65	76
35	101	35	39	44	51	60
30	75		sparse or younger than 30 years			
25	48		sparse or younger than 30 years			

The tables above for mixed-conifer and ponderosa pine display the relationship between canopy cover and basal area for ponderosa pine and mixed-conifer in the KRP. Maximum canopy density varies by site and type. Columns for the ponderosa pine type indicate that they will not exceed 70 percent canopy cover for long before insects or other density induced mortality reduces cover. The mixed-conifer type can sustain higher canopy cover and for longer periods before insects and disease reduce tree density. Density is displayed for high and low sites using Dunning and Rieneke's mixed conifer site curves and Meyer's ponderosa pine site curves. The grey shaded rows indicate canopy cover subject to density induced mortality.

APPENDIX C2

The Uneven-aged Silvicultural Strategy (Prescription) Kings River Project November 2004

Introduction

The uneven-aged silvicultural strategy addresses the objectives of the Kings River Project to achieve historic landscape conditions through altering current stand structure and species composition and returning fire to the ecosystem. The uneven-aged strategy identifies general methods used to implement uneven-aged silviculture for the Kings River Project. Individual proposals in the Kings River Project may change or alter these general principles to meet specific stand objectives or concerns.

The objective of the uneven-aged silvicultural strategy is to approximate a balanced or regulated uneven-aged stand. A histogram depicting the diameter distribution of trees in the stand (trees per acre vs. diameter class) approaches a smooth, inverse J-shaped curve (*fig. B1*), described in detail by Alexander and Edminster (1978). It has three key parameters. First is slope, which results from the diminution quotient (Dq—a value that, when divided into the number of trees in one size class, gives the number of trees expected in the next smaller size class). Second is the largest size a tree is allowed to grow before being harvested. And, third is the stocking level (basal area of trees per acre) represented by the area under the curve.

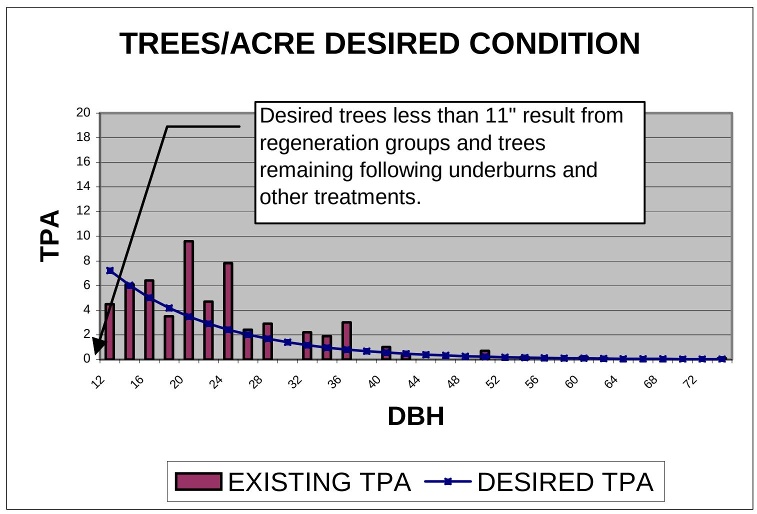


Figure B1 Desired trees per acre by two inch diameter class using a Dq of 1.2. The resulting curve is described as J-shaped.

The uneven-aged prescription is applied across a stand. Both the reforestation groups (RGs) and the matrixes (areas between reforestation groups) are part of the regulated stand. RGs ensure conditions for growing seedlings and the matrix provides growing space for larger trees. Treatments within the matrix are similar to thinning. Treatments in RGs are similar to plantation management. Matrix trees are provided growing spacing through tree removal across all diameters.

