Pre-treatment and Partial-treatment Forest Structure and Fuel Loads in the Lake Tahoe Basin Management Unit

Alison E. Stanton[a] and Scott N. Dailey[b]

[a]BMP Ecosciences, 156 South Park, San Francisco, CA 94107
[b]U.S. Forest Service, Adaptive Management Services Enterprise Team, Tahoe N.F., 631 Coyote Street, Nevada City, CA 95959

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

BACKGROUND

- The National Fire Plan (USDA and USDI 2001) and the Healthy Forest Restoration Act (HRFA 2003) mandate federal land managers to restore forest habitats and reduce the risk of wildfire, particularly on the wildland-urban interface (WUI). The implementation plan for the Healthy Forest Initiative includes tracking performance and monitoring to confirm that these objectives are being met.
- This report presents the first comprehensive monitoring effort of pre- and partial treatment fuel conditions and forest structure on projects slated for fuels reduction in the Lake Tahoe basin.
- Pre-treatment data was collected and summarized for six pairs of treated and not-treated control units on the west shore of the basin and in two unpaired units on the east shore. Half of the west shore units are in protected activity centers (PACs) for California Spotted Owl and Northern Goshawk. Partial-treatment data was collected in two units in the Dollar5 project that had been hand and mechanically thinned.
- Data were collected on biodiversity characteristics including tree size, percent canopy closure, tree density, tree basal area, snag density, shrub height, and understory species abundance and distribution. Measured surface fuel loads were evaluated as three different components: litter and duff, fine woody debris (1-100 hr fuels), and coarse woody debris (1000 hr fuels).

KEY FINDINGS

Forest Structure & Composition

- *CWHR Classification:* Within the un-treated PAC units on the west shore, canopy cover was greater than 50%, but wildlife habitat quality for late seral species like Northern Goshawk and Spotted Owl was only moderate since the majority of trees were small (<24 inches). The untreated Kingsbury units were very open, with small trees that provide low quality habitat for late seral species. Although the thinned units in Dollar5 had larger sized retained trees, the residual canopy cover was too low to provide late seral habitat.

- *Tree Density and Sizes:* Pre-treatment tree density was very high in the untreated units, ranging from 157 to 244 trees per acre (tpa) in the west shore units, and from 191 to 304 tpa in the Kingsbury units. Tree densities in the thinned Dollar5 units were considerably lower than the west shore units at 111 and 130 tpa, but these units are at higher elevation and more dominated by red fir. The lower density is presumed to be the result of thinning treatments, but that cannot be confirmed without pre-treatment data. In the west shore units, almost all trees were less than 24" and very few large trees (>30") were encountered in any of those units. Surprisingly, over 50% of the trees in the hand and mechanically thinned Dollar5 units were less than 6 inches, although these partially treated units did have more large trees (>30 inches).

- *Species Composition:* Although 5 conifer species were present, the mixed conifer forests in the west shore units were heavily dominated by white fir (75% of the trees on average were white fir). The Kingsbury units were composed of Jeffrey pine and white fir only in proportions ranging from 36:64 to 42:58. The Dollar5 units had very low proportions of pine and since the elevation was over 7,000 ft, red fir was the dominant species in those units.

- *Snag and Down Log:* The west shore units had very large quantities of snags (mean of 44 per acre), likely due to widespread insect damage that weakened trees. Snag counts in the Kingsbury units were moderately high (ranging from 14 to 22/acre). The number of retained snags in the thinned Dollar5 units was within prescription in the hand thinned unit (5/acre) and at 60% of the prescribed level in the mechanically thinned unit (2 per acre). Down log density was a mean of 7 per acre in the west shore units and 17 per acre in the Kingsbury units. The number of residual down logs per acre was high in the thinned Dollar5 units, (ranging from 39 to 43 acre).

- *Herbs and Shrubs Herbs and Shrubs:* The total mean species richness per plot declined as total mean duff/litter loads (r^2=0.65) and FWD loads (r^2=0.67) increased in the west shore units. The total number of species detected in the Kingsbury units on the east shore was fewer by 80%. Very few species were detected in the recently thinned Dollar5 units. Mean cover was less than 15% in the west shore units, less than 2% in the Kingsbury units, and less than 0.2% in the Dollar5 units. Without paired pre-post treatment samples it is unknown whether lower abundances and richness in the treated Dollar5 units are due to the treatment or to pre-treatment conditions. Non-native species were not detected on any of the west shore units or Dollar5 units. Cheatgrass was detected in small quantities in the Kingsbury units.

Fuel Loading and Configuration

- *Surface Fuel:* Pre-treatment surface fuel loadings were high across all of the untreated units. Mean total surface fuel loading (litter/duff, 1-100 hr, and 1000 hr) in the untreated units was 41 tons/acre. The hand thinned and mechanically treated Dollar5 units also had high surface fuel loading close to 40 tons/acre.

- *Vegetative Fuel Loading:* In the west shore units, understory live fuel loads ranged from 1 to over 4 tons/acre, which was similar to the load contributed by fine dead and downed fuels.

- *Residual Woodchips:* Percent cover of woodchips ranged from 14 to 27% at the Dollar5 units, the only location where woodchips existed from partial-treatment. The depth of woodchips ranged from 1.9 to 6.3 inches. Bulk density coefficients have not been determined for woodchips in the Lake Tahoe Basin so calculation of biomass is not currently possible.

- *Slash Piles:* Total mean biomass of slash piles located within the mechanically treated Dollar5 unit was 30 tons/acre. Fuel biomass estimates for slash piles could be used to perform smoke production modeling.

- *Canopy Fuels:* Mean pre-treatment canopy base height (CBH) values of 3 to 6 feet across the west shore and Kingsbury units were very low, indicating high risk for crown fire initiation. The mean CBH of 5 feet in the thinned Dollar5 project area was also very low. CBH targets in project plans are generally set at 12-25 ft to reduce the likelihood of crown fire initiation. Pre-treatment mean canopy bulk density (CBD) values were above 0.15 kg/m^3 for all of the pre-treatment west shore units and above 0.10 for the Kingsbury project. In the treated Dollar5 project site CBD's were 0.06 kg/m^3. Desired conditions for CBD are values below 0.1 kg/m^3. Conditions where CBH exceeds this threshold are considered capable of passive crown fire. When CBD values are at or above o 0.15 kg/m^3, a stand is likely to have active crown fire.

IMPLICATIONS FOR MANAGEMENT

- The monitoring protocol was specifically designed to detect significant changes in plant communities and fuel loadings in response to management activities over time, using a statistically valid approach. 10 Plots or less per unit (fixed area 0.1ha plots) were shown to be adequate to determine changes as small as 25% for most of the key characteristics required to evaluate desired conditions and address key management questions with 80% statistical certainty.

- Comparisons of the pre-treatment data with available estimates of the historic range of variability for key forest structure components confirm that existing conditions are severely departed from desired conditions. The overabundance of small trees less than 24" inches diameter and the dominance of fir species over pine are some of the primary departures.

- Differences in forest structure, fuel loads, and herbaceous and shrub species diversity were detected in the thinned units in Dollar5, but without pre-treatment data it is not possible to know how the thinning influenced these different elements. Implementing post-treatment monitoring in these units will provide the statistical strength necessary to determine the long-term response to treatment.

- Post-treatment data collection will be a critical part of this effort. The site-specific pre-treatment data from permanent plots is required as a reference point from which quantitative evaluation is made of 1) short-term project-level NEPA objectives on the implementation of fuels treatments and 2) the longer term effectiveness of treatments in meeting desired conditions for fire, forest health, and wildlife habitat.

- The data from this monitoring effort could be used in modeling software applications like Behave or Fuels Management Analyst in order to predict fire behavior scenarios under un-treated and different treatment conditions, but it was decided not to include fire behavior modeling in this monitoring effort.

1.0 INTRODUCTION AND BACKGROUND

A significant portion of the Lake Tahoe basin is considered a high-risk environment for severe wildfires (Murphy et al 2006). The elevated threat originates from human land use practices over the last 150 years, beginning with Comstock era logging in the 1860's and continuing because of effective fire suppression. By the turn of the 20th century, nearly two-thirds of the entire basin had been clear-cut. The clearing was concentrated in lower elevation pine forests, where much more than 60% of this vegetation type was removed (Murphy and Knopp 2000.) Recovery of the forest over the last 100 years was irreversibly altered by management focused on fire suppression. Prior to this, 2,100 to 8,000 acres burned each year in the Tahoe Basin because of human and natural ignitions, compared to fewer than 500 acres burned per year today through prescribed fire and wildfire (Manley et al. 2000). Modern forests that developed under fire suppression after extensive logging are overly dense and crowded with small trees and extraordinary accumulations of fuels (Barbour et al 2002, Taylor 2004).

In response to the elevated threat of high intensity wildfire throughout much of the western United States, the National Fire Plan (USDA and USDI 2001) and the Healthy Forest Restoration Act (HFRA 2003) mandated federal land managers to restore forest habitats and reduce the risk of wildfire, particularly on the wildland-urban interface (WUI). In general, these policies set a goal of establishing pre-European conditions or at least a historic range of variability that predated modern fire suppression (Parsons et al. 1999, Stephenson 1999). Restoration may employ an integrated strategy that includes methods of thinning trees and brush removal called "fuels treatments" to improve forest health and ecological integrity. The principal goal of fuels reduction treatments is to reduce the amount of burnable materials, thereby reducing fireline intensities, the potential for crown fire, adverse fire effects, and improving suppression capability (Agee 2002).

Addressing the wildfire threat and implementing restoration measures in the Lake Tahoe basin presents unique challenges. First, the topography and climate in the basin, in combination with unparalleled clear cutting and fire exclusion, have produced white-fir and red-fir dominated forests in the lower montane zone unlike others in the Sierra bioregion. Second, the proximity of these unusual forests to populated areas and the importance of tourism have limited the use of prescribed burning as a management option. Smoke and liability issues, along with a small number of allotted burn days in many years has severely limited the number of acres that have been treated with fire. Third, much of the fuel load in the basin is in the form of small trees with low commercial value, thus reducing the cost-effectiveness of mechanical biomass removal. As a result, the vast majority of fuel treatments in the lower montane zone that have been implemented or are scheduled for implementation in the near future have utilized hand thinning with chain saws. The use of a mechanical harvester-forwarding system has been employed on relatively few acres. Mechanical mastication and chipping is often used as a means of fuels reduction. This method is limited by its low profitability, the complex regulatory environment of the Tahoe Basin, and the small number of contractors willing to do the work.

Despite these challenges, fire risk reduction has become a top priority and the amount of funding to implement fuels reduction treatments in the basin has increased in recent years. The National Fire Plan, the HFRA, and the Sierra Nevada Public Lands Management Act (SNPLMA) have made more funds available. In addition, the Lake Tahoe Basin Management Unit (LTBMU) has proposed treatments scheduled for 2008-2011 on more than 12,000 acres (in defense and threat zones) as part of the South Shore Fuels Reduction and Healthy Forest Project.

This report presents the combined efforts of two projects that evaluated pre-treatment forest structure and fuel loads in Forest Service project units in the LTBMU. The Upland Fuels Research Project (UPFU) received Round 5 SNPLMA funds under the Environmental Improvement Program (EIP#10123) to evaluate vegetation composition, structure, fuel loading, and animal communities (vertebrate and invertebrate). The UPFU team consisted of BMP Ecosciences, a private consulting firm, Pat Manley (Pacific Southwest Research Station [PSW]), and Dennis Murphy (University of Nevada Reno [UNR]). The second project, conducted by Adaptive Management Services Enterprise Team (AMSET), was contracted by the LTBMU to augment the vegetation and fuels portion of the UPFU project by incorporating additional vegetation and treatment types.

Project Coordination

Prior to data collection in 2006, the UPFU and AMSET teams collaborated closely with each other and the LTBMU to design and implement complimentary projects. Data collection protocols were based primarily on FIREMON (Fire Effects Monitoring and Inventory System [Lutes et al 2006]), a comprehensive system designed to satisfy fire management agencies' monitoring and inventory requirements.

The UPFU team collaborated closely with the LTBMU to identify available treatment units. Allocated funding was used to collect pre-treatment data on six management units on National Forest Lands slated for fuels reduction and in six paired, not-treated controls on adjacent federal, private, and state lands. Treatment units were located on the west shore of the basin and half of the units are in protected activity centers (PACs) for California Spotted Owl and Northern Goshawk. Planned treatments included hand thinning of trees $\leq$ 10 in diameter with slash piling and future burning and mechanical thinning of trees < 30 in diameter with slash mastication. Treatments were scheduled for implementation in 2006 to 2008. In 2006, treatments were completed on two of the six units. Through a cost-share agreement with UNR, BMP Ecosciences was responsible for the vegetation sampling and analysis components of the UPFU study that are presented in this report. Data on vertebrates and invertebrate communities has been presented in a separate report (Manley 2007).

The AMSET fuels treatment monitoring included collection of data on two projects. The Kingsbury Fuels Reduction site, located in the south-east corner of the Lake Tahoe Basin, is found in a Jeffrey pine, mixed-fir vegetation type. The planned treatment included hand thinning of live trees ≤ 14", and snags ≤ 20". It is understood that hand thinning was completed in the Kingsbury project site during the late summer and fall of 2006. Burning of slash piles has yet to occur there. The Dollar5 Underburn site, located in the north-west corner of the Tahoe Basin, is found in a mixed-fir vegetation type. This project site has been partially treated, with one unit hand thinned and piled in 1999, and a second unit mechanically thinned in 2004 (consisting of harvest of trees <10", with chipping of residual slash). Pile burning and a broadcast burn were originally planned for Fall 2006, but did not occur. It is presumed that burning will occur as soon as proper climatic and regulatory conditions exist.

2.0 GOALS AND OBJECTIVES

2.1 Current State of Knowledge

A large body of scientific literature addresses many issues associated with wildland fire and different fuel treatments applied in various vegetation types. Substantial portions of that work primarily address the use of prescribed fire. Evidence supports the utility of prescribed fire in reducing crown-fire potential or improving the resilience of forest stands to wildfire, but these studies are largely based on informal observations (Brown 2002; Carey and Schumann 2003), post-fire inference (Omi and Kalabokidis 1991; Pollet and Omi 2002) and modeling (Finney 2001; Stephens 1998; Agee and Skinner 2005, Peterson et al. 2006). Empirical studies of on-the-ground effects of fuels reduction treatments in treated versus untreated stands are few (van Wagtendonk 1996; Stephens 1998; Pollet and Omi 2002; Graham et al. 2004; Agee and Skinner 1995; Stephens and Moghaddas 2005). No scientific consensus exists regarding the specifics of how treatments are implemented and the relative effectiveness of different prescriptions across vegetation types (Carey and Schumann 2003; USDA 2004; Stephens and Ruth 2005; Peterson et al. 2006; Fites et al, in progress).

The Joint Fire Science Program (JFS) launched the national Fire and Fire Surrogates Study to address some of the knowledge gaps in fuel treatment effects and effectiveness. JFS projects are underway through-out the country, but only one JFS study is being implemented in the Sierra region in the Blodgett and Sequoia Kings National Forests (see Knapp et. al 2004). This project is addressing the effects of both prescribed fire and mechanical treatments on dry mixed conifer forests. However, these forests occur at lower elevations and have very different climates and mixes of forest types than the LTBMU. Studies in southern Oregon and northern California (e.g., Taylor 2000) suggest fire behavior and resulting stand structure is strongly affected by physiographic conditions and therefore guidelines for forest restoration should reflect differences in fire regimes produced by local conditions. AMSET recently finished collecting data on fuel treatments in all Region 5 National Forests, including the Sierra region; however, too few plots were established in the LTBMU data to be statistically valid. Recent empirical studies in mixed conifer forests in the Sierra region have addressed the effects of the timing of prescribed fire (Knapp et al 2005; Thies et al 2005; Schwilk et al 2006). However, as discussed above, the use of prescribed fire in the basin to date has been limited.

With respect to wildlife habitat, treatments that are primarily designed to reduce fuels tend to simplify and homogenize the landscape. The removal of overstory and understory trees and the more even spacing of remaining trees will likely result in significant changes in vegetation composition and habitat structure and have the potential to greatly affect habitat conditions for a majority of native animal species for many decades after treatment (George and Zack 2001). The most recent synthesis of what is known about wildlife and invertebrate response to fuels reduction treatments in dry conifer forests in the United States concluded that there were tremendous information gaps (Pilliod et al 2006).

While the knowledge base addressing wildland fire continues to grow, the effectiveness of mechanical fuels treatments currently being implemented in the specific forest types in the LTBMU is essentially unknown. There is no empirical data on the long term effects of mastication treatments on vegetation succession and wildlife habitat in the basin or elsewhere. In addition, the extent to which mechanical treatments can mimic the ecological role of fire is poorly understood (Weatherspoon 2000). Although recent studies are beginning to address the effects of mastication treatments (Busse et al. 2005; Stephens and Moghaddas 2005; Kane et al. 2006, and Knapp et al. 2006) only one published study on mastication was conducted in the Lake Tahoe basin (Hatchet et al, 2006). That study focused on soil and was not able to find significant soil compaction or erosion effects in masticated plots located on the west shore in the Lake Tahoe basin.

Several new studies on the effects of mastication are underway (Fites, Hood and Wu, and Keane), but these and past studies all address sites where large masticated chunks were produced using a mechanical harvester-forwarding system. In this study, the treatment in the Dollar5 unit involved chipping of the slash to produce very fine woody particles. Chipping should be considered a distinct treatment from mastication since the resulting fire behavior and ecological effects are related to particle size and associated features (e.g. packing density, thickness, and decomposition rates). One would speculate that a thick layer of wood chips could slow the rate of fire spread but it would also increase residence time, which would raise concerns over potential soil heating effects (Busse et al, 2005), as well as undesired mortality of vegetation components.

2.2 Project Objectives

The objective of this combined study is to address a subset of the many information gaps identified above and provide data on the effects of mechanical and hand fuel reduction treatments currently being implemented in the specific forest types in the LTBMU. The monitoring data has been collected across a range of treatment types including hand thinning, mechanical thinning with chipping (Dollar5), and mechanical thinning with mastication and across a range of vegetation types from west shore mixed conifer to east shore Jeffrey pine/white fir. The resulting dataset represents the first comprehensive monitoring effort of pre-treatment conditions in the Lake Tahoe basin specifically designed to detect significant changes in plant communities and fuel loadings in response to management activities over time.

The overarching goal of this study is to pair the pre-treatment dataset with post-treatment monitoring to determine how different fuel reduction treatments being carried out in the Lake Tahoe basin affect vegetation composition, forest structure, and fuel loads. Understanding how these elements respond to treatments is essential for addressing three key management questions (as identified in the Sierra Nevada Forest Plan Amendment Record of Decision [SNFPA ROD 2004]):

1) Is management direction being implemented as described?
2) Are desired conditions being met?
3) Are management actions resulting in expected outcomes?

The USFS has adopted an adaptive management framework which acknowledges that uncertainty exists about management choices and the impacts of management actions. Operating under this framework introduces the explicit commitment to reduce uncertainty through research and monitoring. It is the adaptive management process which provides the formal linkage between management needs and science to ensure that research is designed to address information gaps, reduce uncertainty, and directly inform management decisions.

In collaboration with the LTBMU adaptive management team, the research teams identified three specific objectives for the combined study:

1) Collect pre-treatment data in 2006 on vegetation composition, forest structure, and fuel loads on National Forest System management units slated for future fuels reduction activities.
2) Summarize and report on pre-treatment conditions in the sampled units.
3) Demonstrate how the data support the adaptive management process and inform the development and implementation of a Vegetation and Fuels Treatment Monitoring Plan for the LTBMU.

Prior to the 2006 field season, the teams coordinated on developing data collection protocols that would be efficient in addressing multiple management and research objectives. Several standardized methods for fuels reduction monitoring were evaluated including the National Park Service Fire Monitoring Handbook (USDI National Park Service 2003) recommendations for vegetation and dead and downed fuels sampling protocols, the USFS Forest Inventory Analysis (FIA) and Common Stand Exam (CSE) methodologies, and the Fire Effects Monitoring and Inventory System (FIREMON). FIREMON was chosen for several reasons. First, the program is specifically designed to detect significant changes in plant communities and fuel loadings in response to management activities over time. The Common Stand Exam protocols typically used for stand inventory by the LTBMU are effective at determining conditions at one point in time, but are not appropriate for determining pre-post changes associated with fuel treatments. Second, the development of the FIREMON program, funded by the Joint Fire Science Program, is currently being integrated with the well established National Park Service Fire Ecology Assessment Tool (FEAT). This effort is strongly supported and is promising to be the primary system to be used for fuels treatment monitoring and associated data management across multiple agencies. Finally, FIREMON is available as a free software package online at www.fire.org. The downloadable material includes detailed protocol descriptions, field forms, an Access database, and an Analysis Tool that allows users to quickly generate summary reports of over 30 parameters relevant to characterizing vegetation structure, composition, and fuel loads. In addition, the latest version has been developed with fuel modeling software in mind and although the software is not currently integrated with any modeling applications, future iterations are reported to be heading in that direction.

The site-specific pre-treatment data from permanent FIREMON plots will provide a valuable reference point from which to evaluate 1) short-term project-level NEPA objectives regarding the implementation of fuels treatments and 2) the longer term effectiveness of treatments in meeting desired conditions for fire control, forest health, and wildlife habitat. In addition, the pre-treatment data can be compared with available estimates of the historic range of variability for key forest structure components to confirm departure from desired conditions. The pre-treatment variables were selected to address specific desired conditions and may be loosely grouped as informing project implementation, forest structure, wildlife habitat, or fire behavior (Table 2.2-1). Immediate, one-year post-treatment data is required to evaluate short term objectives, but a longer monitoring period (minimum of 5 years) will be required to address desired conditions.

Table 2.2-1. Key variables that address different management objectives and desired conditions.

Project implementation	Forest Structure	Wildlife habitat	Fire Behavior
Basal area	Basal area	CWHR (tree size and canopy closure)	Canopy base height
Tree density	Tree density	Snag retention	Crown bulk density
Canopy closure	Canopy closure	CWD retention	Surface Fuel loading
Fuel loading	Tree species composition	Herb and shrub species richness	Photo points to assign fuel models
	Tree size class distribution	Tree size class distribution	
		Plant heights	

If post-treatment data is collected, this project will provide critical project-level data that managers can use to plan future treatments and schedule re-treatments within an adaptive management framework. The Key Management Question (KMQ) framework is an integral component of effective adaptive management because it guides scientific research to address management concerns and the resulting data provides a necessary feedback on management actions. Statistically robust results increase the confidence with which managers can make future decisions and form a sound basis for those decisions. The combined study could inform the following basin-wide KMQs:

1) How effective are current fuels treatments in altering fire behavior, improving suppression effectiveness, and reducing fire severity under the range of fire-weather conditions likely in the Lake Tahoe Basin?
2) What is the relationship of canopy cover and rate of surface and fuels ladder accumulation in the basin after thinning treatments?
3) What is the effect of fuels treatments (thinning, mastication, mulching) on the rate and direction of forest succession, fuel loading, and fuel configuration compared to no treatment at all?
4) What is the longevity of fire hazard reduction produced by mastication treatments?
5) Do thinning, mastication, or other fuels reduction treatment activities change the prevalence of native or non-native understory vegetation?

3.0 METHODS

3.1 Study Sites

Data for this project was collected at 6 general locations in the Lake Tahoe Basin (Figure 3.1-1). Climate in the basin is Mediterranean with a summer drought period. The majority of precipitation falls as snow in the winter from December to March and less than 3 percent falls as rain between May and October. Mean annual precipitation at Tahoe City is 32 inches (80 cm) and mean annual snowfall is 190 inches (483 cm). Average temperatures in January range from 19 to 39 °F (-7 to 4 °C). Summers are mild with average temperatures in August between 44 and 77 °F (7 to 25 °C) (Western Regional Climate Center).

Figure 3.1-1. Location map illustrating combined projects under the Upland Fuels Study (Twin Crags, Ward Creek, Blackwood Creek, and McKinney Creek), and the AMSET Fuels Monitoring projects (Dollar5, and Kingsbury Handthin).

West Shore Study Sites

Study sites for the UPFU study were located on Forest Service land on the western side of the basin near Tahoma, California in the lower montane zone between 6,250 and 7,200 ft (1900-2200 m) elevation. The lower montane zone in the west basin consists primarily of mixed conifer forests with the following tree species; red and white fir (*Abies magnifica* and *A. concolor*), Jeffrey pine (*Pinus jeffreyii*), incense cedar (*Calocedrus decurrens*), and sugar pine (*Pinus lambertiana*). Mixed conifer forests on the west shore of the LTBMU occupy approximately 12,300 acres (Murphy and Knopp 2000)

Plots were located in four watersheds: Twin Crags (TWC), Ward Creek (WRD), Blackwood Creek (BLK), and McKinney Creek (MCK) (Figure 3.1-2). The six treatment units cover approximately 800 acres in mixed conifer forests. Slopes across the study range from 0 to 40%. The Northern Unit Overview (Figure 3.1-3) shows more detailed sample plot and control plot locations for the units in TWC, WRD, and BLK. The Southern Overview (Figure 3.1-4) shows more detailed sample plot and control plot locations for the units in MCK.

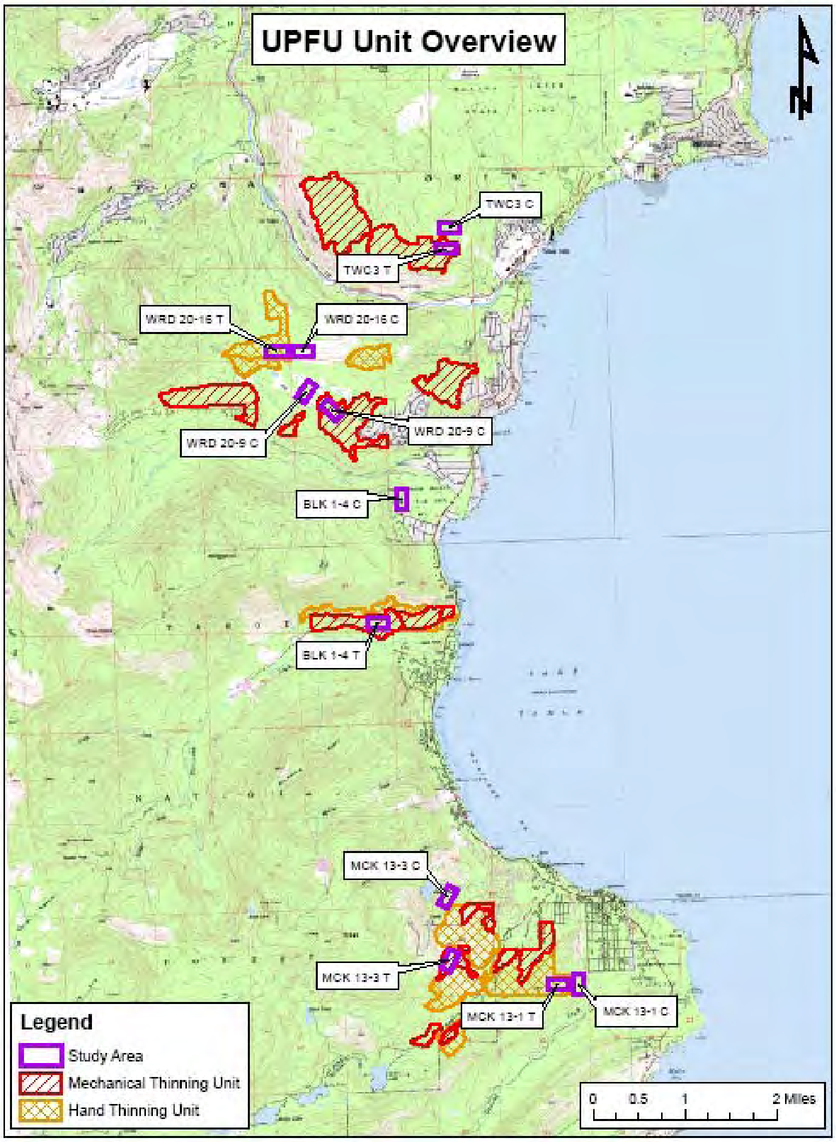

Figure 3.1-2. UPFU treatment units and 2006 sample plot locations on the west shore of the LTBMU.

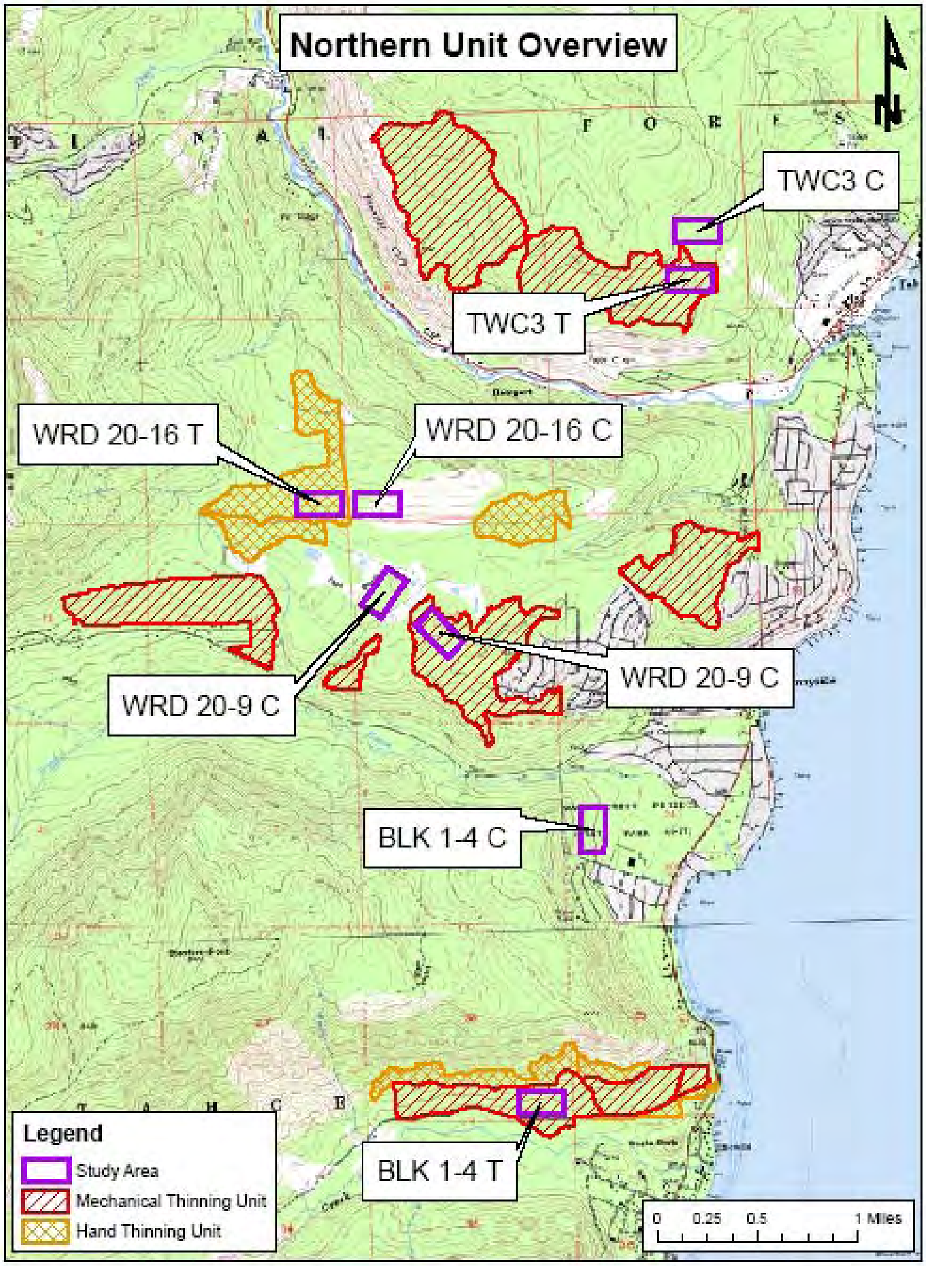

Figure 3.1-3. UPFU treatment units and 2006 sample plot locations in Twin Crags (TWC), Ward Creek (WRD), and Blackwood Creek (BLK).

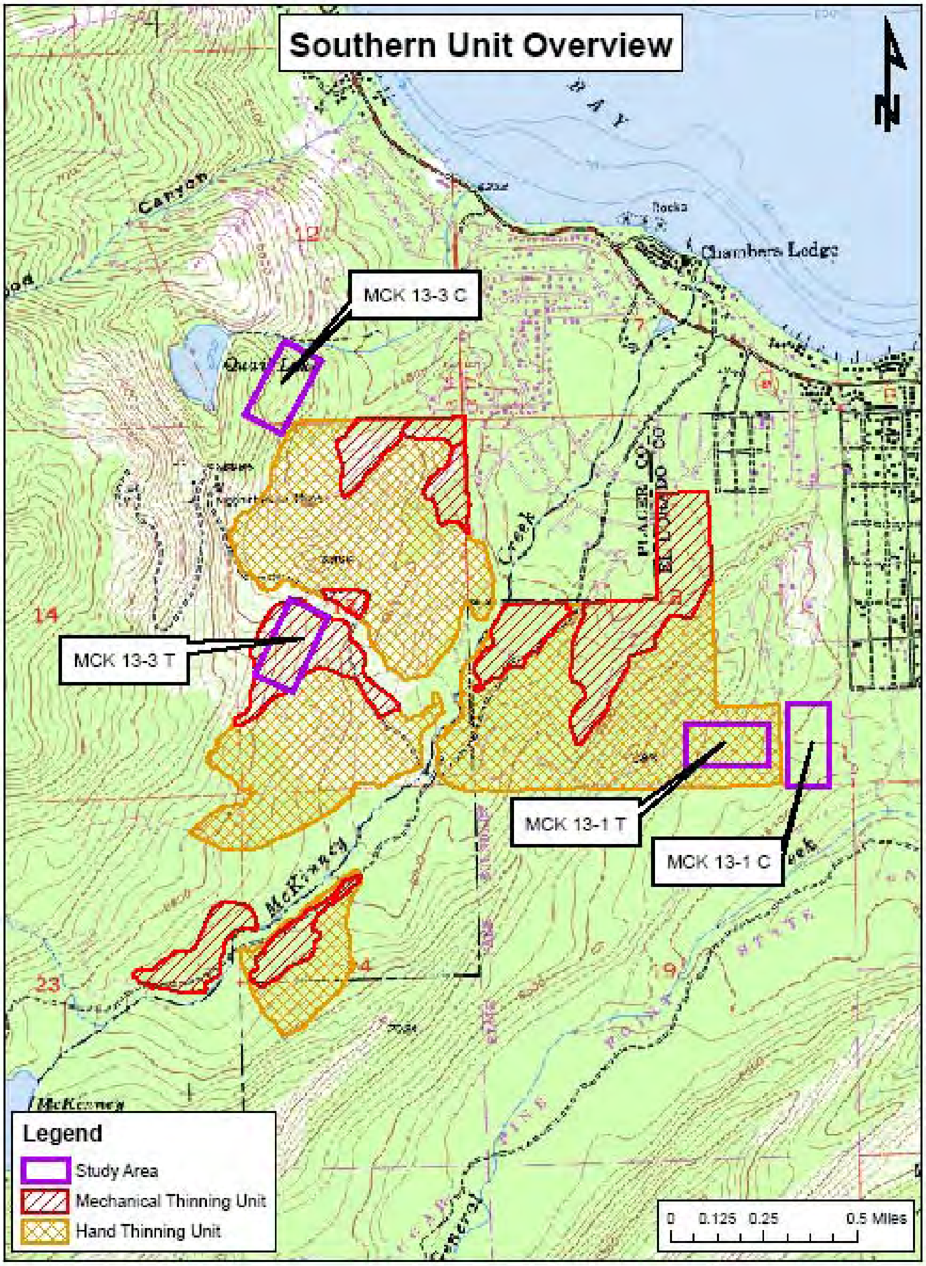

Figure 3.1-4. UPFU treatment units and 2006 sample plot locations in McKinney Creek (MCK).

Dollar5 Study Site

The Dollar5 fuel reduction project is located on the northwestern side of the basin, approximately 2 miles to the northwest of Tahoe City, California in the lower montane zone between 6,800 and 7,200 ft elevation (Figure 3.1-5). The project is located in the Burton Cr-Lake Forest-Dollar Cr Frontal HUC7 watershed. The project area consists primarily of mixed conifer forests with the following tree species; red and white fir (*Abies magnifica* and *A. concolor*), Lodgepole pine (*Pinus contorta*), and Western white pine (*Pinus monticola*). Slopes in the study site range from 0 to 30%, averaging 14%.

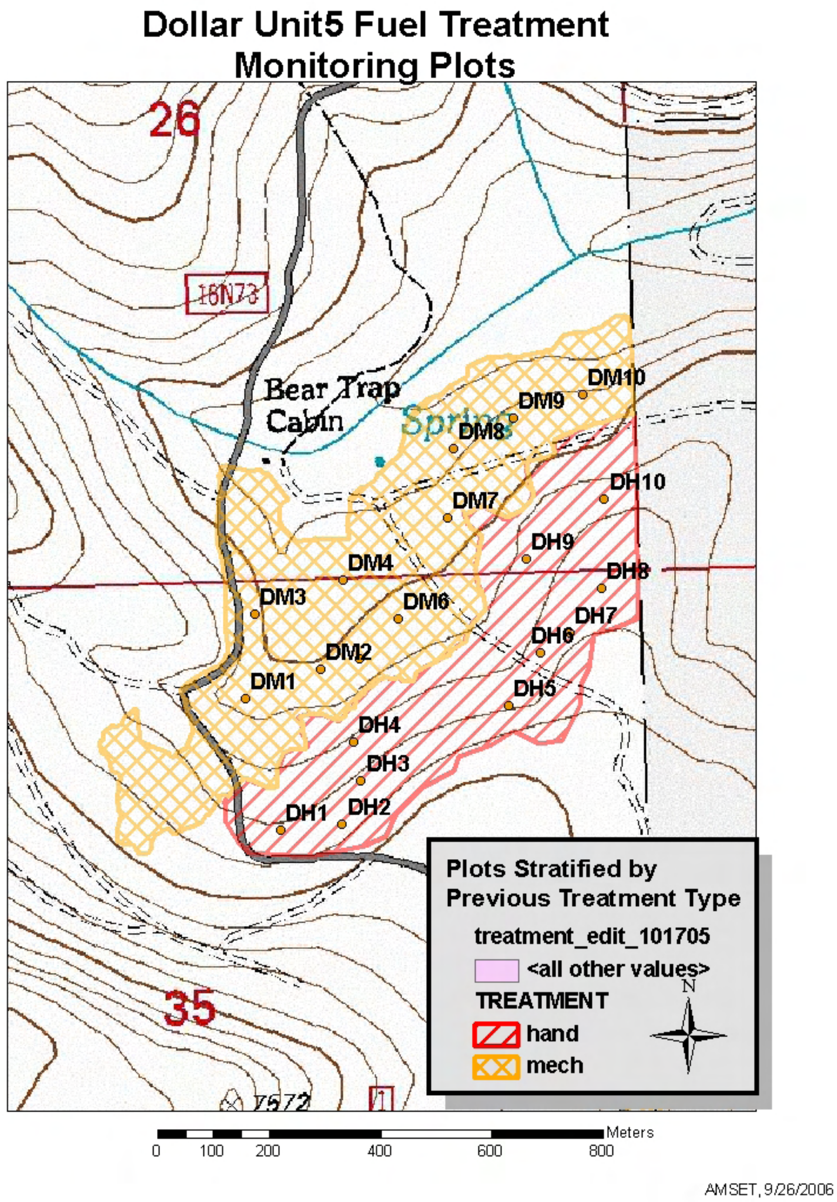

Figure 3.1-5. Dollar5 Treatment Units. Previous treatments of hand thinning (1999), and mechanical thinning (2004), were used to stratify sampling.

Kingsbury Handthin Study Site

The Kingsbury Handthin project site is located on the southeastern side of the Lake Tahoe Basin, approximately 2 miles to the northeast of Stateline, Nevada in the lower montane zone between 6,400 and 7,000 ft. elevation (Figure3.1-6). The plots were located in Burke Creek watershed. The project site consists of just two tree species: white fir (*Abies magnifica* and *A. concolor*), and Jeffrey pine (*Pinus jeffreyii).* Slopes in the study site range from 0 to 45%, averaging 23%.

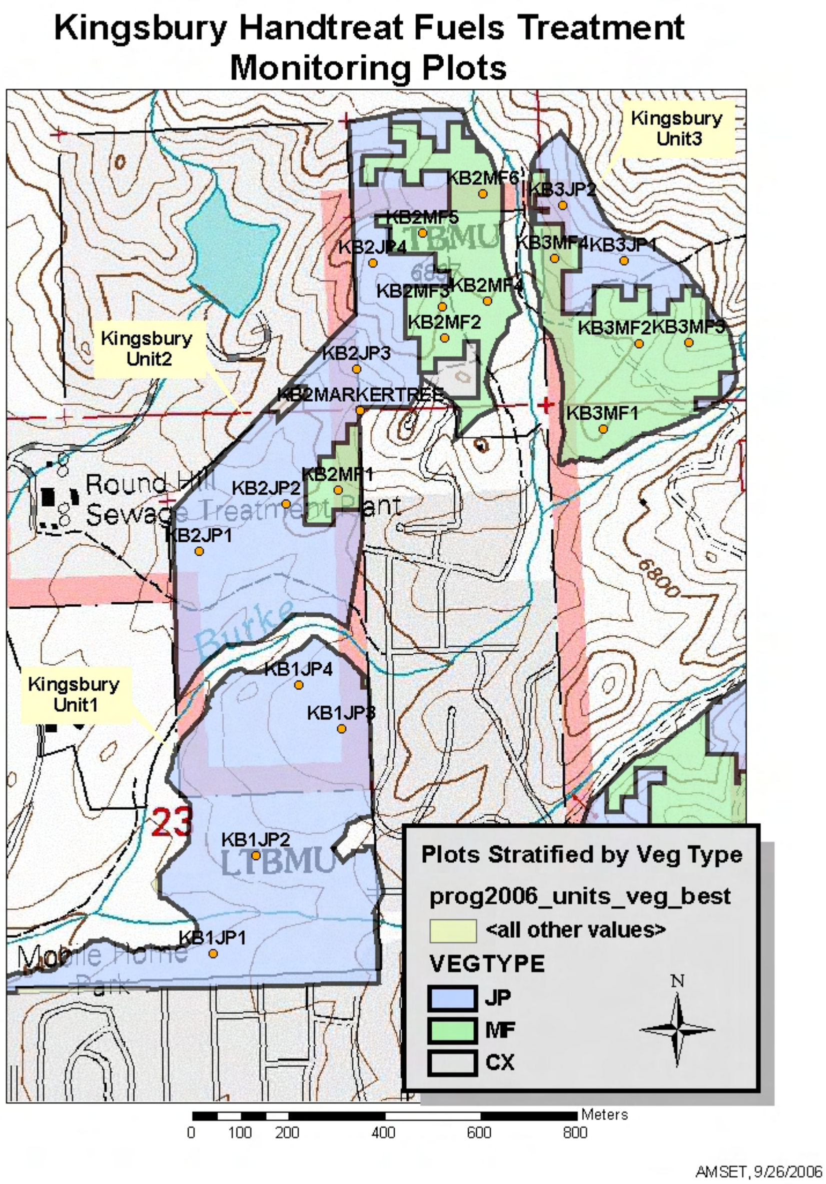

Figure 3.1-6. Kingsbury Project Site. Vegetation types mapped as Jeffrey pine (JP), and mixed fir (MF) were used to stratify sampling. These vegetation types were found to be very similar, but showed considerable differences in tree density. Therefore, these units are further described as “Kingsbury-dense” (KBd) for the Jeffrey pine unit, and “Kingsbury-open” (KBo) for the mixed fir unit.

Table 3.1–1. Vegetation type, topography, and soil series for sampled units.

Unit	Veg type	HUC7 Watershed	Slope (%)	Elevation (ft)	Aspect
BLK 1-4 C	Mixed conifer	Blackwood Cr	21	6,542	E
BLK 1-4 T	Mixed conifer	"	17	6,479	S
MCK 13-1C	Mixed conifer	Eagle Rock-Madden Cr-Homewood-Quail Frontal	10	6,471	E
MCK 13-3 C	Mixed conifer	"	24	6,350	E
MCK 13-3T	Mixed conifer	"	26	6,609	SE
MCK13-1 T	Mixed conifer	"	11	6,827	NW
TWC3 C	Mixed conifer	Lower Truckee R.	11	6,916	S
TWC3 T	Mixed conifer	"	6	6,871	S
WRD 20-16C	Mixed conifer	Ward Cr Frontal	11	7,115	flat
WRD 20-16T	Mixed conifer	"	11	7,048	flat
WRD 20-9 C	Mixed conifer	"	5	7,008	flat
WRD 20-9 T	Mixed conifer	"	5	6,972	NW
KBd	Jeffrey pine/ white fir	Burke Cr	23	6,824	W-SW
KBo	Jeffrey pine/ white fir	"	23	6,686	W-SW
DH	Mixed fir	Burton Cr-Lake Forest-Dollar Cr Frontal	16	7,106	NW
DM	Mixed fir	"	11	7,008	N-NW

3.2 Fuels Reduction Treatments

Fuels treatment projects are being prioritized in the wildland urban interface zone (WUI), where human habitation is mixed with areas of wildland vegetation. The WUI defense zone is the buffer in closest proximity to communities. The defense zone generally extends 0.25 miles from these areas, however, actual boundaries are determined at the project level following national, regional, and forest policy. The WUI threat zone typically buffers the defense zone, extending out 1.25 miles from the defense zone boundary. As with defense zones, actual threat zone boundaries are site-specific and based on fire history, local fuel conditions, weather, topography, existing and proposed fuels treatments, and natural barriers to fire.

The treatments that are applied to reduce fuels loads and alter vegetation structure and fire behavior include hand tool and mechanical treatments such as chainsaw thinning, cut-to-length forwarder/processor thinning, piling, pile burning, mastication, and chipping. It is important to differentiate between mastication and chipping, which produce similar but different residual material. Mastication will hereafter refer to the mechanical processing of fuels in place, resulting in residual woody material that is generally in excess of 3 inches diameter. Chipping will hereafter refer to the mechanical processing of fuels by running those fuels through chipping machinery, generally referred to as a "chipper". The residual woody material resulting from chipping is generally, less than 3 inches diameter, more often closer to 1 inch diameter.

The prescriptions always match hand thinning with piling of the thinned materials and mechanical thinning with mastication or chipping of the slash. Hand treatments are required on units with slopes greater than 30%, but hand treatments are also conducted on slopes less than 30% if there are other limitations on machine access or because of the limited number of operators that are available to implement mechanical treatments in the LTBMU.

Fuel treatment prescriptions are designed to modify fire intensity and spread in treated areas. Treatments are intended to reduce surface and ladder fuels, and crown fuels are modified to reduce the potential for spread of crown fire. In general, fuel objectives have first priority in developing prescriptions. However, prescriptions may address other objectives concerning wildlife habitat parameters or targets for insect- and disease-caused mortality.

The west shore treatment units were covered under three different NEPA review processes; the Twin Crags units were covered under the North Shore EIS project (1996); the Ward units were part of the Ward Management Area Fuel Hazard Reduction Project Environmental Assessment (2002); and the McKinney and Blackwood units were part of the Quail Vegetation and Fuel Treatment Environmental Assessment (2005). As such, the desired conditions and exact fuels treatment prescriptions varied. For instance, the maximum allowable harvestable tree size increased from 24 inches to 30 inches in 2004 in the SNFPA ROD (USDA Forest Service 2004). Control unit locations were selected that matched the general species composition and forest structure of the paired treatment units.

The general hand thinning prescription is as follows:

- In WRD 20-16, hand thin trees 3-10 inches (25 cm) diameter at breast height (DBH) to achieve a crown base height of 20 ft over 85% of the unit.
- In MCK 13-1, hand thin trees 3-14 inches (35 cm) and retain 15 trees/ac < 14 inches DBH (6 trees/ ha < 35 cm).
- Hand pile thinned materials and ground fuels.
- Retain at least 3 snags/ac and 3 downed logs/ac (1.2/ ha) in the largest diameter size class.
- Burn piles the year following treatment
- Underburn from one to four years following pile burn.

The general mechanical harvesting prescription is as follows:

- Mechanically thin trees up to 24 inches (61 cm) DBH (WRD 20-9, BLK 1-4, and TWC 3) or up to 30 inches (76 cm) (MCK 13-3).
- Masticate thinned materials and ground fuels to wood chips less than 4 inches mean diameter.
- Leave masticated material on site to a depth of < 6 inches.
- Retain approximately 140 ft^2/ac in residual basal area (32 m^2 /ha).
- Retain at least 3 snags/ac and 3 downed logs/ac (1.2/ ha) in the largest diameter size class.
- Underburn from one to five years following the treatment.

Half of the treatment units were located in protected activity centers (PACs) for California Spotted Owl and Northern Goshawk. Treatment prescriptions for specific PACs within the west shore units were prepared in consultation with wildlife biologists in order to maintain or enhance habitat conditions while meeting the purpose and need of the proposed fuel reduction objectives. Of the three units with PACs, only BLK 1-4 was treated in 2006. Portions of the East Blackwood Goshawk PAC and the Lower Blackwood Spotted Owl PAC occur in the unit. The prescription for the mechanical treatment in that unit is as follows:

- Remove understory trees from 3 to 19.9 inches (8-51 cm) DBH.
- Maintain two canopy layers.
- Retain approximately 140 ft^2/ac (32 m^2 /ha) in residual basal area and 48% average canopy closure in the treated portion of the stand.
- Retain 6-7 snags/ac (3/ha) in the largest diameter size class.
- Chip existing down logs and slash less then 15 inch (38 cm) DBH to leave approximately 4 tons/acre of down woody debris.

The purpose and treatment prescriptions for the Kingsbury units are described in the Kingsbury Fuel Reduction Project Purpose, Need and Proposed Action (March 22, 2005) as follows:

The general thinning prescription is as follows:

- Upper diameter limit for green trees cut would be 14 inches dbh
- Upper diameter limit for snags dead and down is 20 inches
- Snags would be left where they do not present a safety hazard, averaging three snags per acre of the largest size available.
- Down logs would be left averaging two logs per acre of the largest available.

While the purpose of this project was to collect pre-treatment data, the data collected in the Dollar5 Project site in 2006, is actually capturing the intermediate conditions existing between previous thinning treatments, and a prescribed burn which is planned to occur in the near future. The south-east side of the unit was treated in 1999 with hand thinning treatments which included chainsaw thinning of smaller trees, and piling and chipping of residual slash material. The north-west half of the unit was treated in 2004 with mechanical treatments that included: cut to length removal of smaller trees, and piling of residual slash material. The previously applied mechanical and hand thinning treatments were covered under the North Shore EIS (1996).

The Dollar5 pre-burn thinning prescription was as follows:

- Following commercial harvest, thin trees <10"dbh, in areas with basal area >150 trees/acre.
- Favor retaining pine species over fir, retaining the tallest most vigorous trees.
- Retain approximately 140 ft^2/ac in residual basal area (32 m^2 /ha).
- Retain 5 to 8 snags/ac and 5 to 10 downed logs/ac (1.2/ ha) in the largest diameter size class.
- Underburn three years following the treatment.

The objectives and limitations of the prescribed burn which was to occur in fall 2006 is described in the Prescribed Fire Burn Plan For the Dollar5 (Units 1-4) Burn on the Lake Tahoe Basin Management Unit Version 4 (January 6, 2001) as follows:

Objective
- Reduce 1 and 10 hour fuels by 40 to 90%
- Reduce 100 hour fuels by 50 to 90%
- Keep mortality between 15 to 20%

Range of Acceptable Results Expected
- Reduce 1 and 10 hour fuels by 30 to 100%
- Reduce 100 hour fuels by 40 to 100%
- Keep mortality between 10 to 25%

Throughout the basin, fuels reduction treatments are applied to retain highest priority conifer species as follows:
- Sugar pine, incense cedar
- Jeffrey pine/ Ponderosa pine
- White/ red fir
- Lodgepole pine

Table 3.1–2. Fuels reduction treatment prescriptions by unit.

Unit Name and #	Treatment
Ward Ck 20-16	PAC: Hand thin to 10"dbh, pile/burn
McKinney Ck 13-1	Hand thin to 14" dbh, pile/burn
McKinney Ck 13-3	Cut to length thinning and forwarding of live trees <30"dbh, masticate and surface spread slash
Ward Ck 20-9	Cut to length thinning and forwarding of live trees <24", masticate and surface spread slash
Blackwood Ck 1-4	PAC: Cut to length thinning and forwarding of live trees <24", masticate and surface spread slash
Twin Crags 3	PAC: Cut to length thinning and forwarding of live trees <24", masticate and surface spread slash
Dollar5	Previous treatments included hand thin with slash piling and chipping (DH); and mechanical thin with cut to length removal of commercial material and piling of slash (DM). Future treatment includes piles burning and broadcast burn.
Kingsbury	Hand thin to 14” dbh, achieve 15’ spacing, remove dead trees (standing and down) to 20”dbh, pile/burn

Treatment implementation in the LTBMU is on a complex schedule that is subject to many different factors including contractor availability, LOPs (limited operating periods) to protect special status wildlife species, heavy equipment access issues, weather, and air quality restrictions. NEPA documents propose treatment timelines, but it is not always possible to stay with the schedule because of myriad delays and some projects are years behind. Consequently, identifying suitable treatment units and scheduling the installation of pre-treatment monitoring plots required close coordination with LTBMU staff. To produce the most robust dataset, pre-treatment sampling should occur one year prior to treatment with the first post-treatment sampling following one year after treatment. However, the current timeline has already gotten one or two years behind for some of the sites (Table 3.1.2). Only two of the three units scheduled for treatment in 2006 were treated and two of the units scheduled for 2007 have now been moved back to 2008. An effective monitoring program of both project implementation and effectiveness is necessarily a long-term commitment that requires close on-going coordination between the monitoring teams and fire personnel.

Table 3.1-3. Fuels reduction treatment timetable.

Unit Name and #	Hand or Mechanical Thin Date	Broadcast or Pile Burn Date	Actual Treatment Date
Ward Ck 20-16	2007	2009	
Ward Ck 20-9	2007	2009	
McKinney Ck 13-1	2006	2008	2006
McKinney Ck 13-3	2008		
Blackwood Ck 1-4	2006		2006
Twin Crags 3	2008		
Dollar5	1999 (hand), 2004 (mech)	2006	2007?
Kingsbury Handthin	2006	2007?	2007?

4.0 Results

From this point forward in the report, study sites will be referred to according to general location. The 6 pairs of treatment/control study units will be referred to as the "west shore units". The "Dollar5 units", which are located in the same general area as the west shore units will be referred to separately as they have been partially-treated with previous mechanical (DM), and hand thin treatments (DH). The two units within the Kingsbury hand thin project site had similar vegetation types, but one had a much higher tree density than the other. These units will be referred to as the "Kingsbury open" (KBo) or Kingsbury dense" (KBd) units.

4.1 Forest Structure

General forest structure may be described in many different ways depending on the purpose. The FIREMON system has been designed to measure forest structure with the following variables: mature tree size (QMD), percent canopy closure, tree density, tree basal area, snag density, shrub height, and the amount of coarse woody debris (logs) on the forest floor. In addition, the California Wildlife Habitat Relationship (CWHR) type is a structural stage classification scheme that is commonly used to summarize habitat conditions for wildlife species. Each type is expressed as a number code based on the average tree diameter at breast height (DBH) and a letter code based on the average canopy closure (Table 4.1-1). As an example: the average condition of a forest stand typed 4M has trees between 11 to 24 inches and 40-59% canopy closure.

Table 4.1-1. CWHR classification standards.

Standards for Tree Size			Standards For Canopy Closure		
WHR	***WHR Size Class***	***dbh***	***WHR***	***Closure Class***	***Canopy Closure***
1	Seedling Tree	<1"	**S**	Sparse Cover	10 to 24%
2	Sapling Tree	1" to 6"	**P**	Open Cover	25 to 39%
3	Pole Tree	6" to 11"	**M**	Moderate Cover	40 to 59%
4	Small Tree	11" to 24"	**D**	Dense Cover	60 to 100%
5	Med/Large Tree	>24"			
6	Multi-Layered Tree	Size class5 trees over a distinct layer of class3 or 4 trees, total canopy >60%			

CWHR Type

To determine tree size, QD75 was used instead of DBH or the quadratic mean diameter (QMD). Mean QD75 includes only those trees in the 75th percentile for QMD and because it emphasizes large trees, has been universally accepted as a better indicator for wildlife habitat quality than mean DBH. Pre-treatment California Wildlife Habitat Relationship (CWHR) habitat stages for the west shore units were typed as mostly 4M and 4D, with one unit, TWC-3 control, typed as 5D (Table 4.1-2). The Kingsbury units were classified as 4M for unit KBd and 4P for unit KBo. The previously treated Dollar5 units were classified as 5S for hand thin unit and 5P for the mechanical unit.

QD75

The 75th percentile quadratic mean diameter ranged between 16 to 26 inches for the west shore units and 16 to 18 inches for the Kingsbury units. Mean QD75 in the partially-treated Dollar5 units was considerably higher at 25 (DH) and 31 (DM).

Canopy Closure

Mean canopy closure in all west shore units ranged from 48% to 72%, indicating moderate to dense stands. Canopy closure in the Kingsbury units was 40% for KBd and 32% for KBo. Canopy closure in the partially-treated Dollar5 units was considerably lower at 22% and 31% for the DH and DM units, respectively.

Tree Density

The mean number of trees per acre (>1 inch) within west shore units ranged from a low of 157 to a high of 244. The Kingsbury units ranged from 191 in the KBo unit, to 304 in the KBd unit. For the partially-treated Dollar5 units, trees per acre was less than the other projects with values of 111 for DH, and 130 for DM.

Basal Area

Mean basal area varied considerably for the west shore units, with values ranging from 147 to 309 ft^2/acre. The Kingsbury units had basal areas of 118 and 149 for the KBo and KBd units respectively. Basal area for the Dollar5 DH and DM units were 213 and 177 ft/acre, respectively.

Snags/Acre

Snag density for the west shore units varied considerably with mean values ranging from 25 to114 snags/acre. Snag density was 14 and 22 snags/acre for the Kingsbury KBd and KBo units. As would be expected, mean snag density was considerably lower on the partially-treated Dollar5 units with values of 5 and 2 for DH and DM respectively.

Logs/Acre

The mean number of down logs per acre was generally low in the west shore units, ranging from 4 to 7 in all units except MCK 13-3 control (14 logs/acre). The mean number of logs in the Kingsbury units was moderate (16-17 per acre). In the partially-treated Dollar5 units, the slash generated by the thinning treatments contributed to the much higher values for logs/acre, with 39 in DH to 43 in DM.

Shrub Height

Mean live shrub height ranged from 0.9 to 2.4 feet for the west shore units. Values were 0.8 and 0.9 for the Kingsbury project, and 1.0 and 1.3 for the Dollar5 units.

Table 4.1-2. Mean wildlife related structure and habitat conditions in 2006. (CWHR = CA Wildlife Habitat Relationship class; QD75= Quadratic Mean Diameter, 75th percentile).