The smooth, inverse J-curve was selected to regulate stands for the following reasons:

- "Reverse J-shaped diameter frequency distributions have been observed in forests for several centuries. . . . the reverse-J diameter distribution has always been most constant when applied to large areas . . . " (O'Hara 1998).
- "The negative exponential distribution has long been used to approximate the structure of uneven-aged stands" (Guldin 1991).
- It is conceptually and mathematically easy to describe and understand.
- Uneven-aged management using groups and J-curve has proven sustainable as practiced in mixed-conifer stands in the Sierra Nevada (Heald et al 1996).

Reforestation and Recruitment

The numbers of saplings and poles needed to provide adequate growth into the large tree classes is usually a significant influence on the beginning point of the J-curve (number of trees per acre in the smallest diameter class) and its Dq. For the Kings River Project, however, two contradictory objectives influenced the beginning point. Silviculturists desired to have sufficient numbers of small trees to assure growth into the larger diameter-classes, but fuels specialists wished to minimize the contribution of seedlings, saplings, and poles to fuel ladders leading into the upper tree canopy. Analysis and discussion lead to the compromise values for the reforestation groups. Thus, the seedlings within reforestation groups would provide the stocking levels predicted in the J-curve. They would occupy 10 percent of each stand based upon 20-year reentry cycle and 200 years to achieve the tree of maximum size in the J-curve.

We did not expect a typical acre to be fully stocked with conifers, estimating instead that 80 percent would be occupied by conifers, 10 percent by large oaks, and 10 percent by rock patches and other openings. Thus the stocking of conifers in the smaller diameter classes (1 to 11 inches) of the J-curve should be approximately50 trees per acre in ponderosa pine stands and 110 in mixed-conifer stands.

a. Locating reforestation groups

Guidelines for locating reforestation groups focus on finding under-stocked areas within a stand that have resulted from past harvest, small fires, and insect-caused mortality. Usually under-stocked areas are evident because the majority of the area in most stands is moderately to densely stocked. In stands with few or no under-stocked areas, RGs would be placed in plant aggregations with excesses in a size/age class. RGs are limited to three acres. Once identified by the crew walking through the stand, the RG boundary will be located by expanding the under-stocked area until edges are located where the stand is at least moderately stocked with trees to a maximum of three acres.

b. Regeneration methods (providing legacy trees and growing space)

Regeneration methods seek to leave legacy structures that provide vertical and horizontal diversity and opportunities to grow young conifers and oaks. In general, RGs will maintain up to one third of the potential stocking level (BA or SDI) for the Dq 1.2. This leaves all trees larger than 35 inches dbh in RGs. Where there are no trees larger than 35 inches dbh then four trees larger than 24 inches will be left. If no trees larger than 24 inches are present no legacy trees will remain. By leaving trees over 35 inches, up to one third of the potential basal area will provide a legacy of large trees on the landscape. RGs would generally appear to have a seed tree or light shelterwood appearance.

In the initial version of the uneven-aged prescription for the KRP no limits were placed on the methods to achieve regeneration. The method first employed in groups was essentially a small clearcut. All merchantable trees larger than 10 inches dbh within the groups were removed. This method was successful in achieving regeneration of intolerants. However, structural changes were dramatic and several ecologists felt uncomfortable with the lack of structural diversity. The current adaptation insures that the largest trees on the landscape will remain.

c. Brush field regeneration

Brush fields larger than three acres will be reforested to create a diverse structure and at least three age classes. To accomplish this objective, reforestation in brush field groups will involve at least three plantings over 20 years and variation in precommercial thinning of the RGs.

Tree Distribution - Applying the inverse J-shaped curve

The desired tree distribution is determined by the three factors mentioned above: residual stocking level, (Dq), and the largest tree size. The Dq defines the number of trees in one diameter class vs. the number in the next smaller class. The residual basal area and the size of the largest tree define the number of trees to leave in each diameter class. Previous versions of the J-curve in the Kings River Project had a residual stocking level determined by site, forest type, and land allocation (Smith and Exline 2002). This early approach removed trees that exceeded the maximum tree size. Several research cooperators believed that this approach was depleting a limited and very important ecological component of the stands (very large trees). A new approach has been developed that will change how large trees are maintained on the landscape and residual stocking is assigned to each stand. While normal yield tables and stand density index have been used to determine the maximum residual stocking, canopy cover objectives and legacy tree objectives will help determine the residual stocking levels across the landscape.