Unit	CWHR type	QD75	SE	Canopy Closure (%)	SE	Trees/ Acre (>1")	SE	Basal Area (ft^2/acre)	SE	Snags /Acre	SE	Logs/ Acre (>3")	SE	Shrub Ht (ft)	SE
BLK 1-4 C	4M	23	2	48	3	157	13	190	12	25	5	6	1	2.4	0.3
BLK 1-4 T	4D	23	1	68	4	233	19	309	26	45	6	5	1	1.3	0.2
MCK 13-1 C	4D	21	2	57	4	215	22	221	21	34	16	6	2	1.8	0.2
MCK 13-1 T	4M	19	1	57	7	201	28	147	14	36	12	7	1	2	0.2
MCK 13-3 C	4M	23	1	72	4	223	20	263	15	114	16	14	3	1.2	0.3
MCK 13-3 T	4M	18	1	58	8	221	21	305	23	80	16	9	2	1.9	0.5
TWC 3 C	5D	26	2	62	7	219	25	305	27	36	11	7	2	1.6	0.1
TWC 3 T	4M	23	3	48	4	183	19	191	19	39	6	6	1	1.4	0.2
WRD 20-16 C	4D	20	1	71	11	244	16	264	5	26	7	4	1	0.9	0.1
WRD 20-16 T	4M	22	1	54	9	164	14	219	18	31	4	6	1	1.4	0.2
WRD 20-9 C	4D	20	1	64	9	211	25	227	27	27	5	4	1	1.2	0.1
WRD 20-9 T	4M	20	1	49	7	199	20	217	21	34	6	5	1	1.2	0.1
KBd	4M	16	1	40	5	304	35	149	19	14	3	17	5	0.8	0.3
KBo	4P	18	2	32	4	191	49	118	15	22	5	16	5	0.9	0.2
DH	5S	25	1	22	3	111	10	122	17	5	2	43	13	1.3	0.1
DM	5P	31	2	31	3	130	20	177	13	2	1	39	12	1	0.2

Tree Density by Species

Seven conifer species were recorded across all sampled units: white fir (*Abies concolor*, ABCO); red fir (*Abies magnifica*, ABMA), incense cedar (*Calocedrus decurrens*, CADE); lodgepole pine (*Pinus contorta*, PICO); Jeffrey pine (*Pinus jeffreyi*, PIJE); sugar pine (*Pinus lambertiana*, PILA); and western white pine (*Pinus monticola*, PIMO3). The west shore units contained all species but western white pine, the Dollar5 units did not have any incense cedar or sugar pine, and the Kingsbury units were a mix of white fir and Jeffrey pine only.

The mixed conifer units on the west shore were heavily dominated by white fir. White fir was present in every sample plot (100 % frequency) and mean tree densities (trees/acre, > 1 inch) of ABCO were greater than the other conifer species by orders of magnitude (Table 4.1-3). Mean basal area had the same pattern (data not shown). Across all 12 west shore units, white fir constituted 73% of the mean tree density. White fir was most dominant in MCK 13-3 where it represented 86% of the mean density, and least dominant in WRD 20-09 where white fir mean density was 51 and 48 % in the treatment and control units, respectively. The composition of conifer species was most mixed at MCK 13-1 where each of the five other species was represented by 7 to 28 trees per acre. WRD 20-16 had the least diverse conifer richness with no sugar pines or incense cedar. Variability in the composition of the sample units is likely due to differences in elevation, slope, aspect, and possibly to accessibility and past manipulation.

For the Kingsbury site, mean tree densities considerably different with 304 trees/acre in the “dense” unit, compared to 191 in the “open” unit. These units had similar species composition, with the proportions of Jeffrey pine to white fir of 42:58 for the dense unit, and 36:64 for the open unit.

In the partially-treated Dollar5 site, mean tree densities were heavily dominated by red and white fir. Both the hand thin and mechanical units showed little presence of desired pine species (western white pine and Jeffrey pine), despite treatment prescriptions which prioritized retention of those species. The hand thin unit had a mean value of 14% western white pine and <1% Jeffrey pine. The mechanical unit had a mean value of 4% western white pine and <1% Jeffrey pine. There is much less white fir in the Dollar5 units than measured in the west shore units. This is likely due to the fact that white fir was targeted for reduction which occurred in the pre-burn thinning prescriptions.

Table 4.1-3. Mean density of trees/acre, greater than one inch. **Partially treated with pre-burn thinning.*

Unit	ABCO	ABMA	CADE	PICO	PIJE	PILA	PIMO3	Total
BLK 1-4 C	126	8	11		2	10		157
BLK 1-4 T	178	10		4	42			233
MCK 13-1 C	142	14	16	13	21	9		215
MCK 13-1 T	127	7	9	28	20	10		201
MCK 13-3 C	191	17		4	4	6		223
MCK 13-3 T	190	15			10	6		221
TWC3 C	168	33	4		8	6		219
TWC3 T	128	2	38		8	7		183
WRD 20-16 C	226	12			6			244
WRD 20-16 T	130	27		3	5			164
WRD 20-9 C	103	42		49	13	4		211
WRD 20-9 T	101	55		31	8	4		199
KBd	128				176			304
KBo	68				123			191
DH*	30	65			<1		16	111
DM*	24	87		15	<1		4	130

Tree Density by Diameter Class

Eight diameter classes were used to describe the variation in tree size: 1 (saplings <6”); 6 (6-12”); 12 (12-18”); 18 (18-24”); 24 (24-30”); 30 (30-40”); 40 (40-50”); 50 (>50”). Very large trees greater than 40” were so sparsely distributed that they were not included in the graphs.

For the west shore sites, white fir was so dominant in the sample units across all diameter classes that it was necessary to combine the 5 other species into one category to graphically represent density by each diameter class (Figures 4.1-1 to 4.1-6). Patterns for the paired control units were similar to the treatment units but only graphs for the treatment units are presented.

Small trees (6-12”) dominated most west shore units, accounting for 45% of the mean tree density. In MCK 13-3, a majority of the trees were in the 12-18” class, along with a high proportion of trees in the 18-24” class. This site is the least accessible of the treatment units by vehicle and it is possible that it has experienced less logging the past. There were also greater densities of trees > 12” in WRD 20-16, compared to other units (Figure 4.1-2). WRD 20-16 is in close proximity to Page Meadows and it could be that some combination of greater soil moisture and flat slopes contribute to greater tree growth in this unit.

The density of saplings (<6”) was low across all west shore units, accounting for only 7% of trees. Sapling density ranged from only 2 saplings/acre in WRD 20-16 to 15 saplings/acre in both BLK 1-4 and MCK 13-1. White fir comprised the majority of saplings in all units, constituting 83% of mean sapling density, indicating that this species is regenerating at a greater rate than other conifers.

The density of large trees greater than 24” was low in all west shore units, with a mean density of only 4 trees per acre. Large tree density ranged from only 4 trees/acre in MCK 13-1 to 18 trees/acre in BLK 1-4. Trees larger than 30” were sparsely distributed across the landscape with a mean density of only 2 trees per acre across all 12 units and trees greater than 40 or 50 inches had a mean density of <1 tree per acre. Across all units, trees greater than 24 inches accounted for only 6% of total tree density.

Tree density in the Dollar 5 hand thin unit was dominated by saplings (<6”) and almost 80% of total tree density was composed of small trees < 12 “(Figure 4.1-7). Only 15% of the tree density was large trees greater than 24” and very few red fir greater than 30” were found in the plots. Tree density in the mechanical treatment unit was also dominated by saplings (<6”) and 76% of total tree density was composed of small trees <12“ (Figure 4.1-8). Red fir saplings made up 53% of the trees per acre. Medium and large diameter classes of white fir were almost non-existent and large trees greater than 24” comprised only 20% of total tree density. Western white pine and Lodgepole pine contributed very small percentages of the total trees per acre in both units.

Trees in smaller diameter classes were more abundant than trees in the larger classes in the Kingsbury “dense” (KBd) unit (Figure 4.1-9). Trees in the mid-range diameter classes also made up a large portion of the total trees per acre. Jeffrey pine with diameters of 6-12 and 12-18” made up 31% and 16% of the total density, respectively. White fir had a similar size class distribution in that trees in the smaller diameter classes were more abundant that trees in the larger classes, and many trees were found in the 6-12 and 12-18” diameter classes.

Pre-treatment tree size class distributions and species in the Kingsbury “open” (KBo) plots were very similar. Jeffrey pine in the 0-6, 6-12 and 12-18” diameter classes made up 38%, 27% and 20%, respectively, of the total tree density (Figure 4.1-10). Less Jeffrey pine was found in the larger size classes than in the smaller size class trees. White fir was also found in higher numbers in the smaller size classes, but no white fir in the 24-30 and greater than 30” diameter classes were found. Eighty-eight percent of white fir was less than 12” in diameter.

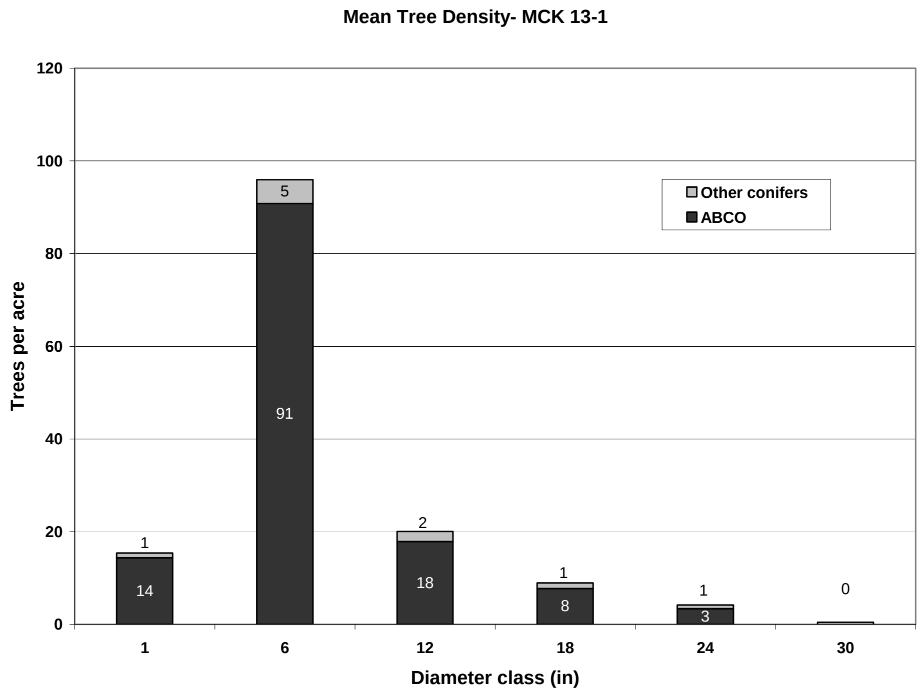

Figure 4.1-1. Mean tree density of white fir and other combined conifer species (ABMA, CADE, PICO, PIJE, PILA) in different size classes at MCK 13-1.

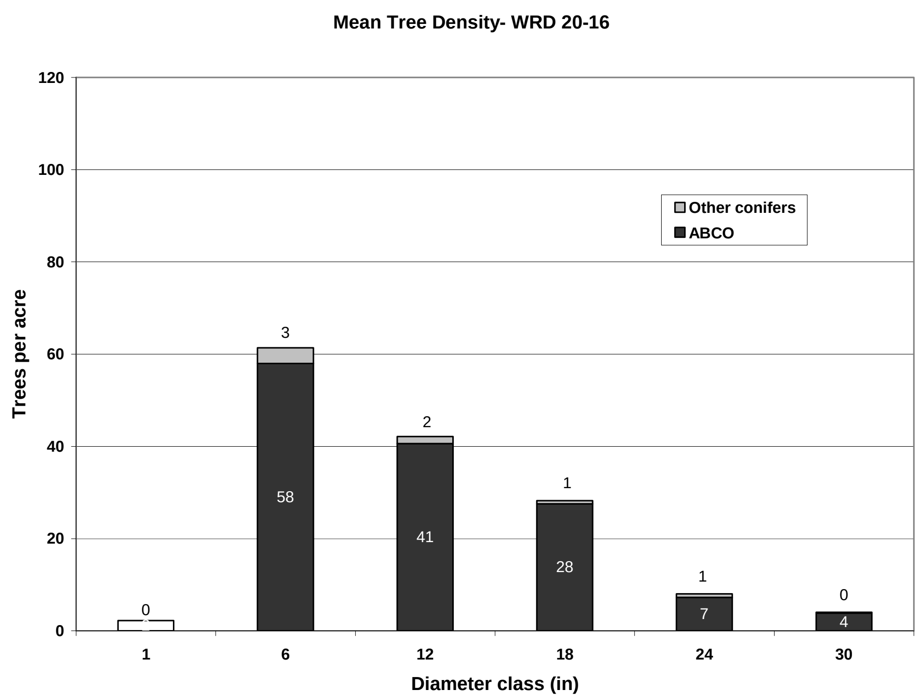

Figure 4.1-2. Mean tree density of white fir and other combined conifer species (ABMA, CADE, PICO, PIJE, PILA) in different size classes at WRD 20-16.

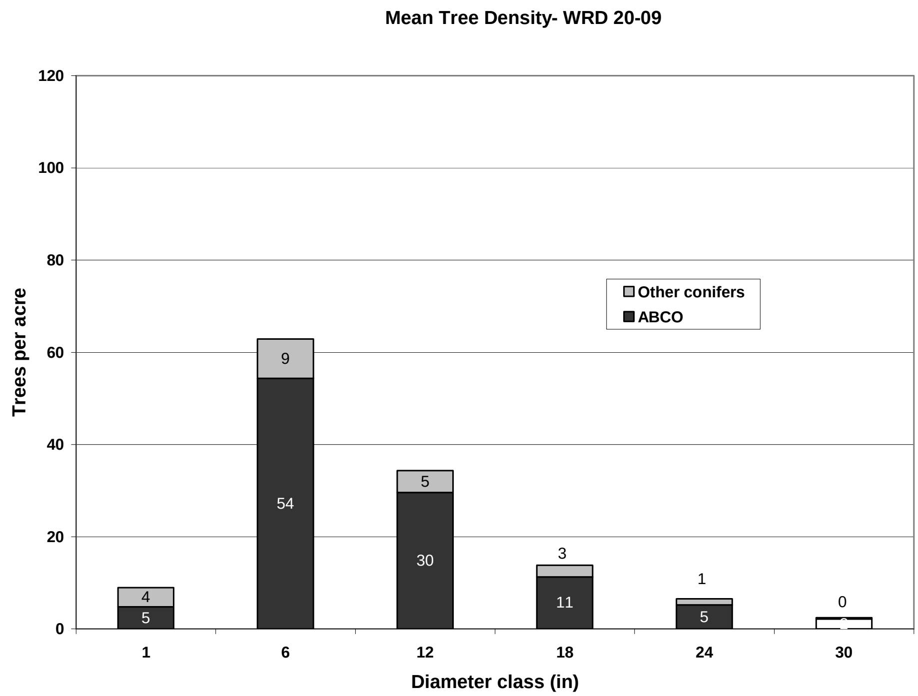

Figure 4.1-3. Mean tree density of white fir and other combined conifer species (ABMA, CADE, PICO, PIJE, PILA) in different size classes at WRD 20-09.

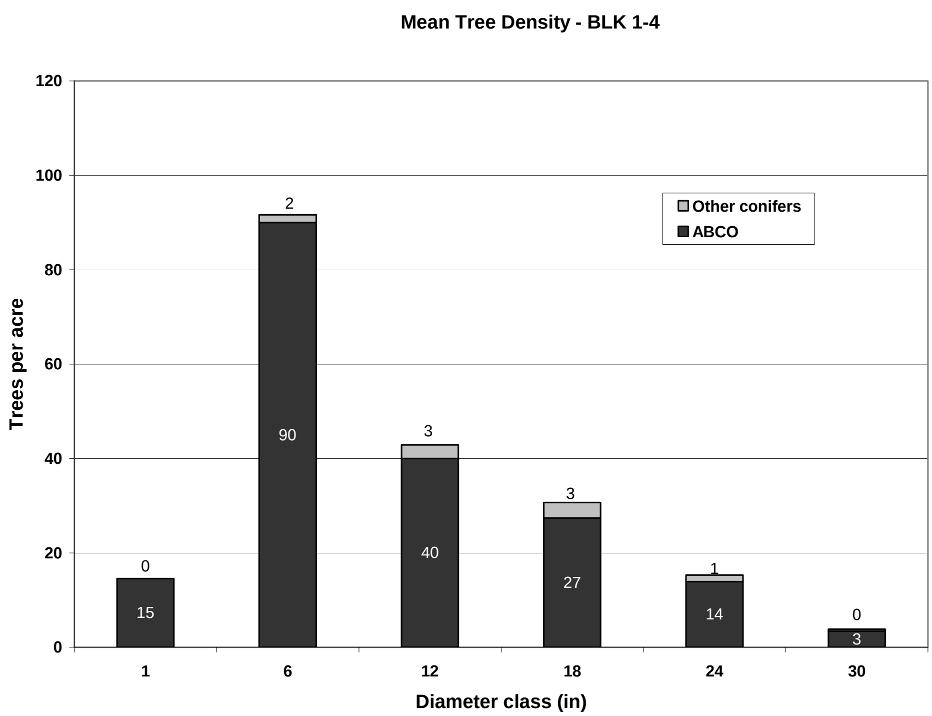

Figure 4.1-4. Mean tree density of white fir and other combined conifer species (ABMA, CADE, PICO, PIJE, PILA) in different size classes at BLK 1-4.

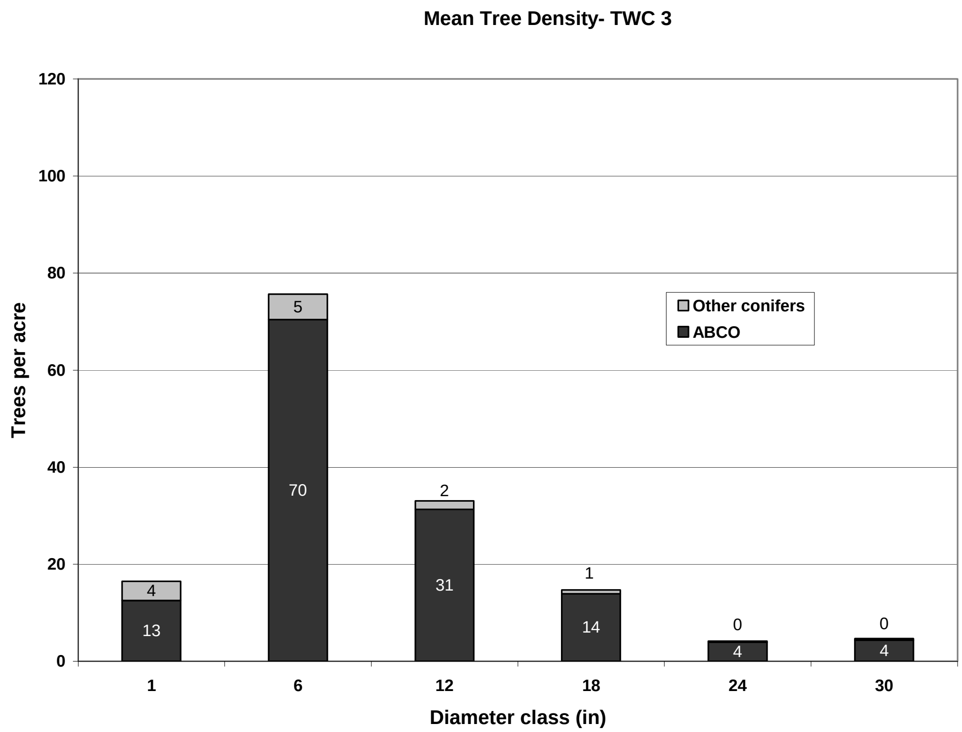

Figure 4.1-5. Mean tree density of white fir and other combined conifer species (ABMA, CADE, PICO, PIJE, PILA) in different size classes at TWC 3.

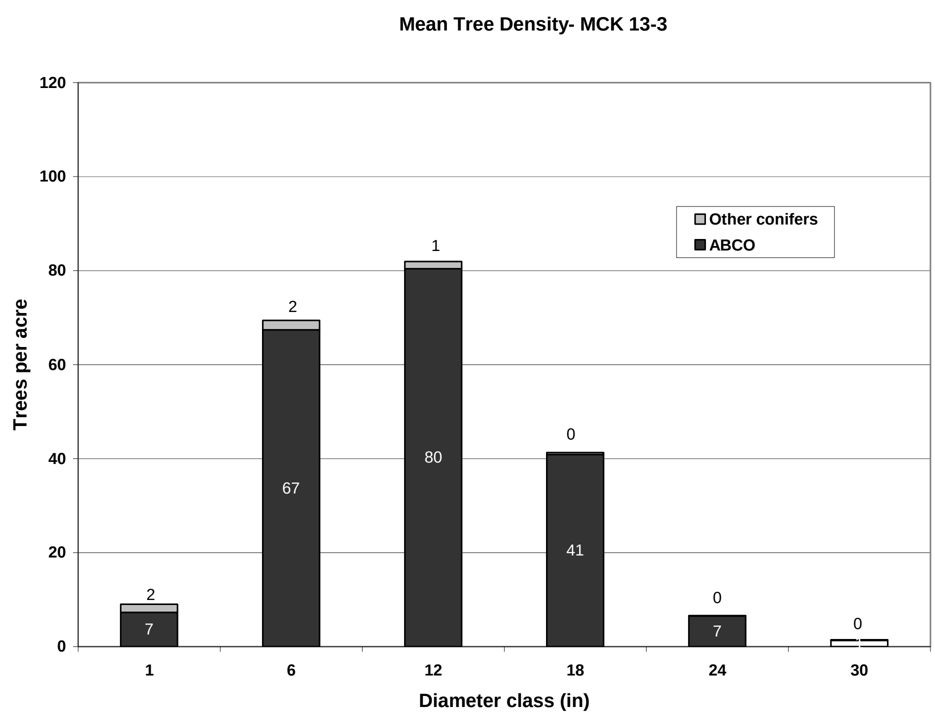

Figure 4.1-6. Mean tree density of white fir and other combined conifer species (ABMA, CADE, PICO, PIJE, PILA) in different size classes at MCK 13-3.

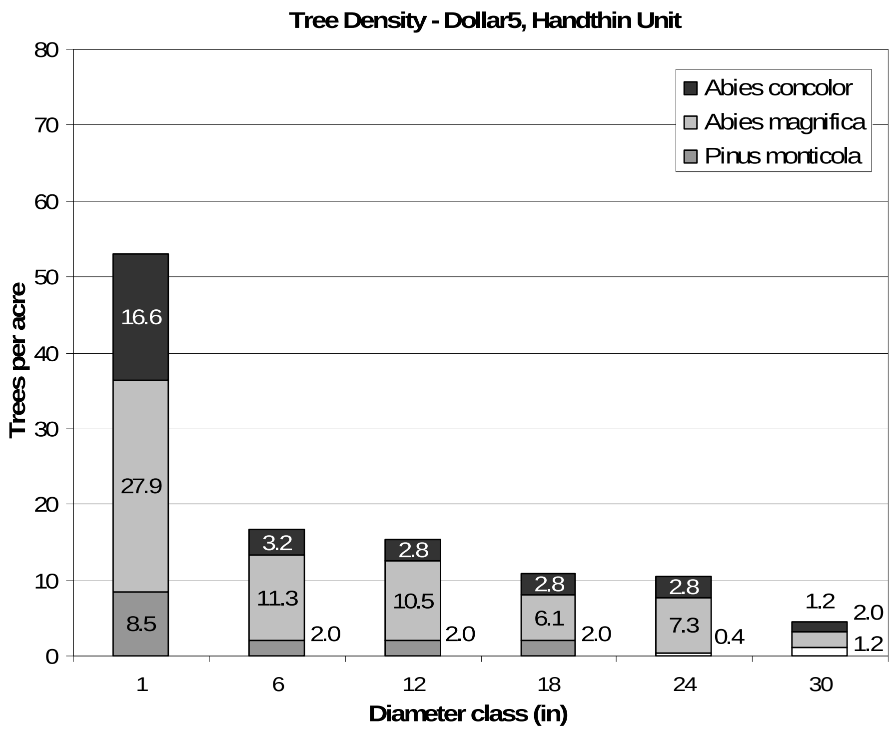

Figure 4.1-7. Pre-treatment tree density by species and diameter class for the Dollar5 hand thin treatment unit.

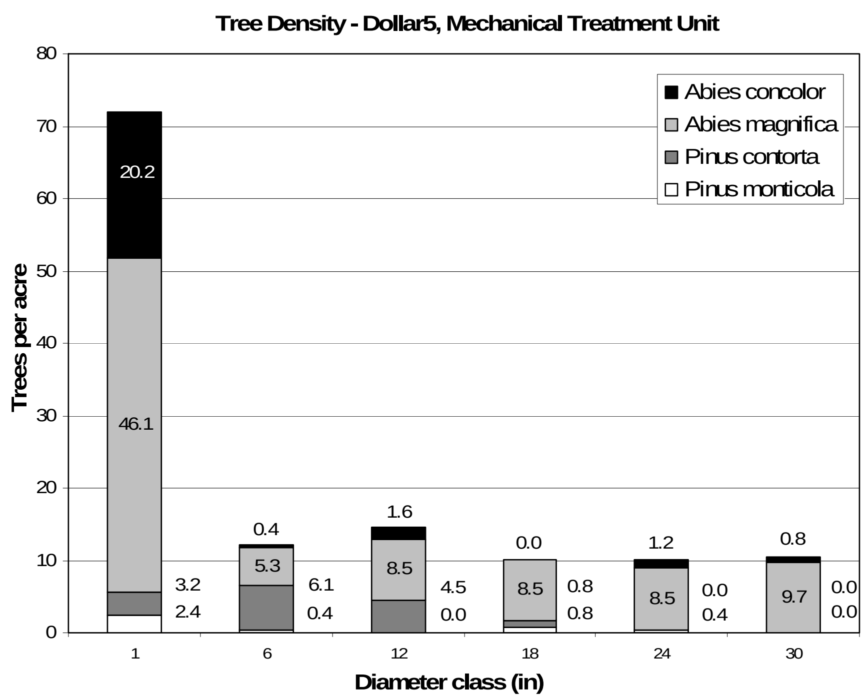

Figure 4.1-8. Pre-treatment tree density by species and diameter class for the Dollar5 mechanical treatment unit.

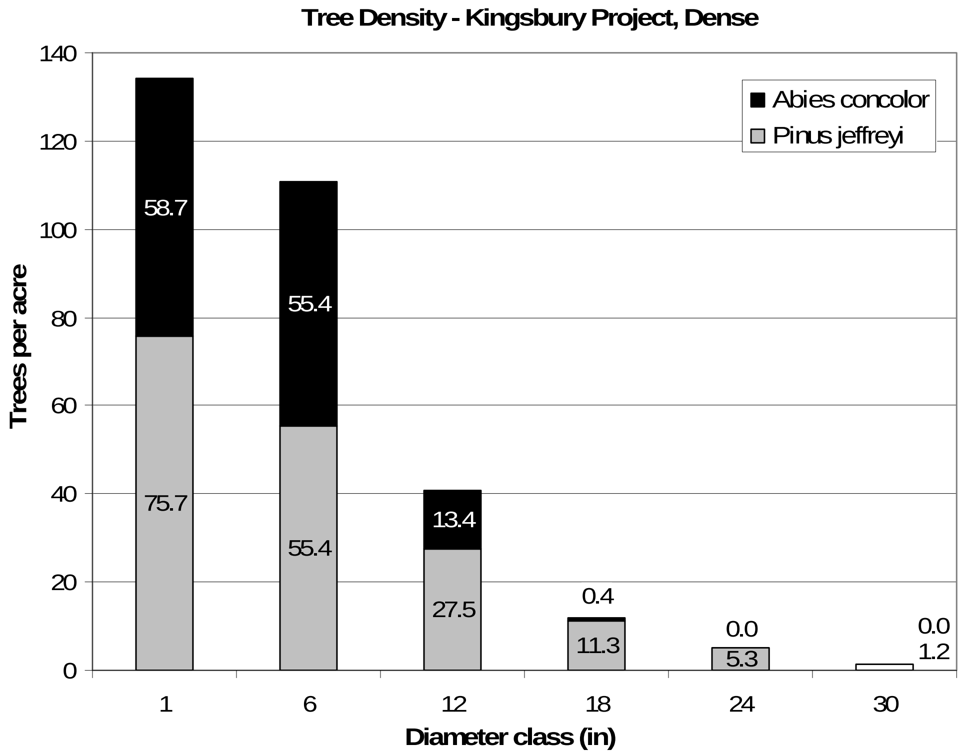

Figure 4.1-9. Pre-treatment tree density by species and diameter class for Kingsbury dense (KBd).

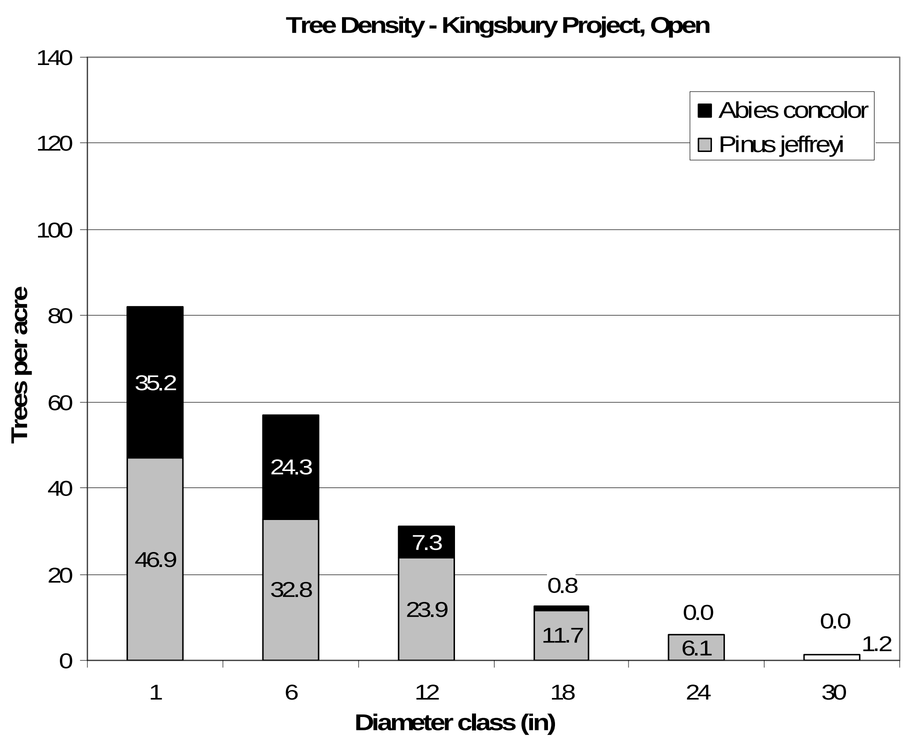

Figure 4.1-10. Pre-treatment mean tree density by species and diameter class for the Kingsbury open (KBo).

Seedlings

Total seedling density was less than or equal to one per acre in almost 60% of the west shore units (Table 4.1-4). Paired units in MCK 13-1 and WRD 20-09 had very high seedling densities (ranging from less than one, to 3885 seedlings/acre in WRD 20-09, and 2507 in MCK 13-1), but the variability on these units was also very large. The overall small sample of seedlings that were detected suggests that the sub-sample plot of .01 acre for the west shore units was too small. Unlike other size categories, white fir was the dominant seedling species in only one of the units (MCK 13-1 T). Incense cedar was co-dominant in the paired control in MCK 13-1, while red fir density was greater than white fir in WRD 20-09. Both red fir and incense cedar are shade tolerant species like white fir. Regeneration of the less shade tolerant pines was negligible across all units.

The mean value of white fir seedlings in the Kingsbury dense unit (KBd) was 10 per acre. Otherwise, no fir seedlings were found in the Kingsbury project site. A mean value of 40 seedling/acre of Jeffrey pine seedlings were found in the open plots (KBo) of the Kingsbury project.

The Dollar5 units had large numbers of red fir and some white fir seedlings, with more red fir seedlings in the mechanical project and more white fir seedlings in the hand thin project. Western white pine seedlings were found in small quantities in DH and DM.

Table 4.1-4 Mean density of seedlings/acre by species in 2006.

Unit	ABCO	ABMA	CADE	PICO	PIJE	PILA	PIMO3	UNKN	Total
BLK 1-4 C	1	1	3	0	0.1	<0.1	0	0	4
BLK 1-4 T	<1	<1	0.0	0	0	0	0	0	<1
MCK 13-1 C	328	139	308	30	0	0	0	0	774
MCK 13-1 T	328	27	29	<1	<0.1	0	0	0	369
MCK 13-3 T	0	0	0	0	0	0	0	0	<1
MCK 13-3 C	0.1	0.1	0	0	0	0	0	0	<1
TWC3 C	<1	<1	<0.1	0	0	0	0	0	1
TWC3 T	<1	0.1	<1	0	<0.1	<0.1	0	0	1
WRD 20-16 C	<1	0	0	0	0	0	0	0	<1
WRD 20-16 T	0.1	<0.1	0	<0.1	<1	0	0	0	<1
WRD 20-9 C	146	385	0	5	<0.1	0	0	0	535
WRD 20-9 T	223	336	0	5	7	0	0	0	567
KBd	10	0	0	0	0	0	0	0	10
KBo	0	0	0	0	40	0	0	10	50
DH	233	961	0	0	0	0	51	0	1245
DM	10	2074	0	10	0	0	10	0	2104

4.2 Herbaceous and Shrub Species

Understory vegetation should be included as an element of any fuels treatment monitoring program in order to determine the influence of treatments on rare and threatened plant populations and to track the introduction of invasive species. Understory vegetation is also a critical component of wildlife habitat and it can strongly influence fire behavior.

A total of 169 vegetative species were identified in the units (not including trees), along with 13 unknowns (see complete species list in Appendix 1). The complete suite of species included 112 herbs, 19 grasses, 14 sub-shrubs, and 24 shrubs. Unidentified moss was also recorded. The majority of species were captured with the FIREMON cover/frequency nested quadrat method; however, 27 of the species were recorded as occurring within the sample plot but not within a designated quadrat. No threatened and endangered plant species were identified in any of the units.

Species Richness

A total of 142 species were identified in the west shore units including 22 shrubs, 3 sub-shrubs, 14 grasses, and 103 herbs. The most common herbs across all the west shore units were dogbane (*Apocynum androsaemifolium*), milk kelloggia (*Kelloggia galioides*), mountain pennyroyal (*Monardella odoratissima)*, little prince's pine (*Chimaphila menziesii*), and wirelettuce (*Stephanomeria lactucina*). Common grasses included squirrel tail (*Elymus elymoides*), western needlegrass (*Acnatherum occidentalis*), and native bromes (*Bromus spp.).*The three sub-shrubs, pinemat manzanita (*Arctostaphylos nevadensis*), creeping snowberry (*Symphoricarpos mollis*), and squaw carpet (*Ceanothus prostrates*) were all quite common. The most common shrub by far was whitethorn (*Ceanothus cuneatus*), and other common shrub species included greenleaf manzanita (*Arctostaphyllos patula*), huckleberry oak (*Quercus vaccinifolia*), and bush chinquapin (*Chrysolepis sempervirens*). Non-native species were not detected.

Similar species were present in the Dollar5 units due to its close proximity with the west shore units, but only 10 species were detected. Of the 8 herb species, dogbane was the most common. Pinemat manzanita was the only sub-shrub present and whitethorn was the only shrub species. Non-native species were not detected.

Species richness in the drier forest typical of the eastside was moderate in the Kingsbury units. A total of 34 species were detected, including 22 herbs, 4 shrubs, and 8 grasses. The only non-native species recorded was cheatgrass (*Bromus tectorum*).

Across the west shore units, total mean richness per plot (size of 0.25 ac) ranged from 2 to 20 species (Table 4.2-1). Herbs were the most species rich lifeform, representing an average of 45% of the total mean number of species per plot. The mean number of herb species per plot ranged from 1 to 13. Shrubs were the second most specious lifeform, constituting 35% of the total mean richness in a plot. The mean number of shrub species per plot ranged from 1 to 4. The mean number of sub-shrub and grass species per plot ranged from 0 to 3.. The total number of species found within a single plot ranged from zero in several plots in MCK 13-3 to 31 species in a plot in WRD 20-09.

Table 4.2-1. Mean vegetative species richness per plot by lifeform.

Unit	Herb	Grass	Sub-shrub	Shrub	Total
BLK 1-4 C	7	1	2	4	14
BLK 1-4 T	3	0	1	3	7
MCK 13-1 C	6	2	0	3	11
MCK 13-1 T	3	1	1	3	8
MCK 13-3 T	1	0	0	1	2
MCK 13-3 C	1	0	0	2	3
TWC3 C	2	0	1	2	5
TWC3 T	6	0	3	4	13
WRD 20-16 C	6	1	1	2	10
WRD 20-16 T	7	1	1	3	12
WRD 20-9 C	13	3	1	3	20
WRD 20-9 T	9	2	1	3	15
KBo	3	2	0	3	8
KBd	2	1	0	3	6
DH	1	0	1	2	4
DM	1	0	1	1	3

Units with a mean ≥10 species per plot tended to be in close proximity to meadows (the Ward Creek units are adjacent to Page Meadows) or had a greater quantity of stream environment zones (SEZs) within the perimeter. The MCK 13-3 unit was nearly devoid of understory vegetation, likely due to very high surface fuel loads (see section 4.3).

Total mean richness per plot for the Kingsbury site was 8 in the KBo and 6 in KBd. The greater richness in KBo is likely due to the more open forest structure and lower tree density compared to KBd.

The residual slash on the surface of the thinned Dollar5 units likely reduced the number of species present in those units, however, without pre-treatment data it is not possible to determine if the low species richness per plot in that unit is the result of the treatments.

Understory Cover

Understory vegetative cover for the west shore units was sparse. Mean percent cover was less than 10% in most units (Figure 4.2-1). While local cover in shrub patches could be quite high, in general, the understory vegetation is patchily distributed across the landscape. The lowest mean cover (<3%) was recorded in MCK-3 T, while the highest mean cover was in TWC3 T (13%). Shrubs and sub-shrubs constituted the majority of cover in all units, while grass and herb cover was less than 1% in all units but TWC3 T. It should be noted that the quadrat method used to assess cover is most suited to plants less than 3 ft (1m) in height. In the west shore units, although the dominant shrub (whitethorn) was generally less than 3 ft tall, several of the other shrub species (Greenleaf manzanita and tobacco bush) often exceeded this height. This may have skewed the total shrub cover values to be lower than they would have been recorded using a line intercept method.

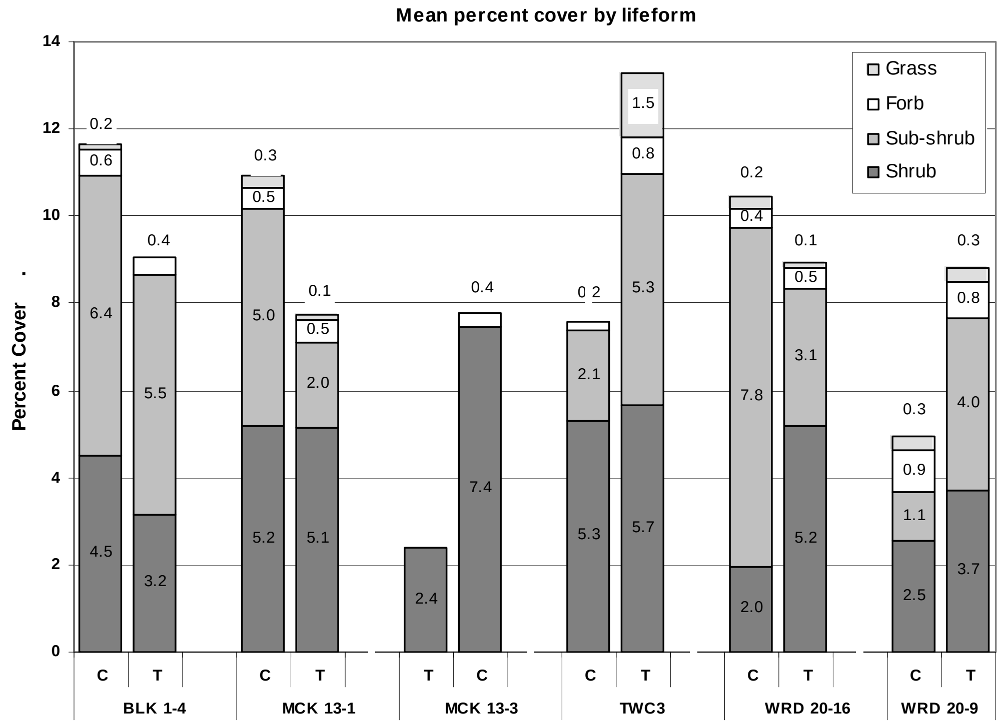

Figure 4.2-1. Mean percent cover by lifeform for west shore units in 2006.

Understory cover was very sparse in the Dollar5 and Kingsbury project sites, (Figure 4.2-2). The Dollar5 units had very sparse mean herb cover (<0.3%), with no grasses present. The Kingsbury open unit had a mean total understory cover of 1.8% and the dense unit had a mean total understory cover less than one percent. The Kingsbury units did have some grass cover with mean values of 0.1% for the KBd unit and 1.2% for the KBo unit.

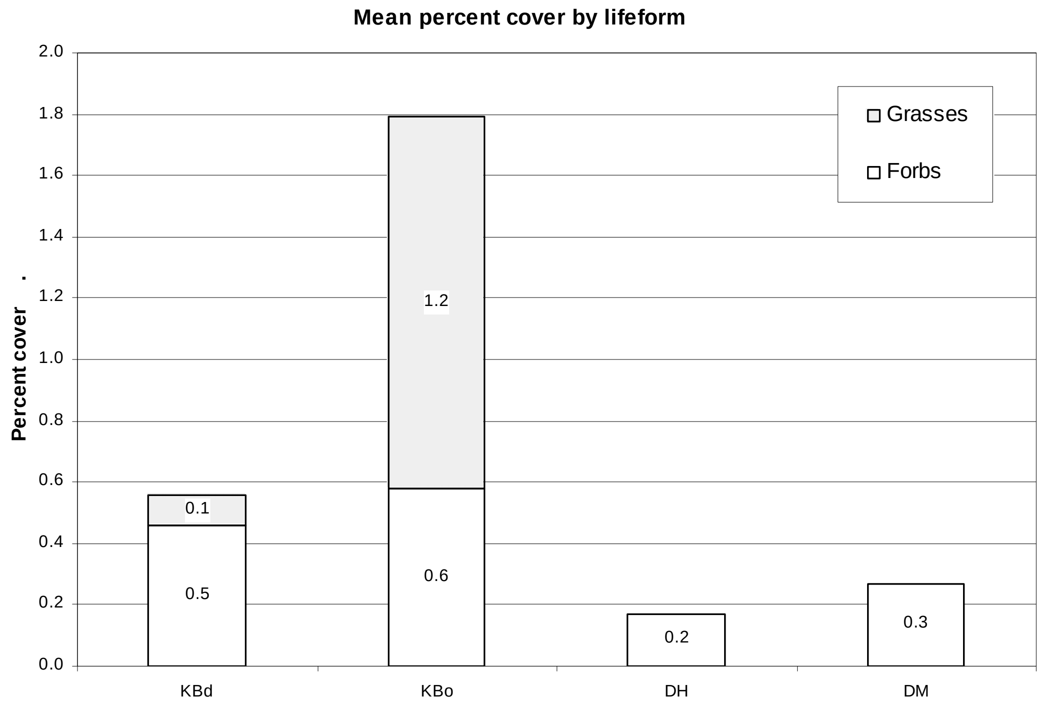

Figure 4.2-2. Mean percent cover by lifeform for Dollar5 and Kingsbury units in 2006.

The line intercept protocol was chosen for sampling shrubs in the Dollar5 and Kingsbury units instead of the quadrat method. Mean live shrub cover was 37.4% in the Dollar5 hand thin unit and only 7.3% in the mechanical unit (Figure 4.2-3). In the Kingsbury project, live shrub cover was 17.7% in the dense unit and 28.3% in the open unit. Dead shrub cover was low in both the Dollar5 or Kingsbury units, at 0.4% and 0.5% for DH and DM respectively, and 1.2% and 2.3% for KBo and KBd.

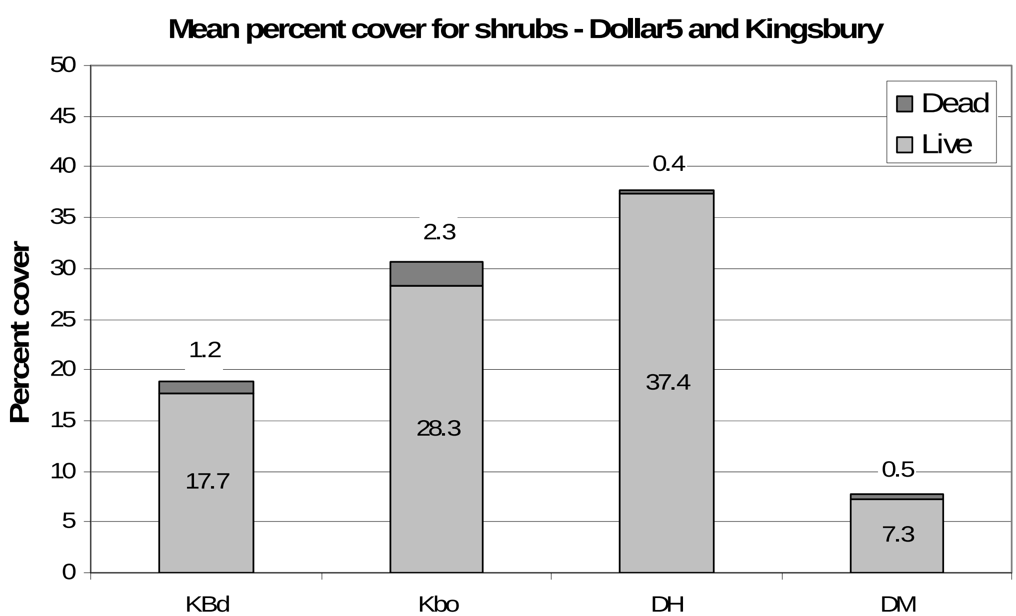

Figure 4.2-3. Mean percent cover for shrubs, Dollar5 and Kingsbury units in 2006.

Understory Species Frequency
Frequency describes the abundance and distribution of species and is very useful for comparing significant differences between two plant communities or detecting significant change in a single community over time. It is typically defined as the number of times a species occurs in the total number of sampled quadrats, usually expressed as a percent. Frequency is one of the fastest and easiest methods for monitoring vegetation because it only requires one decision (whether a plant is rooted within the quadrat frame) and is therefore objective and repeatable.

In the west shore units, sub-shrubs constituted the most frequently encountered lifeform in most units with mean frequency ranging from 10 to 38% in the units where they occurred (Figure 4.2-4). Shrubs were less frequently encountered in come units, with average frequencies ranging from 9 to 19%. The mean frequency of herbs and grasses was similar with ranges from 5 to 16 % and 6 to 19%, respectively.

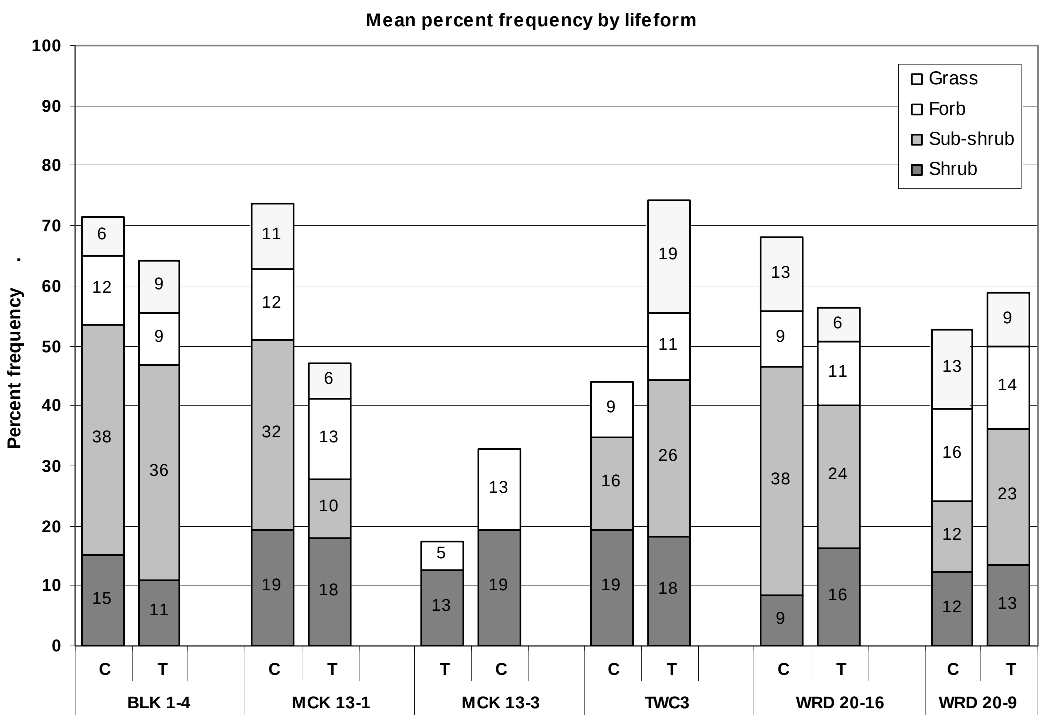

Figure 4.2-4. Mean percent frequency by lifeform for west shore units in 2006. Species listing is available in Appendix 1.

Mean percent frequency values were generally low for the Dollar5 and Kingsbury units (Figure 4.2-5). Mean frequency for herbs was 27% and 38% in the Dollar5 DH and DM units, and in 36% and 53% of quadrats in Kingsbury dense (KBd) and open (KBo) units respectively. Grasses were found in a mean of 17 and 37% quadrats in the Kingsbury KBd and KBo units, respectively. The greater frequency of herbs and grasses in the

Kingsbury "open" unit compared to the "dense" unit would be expected because of the lower canopy cover and greater exposure to light on the forest floor.

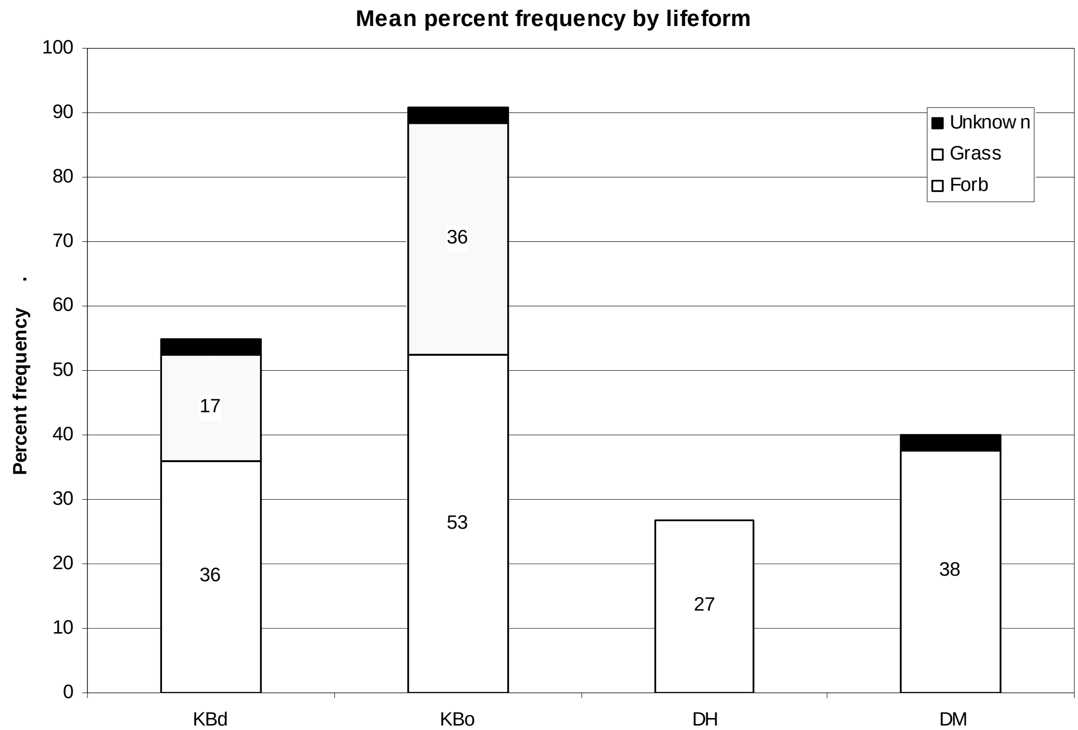

Figure 4.2-5. Mean percent frequency by lifeform for Dollar5 and Kingsbury units in 2006. Species listing is available in Appendix 1.

4.3 Fuel Loading

Measured surface fuel loads were evaluated as three different components: litter and duff, fine woody debris (1-100 hr fuels), and coarse woody debris (1000 hr fuels). In the partially-treated Dollar5 units, surface fuels also included residual woodchips and slash piles. Pre-treatment vegetative fuel loading of live and dead shrubs and herbs was calculated for the west shore and Kingsbury units. Crown fuel parameters of canopy base height and crown bulk densities are presented as they are the primary metrics used for crown fire assessment.

Total Surface Fuel Loading

For the west shore units, total mean surface fuel load ranged from 28 tons/acre in the WRD 20-16 control unit to 49 tons/acre in the WRD 20-16 control unit (Figure 4.3-1). For the Kingsbury units, total mean surface fuel loading ranged from 39 tons/acre in the dense unit "KBd" to 44 tons/acre in the "open" unit "KBo". For the previously treated Dollar5 units, total mean surface fuel loading ranged from 36 tons/acre in the mechanically treated unit "DM" to 42 tons/acre in the hand treated unit "DH".

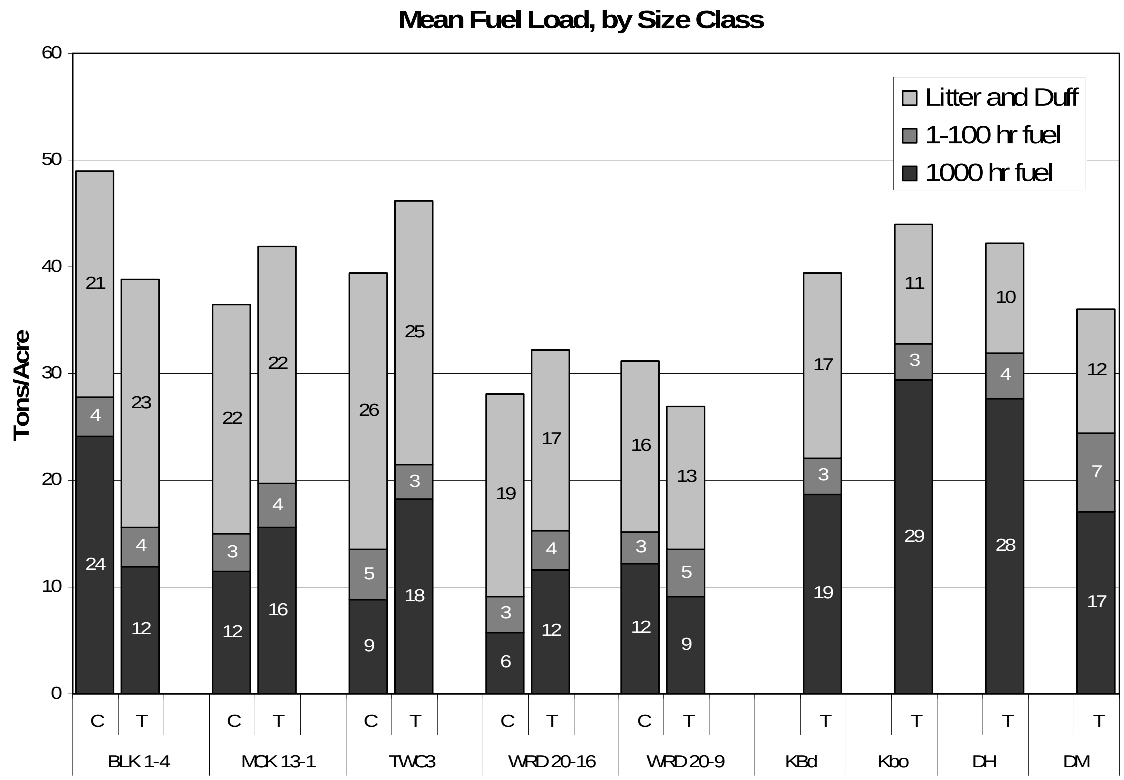

Figure 4.3-1. Fuel loading (tons/acre) of duff and litter, fine woody debris (1-100 hr), and coarse woody debris (1000 hr).

Litter and Duff

For the west shore units, mean fuel load for combined litter and duff ranged from 13 tons/acre in the WRD 20-9 treatment unit to 30 tons/acre in the MCK 13-3 control unit (Figure 4.3-2). The duff component was considerably higher than litter in all cases for the west shore units, with duff percentages ranging from 66% to 91% of the litter/duff total. For the Kingsbury units, mean fuel loading for combined litter and duff ranged from 11 tons/acre in the dense unit to 17 tons/acre in the open unit. The proportions of duff to litter were considerably less than the west shore plots, with duff percentages ranging from 38% to 44%. This could be the result of several factors including differences in vegetation types and climate. For the partially treated Dollar5 units, mean fuel loading for combined litter and duff was 10 and 12 tons/acre for the hand thin and mechanical thin units, respectively. Proportions of duff to litter were more similar to the west shore units, ranging from 54% to 73%.

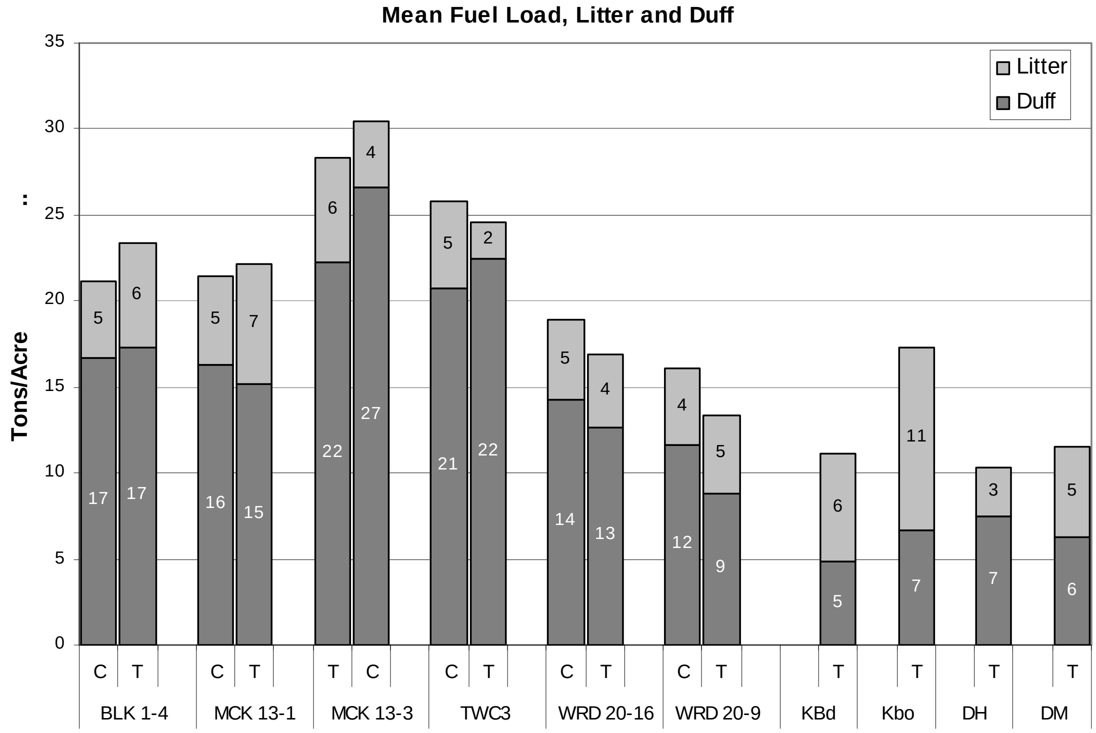

Figure 4.3-2. Mean Fuel loading (tons/acre) of litter and duff.