a. Age and diameter distribution - Diminution quotient

Different Dq's for a J-curve comprised of 2-inch diameter classes were tried and discarded until the J-curve that satisfied the desired number of saplings and poles for regeneration groups was achieved. This resulted in a Dq of 1.2 and it has a rather flat distribution curve with greater growing space allocated to trees larger than 24 inches dbh. The use of this flat distribution has been used by others to represent the pre-settlement forests and mimic the frequent disturbance pattern of the Sierra Nevada and Kings River Project area (Hollenstein et al 2001).

b. Residual stocking

The stocking level of trees was taken from even-aged yield tables, based on the suggestions of Curtis (1978) and Foiles (1978). Commercial tree removal schemes were developed both for groups of existing trees and for new groups established by reforestation using the Forest Vegetation Simulator (FVS) and professional judgment. Desired maximum basal area per acre or residual stocking was set at 65 percent of full stocking (growing space 100 percent occupied) in the applicable yield table, which, according to FVS, would result in stands returning to 85 percent of full stocking in about 20 years (*fig. 3*). The desired basal area would be expected to maintain a healthy stand with moderate growth and a canopy cover between 40 and 70 percent. Canopy cover was measured following treatments. These post treatment measurements indicated that canopy targets were met for most stands in treatments completed in 1996.

This revised uneven-aged silvicultural strategy seeks to have a desired canopy cover play a significant role in dictating the residual stocking level. Recent work by Landram and Steger (2002 unpublished) has developed a linear equation that explains 78 percent of the variations in photo-interpreted canopy cover by the variation in basal area. The work was completed within the Kings River Project. This basal area and crown canopy relationship is consistent with other work that has found a strong relationship between canopy cover expressed in leaf area and stocking level represented by stem number or relative measures such as percent of normal basal area or stand density index (Assmann 1970, Dean and Baldwin 1996, Rieneke 1933). The strong relationship is the result of the supporting function of the stem (Oliver and Larson 1996); the stem supports the crown and the larger the crown the bigger the stem needed to support the crown. The table below describes the desired canopy cover and the corresponding residual stocking level in terms of stand density index and square feet of basal area per acre. Each range in canopy cover is applied to meet objectives outlined in the landscape treatment strategy.

Canopy cover objectives also incorporate the need to maintain stands below a level that could lead to catastrophic insect attack. The different residual stocking levels for ponderosa pine and mixed conifer stands reflect the known thresholds for insect mortality. The ranges allow for the variation in site quality.

DESIRED CANOPY COVER RANGE	PERCENT OF MAX STAND DENSITY INDEX	DESIRED RESIDUAL BASAL AREA PER ACRE MIXED-CONIFER	DESIRED RESIDUAL BASAL AREA PER ACRE PONDEROSA PINE
60+	60	267 +	246 high site only
50 TO 60	45 TO 60	200 TO 267	200 TO 246
40 TO 50	35 TO 45	133 TO 200	120 TO 200
25 TO 40	25 TO 35	33 TO 133	25 TO 120

In the table above, mixed-conifer ranges are based on unpublished data in the KRP by Landram and Steger, 2002. The ponderosa pine ranges are based on maintaining stands below the level of catastrophic insect attack and canopy measurements on the 10S18 Project.

Field implementation of the desired residual basal area displayed in the table is limited by measurement tools such as standard prism or releskop. These tools typically allow measurement in increments of ten and have a certain number of desired trees (Barber 1984).

c. Maximum tree size and age

Our approach to determining the largest tree size used to define the shape of the J-curve was driven by a desire to maintain the presence of very large trees in the stand. Initially, we estimated the diameter at breast height (dbh) in inches, expected in 200 years, based on professional judgment and data from yield tables (Dunning and Reineke 1933, Meyers 1938). Subsequent modeling with the uneven-aged routine in the Forest Vegetation Simulator (USDA 1996) resulted in the following diameters at 200 years of age:

	Good Site	Poor Site	Avg. Site
Thin at 50 yrs. then every 20	58"	49"	54'
No Removal	39"	33"	36"

Assuming actual management would involve some tree removal, but probably not every 20 years after the initial commercial uneven-aged silvicultural tree removal, it appears reasonable to set the maximum dbh expected in 200 years at 50 inches in ponderosa pine and 55 inches in mixed-conifer. The higher expected dbh in mixed conifer reflects a significant presence of sugar pine, which maintains a higher growth rate for a longer time than ponderosa pine or white fir (Oliver 1992).

d. Legacy stocking in the matrix

Large trees are an especially important component of habitat for many wildlife species such as spotted owl and fisher (Verner et al 1992, Mazzoni 2002). Maintaining as many large trees in the landscape as possible is important for habitat suitability. To decide how to accomplish this objective, the following different approaches were considered:

- Silviculturists define an uneven-aged stand as one with trees of three or more distinct age classes (Smith 1986, Oliver and Larson 1996). The largest trees are the ones in the oldest third of the age classes.

- Ecologists describe large trees as the large old ones whose retention is essential to maintaining ecosystem processes (Franklin per com).

The objective can be accomplished by retaining the trees that would potentially make up the oldest third of the age classes in the stand (the large trees) and developing the historic uneven-aged structure and species composition, as much as possible, by working on the young and middle age classes. Similar approaches for retaining large trees have been used in the southwest (Covington et al 1997). Model results using uneven-aged treatments in the Sierra Nevada have demonstrated the feasibility of maintaining the largest third of the diameter distribution to keep large trees in the landscape (Hollenstein et al 2001).

The young and middle age classes would be that portion of the residual matrix stocking that will be regulated by the J-curve (the lower two thirds). Leaving the upper third of the J-curve as legacy trees will ensure that large trees remain well distributed across the landscape. As described in the regeneration section, one-third of the residual basal area will be maintained in large trees to the extent trees over 24 inches dbh are present. Typically, one-third of the residual stocking level (BA) for the Dq 1.2 will be maintained in large trees in the matrix. At a Dq of 1.2 and using a large tree size (the right tail of the J-curve) of 58 inches, this uneven-aged silvicultural strategy leaves one-third of the residual stocking in trees larger than 35 inches dbh. In stands with a residual stocking of 200 ft^2/acre basal area, one-third equals 66 ft^2/acre basal area. All trees larger than 35 inches dbh up to 66 ft^2/acre basal area will remain. This stocking level provides room for large trees and room to regulate the distribution of young and middle age diameter classes per the J-curve.

One could argue some amount other than one-third of the potential basal area should be retained in large trees, even to the extreme such as only ten percent or all trees over 20 inches dbh. The former, in the opinion of silviculturists and ecologists involved in the development of this uneven-aged strategy, would not be sufficient to maintain the ecological process dependent on large trees. The latter would limit the range of diameter class that could be manipulated to such an extent that it would not be a reasonable trial of the uneven-aged management system. Ultimately it is a judgment call based on definitions of uneven-aged management in the literature and the perspective of ecologists that must be used to set the proportion of the potential basal area to be retained in large trees.

e. Growing space for oaks

How much growing space should be allocated for oaks with desirable decadent qualities is an important question. Since oaks are rarely harvested in a typical forest treatment, the question is better stated as, “When should we remove trees from around desirable oaks?” Oaks with cavities are typically the result of overtopping from conifers and decadence (McDonald 1990). The resulting overtopped oaks often have only one stem as a result of successive mortality of branches. This overtopped condition will result in the eventual death of the oak. The very quality that makes an old (and usually large) oak desirable for nesting/denning quality (Verner 1992) also is indicative of its loss from the stand. Giving an old tree with a poor crown more growing space will not increase its crown (Oliver and Larson 1996). A strategy that permits more growing space around existing oaks will increase oak cover, while maintaining the decadent oaks for wildlife habitat. So, the strategy is to remove conifers from around oaks when oaks will benefit from increased growing space, unless the oak must be removed because it is a hazard.