Fine Woody Debris (1 to 100hour fuel)

For the west shore units, total mean fuel load for fine woody debris ranged from 3 tons/acre on the WRD 20-9 control unit to 6.1 tons/acre on the MCK 13-3 treatment unit. Averaged across the west shore units, the total fine woody debris load was comprised of 9% 1hour fuels, 41% 10 hour fuels, and 50% 100 hour fuels. One hour fuel loads ranged from 0.2 to 0.6 tons/acre; 10 hour loads from 1.2 to 2.8 tons/acre; and 100 hour loads from 1.5 to 3.1 tons/acre. For the Kingsbury units, total mean fuel load for fine woody debris was 3.4 tons/acre for both the KBd and KBo units. Averaged across the two units, the total fine woody debris load was comprised of 4% 1 hour fuels, 33% 10 hour fuels, and 63% 100 hour fuels. One hour fuel loads were 0.1 tons/acre for the KBo unit and 0.2 tons/acre for the KBd unit; 10 hour fuels were 1.1 for the KBd unit and 1.2 tons/acre for the KBo unit; and 100 hour fuels were 2.2 tons/acre for both units. For the previously treated Dollar5 units, total mean fuel load for fine woody debris was considerably different among treatment types performed within the unit. The values for total mean fuel load for fine woody debris were 4.3 for the hand thin unit, and 7.4 tons/acre for the mechanical unit. Averaged across the two units, the total fine woody debris load was comprised of 9% 1 hour fuels; 26% 10 hour fuels; and 65% 100 hour fuels. One hour fuel loads were 0.4 for DH and 0.6 tons/acre for DM; 10 hour fuels were 1.1 for DH and 1.9 tons/acre for DM; and 100 hour fuels were 2.7 for DH and 4.9 tons/acre for DM.

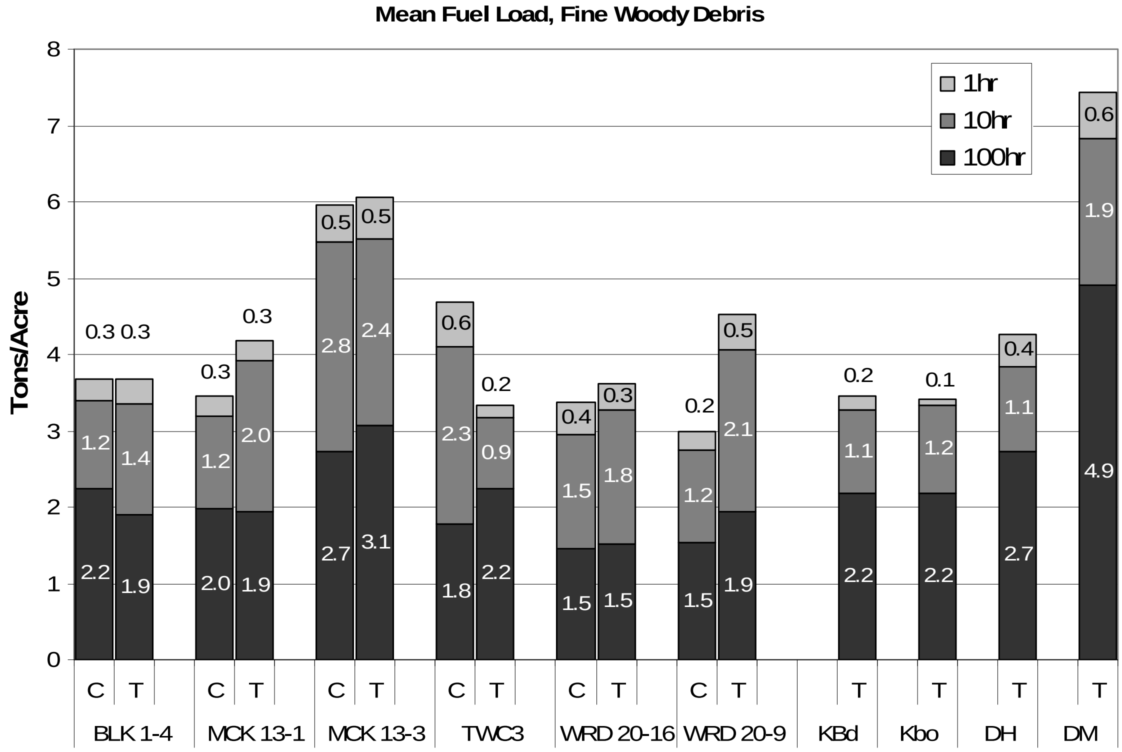

Figure 4.3-3. Mean Fuel loading (tons/acre) of fine woody debris (1-100 hr).

Coarse Woody Debris (1000 hour fuel)

For the west shore units, total fuel loads of coarse woody debris were variable. Combined sound and rotten coarse woody debris loads ranged from 6 tons/acre for the WRD 20-16 unit to 28 tons/acre for the MCK 13-3 unit. The proportion of sound to rotten coarse woody debris varied considerably, with the percentage of sound woody debris ranging from 20% to 57%. For the Kingsbury units, total coarse woody debris loads varied considerably, ranging from 19 tons/acre on the KBo unit to 29 tons/acre for the KBd unit. The proportion of sound to rotten coarse woody debris was similar in the two units; 45%/55% for KBd and 60%/40% for KBo. For the Dollar5 units, total coarse woody debris loads varied from 17 tons/acre on the DM unit to 28 tons/acre on the DH unit. The proportion of sound to rotten coarse woody debris was similar in the two units; 37%/63% for DH and 41%/59% for DM.

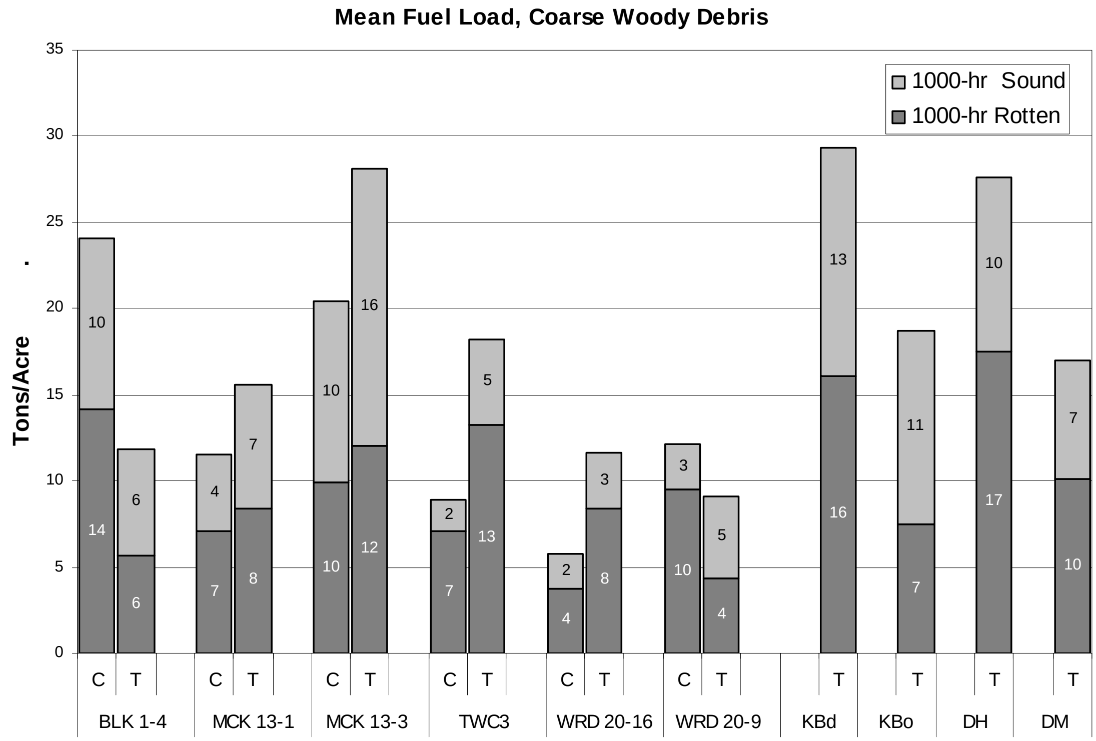

Figure 4.3-4. Mean Fuel loading (tons/acre) of coarse woody debris, sound and rotten 1000 hours.

Vegetative Fuel Loading

The biomass of live and dead vegetation is strongly associated with fire behavior and crown fire potential. Pre-treatment vegetative fuel loading was calculated for the west shore units but not for the Kingsbury or Dollar5 units. FIREMON uses volume estimates derived from percent cover and height values from the fuel transect vegetation cylinders to calculate fuel loads of live and dead shrubs and herbs. Live shrubs comprised over 75% of the total mean vegetative fuel loading in all units, which ranged from 1 to 4.6 tons/acre (Figure 4.3-5). Dead shrubs constituted from 6 to 24% of the total mean fuel load, while live herbs contributed less than 5% in all units except WRD 20-09 (10-12% live herbs). Only traces of dead herbs were detected. The live shrub component was dominated in various proportions across the units by whitethorn (*Ceanothus cuneatus*), greenleaf manzanita (*Arctostaphyllos patula*), huckleberry oak (*Quercus vaccinifolia*), or bush chinquapin (*Chrysolepis sempervirens*). These species are all highly flammable due to extensive dead branch retention and the presence of volatile resins and oils in the leaves or other plant parts.

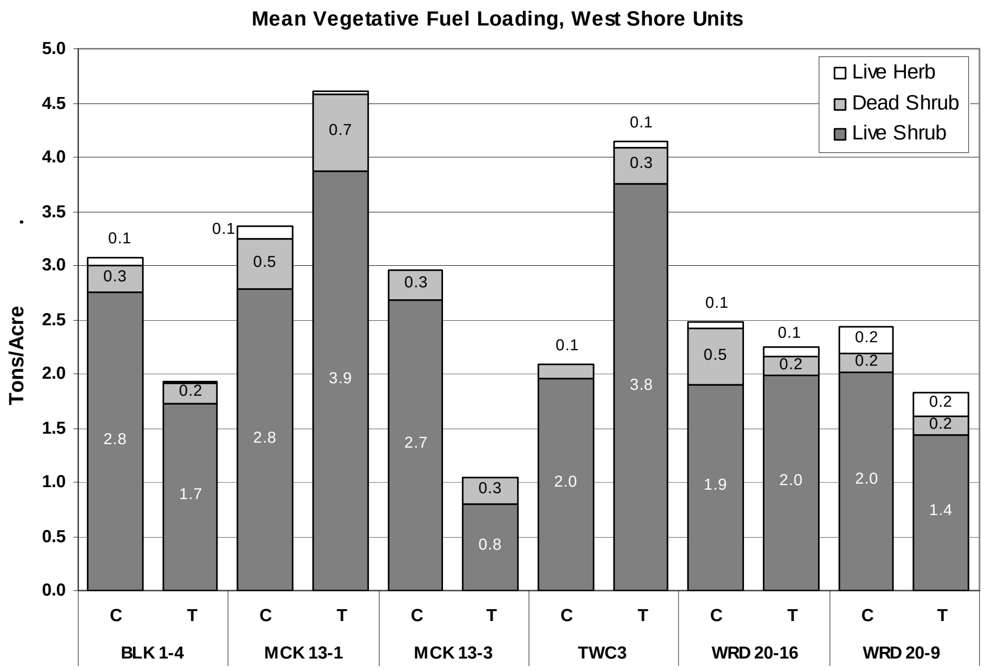

Figure 4.3-5. Average fuel loading (tons/acre) of live and dead shrubs and herbs.

Residual Woodchips

Pre-burn thinning treatments implemented in the Dollar5 hand thin unit (DH) involved chipping of slash material and small trees, into small woodchips. Because woodchips have different physical characteristics than natural woody debris a different protocol for field measurements and reporting is necessary. We based our data collection protocol for woodchips on a recent study performed on methods for estimating masticated material (Hood and Wu, 2006). Details on our chipped material data collection methods are provided in Appendix 1. The measurements taken allow for calculation of volume and ultimately, biomass. However, bulk density values have not been determined for woodchips in the Lake Tahoe Basin, therefore calculation of biomass is not possible. Reporting of volume is probably not useful and so three characteristics of the woodchips are reported: percent cover, depth averaged across the entire plot area "Whole Plot", and depth averaged across only those locations where woodchips were present "Where Woodchips Present Only" (Table 4.3-1). Measurements indicated slightly more coverage and whole plot depth of woodchips on plot 1 than plot 2. Percent cover of woodchips ranged from 14 to 27 percent. Mean woodchip depth calculated for the entire plot area was 1.2 and 0.2 inches for plots 1 and 2 respectively. In areas where woodchips existed, mean plot woodchip depths were deeper for Plot1 (6.3 inches) than Plot2 (1.9 inches).

Table 4.3-1. Woodchip conditions measured at two plots within the Dollar5 hand thin unit (DH). Woodchip depth values are presented from two perspectives: 1) mean depth across the entire plot, and 2) woodchip depth values which only account for locations where woodchips were present.

	Cover %	Mean Woodchip Depth(in) Whole Plot	Mean Woodchip Depth(in) Where Woodchips Present Only
Plot1	27	1.2	6.3
Plot2	14	0.2	1.9
Mean	21	0.7	4.1

Slash Piles

Slash piles consist of the residual material generated in tree thinning treatments. Slash piles are typically targeted for burning after 1 to 2 years, following a curing time that is necessary for complete combustion. Estimating the biomass of fuels making up slash piles allows for calculations of smoke generated from the burning of those piles. However, smoke calculations were not conducted for this report. Slash piles were only present on the previously treated Dollar5 mechanical treated unit (DM). To collect and analyze slash pile biomass, a set of guidelines developed specifically for determining biomass of piled slash (Hardy, 2006) was used (see methods in Appendix 1).

Measurements taken on slash piles in the DM unit indicate that litter, 1, 10, 100 and 1000-hour fuels all make up similar proportions of piles (Table 4.3-2). Amounts of litter in piles were found to range from 0.6 to 14.5 tons/acre. Loadings of 1, 10 and 100-hour fuels in piles were all found to range from 2 to 11.6 tons/acre. Thousand-hour fuel loads in slash piles in these units ranged from 2.7 to 14.5 tons/acre.

Table 4.3-2. Slash pile fuel, by size class (tons/ac). Results are for slash piles located within the Dollar5 Project, Mechanical Treatment Unit.

	Litter	1hr	10hr	100hr	1000hr
Mean	5.2	5.7	7.4	5.5	6.4
SE	1.7	1.8	2.3	1.7	2.0
Range	(0.6 - 14.5)	(2.0 - 10.8)	(2.5 - 13.3)	(3.0 - 11.6)	(2.7 - 14.5)

Crown Fuels – Canopy Base Height

Canopy base height (CBH) is a metric found to be significantly correlated with crown fire initiation (Van Wagner 1977, Omi and Martinson, 2002). Reducing the potential for crown fire is a primary goal in fuel reduction treatments. Increasing canopy base height (CBH) and reducing crown bulk density (CBD) has been determined to be effective in reducing crown fire initiation, and minimizing crown fire behavior. Crown fire is a complex phenomenon, with many variables involved. Although it is reasonable to assume the proper adjustments to CBH and CBD will help minimize the potential for crown fire, it is unrealistic to assume that manipulating CBH and CBD levels alone will dictate crown fire behavior.

CBH targets are determined at the project level, generally set in the range from 12-25ft as part of the effort to achieve the desired condition to lower the probability of crown fire. The treatment prescriptions in the Ward EA (2002) specify a minimum CBH of 20 ft (6 m). For the west shore units, mean CBH ranged from a low of 4 feet on the MCK 13-1 units and the TWC 3 unit to a high of 17 feet on the MCK 13-3 unit (Figure 4.3-6). All but two of the west shore units had a CBH of 6 feet or less which is 3 to 7 times lower than the desired condition. The higher CBH of 17 feet in MCK 13-1 was likely a function of the insect and pathogen infestations that have inhibited conifer regeneration in that unit and created a very sparse understory with dense accumulations of DWD. In the Kingsbury units, mean CBH was 3 feet in the KBd unit and 5 feet in the KBo unit. In the partially-treated Dollar5 units, mean canopy base height was 5 feet in the DH unit, and 8 feet for the DM unit. Although not specifically listed as a resource objective in the Dollar5 Prescribed Burn Plan, it is presumed that broadcast burns will consume a considerable portion of sapling sized trees (<6”). Removal of those smaller trees with the prescribed burn treatment will most certainly result in higher mean CBH values at the plot and stand level. Post-treatment measurements would be necessary to confirm this assumption.

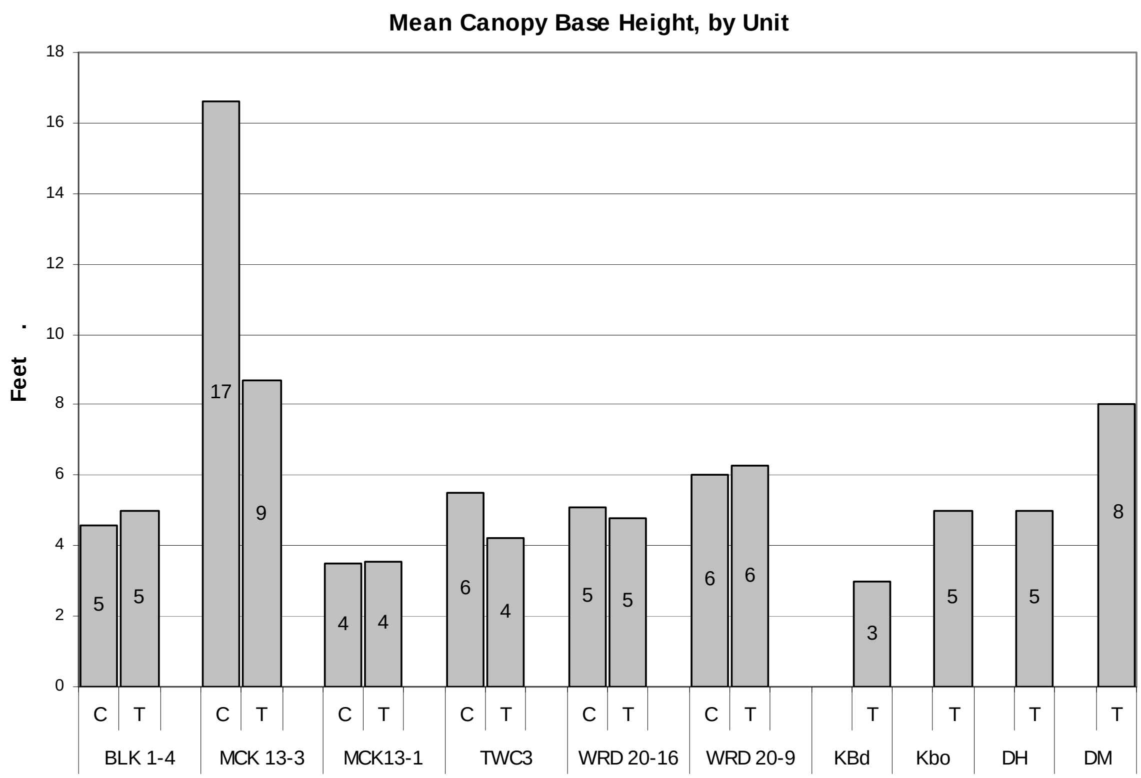

Figure 4.3-6. Mean canopy base height (ft), trees >1”dbh, by project unit.

Fires behavior changes constantly on a micro-scale depending on many factors so it is useful and relevant to look at the data on the finest possible scale. The CBH data from the 60 west shore plots in the units slated for treatment, the 20 Kingsbury plots, and the 20 Dollar5 plots are presented in Figure 4.3-7. Of the west shore plots, only one plot in the MCK 13-3 treatment unit had a CBH exceeding 20 feet. Two other plots in the same unit achieved a 12 foot CBH. In the treatment units, 85% of the plots had a CBH of 6 feet of less, which is two times lower than a desired CBH of 12 feet and 4 times lower than a

CBH of 24feet. The situation was similar in the Kingsbury units where 85% of the plots also have a mean of 6 feet or less. In the partially treated units in Dollar5, only one plot had a CBH greater than 20 feet, and only 4 had a BCH greater then 12 feet.

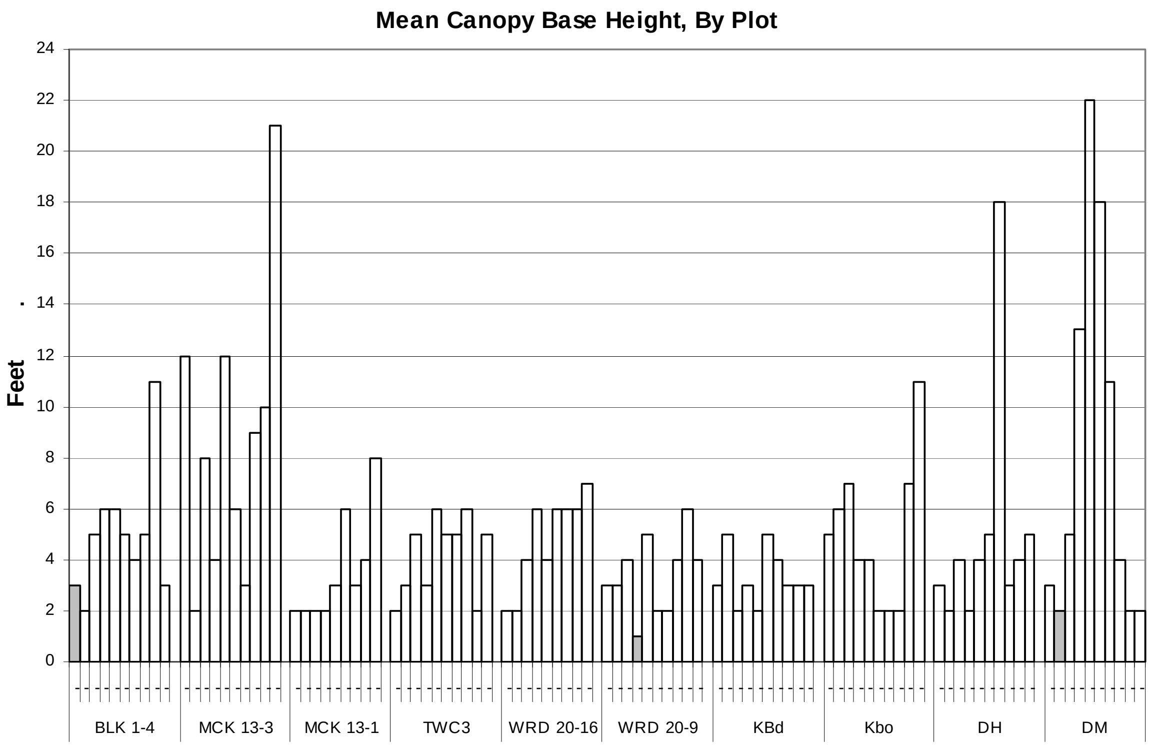

Figure 4.3-7. Mean canopy base height (ft.), trees >1”dbh, by plot.

Crown Fuels – Canopy Bulk Density

Crown bulk density (CBD) is a measure of canopy fuels that is a key characteristic for determining the potential for crown fire spread (Scott and Reinhardt, 2001). Several studies have shown that higher crown fire activity exists with higher CBD present (Agee 1996, Omi and Martinson 2002). Crown fire is considered possible under extreme conditions when CBD values reach a threshold of 0.1 kg/m^3 (Agee 1996). Although dependant on the interaction of several other factors as well, it is generally accepted that the transition from passive to active crown fire becomes more likely at higher CBD levels, above 0.15 kg/m^3. CBD levels of 0.1 and 0.15 kg/m^3 will be used to describe relative differences in CBD, but should not be considered strict thresholds that dictate crown fire activity.

For the west shore units, mean canopy bulk density (CBD) for the entire unit ranged from a low of 0.16kg/m^3 on the WRD 20-16 treatment unit to a high of 0.31kg/m^3 on the MCK 13-3 treatment unit (Figure 4.3-8). All of the west shore units are above the threshold of 0.15kg/m^3 where active crown fire is possible. Both of the Kingsbury units were below this threshold. Mean CBD was 0.11kg/m^3in the KBo unit and 0.14kg/m^3in the KBd unit. For the partially-treated Dollar5 units, mean CBD was well below the crown fire threshold with 0.06kg/m^3 for both the hand treated and mechanical units.

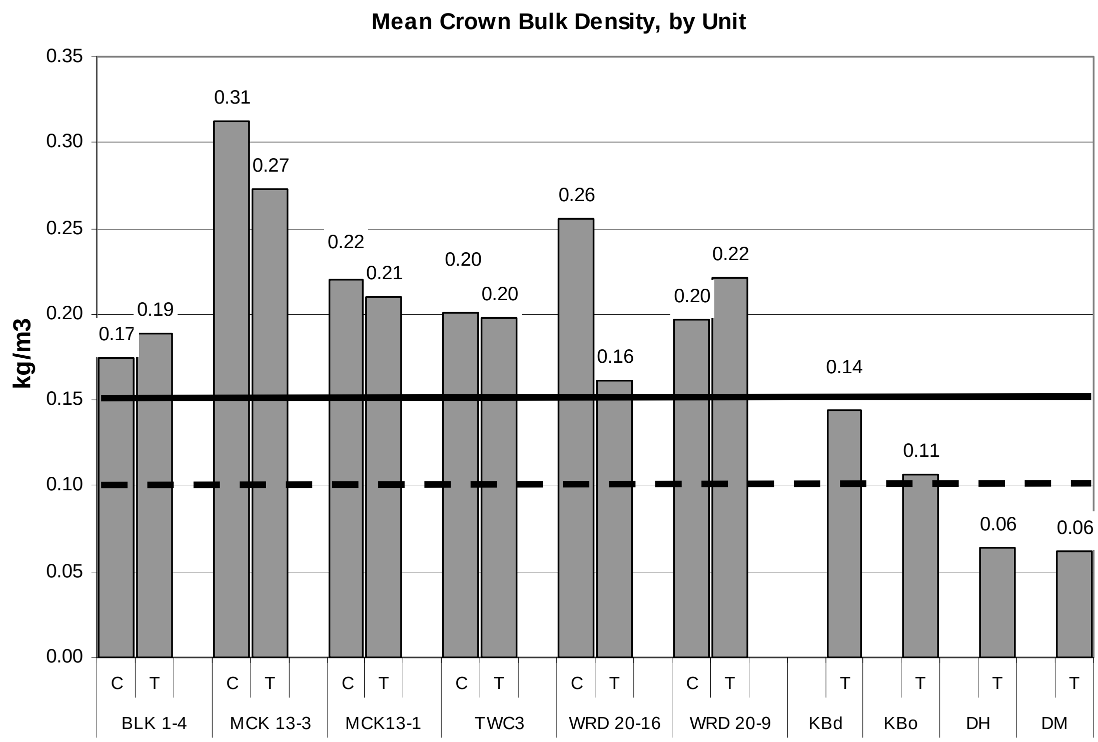

Figure 4.3-8. Mean crown bulk density, by project unit. Threshold values of CBD are marked where crown fire potential generally occurs. Passive crown fire potential is considered high when CBD exceeds 0.10 (dashed line); Active crown fire potential is considered high when CBD exceeds 0.15 (solid line).

Like CBH values, it is also preferable to present CBD data on the smallest scale possible because fir dominated forests tend to have clustered spatial arrangements that can affect fire behavior on very small scales. Therefore, CBD is presented for each sample plot (.25 ac) in the treatment units. The plot level data for the west shore units shows that only 5 plots (4%) were below the threshold of $0.1 kg/m^3$ where passive crown fire is possible. Of the 120 plots, 75% had mean CBD values that exceeded the $0.15 kg/m^3$ threshold where active crown fire is possible (Figure 4.3-9). For the Kingsbury units, 65% of the plots were above the $0.1 kg/m^3$ threshold and 40% of the plots were above the $0.15 kg/m^3$ threshold. In the Dollar5 project, only 1 plot out of 10 in the hand thinned unit was at the threshold of $0.1 kg/m^3$, all other plots in the Dollar5 unit were well below $0.1 kg/m^3$. Overall variation in CBD in the treated Dollar5 units is much less than the untreated units, but without pre-thinning data it is not possible to determine if that relative homogeneity was inherent in the stands or the result of the treatments.

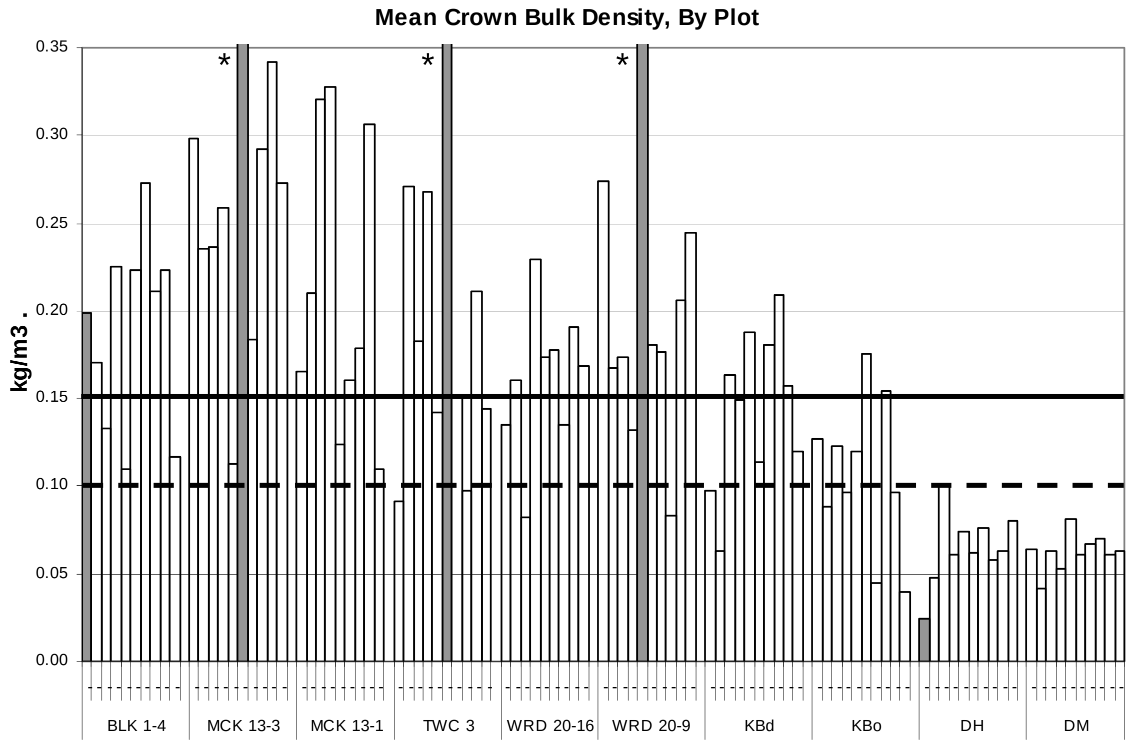

Figure 4.3-9. Mean crown bulk density, by plot. Threshold values of CBD are marked where crown fire potential generally occurs. Passive crown fire potential is considered high when CBD exceeds 0.10 (dashed line); Active crown fire potential is considered high when CBD exceeds 0.15 (solid line).

4.4 Sample Size Analysis

A sample size analyses was performed in order to determine change detection capabilities of the data that was collected. Guidance and equations used for this analysis was obtained from the National Park Service Fire Monitoring Handbook (USDI National Park Service 2003). In order to fully understand the results presented here, it is necessary to clarify a few assumptions that were made in the sample size calculations:

The following equation was used to determine the change detection:
$n = SD^2 (t\alpha + t\beta)^2 / (MDC)^2$,where:

n = minimum number of plots needed

SD = standard deviation

$t\alpha$ = t based on chosen level of significance (obtained from Student's t table, once significance is chosen). It was assumed that we were detecting change in one direction, so the one-tailed values were used, according to 9 degrees of freedom (10 plots minus 1).

$t\beta$ = t based on selected level of power (obtained from Student's t table).

MDC= minimum detectable change

Chosen level of significance, α (alpha): An alpha level of 0.2 was used, meaning that we are willing to accept a 20% probability that any detected change is the result of random variability on the landscape.

Chosen level of power, β: Power is the probability of detecting a change when a real change has occurred. In ecological evaluation, the accepted minimum level of power is 80%. That value was applied in our calculations.

Minimum detectable change, MDC: Three levels of MDC were evaluated, 10% change, 25% change, and 50% change. Most parameters were incapable of detecting ≤10% change, therefore we reported according to whether the l0 plots/unit would be capable of detecting a minimum of 25% change, minimum 50% change, or minimum greater than 50% change.

The sample size analysis showed that most of the primary variables of concern could be tracked for minimum changes of 25% or 50% with 10 plots (Table 4.4-1). The results vary due to differing variation found between differing vegetation types, and between similar vegetation types where one area has been partially treated.

For forests structure, all project sites were shown to be capable of detecting 25% change with 10 plots for the primary forest variables of density, cover, dbh, and basal area. Detecting 50% change for sapling density is possible in the mixed fir types, but not possible for the mixed Jeffrey and fir types of the east shore. Results for detecting changes in seedling density indicate that it might not be worth including in monitoring efforts. Snag density showed that 50% change could be detected with 10 plots.

For herbs and shrubs, species richness appears to be the most promising parameter for tracking change, with the mixed fir types capable of detecting 25% change, and the PIJE/ABCO type capable of detecting 50% change with 10 plots. Changes in herb/shrub frequency, height, and cover can show 50% change at best. With many parameters requiring greater than 10 plots in order to detect 50% change.

For fuels, total fuel loading and CBD change detection of 25% were possible for all project sites. 1 and 10 hour fuels can show 25% for in the mixed fir types. With less variation in the west shore plots, change detection of 25% for all fuel size classes, except for highly variable 1000 hour fuels was shown to be possible. The Kingsbury site, and partially-treated Dollar5 site showed that detection minimum of 50% change was possible for all parameters.

Detailed sample size analysis results are not presented here, but are available.

Table 4.4-1. Minimum change detection possible with 10 plots or less.

	25%			**50%**			**>50%**		
	West Shore	Kingsbury	Dollar5	West Shore	Kingsbury	Dollar5	West Shore	Kingsbury	Dollar5
Forest Structure									
Tree density	X	X	X						
Canopy cover	X	X	X						
QMD 75	X	X	X						
Basal area	X	X	X						
Sapling density				X		X		X	
Seedling density							X	X	X
Snag density				X	X				X
Herbs/Shurbs									
Species Richness	X		X		X				
Herb/shrub frequency				X				X	X
Herb/shrub height				X	Shrub	Shrub			
Herb/shrub cover					Shrub	Shrub	X	Herb	Herb
Herb fuel load							X		
Shrub fuel load				X					
Fuels									
Total fuel load	X	X	X						
1 hr fuels	X		X		X				
10hr fuels	X		X		X				
100hr fuels	X				X	X			
1000 hr fuels					X	X	X		

5.0 DISCUSSION

Fuels management in the Lake Tahoe Basin requires 1) a vision for the forest-urban interface stated in terms of desired future conditions, and 2) a scientific assessment of the current status of the forest stated in terms of forest structure (e.g. tree density, size class distribution, and species composition). Current status is the starting point and the vision is the end point for application of fuels reduction treatments to be evaluated with respect to reduction in fire risk, ecological impacts, and cost effectiveness. This report represents an important first step in fuels management because it provides a robust framework for assessing forest structure and evaluating the available treatment options. Herein we discuss possible desired conditions and what the data demonstrate about the current status of the sampled forest units.

5.1 Desired conditions

Desired conditions were specified in the Sierra Nevada Forest Plan Amendment Record of Decision in 2004 (SNFPA ROD 2004). That decision replaced earlier guidelines and standards to ensure that fuels treatments would be effective in modifying wildland fire behavior. It also broadened the strategy to make sure that fuels reduction efforts also addressed other management objectives such as reducing stand density for forest health, restoring and maintaining ecosystem structure and composition, and restoring ecosystems after severe wildfires or other catastrophic disturbances.

Table 5.1-1 presents the desired conditions for five different land allocations. As stated, the desired conditions address attributes of forest structure, fuel conditions, fire behavior, and wildlife habitat, but they are mostly stated in descriptive terms and quantifiable values are not given for most variables. While this approach provides a great deal of flexibility, when it comes to establishing a monitoring program to address the question of whether desired conditions are being met, it fails completely. For example, to accurately measure the success of fuel reduction treatments applied in the WUI defense zone it would be necessary to objectively translate what is meant by a stand that is “fairly open and dominated by large, fire tolerant trees” into numerical targets (e.g. the maximum number of trees per acre of ponderosa pine that have diameters greater than 30 inches).

Table 5.1-1. Desired conditions for selected land allocations (as specified in the SNFPA ROD 2004).

Land Allocation	Desired conditions
WUI Defense Zones	• Stands in defense zones are fairly open and dominated primarily by larger, fire tolerant trees. • Surface and ladder fuel conditions are such that crown fire ignition is highly unlikely. • The openness and discontinuity of crown fuels, both horizontally and vertically, result in very low probability of sustained crown fire.
WUI Threat Zones	Under high fire weather conditions, wildland fire behavior in treated areas within the threat zone is characterized as follows: • Flame lengths at the head of the fire are less than 4 feet • The rate of spread at the head of the fire is reduced to at least 50 percent of pre-treatment levels • Hazards to firefighters are reduced by managing snag levels in locations likely to be used for control of prescribed fire and fire suppression consistent with safe practices guidelines • Production rates for fire line construction are doubled from pre-treatment levels • Tree density has been reduced to a level consistent with the site's ability to sustain forest health during drought conditions.
CA spotted owl and northern goshawk PACs	• At least two tree canopy layers are present • Dominant & co-dominant trees average at least 24 inches DBH • Area within PAC has at least 60 to 70% canopy cover (50 to 70% is acceptable in HRCAs) • Some very large snags (>45 inches DBH) are present • Levels of snags and down woody material are higher than average
Old Forest Emphasis Areas	• In old forest emphasis areas forest structure and function generally resemble pre-settlement conditions • High levels of horizontal and vertical diversity exist at the landscape-scale • Stands are composed of roughly even-aged vegetation groups varying in size, species composition, and structure. Individuals groups range from 0.5 to more than 5 acres in size • Tree sizes range from seedlings to very large trees • Species composition varies by elevation, site productivity, and related environmental factors • Multi-tiered canopies, particularly in older forests provide vertical heterogeneity • Dead trees, both standing and fallen, meet habitat needs of old-forest-associated species • Where possible, areas treated for fuels also provide for the successful establishment of early seral vegetation
General Forest	Same as above

Ideally, it would be possible to create a table that portrayed desired conditions alongside current conditions to see the status of any given forest attribute. However, the descriptive nature of the desired conditions and the lack of quantifiable numbers make this impossible. In the absence of a one-to-one relationship between desired conditions and stand-level data, we chose to address several methods for characterizing existing and desired conditions at multiple scales. In the following sections, we discuss existing conditions for the specific attributes of forest structure, herbaceous and shrub species, and fuel loading as we demonstrate how the data can inform the development and implementation of a monitoring plan that informs fuel reduction actions.

Recent legislation in the Healthy Forest Restoration Act (HFRA 2003) mandates use of Fire Regime Condition Class (FRCC) among agencies in reporting vegetation treatments. FRCC is a national program that compares current vegetation structure with historic reference structure to infer departure from the historic range of variability (HRV). The FRCC index describes a calculated departure between historic and current conditions for three different variables: 1) Fire frequency, 2) Fire severity, and 3) Vegetation seral stage (age class) distribution. The combination of the first two variables describe fire regime and the third describes vegetation structure. FRCC vegetation structure is classified in five seral stages: early-open, middle-closed, middle-open, late-open, and late-closed (Table 5.1-2).

Table 5.1-2. Example of Seral Stages defined by FRCC. These stages may be different for each vegetation type**.**

Stage	Description	Tree Size (Diameter)	Canopy	% Canopy Closure
A	Early	0-4.9 inches	Open	NA
B	Mid	5-24.9 inches	Closed	≥50
C	Mid	5-24.9 inches	Open	<50
D	Late	25+ inches	Open	<50
E	Late	25+ inches	Closed	≥50

FRCC Condition Class is a categorical measure of departure from historic conditions (e.g. pre fire-suppression) that considers both vegetation structure departure (as primarily indicated by seral stage) and fire regime departure (Table 5.1-3). This tool can be broadly used to describe the departure from desired conditions (DC)s. FRCC 1 is the desired condition for all vegetation types since the ultimate goal of forest management activities is to bring fire regimes within the historic range of variability.

The existing FRCC of much of the land area in the LTBMU is in category 3 since fire has been excluded for many return intervals. Recent R5 modeling of reference conditions, based on National LANDFIRE and FRCC workshops and peer review indicate that a majority (32 to 37%) of historic white fir mixed conifer forests in the LTBMU were late-open (H. Safford, pers comm. 2005). Current modeling and mapping exercises are under way (D. Fournier pers comm. 2007) but it is safe to say that majority of the contemporary white fir mixed conifer forest is mid-closed. Fuels treatments in the WUI designed to make stands more “open” are attempting to move existing seral stage from mid-closed to the pre-fire suppression stage characterized by late-open. Likewise, the ultimate way to improve forest health is to bring fire regimes within the historic range of variability and move stands from FRCC 3 to FRCC 1.

Table 5.1-3. Fire Regime Condition Classes

Class	Description
1	Fire regimes are **within the historical range of variability** (0 – 33% departure) and risk of losing key ecosystem components is low. Vegetation attributes (composition and structure) are intact and functioning.
2	Fire regimes have been **moderately altered** (34 – 66% departure). Risk of losing key ecosystem components is moderate. Fire frequencies may have departed by one or more return intervals (either increased or decreased). This may result in moderate changes in fire and vegetation attributes.
3	Fire regimes have been **substantially altered** (67 – 100% departure). Risk of losing key ecosystem components is high. Fire frequencies may have departed by multiple return intervals. This may result in dramatic changes in fire size, fire intensity and severity, and landscape patterns. Vegetation attributes have been substantially altered.

While the FRCC system is useful for a broad assessment of desired conditions on a landscape or regional level that may be incorporated into the planning process, to address specific DCs related to forest structure and wildlife habitat it is necessary to move beyond such broad desired conditions and focus on stand level data. Pre-treatment data from this study can be compared with the few available estimates in the literature of the historic range of variability for key forest structure components to confirm departure from desired conditions. A recent study of mixed conifer forests in Yosemite that measured trees greater than 4” (rather than the 6” in this study) developed a reconstruction of historical conditions (using stump data) and concluded that pre-settlement forests had an average density of only 54 trees/acre, a BA of 187 ft^2/acre, and a QMD of 27 inches (Paintner and Taylor 2005) (Table 5.1-4). A similar study conducted in the Lake Tahoe basin evaluated historical and contemporary conditions in Jeffrey pine/white fir forests on the east shore (Taylor et . al 2004). They reconstructed historic reference conditions of an average density of 28 trees/acre, a BA of 113 ft^2/acre, and a mean QMD of 26 inches. In the present study, mean tree density in the west shore mixed conifer units is almost 4 times greater, average basal area is 25% greater, and mean tree size (measured as QMD) is 11 inches smaller than the reconstructed forest reference condition. In the east shore Jeffrey pine/white fir units, mean tree density is 9 times greater, average basal area is somewhat greater, and mean QMD is 12 inches smaller.

Table 5.1-4. Comparison to sites of reconstructed forest reference conditions.

Vegetation type		Tree density (trees/acre)	BA (ft2/acre)	QMD (inches)
Yosemite mixed conifer	historic	54	187	27
(Taylor and Paintner 2005)	contemporary	233	287	17
West shore units - mixed conifer	***contemporary***	***194***	***239***	***16***
Lake Tahoe east shore JP/WF	historic	28	113	26
(Taylor et al 2004)	contemporary	139	200	11
Kingsbury units - JP/WF	***contemporary***	***261***	***133***	***14***

A strict comparison between those studies and the data presented is hindered by several factors. The lower mature tree breakpoint diameter (4 in.) in the reference studies would tend to yield greater tree densities and basal area values and lower QMD values so that we may be understating the difference between the contemporary and reference forests. Also, the mixed conifer forests in Yosemite and Lake Tahoe have different climates and the species composition and forest types and are not strictly comparable because of the geographic differences and differences in past logging and practices and other management. Still, the reference data above does provide valuable metrics by which we can compare the current conditions of the forest and conclude that existing conditions are far from the historical range of variability that could be expected.

As the above example shows, stand level data does a better job of assessing the status of desired conditions than do broad landscape tools like FRCC. Stand level data is also required to assess project implementation. The site-specific pre-treatment data from permanent FIREMON plots provides the necessary reference point from which to evaluate 1) short-term project-level NEPA objectives regarding the implementation of fuels treatments and 2) the longer term effectiveness of treatments in meeting desired conditions for fire control, forest health, and wildlife habitat. Immediate, one-year post-treatment data is required to evaluate short term objectives, but a longer monitoring period (minimum of 5 years) will be required to address desired conditions.

5.2 Forest Structure

The FIREMON system has been designed to measure the following variables related to forest structure: mature tree size (QMD), percent canopy closure, tree density, tree basal area, snag density, shrub height, and the amount of coarse woody debris (logs) on the forest floor. As previously mentioned, these variables constitute the attributes of many of the desired conditions, even thought there are not specific values assigned to the desired conditions. In this section, we discuss the existing conditions for CWHR type, tree density, size class distribution, species composition, and snag and down log retention. Where possible, the departure from the desired condition is also discussed.

CWHR Type

Table 5.2-1. Forest structure characteristics

Project	CWHR type	Canopy Closure (%)	QMD75 (inches)	Basal Area (ft^2/acre)
West shore	4M or 4D	59	21	239
Kingsbury	4M or 4P	36	17	133
Dollar5 hand	5S	22	25	122
Dollar5 mech	5P	31	31	177

In the west shore, the average canopy closure of 59% is considered dense, although the CWHR classification was split fairly evenly among the units between moderate 4M (40-59%) and dense 4D (>60%) (Table 5.2-1). Average tree size, with a QMD75 of 21 inches, is small. The mean basal area of 239ft^2/acre is high. None of the units could be described as having "stands that are fairly open and dominated by large, fire tolerant trees" since "open" generally means <50% canopy cover and "large" means >25 inches DBH. Instead, these units are overcrowded with small trees.

In terms of optimal wildlife habitat, desired conditions for mixed conifer types on the west shore of Lake Tahoe are CWHR classes 5M, 5D, or 6. These types are considered more characteristic of old-growth and are only expected to occur in PACs. Treatment prescriptions are intended to decrease density, thereby decreasing canopy cover and increasing the average residual tree size. It is possible that the treatments could move some of the units closer toward the desired CWHR types. Post- treatment data will be necessary to confirm the effects of treatment prescriptions

In the Kingsbury site, tree size was small in both units while canopy cover was moderate in one and sparse in the other unit. The basal area of 133ft2/acre is similar to the historic value calculated by Taylor (2004) in eastside Jeffrey pine/white fir (Table 5.1-4). While the treatments would be expected to increase the average tree size, the CWHR types would likely not change. These units are many restoration cycles away from achieving any old-growth characteristics.

The Dollar5 hand thinned unit is designated as 5S, which indicates "sparse" canopy cover and large trees. However, the average tree size (QMD75 of 25 inches) is at the lower end of what is considered a large tree in CWHR. The Dollar5 mechanically thinned unit is designated as a type 5P, which indicates an "open" canopy. The average tree size was larger at 31 inches (QMD75) which may have been due to the fact that the mechanical treatment was able to take larger trees than the hand treatment. Without pre-treatment data it is not possible to confirm this. Although the trees were relatively large, the wildlife habitat quality would be considered low in both units. The prescribed burn that is planned for these units might result in a small amount of mortality (acceptable limit is 10-25%) but this will not likely have an impact on the CWHR designation. The larger trees in the stand are more resistant to fire so the average tree size will likely remain unchanged or may increase, but the fire will not lead to any immediate change increase canopy cover.

Tree Density

In the west shore units, the mean tree density of 194 trees/acre is high. As previously mentioned it is almost 4 times higher than one estimated value for historic forest conditions in the Sierra. Mean tree density was considerably higher in the Kingsbury "dense" unit (320 trees/ac >1"), but similar in the "open" unit (201 trees/ac).

Mean tree density was much lower in the partially-treated Dollar5 project site. The unit that was hand thinned in 1999 had 115 trees/ac while the unit that received a mechanical treatment in 2004 had 133 trees/ac. These densities were 28 to 41% lower than the west shore units, but the vegetation types are not strictly comparable. The lower density in Dollar5 is presumed to be the result of thinning treatments, but that cannot be confirmed without pre-treatment data. The target basal area according to the prescription for the Dollar5 mechanically treated unit was 140 ft^2/ac. The current mean basal area for that unit is 177ft^2/ac based on all trees >1", but only 123ft^2/ac based on mature trees >6 inches. It is likely that the prescription applied to mature trees only and so the thinning treatments may have achieved the desired basal area target, but again, pre-treatment data would be required for confirmation.

The desired condition for tree density is that treatments reduce density to a level consistent with the site's ability to sustain forest health during drought conditions. The appropriate tree density may vary considerably across the landscape and only long-term monitoring that includes assessment of tree health and vigor will be able to address this objective.

Size Class Distribution

The desired condition is that trees range from seedlings to very large size. While a range of tree sizes was present, the distribution was heavily skewed toward small trees. In the west shore units, small trees between 6 and 12 inches comprised almost half of the total tree density while medium trees between 12 and 24 inches made up most of the other half of the total tree density. Sapling (1-6 in.) density was low, indicating that the high density of small trees is inhibiting regeneration of new trees. Seedling density was extremely variable because our sample plots were too small, so it was not possible to draw inferences about more recent regeneration. At the other end of the spectrum, large trees (>24 in.) were uncommon, comprising only 6% of the total tree density (average of only 8 trees/acre across the units).

All of the treatment prescriptions have an upper removal limit imposed on dbh in order to emphasize the retention of the largest trees. However, very few large trees were encountered. In MCK 13-3, the treatment prescription calls for mechanical removal of trees up to 30 inches which would leave only 1 large tree/acre remaining if all trees were removed. In the other mechanical units, the number of large trees per acre would be 10 in BLK 1-4 and 9 trees/acre in both TWC 3 and WRD 20-09. In the hand thin units the 10 inch upper limit in WRD 20-09 would leave at least 82 trees/acre greater than 12 inches while the 14 inch upper limit in MCK 13-1 would leave fewer than 33 tree/acre greater than 12 inches. The impacts of these levels of residual trees on wildlife are unknown and post-treatment monitoring will be required to assess both project implementation and effects on wildlife.

The size class distribution of sampled trees in the Dollar5 units was even more heavily weighted toward smaller diameter trees. This was not expected, as these units were previously thinned. Over half of the total tree density in both the hand thin unit and mechanical unit was dominated by saplings (<6"). The treatment prescription called for removal of trees < 10" and one would have expected that implementation of this would have shifted the size class distribution toward larger trees, but 80% of the tree density in the hand thin unit and 76% of the density in the mechanical unit was comprised of small trees < 12". Less than 20% of the tree density in both units was made up of large trees greater then 24”. Without pre-treatment data it is not possible to assess exactly how the thinning treatments altered forest structure, but it appears that the thinning did not move the units toward desired conditions to increase structural diversity. It is expected that the scheduled prescribed burn in these units will significantly reduce the number of trees in the small size classes, but post-treatment data would confirm this.

For the Kingsbury project site the distribution of tree sizes is heavily weighted to the smaller size classes. Both units had similar size class distributions with 44% and 43% of the trees were saplings (<6”), and 80% and 73% of trees were small trees <12” in the open and dense, respectively. It is anticipated that the hand thinning prescribed for this site will significantly reduce the number of small sized classed trees in this area, but again, post-treatment data is needed to confirm this.

Species Composition

The desired condition is that tree species composition varies by elevation, site productivity, and related environmental factors. Instead, white fir heavily dominated all of the west shore units. White fir comprised over two thirds of the total tree density and dominated all size classes. On average all other species contributed less than 10% each of the total tree density. The composition of these species other than white fir did vary across the units, likely due to differences in elevation, slope, aspect, and possibly to accessibility and past manipulation.: MCK 13-1 contained all five species; the TWC units contained all species except lodgepole pine; the WRD 20-16 units contained all species except incense cedar; the WRD 20-09 units did not contain incense cedar, sugar pine, or lodgepole (except very sparse lodgepole in the treatment unit); the BLK and MCK 13-3 units had different mixes of 4 species in all four of the units.

The dominance of white fir in the west shore units is the result of past logging practices and subsequent fire suppression. As mentioned in the introduction, the majority (more than 60%) of low elevation mixed conifer was clear cut during the Comstock era. The subsequent lack of fire in the system has lead to overly dense conditions and promoted shade tolerant white fir at the expense of the more shade intolerant pines. Treatment prescriptions prioritize firs for removal over pine species, but it will likely take many restoration cycles to reduce the extreme dominance of white fir and move the forests toward desired conditions.

Tree species composition for the Dollar5 unit is not as diverse as other stands on the west side of the Tahoe Basin. The hand thin unit (DH) consisted primarily of red fir (almost 60%) with lesser amounts of white fir and Western white pine. The mechanically treated unit (DM) had a similar species composition. The density of Western white pine and lodgepole pine was so low that species composition would not likely shift away from fir dominance following the scheduled prescribed burns. However, post-treatment monitoring will be required to determine if the fire is successful in reducing the abundance of red fir saplings found in the units. As with the other west shore units, the dominance of fir over pine will likely take many restoration cycles to repair.

Species composition for the Kingsbury project site is typical of the drier eastside forests in the basin that consist of only white fir and Jeffrey pine. This site is shown in the EVEG mapping to be dominated by Jeffrey pine in some areas and dominated by mixed fir in other areas. Because of this expected difference in species composition, we chose to stratify our sampling for this site into a Jeffrey pine unit and a mixed fir unit. It turns out that the compositions of the two mapped vegetation types are quite similar. The area mapped as mixed fir shows 58% Jeffrey pine and 42% white fir, while the area mapped as Jeffrey pine shows 64% Jeffrey pine and 36% white fir. Instead of species composition, tree density turned out to be the defining character of the two units. The tree density for the unit mapped as mixed fir type was 320 trees/acre and we have referred to it as the dense unit, "KBd". The unit mapped as Jeffrey pine had 201 trees/acre and has been referred to as the open unit, "KBo". The distribution of trees in the smaller size classes is similar for both white fir and Jeffrey pine. The prescription does not call for preferential thinning of white fir over Jeffrey pine. If this was done, the result would be a condition which more closely resembled pre-European conditions.

Snag and Down Log Retention
The desired condition for snag and log retention is that dead trees, both standing and fallen, meet habitat needs of old-forest-associated species. The west shore units had very high numbers of snags with a mean of 44 per acre. It is not known if this is an acceptable level.

Although the large number of snags in the plots could provide valuable habitat, the high snag count is indicative of widespread insect and pathogen infestation. Trees weakened and damaged by disease and insects are prone to blow-down in high winds and often snap along the bole. This was definitely the case in MCK 13-3 where evidence of insect damage was extensive and there was a mean count of 114 snags/ac in the control unit and 80 in the treatment unit. If these two units are excluded the mean number for the other ten units drops to 33 snags/ac, but this is still very high. While the treatments are designed to reduce the number of snags, this biomass will remain onsite as down woody debris until it is burned. The number of down logs greater then 3 inches averaged between 6 and 7 per acre for all units. Again, the number of down logs was greater in MCK 13-3 compared to the other units.

The Dollar5 hand thinned unit had an average of 5 retained snags/acre (>6" dbh), which achieves the desired treatment prescription of 5 to 8 snags per acre, assuming that snags as small as 6 inches are included. The mechanical unit (DM) had a mean value of only 2 snags per acre >6 inches, which is less than the treatment prescription. Pre-treatment data, would allow us to know whether or not this was the pre-existing condition for snag density. It is likely that the recent thinning treatments were responsible for the high densities of down logs in the Dollar5 units, which were about 6 times higher than the other west shore units. We found 43 logs (>3" diameter) per acre for the hand thinned unit, and 39 for the mechanically treated unit. The thinning treatment calls for retention of 5 to 10 down logs per acre that are ≥ 12" diameter, and ≥ 10 feet long. We found 5 logs per acre ≥12" post-thin in the DH unit, and 3 logs per acre in the DM unit. These logs do not include those which were piled. The DH unit currently meets the prescription, while number of down logs in the DM unit was at 60% of the prescribed level. Values for pre-treatment log density would be necessary to determine whether the pre-treatment condition was below the minimum prescription level for unit DM.

Pre-treatment snag levels for the Kingsbury site are 14 snags per acre (>6” dbh) for the dense unit, “KBd”, and 22 for the open unit, “KBo”. The prescription for snag removal at the Kingsbury site calls for removal of all dead trees (standing and down) up to 20” dbh. Based on data collected at the Kingsbury site, if all snags were removed up to 20 inches, this would result in a mean value of 2 snags per acre retained. Logs per acre >3” are 17 for the KBd unit, and 16 for the KBo unit. If all logs per acre up to 20 inches were removed, this would leave a mean value of 2 logs/acre for the KBd unit, and <1 snag/acre (mean of 0.6) for the KBo unit. There is no prescription for logs/acre for the Kingsbury Project, but based on the prescription of 5 to 8 logs/acre for the Dollar5 Project, mean values of 2 and 0.6 logs/acre are probably less than desired.

5.3 Herbaceous and Shrub Species

Desired conditions do not directly address understory species richness or species abundance and distribution. Outside of the WUI, the desired condition is that tree species composition varies by elevation, site productivity, and other environmental factors, and presumably this diversity should extend to the understory. Herb and shrubs are important components of wildlife habitat, particularly for species that have narrow habitat tolerances in association with features such as canopy cover, understory structure, and herbaceous plant composition (e.g., seed eaters and understory foraging species).

We expect to see changes in the understory resulting from fuels reduction treatments over time. While the immediate vegetation response to is likely to be dramatic and fairly easy to compare among treatments, longer term responses pose more of a challenge. Fuel reduction treatments necessarily alter the successional trajectory of a stand in a number of ways. For example, thinning the overstory and opening the canopy increases light penetration to the forest floor, which would not only favor the regeneration of more shade-intolerant conifers like pine, it may also promote the release of nitrogen-fixing species like ceanothus and lupine, alter shrub composition and density, and promote perennial bunch grasses.

Species Richness

Total species richness of herbs and shrubs was relatively high across the units in the mixed conifer forests on the west shore (143 species were detected). The species rich nature of both WRD units was likely due to their proximity with Page Meadows and the inclusion of meadow species within the sample plots. The total number of species detected in the Kingsbury units on the east shore was fewer by 80%. This was expected since the west shore receives considerably more precipitation than the east.

Only 10 species were detected in the thinned Dollar5 units, indicating that the thinning treatments could have drastically reduced species. The mean number of species per plot was 4 compared to a range of 2 to 20 for the untreated units on the west shore. The Dollar5 units could have fewer species because of the treatments, but pre-treatment data would have been required to confirm this.