As described above, one-third of the growing space is maintained in large trees in the matrix. For example, 90 percent of full stocking for a mixed-conifer site of moderate productivity equals 290 ft2/acre and one-third of the growing space in large trees equals 97 ft2/acre or alternatively, maximum stand density index for the same site would be 600 calling for 200 units of stand density index devoted to large trees.

Of the growing space allocated to large trees, some of it should be in large oaks. Unless specified otherwise in the LRMP or the Landscape Analysis Plan, maintain ten percent of the residual basal area for large trees in oaks. For example, of the 97 ft2/acre in larger trees on the mixed-conifer site, ten percent of the growing space, or 10 ft2/acre, could be maintained in the largest oaks, or alternatively 20 units of stand density index. Also, maintain all decadent oaks throughout the stand within the limits set by the LRMP or Landscape Analysis Plan. Do not prevent over topping of oaks by conifers.

Decadence

Decadence is an important consideration in providing nesting and denning sites for Pacific fisher and California spotted owls. Wood rot is not equally distributed or equally represented in each forest type. Decadence in pine stands is found in snags or in oaks, while decadence in fir stands is found in standing live firs as well. More rot is found in old trees than young trees. Thus older and typically the largest individuals provide rotten wood for nesting cavities. This is true for pines, oaks, or firs. The uneven-aged prescription provides for decadence by maintaining large and old oaks, pines, and firs in both reforestation areas and the matrix. Maintaining the largest oaks as described above and largest fir will provide the potential for cavities.

Aerial Arrangement - Single story vs. Multi-story Stands

While the J-curve identifies the distribution of tree sizes and by proxy the age classes across a stand, the arrangement of this distribution is not explicitly dictated by the J-curve. The arrangement of the J-curve distribution can vary greatly across a stand. Trees are often found clumped in groups and only rarely are size/age classes evenly distributed across a stand. Wildlife habitat requirements and fuels management necessities dictate the arrangement of tree size/age classes across the Kings River Project landscape. Multi-story stands offer greater habitat benefits for fisher and spotted owl (Verner et al 1992, Zielinski et al 2004). In the wildland urban interface, single story stands with minimal fuel ladders will provide less probability of crown fires being initiated and sustained. Each aerial arrangement of tree size/age classes contains natural openings (meadows, rock, low site), young reforestation groups, various middle-aged groups, and large trees. Within single storied stands size/age classes are juxtaposed to provide a mosaic distributed horizontally. Within a multi-storied stand size/age classes are found distributed vertically one or two under another as well as horizontally. The landscape would be composed of a mosaic of patches of single and multi-storied stands. Single story stands would be emphasized in the wildland urban interface. Multi-storied stands would be emphasized in PACs, fisher habitat, and drainage bottoms. The decision tree and table in Appendix C3 identify stand objectives and conditions that determine whether a stand would be managed for multi-stories or a single story.

Tree removal and retention priorities

Trees that remain after uneven-aged silviculture are selected on their ability to make use of increased growing space, protect important habitat structures (nest trees and stream bank trees), and reduce vertical and horizontal fuel continuity. Criteria used in determining trees to remove and trees to leave are listed below in order of priority:

1. **Size-**In uneven-aged management leave all trees above largest diameter unless they pose a hazard or limit operability. With in regeneration groups leave all trees greater than 35" unless they pose a hazard or limit operability. Leave trees over 24" (up to 4 per acre) if trees over 35" are not present.

2. **Growth**-Leave trees capable of growth. Signs of growth potential are live crown ratio greater than 40%, advancing leader growth, good needle retention, and good vigor. Maintain dominant and codominant trees in cohort. Avoid leaving suppressed except to meet wildlife priority.