The especially low number of species in MCK 13-3, which had an average of barely one species per plot, was likely a function of the excessive amount of down woody debris in those units that would inhibit regeneration of most plant species. A regression analysis of total mean species richness per plot to total fuel load revealed that species richness in the west shore units declined with increasing fuel loading, but the relationship was not that strong (r^2=0.45). Further analysis revealed that total mean species richness per plot was most strongly correlated with total mean duff/litter load (r^2=0.65) and FWD load (r^2=0.67). This relationship makes intuitive sense since these two components of the fuel load would have the greatest contact with the ground and therefore reduce the amount of space available for germination sites.

Distribution and Abundance
The low abundance and distribution of the herbaceous vegetation could make it difficult to detect changes resulting from the treatments. However, because mean cover was less than 15% in the west shore units, less than 2% in the Kingsbury units, and less than 0.2% in the Dollar5 units, very small increases in any lifeform would likely represent a 100% or greater change which would be much more easily detected by the quadrat sampling methods.

The line intercept method captured much higher shrub covers than did the quadrat method. Mean shrub cover in the west shore units using the quadrat method ranged from 2 to 7%. In contrast, mean shrub cover in the Kingsbury units was 19 and 30%. The quadrat method of cover assessment is most suited to plants less than 3 ft (1m) in height. In the west shore units, although the dominant shrub (whitethorn) was generally less than 3 ft tall, several of the other shrub species (Greenleaf manzanita and tobacco bush) often exceeded this height. This may have skewed the total shrub cover values to be lower than they would have been recorded using a line intercept method.

Considerable differences in mean shrub cover were shown between the hand thinned unit (37%) and the mechanically thinned unit (7%) in the Dollar5 project. However, without pre-treatment data it is not possible to determine if the difference is due to the different treatment method or to inherent differences between the units.

Smaller differences were detected in mean shrub cover between the Kingsbury units: dense (19%) and open (30%). The greater mean shrub cover in the open unit is likely due to the greater amount of space and light that is available because of the less dense forest structure. These differences can be taken into account in the post-treatment monitoring that is designed to provide the information needed to predict the effects of the treatments on understory fuel reductions and post-treatment regeneration.

Weeds
Desired conditions do not directly address herbaceous and shrub species other than noxious weeds. Standards and guidelines are in place that seek to prevent or minimize the introduction of weeds and to insure their early detection, containment, and control. Fuels reduction activities have the potential to increase the spread of weeds and the more recent environmental assessments and impact state for specific projects all include various weed management components. Sound weed management practices, including long-term monitoring should be incorporated in to fuels reduction projects.

Non-native species were not detected in any of the untreated west shore units or in Dollar5. Cheatgrass was detected in small quantities in the Kingsbury unit. This species has devastating environmental consequences in the Great Basin and deserts where it can increase fire frequency and severity. Control is difficult because of prolific seed production, especially in wet years. Prevention of spread is the best approach through equipment washing stations and other measures.

5.4 Fuel Loading

To reduce wildfire risk, the principal goal of fuels reduction treatments is to reduce the amount of burnable materials, thereby reducing fire intensity, the potential for crown fire, and improving suppression capability. This means that in a given stand, resistance to control is minimized to a point which allows firefighters to safely and effectively suppress wildfires threatening urban communities. The specific desired conditions for the WUI is that fuel conditions are such that crown fire ignition is unlikely, flame lengths are less than 4 feet, rate of spread is minimized (50% of pre-treatment levels), and suppression crew production rates are increased (double pre-treatment levels) (SNFPA ROD 2004).

The primary way to address whether a fuel reduction treatment has achieved these desired conditions is to conduct fire behavior modeling. Modeling was not included as part of this study. However, the pre-treatment surface fuel loading data presented here and the accompanying plot photos should be utilized to properly select and apply any fuels models used to predict fire behavior. Fire prediction models and resistance to control calculators are tools which provide general estimates of fire activity and managers can apply these tools more effectively if they have accurate estimates of surface fuel loadings and a statistically robust assessment of the variation in fuel conditions across a stand.

Post-treatment data collected through a statistically valid monitoring design such as FIREMON is required to quantify the effectiveness of different treatments in meeting project objectives to reduce fuel loads and alter fire behavior. Long-term monitoring is also required to determine the longevity of the treatments and to plan for follow-up treatments necessary to maintain desired conditions. If it is determined that desired conditions are not met, then adaptive management can be employed to make the adjustments needed to achieve desired results.

Surface Fuel

The pre-treatment surface fuel data presented here indicates that surface fuel loadings are high across all of the untreated units. Mean total surface fuel loading (litter/duff, 1-100 hr, and 1000 hr) in the untreated units was 41 tons/acre. This value may be almost four times higher than would be expected if the forest had not experienced such intense management over the last 100 years, including fire suppression and logging. Stephens (2004) sampled an unmanaged high elevation mixed conifer forest in northwestern Mexico (Sierra San Pedro Martir) that has a similar species composition to the west shore of Lake Tahoe and found a total mean fuel loading in that forest of only 11 tons/ac. The mean fuel load of 4.1 tons/acre of fine woody debris (1-100hr) calculated in this study was similar to a previous study conducted in mixed conifer plots on the west shore of the basin that found an average fine fuel load of 3.8 tons/acre (Stephens and Finney 2002), indicating that the high fuel loadings are representative of current conditions.

The Dollar5 project site, which was partially treated with hand and mechanical thinning in 1999 and 2004, also had high surface fuel loading close to 40 tons/acre. This is to be expected, as the objective of initial thinning treatments on this site was to change the structure of the fuel load and alter fire behavior. The end result of the first step of both hand and mechanical thinning treatments is that the fuel load is taken out of the canopy and moved to the ground. Planned broadcast and pile burning is intended to achieve the desired reductions in the surface fuel load.

Vegetative Fuel Loading

Data collected on the west shore units allows for determination of live vegetation fuel loading. Vegetative fuel loading is a very significant element in driving fire behavior, and therefore important in selecting fuel models for predictive fire behavior modeling. Furthermore, vegetative fuel loading in terms of cover and biomass is a significant factor considered in calculating suppression crew production rates and resistance to control. For the west shore project sites, live shrubs made up the majority of the understory vegetative biomass, ranging from 0.8 to 3.9 tons/acre. Live herbaceous biomass ranged from non-existent to 0.2 tons/acre. In many cases live herbaceous biomass was similar to 1 hour dead and downed fuels, effectively doubling the fine fuels component which is the primary element in determining fire rate of spread.

Residual Woodchips

In the Dollar5 project hand treated unit (DH), residual fuels were chipped and spread across the forest floor. This unit is scheduled to be broadcast burned in the near future as the final step in completion of the treatment prescription. The partial-treatment data now collected on the cover and volume of woodchip material at this site provides a great opportunity to quantify the effects of burning chipped fuels. Several questions surrounding the burning of woodchips that could be answered include: What are the characteristics of the resulting fire? Was the treatment effective in altering fire behavior?; Will there be increased levels of tree mortality due to increased temperatures and residence time?; How does plant and animal species diversity and abundance change? Is vegetation regeneration inhibited or stimulated? What are the effects on local soils and erosion potential?

Slash Piles

Piling and burning of slash material generated in tree thinning is a common practice in the Lake Tahoe Basin. Of the projects measured for this report, slash piles were only present and measured on the partially-treated Dollar5 mechanical unit (DM). The piles were generated as part of the thinning treatment that occurred in 2004. This unit is scheduled for pile and broadcast burning in the near future. Detailed measurements were taken of each slash pile located with a plot following guidelines established by Hardy (1996). The estimates of fuel biomass contained in the DM unit slash piles here could be used to calculate predicted smoke generation from the burning of those piles.

Canopy Base Height

Measured crown base height values indicate resistance to crown fire initiation. CBH targets are determined at the project level, generally set in the range from 12-25ft as part of the effort to achieve the desired condition to lower the probability of crown fire. Mean pre-treatment CBH values of 3 to 6 feet across the west shore and Kingsbury units were very low, indicating high risk for crown fire initiation. The higher mean CBH of 17 feet in the MCK 13-3 control unit and 9 feet in the unit slated for treatment were likely a function of the insect and pathogen infestations that have inhibited conifer regeneration in those units, resulting in a sparse understory and very dense accumulations of dead and downed surface fuels. Only one of the west shore plots in the units slated for treatment is greater than the 20 feet desired condition for CBH as specified in the Ward EA (2002).

Unexpectedly, canopy base heights were not appreciably higher in the previously thinned units in Dollar5. The mean CBH was only 5 feet in the hand thinned unit which still indicates a high potential for crown fire initiation. In the mechanically treated unit a mean CBH of 8 feet is also still below desired conditions. It remains to be seen if the broadcast burn scheduled for those units is capable of increasing the CBH by eliminating smaller understory trees which effectively contribute to reducing the mean CBH.

Crown Bulk Density

Calculated crown bulk density values, derived from field measures, indicate resistance to passive as well as active crown fire. Desired conditions for CBD are values below 0.1 kg/m^3. Conditions where CBH exceeds this threshold are considered capable of passive crown fire condition where individual or group tree torching occurs. Under the most extreme fire weather conditions, these stands could be capable of carrying active crown fire. When CBD values are at or above the threshold of 0.15 kg/m^3, a stand is considered capable of carrying a Dependent (sustained crowning or continuous crown spread supported by surface fire) or an Independent fire (sustained crowning or continuous crown spread that is independent of the surface fire). Pre-treatment mean CBD values were above the 0.15 kg/m^3 threshold for all of the pre-treatment west shore units indicating a high potential for crown fire across the area. At the plot-level, 25% of the plots in the units slated for treatment had CBD values exceeding 0.25 kg/m^3. In the

Kingsbury project site, pre-treatment mean CBD values were above the 0.1 kg/m^3 threshold in both units but below the 0.15 kg/m^3 threshold. This indicates that passive crown fire is possible for the project sites but active crown fire is less likely unless more severe fire weather conditions exist. However, in looking at CBD at the plot level, 50% of the mean CBD values were above the 0.15 kg/m^3 threshold for the Kingsbury "dense" (KBd) unit, indicating that active crown fire potential is higher for some areas within the stand.

Mean CBD values for the Dollar5 project site were well below the 0.1 kg/m^3 threshold, with both units at 0.06 kg/m^3. Both units were partially treated with mechanical or hand thinning. Looking at mean CBD values at the plot level, only one plot out of ten in the DH unit is at the 0.1 kg/m^3 threshold and none of the plots in the mechanical unit. This would indicate that the thinning projects have effectively limited the possibility of crown fire. Still, the canopy base heights in the units are low at 5 and 8 feet, respectively. It could be said that the current condition for the Dollar5 project site would support crown fire initiation, but that independent or active crown fire potential has been reduced.
Fire is opportunistic so the combination of raising CBH and lowering CBD to below the current excepted critical threshold along with adequate surface fuel treatment is key to treatment effectiveness (Sid Beckman, pers comm. 2007). Post treatment data and long-term monitoring will be required to assess the effectiveness of any stage of the treatment process.

6.0 CONCLUSION

The results of this combined study represent the first comprehensive monitoring effort of pre-treatment fuel conditions and forest structure in the Lake Tahoe basin. The monitoring protocol was specifically designed to detect significant changes in plant communities and fuel loadings in response to management activities over time. Data collection occurred across a range of treatment types including hand thinning, mechanical thinning with chipping (Dollar5), and mechanical thinning with mastication and across a range of vegetation types from west shore mixed conifer to east shore Jeffrey pine/white fir. The resulting dataset is both statistically valid and representative of a variety of conditions present in the basin so that results obtained through post-treatment monitoring may be widely applied.

Comparisons of the pre-treatment data with available estimates of the historic range of variability for key forest structure components confirm that existing conditions are severely departed from desired conditions. The forests are densely stocked with small trees less than 24" inches diameter and large, fire-tolerant trees are very sparsely distributed across the landscape. The mixed conifer forests on the west shore are heavily dominated by white fir, while the east shore forests consist of only white fir and Jeffrey pine. In terms of wildlife habitat, the west shore units provide moderate quality habitat according to the CWHR type system since canopy cover is high. The east shore units are too open and the trees are too small to provide high quality habitat.

Tree density is lower in the thinned units in Dollar5, but a surprisingly large proportion of trees are saplings under 6 inches. The units are dominated by red fir since they are over 7,000 ft, but the canopy is sparse or open. Wildlife habitat quality is low because the units are too open, although the average residual tree is relatively large. Without pre-treatment data it is not possible to know how the thinning influenced these different elements of forest structure.

Post-treatment data collection will be a critical part of this effort. Without it, all we have is a dataset describing current forest structure in untreated units. In the Dollar5 units, we have data on post-thin conditions, but the lack of pre-treatment data means we can only speculate on the effects of the thinning treatments. Post-treatment data collection in these units after the prescribed burns will enable us to quantify and monitor the effects of that treatment.

The site-specific pre-treatment data from permanent plots provides is required as a valuable reference point from which we can evaluate 1) short-term project-level NEPA objectives regarding the implementation of fuels treatments and 2) the longer term effectiveness of treatments in meeting desired conditions for fire control, forest health, and wildlife habitat. The data could also be used in modeling software applications like Behave or Fuels Management Analyst in order to predict fire behavior scenarios under un-treated and different treatment conditions. However, the LTBMU has elected not to include fire behavior modeling under the pre-treatment analysis contract.

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APPENDICES

Appendix 1. Data Collection Details

UPFU Data Collection Protocol

Vegetation was measured within a fixed 17.58 meter (58 ft) radius plot of 0.1 ha (0.25 ac). A random azimuth was selected for the first transect and then three additional transects were established at subsequent 90° angles with the 0 meter marks at the plot center. The four transects were the basis for sampling down woody debris (DWD), herbaceous and shrub cover and frequency, and duff and litter depths (Figure 2). Plots were monumented with five 2 foot pieces of rebar capped with yellow plastic caps imprinted with “USFS UPFU”; one at the plot center and one at the distal end of each transect.

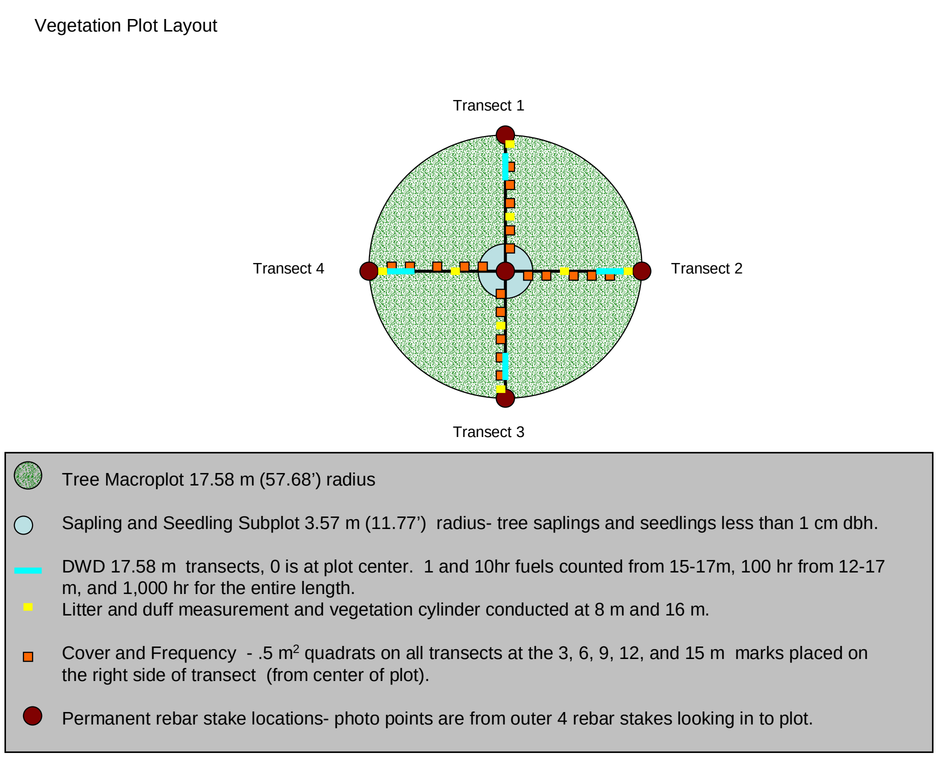

Figure A1-1. UPFU Vegetation plot lay-out.

Plot Description
Descriptive data collected in each plot included: UTM coordinate in NAD 27, slope, aspect, general landform, horizontal and vertical slope shape. The two most dominant species with greater than 10% canopy cover were recorded for three stratums; upper (> 3 m tall), mid (3 to 10 m tall), and low (< 1 m tall). A photo point was established at the distal end of each transect looking down the meter tape toward the plot center.

Tree Data
A breakpoint of 15 cm (6 in) diameter at breast height (DBH) was selected for sampling mature trees. The following data was recorded for all mature trees within the entire plot: species, DBH, total height, height to live crown base, live crown ratio, crown position, and observed damage. Snags were also sampled within the entire plot. Snag data included: species, DBH, total height, and decay class. Within a 3.57 m (11.7 ft) fixed radius subplot of 0.01 ac (0.004ha) nested at the plot center, the species, DBH, total height, and live crown ratio was recorded for all saplings greater than 1.37 m (4.5 feet) tall with a DBH less than the breakpoint. Saplings were categorized by 4 size classes based on DBH: 0-2.5, 2.5-5, 5-10, 10-15 cm. The number of all seedlings less than of 1.37 meters tall was recorded for each species. Seedlings were categorized by 5 height classes: 1-15, 15-30, 30-60, 60-100, and 100-140 cm. The midpoint values of size and height classes were used in calculations. Each mature tree and snag was permanently marked with an aluminum tree tag and nail. Canopy cover was measured at 25 points using a 5 m by 5 m grid using a GRS site-tube densitometer.

Fuels Data
Surface and ground fuels were sampled on all four transects in each inventory plot using the line-intercept method (Brown, 1974). One-hour (0-0.64 cm) and ten-hour (0.64-2.54 cm) fuels were tallied from 15-17 meters, 100-hour (2.54-7.62 cm) fuels from 12-17 meters, and 1000-hour (>7.62 cm) fuels were sampled along the entire length (17.58 meters) of each transect. The larger fuels (1000-hour) represent coarse woody debris (CWD) that has high value for many wildlife species, so the following information was collected for each CWD: species, diameter at the tape, diameter at each end, length, and decay class. Duff and litter depth (cm) was measured at the 8 and 16 meter marks.
At the same locations, the surveyors estimated the following within an imaginary 2m by 2m cylinder: live and dead tree/shrub cover, average tree/shrub height, live and dead herb cover, and average herb height. Measurements were conducted towards the distal ends of the transects to avoid the disturbance that was generally concentrated in the plot center.

Herbaceous and Shrub Cover/Frequency
Herb and shrub percent cover, height, and nested frequency were measured in five $0.25m^2$ quadrats located at 3 meter intervals (3,6,9,12,15) along all four transects, for a total sample area of 1.25 m^2. Frequency describes the abundance and distribution of species and is very useful for comparing significant differences between two plant communities or detecting significant change in a single community over time. A reasonable sensitivity to change results from capturing frequencies between 20 and 80 percent, and therefore, a nested quadrat system was used to avoid problems resulting

from using a single quadrat size. Nested quadrat sizes (5x5, 25x25, 25x50, 50x50 cm) corresponded to a nested rooted frequency ratio of 1:25:50:100.

Plant cover was measured as the vertical projection of foliage within a percentage of the quadrat and the percent value indicates the relative influence of each species on the community. A system of 12 cover classes, (0-1, 1-5, 5-15, 15-25, 25-35, 35-45, 45-55, 55-65, 65-75, 75-85, 85-95, 95-100) was used to reduce human error and increase the consistency of estimates. Midpoint values were used for computation.

Height gives detailed information about the vertical distribution of plant species cover with in the plot. It allows calculations of 1) plant species volume (cover x height) and 2) biomass (height x cover x bulk density). FIREMON uses 0.8 kg/ m^3 for herbaceous BD and 1.8 kg/m^3 for shrubs.

AMSET Data Collection Protocol

Vegetation was measured within a fixed 17.84 meter (58.5 ft) radius plot of 0.1 ha (0.25 ac) (Figure A.1-2). A random azimuth was selected for the first transect and then three additional transects were established at subsequent 90° angles with the 0 meter marks at the plot center. The four transects were the basis for sampling shrub cover and height, surface fuels, and herbaceous cover and frequency. Plots were monumented with five 2 foot pieces of rebar; one at the plot center and one at the distal end of each transect. The rebar marking the center of the plot has a tag attached that identifies the project and plot number. The rebar marking the end of each transect includes a tag identifying the transect as T1, T2, T3, or T4.

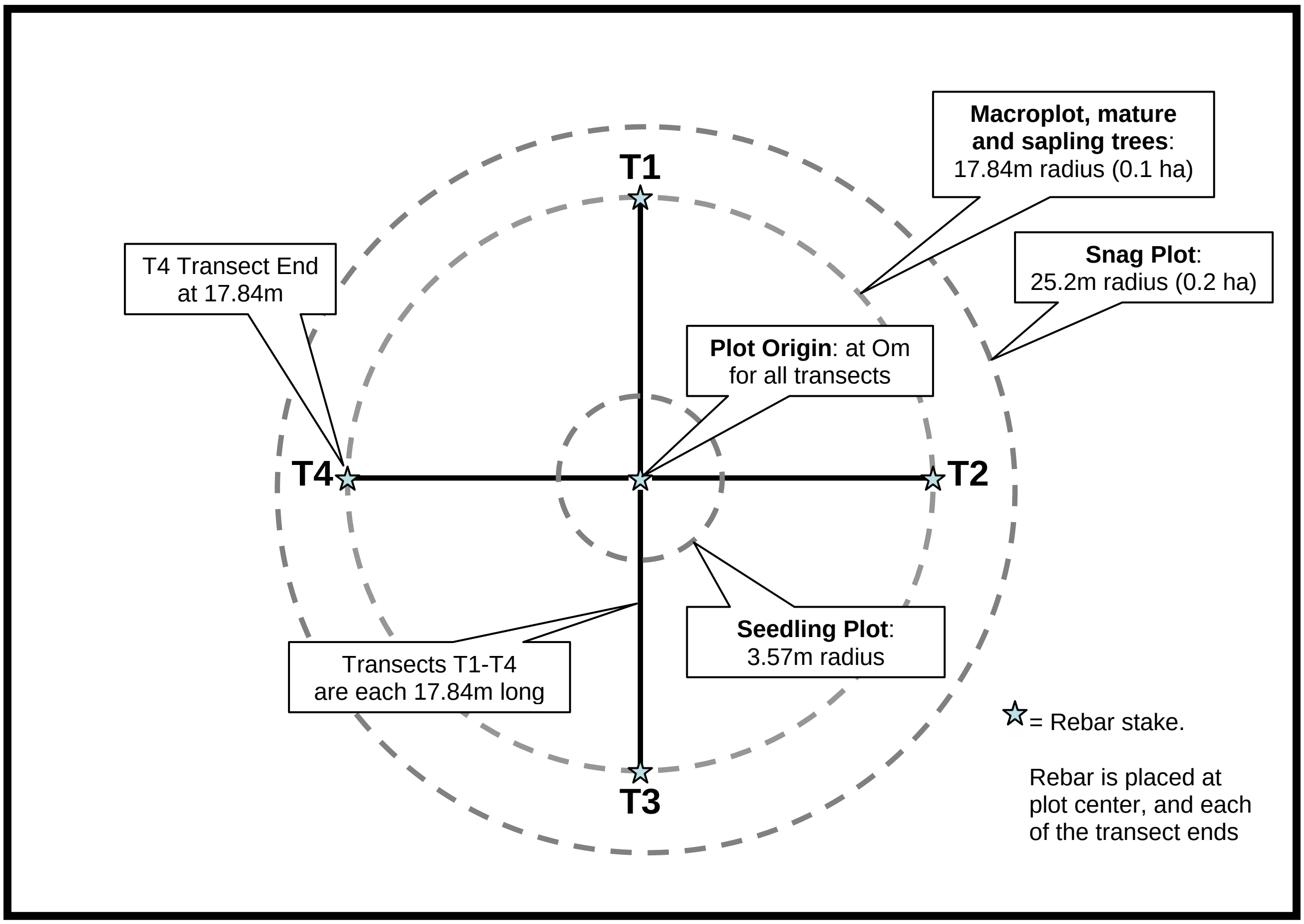

Figure A.1-2. Vegetation plot lay-out.

Plot Description

Descriptive data collected in each plot included: UTM coordinate in NAD 27 zone 10N, elevation, aspect, and slope.

Photo Points

Photo points were collected for visual detection of changes associated with fuels treatments, as well as a valuable tool for fuel model assignment. A total of 4 photos were taken in the 4 cardinal directions (N, S, E, and W) from behind the origin of the plot looking out. All photos were taken from a measured location of 3 meters from behind the origin, with a meterboard, target placed at the origin for reference. All photos were taken such that the meterboard was centered in the picture frame, with the base of the meterboard aligned with the base of the picture frame (Figure A.1-3).

Figure A.1-3. Example of photo point image.

Tree Data

Mature tree data was collected with in the 17.84m radius (0.1ha) plot area. A breakpoint of 6 inches 15 cm (6 in) was selected for differentiating mature trees from smaller sapling trees. The following data was recorded for all mature trees within the entire plot: species, DBH, total height, height to live crown base, live crown ratio, crown position, and observed damage. Sapling data was collected with the same 0.1ha plot as mature trees. Saplings were defined as less than 6 inches dbh, taller than 4.5 feet (1.37m) and greater than 1 inch dbh. Sapling data collected included: dbh, total height, height to live crown base, and live crown percent. Snags were sampled in a larger plot area with 25.2m radius (0.2ha). Snag data included: species, DBH, total height, and decay class. A tally of all seedlings less than of 1.37 meters tall was recorded for each species. Seedlings were categorized by 5 height classes: 1-15, 15-30, 30-60, 60-100, and 100-137 cm. The midpoint values of size and height classes were used in calculations. Each mature tree and snag was permanently marked with an aluminum tree tag. Canopy cover readings were taken at one meter intervals along each transect for a total of 17 readings per transect, and 68 measures total per plot. Canopy cover was measured using a "Moosehorn" brand site-tube densitometer.

Fuels Data
Surface and ground fuels were sampled on all four transects in each inventory plot using the line-intercept method (Brown, 1974). One-hour, (0 - 0.25 in) and ten-hour (0.25 – 1 in) fuels were tallied from 15-17 meters, 100-hour (1 – 3 in) fuels from 12-17 meters, and 1000-hour (>3 in) fuels were sampled from 0 to 17 meters of each transect. The larger fuels (1000-hour) represent coarse woody debris (CWD) that has high value for many wildlife species, so the following information was collected for each CWD: diameter where it crosses the transect, length, and decay class. Duff and litter depth (cm) was measured at 2 points along each transect, at the 10 and 15 meter marks (Figure A.1-4).

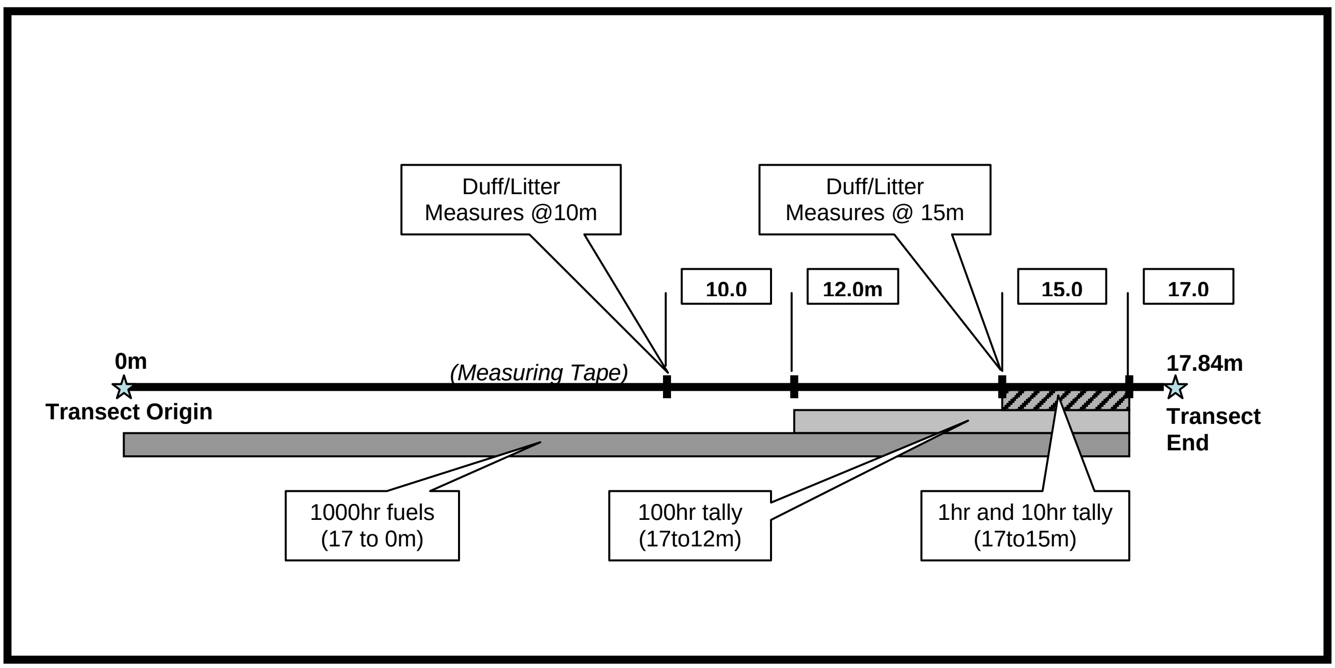

Figure A.1-4. Diagram illustrating layout and detail of fuels data collection methods.

Woodchip Data Collection Methods
It was known in advance that the Dollar5 hand thinned unit included chipping of residual material. Because chipped material loses the dimensions of natural fuels, it was determined that a methodology alternative to those based the standard Brown's planar transect protocol would need to be used. Although a formally established protocol for collecting volume/mass data on woodchips had not been established at the time of this program, it was discovered that attempts had been made to develop such a methodology. A paper in progress by Hood and Wu (2006), was used for direction on this topic. A variation of their methodology was used. The protocol used involved using 1 meter quadrats to collect woodchip cover and fuel depth information. This data was collected at the same location as the quadrats placed for collection of herbaceous cover/frequency data (Figure A.1-5). Within the quadrats, individual and combined fuels cover was recorded according to fuel type: duff, litter, natural woody debris, and chipped material.