3. **Species**- healthy black oaks are given first priority for leave trees. Ten percent of dominant oaks will be provide up to .25 acre opening for crown expansion. This meets the LRMP objective of providing oak canopy cover. Healthy Sugar pine is second priority, leaving sugar pine resistant to White Pine Blister Rust is consistent with the Districts Sugar Pine Strategy. Ponderosa Pine is given third priority. Incense cedar, white fir, lodgepole pine, and red fir are given last priority. Incense cedar and white fir have encroached in the understory. These two species now dominate most mixed conifer and pine stands.

4. **Wildlife**-Trees that have cavities or provide potential nest habitat remain. Known nest trees and roost trees remain following tree removal. Decadent oaks are allowed to be overtopped. Priority wildlife leave trees are large trees with rot, cavities, and witches brooms in dense canopy pockets outside of WUI (potential denning or nesting tree). Maintain dense condition and canopy layering. Inside WUI retain priority wildlife trees but reduce canopy layering.

5. **Disease**-, understory trees (< 6", 10" or 20") with mistletoe, white pine blister rust, and damage are discriminated against. Trees with less mistletoe or those with mistletoe in the lower third or where the mistletoe is found on the outer crown are favored over those with high amounts of mistletoe and infections close to the bole or in the upper two thirds of the crown. Damaged or diseased trees should be removed prior to healthy trees. Maintaining trees with good form and growth is higher priority than spacing or target structure.

6. **Erosion**-Trees along stream banks remain to provide stability, prevent accelerated soil erosion, and provide habitat.

7. **Crown position**-Trees in the lower crown layers are removed to provide space for trees in the upper crown layers. Crown position is a strong indicator of a trees ability to make use of site resources. Leave dominant and codominant trees in each cohort.

8. **Fuel ladders**-Trees that provide fuel ladders to larger trees are removed to create conditions suitable for underburning and reduce the potential for torching. Protecting larger trees from underburning maintains stand structures that will contribute to future habitat diversity. Canopy layering is reduced in WUI and DFPZ by accentuating age classes (e.g. a 10" tree among 30" trees is removed to accentuate the 30" class). Maintain canopy layering in PACs and HRCAs outside WUI.

9. **Spacing or residual stand density**- Trees <11" are spaced apart to provide room for crowns and root expansion and meet objectives to reduce tree stress and reduce potential for sustained crown fire. Residual stand density guides provide a means to maintain desired stand structure elements (canopy cover, tree dominance, and growing space). In uneven-aged silviculture the target stand distribution determines tree removal instead of spacing. Do not create openings except for regeneration groups or oak enhancement. Maintain at least 40 percent of existing basal area.

APPENDIX C3

HISTORIC CANOPY ASSIGNMENTS

Key to the Following Tables			
S = Sparse	P = Open	M = Moderately dense	D = Dense
Site is Forest Survey Site Class			

Site							
		Ponderosa pine					
2 3 4		PNV	1	2	3	4	5
		Aspect /Slope	•0-15 %	•15-25%	•25-35%	•35-55%	•>55%
	-1	Ridge top	d	d	m	none	none
	-9	Drainage bottom	d	d	m	m	none
	1	North	d	d	m	s	none
	2	Northeast	d	d	m	p	none
	3	East	m	m	m	p	none
	4	Southeast	m	m	p	p	none
	5	South	m	p	p	s	none
	6	Southwest	m	p	p	s	none
	7	West	m	p	p	p	none
	8	Northwest	m	m	p	s	none

Site						
	Ponderosa pine					
5 6 7	PNV					
	Aspect /Slope	•0-15 %	•15-25%	•25-35%	•35-55%	•>55%
	Ridge top	s	s	s	s	none
	Drainage bottom	s	s	s	s	none
	North	s	s	s	s	none
	Northeast	s	s	s	s	none
	East	s	s	s	s	none
	Southeast	s	s	s	s	none
	South	s	s	s	s	none
	Southwest	s	s	s	s	none
	West	s	s	s	s	none
	Northwest	s	s	s	s	none

Site						
2 3 4	Mixed-conifer PNV	1	2	3	4	5
	Aspect /Slope	•0-15 %	•15-25%	•25-35%	•35-55%	•>55%
-1	Ridge top	d	d	d	none	none
-9	Drainage bottom	d	d	none	none	none
1	North	d	d	d	d	none
2	Northeast	d	d	d	d	none
3	East	d	m	m	m	none
4	Southeast	d	m	p	p	none
5	South	d	m	p	p	none
6	Southwest	d	m	p	p	none
7	West	d	m	p	p	none
8	Northwest	d	m	m	m	none
	Soil types 156 157 139 =m 136=d on dinkey mt					

Site						
5 6 7	Mixed-conifer PNV					
	Aspect /Slope	•0-15 %	•15-25%	•25-35%	•35-55%	•>55%
	Ridge top	s	s	s	s	
	Drainage bottom	s	s	s	s	
	North	s	s	s	s	
	Northeast	s	s	s	s	
	East	s	s	s	s	
	Southeast	s	s	s	s	
	South	s	s	s	s	
	Southwest	s	s	s	s	
	West	s	s	s	s	
	Northwest	s	s	s	s	

Site
2 3 True fir PNV

		1	2	3	4	5
	Aspect /Slope	•0-15 %	•15-25%	•25-35%	•35-55%	•>55%
-1	Ridge top					
-9	Drainage bottom					
1	North	d	d	d	d	
2	Northeast	d	d	d	d	
3	East	d	d	d	d	
4	Southeast	d	d	m	m	
5	South	d	d	m	m	
6	Southwest	d	d	m	m	
7	West	d	d	m	m	
8	Northwest	d	d	d	d	

Site
4 True fir PNV

	Aspect /Slope	•0-15 %	•15-25%	•25-35%	•35-55%	•>55%
-1	Ridge top	d	d	d		
-9	Drainage bottom	d	d	d	d	
1	North	d	d	m	m	
2	Northeast	d	d	d	d	
3	East	d	d	d	d	
4	Southeast	d	d	m	m	
5	South	d	d	m	m	
6	Southwest	d	d	m	m	
7	West	d	d	m	m	
8	Northwest	d	d	d	m	

Site
5 6 7 True fir PNV

	•Slope				
Aspect/Slope	•0-15 %	•15-25%	•25-35%	•35-55%	•>55%
Ridge top	s	s	s	s	
Drainage bottom	s	s	s	s	
North	s	s	s	s	
Northeast	s	s	s	s	
East	s	s	s	s	

Southeast	s	s	s	s
South	s	s	s	s
Southwest	s	s	s	s
West	s	s	s	s
Northwest	s	s	s	s

Site
2 3 4 Jeffrey pine PNV

		1	2	3	4	5
	Aspect/Slope	•0-15 %	•15-25%	•25-35%	•35-55%	•>55%
-1	Ridge top	m	m	m	none	none
-9	Drainage bottom	m	m	m	none	none
1	North	m	m	m	m	none
2	Northeast	m	m	m	m	none
3	East	m	m	m	m	none
4	Southeast	m	m	p	p	none
5	South	m	m	p	p	none
6	Southwest	m	m	p	p	none
7	West	m	m	p	p	none
8	Northwest	m	m	m	m	none

Site
5 6 7 Jeffrey pine PNV

Aspect/Slope	•0-15 %	•15-25%	•25-35%	•35-55%	•>55%
Ridge top	s	s	s	s	none
Drainage bottom	s	s	s	s	none
North	s	s	s	s	none
Northeast	s	s	s	s	none
East	s	s	s	s	none
Southeast	s	s	s	s	none
South	s	s	s	s	none
Southwest	s	s	s	s	none
West	s	s	s	s	none
Northwest	s	s	s	s	none

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