The thickness of each of these fuels components was measured at 5 locations in each quadrat: at each of the four corners, and one depth measure taken at the very center of the quadrat. Because we did not follow the additional procedures required to determine dry weight bulk density of the chipped material, it is impossible to provide estimates of the density of the chipped material in terms of tons/acre. However, the data collected is effective for determining cover, mean depth, and volume of onsite chipped material.

Slash Pile Data Collection Methods

It was known in advance that the Dollar5 mechanically thinned unit included the piling of slash material. Piled woody debris creates a difficult arrangement of fuels for sampling. Standard sampling using the Brown's planar intercept method may prove to be very inaccurate, since the scale of the sampling may result in line intercepts which do not include a representative number of slash piles. We used a methodology created specifically designed for sampling slash piles, and outlined in PNW-GTR-164 (Hardy, 1996). The methodology includes defining the slash pile according to shape, specific pile dimensions measured, and percent of material derived from defined tree species. We added collection of fuels size classes percentages in each slash pile, which allows for a reporting of material by fuels size class.

Herbaceous and Shrub Cover/Frequency

Herb and shrub percent cover, height, and nested frequency were measured in three $1m^2$ quadrats located at 3 locations along all four transects (5, 10, and 15m), for a total sample area of $9m^2$ per plot. Frequency describes the abundance and distribution of species and is very useful for comparing significant differences between two plant communities or detecting significant change in a single community over time. A reasonable sensitivity to change results from capturing frequencies between 20 and 80 percent, and therefore, a nested quadrat system was used to avoid problems resulting from using a single quadrat size. Nested quadrat sizes (10x10, 50x50, 50x100, 100x100 cm) corresponded to a nested rooted frequency ratio of 1:25:50:100 (Figure A.1-5).

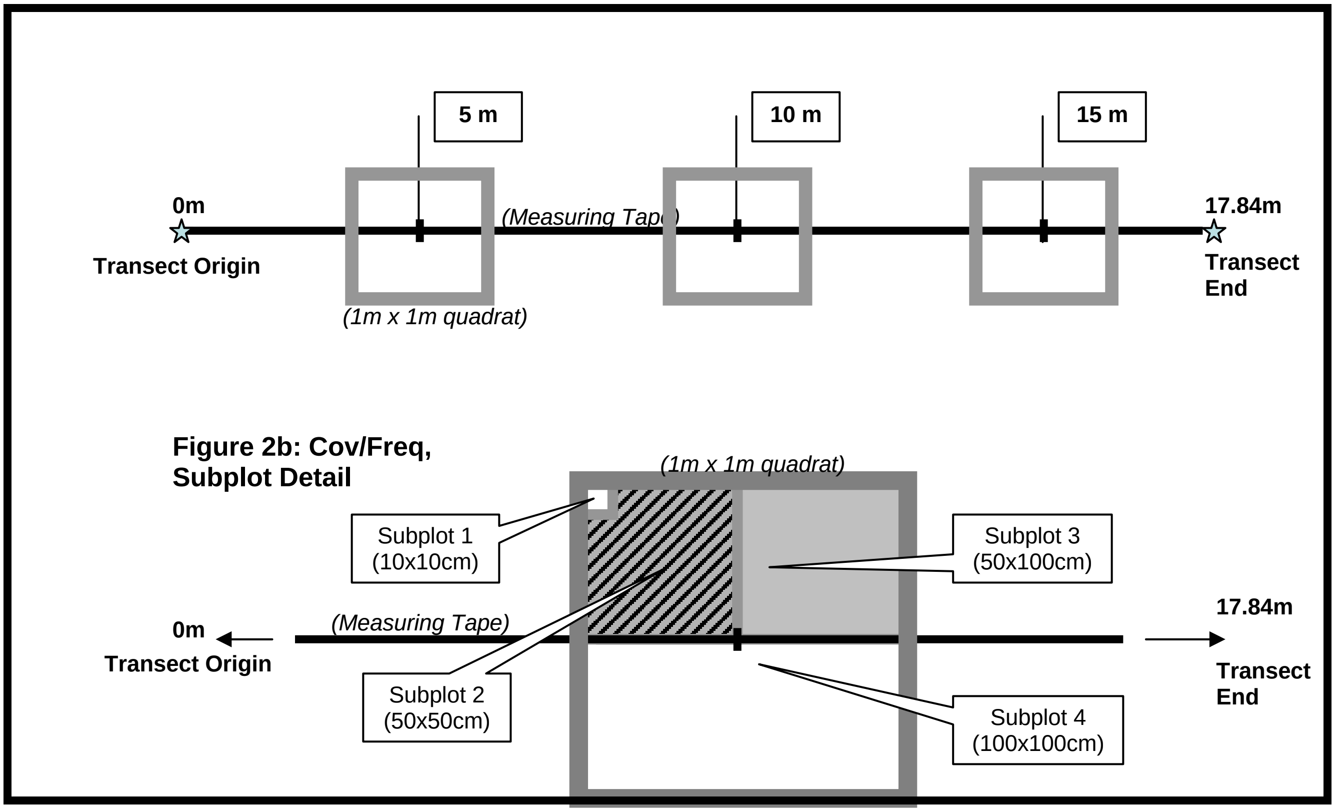

Figure A.1-5. Diagram illustrating layout and detail of subplots used to collect cover/frequency data on herbaceous species.

Plant cover was measured as the vertical projection of foliage within a percentage of the quadrat and the percent value indicates the relative influence of each species on the community. A system of 12 cover classes, (0-1, 1-5, 5-15, 15-25, 25-35, 35-45, 45-55, 55-65, 65-75, 75-85, 85-95, 95-100) was used to reduce human error and increase the consistency of estimates. Midpoint values were used for computation.

Height gives detailed information about the vertical distribution of plant species cover with in the plot. It allows calculations of 1) plant species volume (cover x height) and 2) biomass (height x cover x bulk density). FIREMON uses 0.8 kg/m^3 for herbaceous BD and 1.8 kg/m^3 for shrubs.

Appendix 2. Species lists

Table A.2-1. Understory Species for the Upland Fuels Project

Code	Lifeform	Scientific name	Common name	Family	In/OUT Sample Quads
ACMI2	FORB	Achillea millefolium	common yarrow	Asteraceae	
ALCA2	FORB	Allium campanulatum	dusky onion	Liliaceae	
ALLIU	FORB	Allium	onion	Liliaceae	
ANBR5	FORB	Angelica breweri	Brewer's angelica	Apiaceae	OUT
ANMA	FORB	Anaphalis margaritacea	western pearly everlasting	Asteraceae	OUT
APAN2	FORB	Apocynum androsaemifolium	spreading dogbane	Apocynaceae	
AQFO	FORB	Aquilegia formosa	western columbine	Ranunculaceae	
ARABI2	FORB	Arabis	rockcress	Brassicaceae	
ARCO9	FORB	Arnica cordifolia	heartleaf arnica	Asteraceae	
ARHO2	FORB	Arabis holboellii	Holboell's rockcress	Brassicaceae	
ARPL	FORB	Arabis platysperma	pioneer rockcress	Brassicaceae	
ASAS5	FORB	Aster ascendens	Ascending aster	Asteraceae	
ASBR12	FORB	Aster breweri	Brwer's aster	Asteraceae	
BASA3	FORB	Balsamorhiza sagittata	arrowleaf balsamroot	Asteraceae	OUT
BRGR	FORB	Brickellia grandiflora	tasselflower brickellbush	Asteraceae	
CAAP4	FORB	Castilleja applegatei	wavyleaf Indian paintbrush	Scrophulariaceae	
CAMIM5	FORB	Castilleja miniata ssp. miniata	giant red Indian paintbrush	Scrophulariaceae	
CAPA26	FORB	Castilleja parviflora	mountain Indian paintbrush	Scrophulariaceae	
CASTI2	FORB	Castilleja	Indian paintbrush	Scrophulariaceae	
CHDOD	FORB	Chaenactis douglasii var. douglasii	Douglas' dustymaiden	Asteraceae	
CHME	FORB	Chimaphila menziesii	little prince's pine	Pyrolaceae	
CHUM	FORB	Chimaphila umbellata	pipsissewa	Pyrolaceae	
CIAN	FORB	Cirsium andersonii	rose thistle	Asteraceae	
CIUMU	FORB	Cistanthe umbellata var. umbellata	Mt. Hood pussypaws	Portulacaceae	
COMA4	FORB	Corallorrhiza maculata	summer coralroot	Orchidaceae	
COPA3	FORB	Collinsia parviflora	maiden blue eyed Mary	Scrophulariaceae	
COTE3	FORB	Cordylanthus tenuis	slender bird's beak	Scrophulariaceae	OUT
COTO	FORB	Collinsia torreyi	Torrey's blue eyed Mary	Scrophulariaceae	
CRAF	FORB	Cryptantha affinis	quill cryptantha	Boraginaceae	
CRYPT	FORB	Cryptantha	cryptantha	Boraginaceae	
EPANC	FORB	Epilobium angustifolium ssp. circumvagum	fireweed	Onagraceae	
EPILO	FORB	Epilobium	willowherb	Onagraceae	OUT
ERBR4	FORB	Erigeron breweri	Brewer's fleabane	Asteraceae	
ERNU3	FORB	Eriogonum nudum	naked buckwheat	Polygonaceae	
ERSP6	FORB	Eriogonum spergulinum	spurry buckwheat	Polygonaceae	
ERUM	FORB	Eriogonum umbellatum	sulphur-flower buckwheat	Polygonaceae	
FRVI	FORB	Fragaria virginiana	Virginia strawberry	Rosaceae	
GADI2	FORB	Gayophytum diffusum	spreading groundsmoke	Onagraceae	
GILE	FORB	Gilia leptalea	Bridges' gilia	Polemoniaceae	

Code	Lifeform	Scientific name	Common name	Family	In/OUT Sample Quads
GNAPH	FORB	Gnaphalium	cudweed	Asteraceae	
GOOB2	FORB	Goodyera oblongifolia	western rattlesnake plantain	Orchidaceae	
HACKE	FORB	Hackelia	stickseed	Boraginaceae	OUT
HANE	FORB	Hackelia nervosa	Sierra stickseed	Boraginaceae	
HIAL2	FORB	Hieracium albiflorum	white hawkweed	Asteraceae	
HOFU	FORB	Horkelia fusca	pinewoods horkelia	Rosaceae	
HOLO	FORB	Houstonia longifolia	longleaf summer bluet	Rubiaceae	OUT
IPAG	FORB	Ipomopsis aggregata	scarlet gilia	Polemoniaceae	
KEGA	FORB	Kelloggia galioides	milk kelloggia	Rubiaceae	
LANE3	FORB	Lathyrus nevadensis	Sierra pea	Fabaceae	OUT
LINU3	FORB	Linanthus nuttallii	Nuttall's linanthus	Polemoniaceae	
LIWA	FORB	Lilium washingtonianum	Washington lily	Liliaceae	
LODI	FORB	Lomatium dissectum	fernleaf biscuitroot	Apiaceae	
LONE	FORB	Lomatium nevadense	Nevada biscuitroot	Apiaceae	
LUAR3	FORB	Lupinus argenteus	silvery lupine	Fabaceae	
LUAR6	FORB	Lupinus arbustus	longspur lupine	Fabaceae	
LUBR3	FORB	Lupinus breweri	Brewer's lupine	Fabaceae	OUT
LUFU	FORB	Lupinus fulcratus	greenstipule lupine	Fabaceae	OUT
LULE2	FORB	Lupinus lepidus	Pacific lupine	Fabaceae	
LUPIN	FORB	Lupinus	lupine	Fabaceae	
MIBR5	FORB	Mimulus breweri	Brewer's monkeyflower	Scrophulariaceae	
MICRO6	FORB	Microseris	silverpuffs	Asteraceae	
MIGU	FORB	Mimulus guttatus	seep monkeyflower	Scrophulariaceae	OUT
MINU	FORB	Microseris nutans	nodding microceris	Asteraceae	
MINUA	FORB	Minuartia	stitchwort	Caryophyllaceae	OUT
MIPR	FORB	Mimulus primuloides	primrose monkeyflower	Scrophulariaceae	OUT
MITO	FORB	Mimulus torreyi	Torrey's monkeyflower	Scrophulariaceae	
MOOD	FORB	Monardella odoratissima	mountain monardella	Lamiaceae	
NAVAR	FORB	Navarretia	pincushionplant	Polemoniaceae	
ORSE	FORB	Orthilia secunda	sidebells wintergreen	Pyrolaceae	OUT
OSCH	FORB	Osmorhiza chilensis	sweet cicely	Apiaceae	
OSOC	FORB	Osmorhiza occidentalis	western sweetroot	Apiaceae	
PABR	FORB	Paeonia brownii	Brown's peony	Paeoniaceae	
PEGR4	FORB	Penstemon gracilentus	slender penstemon	Scrophulariaceae	
PENST	FORB	Penstemon	beardtongue	Scrophulariaceae	
PERO12	FORB	Penstemon roezlii	Roezl's penstemon	Scrophulariaceae	
PESE2	FORB	Pedicularis semibarbata	pinewoods lousewort	Scrophulariaceae	
PHHA	FORB	Phacelia hastata	silverleaf phacelia	Hydrophyllaceae	
PLFI2	FORB	Pleuricospora fimbriolata	fringed pinesap	Monotropaceae	OUT
PLLE5	FORB	Platanthera leucostachys	Sierra bog orchid	Orchidaceae	
PLSP2	FORB	Platanthera sparsiflora	sparse-flowered bog orchid	Orchidaceae	OUT
POGL9	FORB	Potentilla glandulosa	sticky cinquefoil	Rosaceae	
POGR9	FORB	Potentilla gracilis	slender cinquefoil	Rosaceae	OUT
POTEN	FORB	Potentilla	cinquefoil	Rosaceae	
POTR5	FORB	Populus tremuloides	quaking aspen	Salicaceae	OUT

Code	Lifeform	Scientific name	Common name	Family	In/OUT Sample Quads
PTAN2	FORB	Pterospora andromedea	woodland pinedrops	Monotropaceae	
PTAQP2	FORB	Pteridium aquilinum var. pubescens	hairy brackenfern	Dennstaedtiaceae	
PYPI2	FORB	Pyrola picta	whiteveined wintergreen	Pyrolaceae	
SASA5	FORB	Sarcodes sanguinea	snowplant	Ericaceae	OUT
SATU	FORB	Sanicula tuberosa	turkey pea	Apiaceae	
SEIN2	FORB	Senecio integerrimus	lambstongue ragwort	Asteraceae	
SIGL2	FORB	Sidalcea glaucescens	waxy checkerbloom	Malvaceae	
SOCAE	FORB	Solidago canadensis ssp. elongata	salebrosa goldenrod	Asteraceae	
STLA	FORB	Stephanomeria lactucina	lettuce wirelettuce	Asteraceae	
STTO3	FORB	Streptanthus tortuosus	shieldplant	Brassicaceae	OUT
THFE3	FORB	Thalictrum fendleri	Fendler's meadow-rue	Ranunculaceae	
TRIFO	FORB	Trifolium	clover	Fabaceae	
VACA2	FORB	Valeriana californica	California valerian	Valerianaceae	
VIAD	FORB	Viola adunca	Western dog violet	Violaceae	OUT
VIOLA	FORB	Viola	violet	Violaceae	
VIPI2	FORB	Viola pinetorum	goosefoot yellow violet	Violaceae	OUT
VIPU4	FORB	Viola purpurea	goosefoot violet	Violaceae	
WYMO	FORB	Wyethia mollis	woolly mule-ears	Asteraceae	
ACHNA	GRASS	Achnatherum	needlegrass	Poaceae	
ACOC3	GRASS	Achnatherum occidentale	western needlegrass	Poaceae	
ACSP12	GRASS	Achnatherum speciosum	desert needlegrass	Poaceae	
AGROS2	GRASS	Agrostis	bentgrass	Poaceae	
AGVA	GRASS	Agrostis variabilis	mountain bentgrass	Poaceae	
BRMA	GRASS	Briza maxima	big quakinggrass	Poaceae	
BROMU	GRASS	Bromus	brome	Poaceae	
BRSU2	GRASS	Bromus suksdorfii	Suksdorf's brome	Poaceae	
CAREX	GRASS	Carex	sedge	Cyperaceae	
CARO5	GRASS	Carex rossii	Ross' sedge	Cyperaceae	
CAWH	GRASS	Carex whitneyi	Whitney's sedge	Cyperaceae	
ELEL5	GRASS	Elymus elymoides	squirreltail	Poaceae	
ELGL	GRASS	Elymus glaucus	blue wildrye	Poaceae	
LEYMU	GRASS	Leymus	wildrye	Poaceae	OUT
ACGLT	SHRUB	Acer glabrum ssp. torreyi	Mountain maple	Aceraceae	
ALINT	SHRUB	Alnus incana ssp. tenuifolia	thinleaf alder	Betulaceae	OUT
AMAL2	SHRUB	Amelanchier alnifolia	Saskatoon serviceberry	Rosaceae	OUT
AMUT	SHRUB	Amelanchier utahensis	Utah serviceberry	Rosaceae	
ARPA6	SHRUB	Arctostaphylos patula	greenleaf manzanita	Ericaceae	
CEANO	SHRUB	Ceanothus	ceanothus	Rhamnaceae	
CECO	SHRUB	Ceanothus cordulatus	whitethorn ceanothus	Rhamnaceae	
CEVE	SHRUB	Ceanothus velutinus	snowbrush ceanothus	Rhamnaceae	
CHSE11	SHRUB	Chrysolepis sempervirens	bush chinquapin	Fagaceae	
LOCO5	SHRUB	Lonicera conjugialis	purpleflower honeysuckle	Caprifoliaceae	
PREM	SHRUB	Prunus emarginata	bitter cherry	Rosaceae	
QUVA	SHRUB	Quercus vacciniifolia	huckleberry oak	Fagaceae	
RICE	SHRUB	Ribes cereum	wax currant	Grossulariaceae	

Code	Lifeform	Scientific name	Common name	Family	In/OUT Sample Quads
RINE	SHRUB	Ribes nevadense	Sierra currant	Grossulariaceae	
RIRO	SHRUB	Ribes roezlii	Sierra gooseberry	Grossulariaceae	
RIVI3	SHRUB	Ribes viscosissimum	sticky currant	Grossulariaceae	
RUPA	SHRUB	Rubus parviflorus	western thimbleberry	Rosaceae	
SACE3	SHRUB	Sambucus cerulea	blue elderberry	Sambucaceae	OUT
SALIX	SHRUB	Unknown willow			
SARA2	SHRUB	Sambucus racemosa	red elderberry	Sambucaceae	
SYRO	SHRUB	Symphoricarpos rotundifolius	roundleaf snowberry	Rosaceae	
ARNE	SUB	Arctostaphylos nevadensis	pinemat manzanita	Ericaceae	
CEPR	SUB	Ceanothus prostratus	squawcarpet	Rhamnaceae	
SYMO	SUB	Symphoricarpos mollis	creeping snowberry	Rosaceae	

Table A.2-2. Understory species list for Dollar5 plots.

Code	Lifeform	Scientific name	Common name	Family	Treatment type
APAN2	FORB	Apocynum androsaemifolium	spreading dogbane	Apocynaceae	handthin
ARHO2	FORB	Arabis holboellii	Holboell's rockcress	Brassicaceae	handthin
ARNE	SHRUB	Arctostaphylos nevadensis	pinemat manzanita	Ericaceae	handthin
CECO	SHRUB	Ceanothus cordulatus	whitethorn ceanothus	Rhamnaceae	handthin
CRAF	FORB	Cryptantha affinis	quill cryptantha	Boraginaceae	handthin
ERNU3	FORB	Eriogonum nudum	naked buckwheat	Polygonaceae	handthin
GAHE3	FORB	Gayophytum heterozygum	zig zag groungsmoke	Onagraceae	handthin
HIAL2	FORB	Hieracium albiflorum	white hawkweed	Asteraceae	handthin
KEGA	FORB	Kelloggia galioides	milk kelloggia	Rubiaceae	handthin
PYPI2	FORB	Pyrola picta	whiteveined wintergreen	Pyrolaceae	handthin
ARNE	SHRUB	Arctostaphylos nevadensis	pinemat manzanita	Ericaceae	mechanical
CECO	SHRUB	Ceanothus cordulatus	whitethorn ceanothus	Rhamnaceae	mechanical
CIAN	FORB	Cirsium andersonii	rose thistle	Asteraceae	mechanical
ERBR4	FORB	Erigeron breweri	Brewer's fleabane	Asteraceae	mechanical
EUBR12	FORB	Erigeron concinnus	Navajo fleabane	Asteraceae	mechanical
GAHE3	FORB	Gayophytum heterozygum	zig zag groungsmoke	Onagraceae	mechanical
HANE	FORB	Hackelia nervosa	Sierra stickseed	Boraginaceae	mechanical
HASQ2	subSHRUB	Hazardia squarrosa	sawtooth goldenbrush	Asteraceae	mechanical
HIAL2	FORB	Hieracium albiflorum	white hawkweed	Asteraceae	mechanical
KEGA	FORB	Kelloggia galioides	milk kelloggia	Rubiaceae	mechanical
LUAR6	FORB	Lupinus arbustus	longspur lupine	Fabaceae	mechanical
MOOD	FORB	Monardella odoratissima	mountain monardella	Lamiaceae	mechanical
PESE2	FORB	Pedicularis semibarbata	pinewoods lousewort	Scrophulariaceae	mechanical
PHHA	FORB	Phacelia hastata	silverleaf phacelia	Hydrophyllaceae	mechanical
PHHY	FORB	Phacelia hydrophylloides	waterleaf phacelia	Hydrophyllaceae	mechanical
PYPI2	FORB	Pyrola picta	whiteveined wintergreen	Pyrolaceae	mechanical
SILA	FORB	Sicyos laciniatus	cutleaf bur cucumber	Cucurbitaceae	mechanical

Table A.2-3. Understory species list for Kingsbury plots

Code	Lifeform	Scientific name	Common name	Family
ABAB	FORB	Abutilon abutiloides	shrubby Indian mallow	Malvaceae
ALCA2	FORB	Allium campanulatum	dusky onion	Liliaceae
ALGI	FORB	Allophyllum gilioides	dense false gilyflower	Polemoniaceae
APAN2	FORB	Apocynum androsaemifolium	spreading dogbane	Apocynaceae
ARABI2	FORB	Arabis	rockcress	Brassicaceae
ARHO2	FORB	Arabis holboellii	Holboell's rockcress	Brassicaceae
ARPA6	SHRUB	Arctostaphylos patula	greenleaf manzanita	Ericaceae
BASA3	FORB	Balsamorhiza sagittata	arrowleaf balsamroot	Asteraceae
BRTE	GRASS	Bromus tectorum	cheatgrass	Poaceae
CARO5	GRASS	Carex rossii	Ross' sedge	Cyperaceae
CAREX	GRASS	Carex spp.	sedge	Cyperaceae
CAAP4	FORB	Castilleja applegatei	wavyleaf Indian paintbrush	Scrophulariaceae
CECU	SHRUB	Ceanothus cuneatus	buckbrush	Rhamnaceae
CHSE11	SHRUB	Chrysolepis sempervirens	bush chinquapin	Fagaceae
CAUM2	FORB	Cistanthe umbellata	Mt. Hood pussypaws	Portulacaceae
COGR2	FORB	Collinsia grandiflora	giant blue eyed Mary	Scrophulariaceae
CRYPT	FORB	Cryptantha	cryptantha	Boraginaceae
CRAF	FORB	Cryptantha affinis	quill cryptantha	Boraginaceae
CRYPT10	FORB	Cryptothallus	liverwort	Aneuraceae
DISP	GRASS	Distichlis spicata	saltgrass	Poaceae
ELEL5	GRASS	Elymus elymoides	squirreltail	Poaceae
ERIN	GRASS	Eragrostis intermedia	plains lovegrass	Poaceae
ERBR4	FORB	Erigeron breweri	Brewer's fleabane	Asteraceae
FEID	GRASS	Festuca idahoensis	Idaho fescue	Poaceae
FEOC	GRASS	Festuca occidentalis	western festuca	Poaceae
GAHE3	FORB	Gayophytum heterozygum	zig zag groundsmoke	Onagraceae
LEPU	FORB	Leptodactylon pungens	granite prickly phlox	Polemoniaceae
LICI	FORB	Linanthus ciliatus	whiskerbrush	Polemoniaceae
LUAR3	FORB	Lupinus argenteus	silvery lupine	Fabaceae
MADIA	FORB	Madia	tarweed	Asteraceae
PHHA	FORB	Phacelia hastata	silverleaf phacelia	Hydrophyllaceae
PHDI3	FORB	Phlox diffusa	spreading phlox	Polemoniaceae
PUTR2	SHRUB	Purshia tridentata	antelope bitterbrush	Rosaceae
SEIN2	FORB	Senecio integerrimus	lambstongue ragwort	Asteraceae

Appendix 3. Crown fuel calculation methods

Canopy bulk density and canopy base height

Reinhardt and others discuss the need for, uses of, and techniques for determination of forest canopy fuel attributes (Reinhardt, Scott, Gray, and Keane 2006). Fire managers and researchers use software tools including BehavePlus (Andrews et al. 2005), FARSITE (Finney 1998), NEXUS (Scott 1999), and FVS-FFE (Reinhardt and Crookston 2003) to predict crown fire initiation and spread across forested landscapes and/or within forest stands. These software tools rely on numeric estimates of canopy bulk density and canopy base height. Canopy bulk density (CBD) is defined as the mass of available canopy fuel per unit of canopy volume (Scott and Reinhard 2001). Canopy base height (CBH) is the lowest height above the ground at which there is sufficient canopy fuel to propagate fire vertically through the canopy (Scott and Reinhard 2001). For this project, we calculated (CBH) and (CBD) for each plot, for each project, and each measurement period using the techniques described below. CBH and CBD were then used as input to NEXUS (Scott 1999; Scott and Reinhardt 2001), as described elsewhere in this report.

Calculation algorithm

Calculation of CBH and CBD follows methodology used in FVS-FFE. The essential steps are:

1. Estimate the available canopy fuel weight for each tree 4.5 feet in height and greater.
2. Calculate a vertical profile, in 1 foot increments from ground surface to top of the canopy, of average canopy fuel load per acre, by combining the crown weights of the individual trees, distributed from base of crown to tip
3. Detect CBH as the lowest height at which the average canopy fuel load exceeds 30 lbs/acre/foot, based on a 3- running average
4. Determine CBD as the highest average canopy fuel load within the profile, based on a 13 foot running average

Tree crown weight

Estimated tree crown weights are based on equations used in the western variants of FVS-FFE. The FVS-FFE equations are from various sources, principally Brown & Johnston, 1976, 'Debris Prediction System', Fuel Science RWU 2104 (FSMC Staff, 01/04/05). The equations predict weight of crown materials in various size classes, and depend on species, diameter, height, and in some cases, crown ratio. There are separate equations for small trees less than 1" dbh and for trees greater than 2" dbh. For trees with dbh between these limits, a diameter based weighted average is used. The general methodology is to first estimate the total weight of the crown, and then apportion the total crown weight to the size classes: foliage, live twigs, and dead twigs. Table XY lists the coefficients and model forms used for trees 2" dbh and larger. We followed the convention in FVS-FFE, which is to include all foliage and one half of the live and dead twigs, up to ¼" diameter, in the available canopy fuels. This material is assumed to be consumed during the passage of the flaming front of a crown fire. We included hardwoods, an option in FVS-FFE, and modeled crown weight for Jeffery pine using ponderosa pine equations, rather than western white pine, as in FVS-FFE.

Vertical profile of canopy fuel load

The vertical profile of available canopy fuel load can be visualized as a stack of 1 cubic foot boxes, extending from the ground surface to the top of the canopy. Each box contains the sum of available canopy fuel weight per acre for the 1' horizontal layer of canopy it occupies. Available fuel for each box (i.e., layer) is determined by calculating available fuel per acre for each tree, divided by the crown length. We differ from FVS-FFE in that the minimum CBH, corresponding to ground surface, is 0, whereas in FVS-FFE, it's 1.

Distribution of tree crown weight

The above procedure assumes that crown weight within a tree's crown is distributed evenly from base to top of the crown. Reinhardt and others found that crown weight was unevenly distributed (Reinhard, Scott, Gray, and Keane 2006). We use crown weight distribution functions for ponderosa/Jeffery pine, Douglas-fir, lodgepole pine, and incense-cedar that were developed by Kathy Gray and included in the source code file for the FuelCalc application (Reinhardt, Lutes, and Scott 2006). For other species, crown weight was assumed to be distributed uniformly, due to lack of appropriate equations, rather than conviction. The crown weight distribution function is applied during the process of adding each tree's crown weight contribution to the vertical profile of canopy fuel load.

Canopy base height and canopy bulk density

Detection of canopy base height (CBH) follows methodology used in FVS-FFE. Starting at the ground surface, and working up the canopy fuel load profile in 1 foot increments, calculate a 3 foot running mean. CBH is defined as the lowest layer in which the 3 foot running mean is 30 lbs/ac-foot (.011 kg/m^3) or more. Calculation of canopy bulk density (CBD) follows a similar methodology, except that the running mean of the canopy fuel profile is calculated over 13 feet, rather than three. CBD is maximum 13 foot running mean occurring within the tree canopy.

Adjustments to account for crown recession

The crown weight equations for some species and canopy position classes shown in Table XY lack a crown ratio term. These include Douglas-fir, true fir, and hardwoods, as well as ponderosa and Jeffrey pine in the intermediate and suppressed canopy position classes. This lack of sensitivity to changes in crown ratio could lead to overestimation of canopy bulk density following fire. For example, consider a stand of Douglas-fir, in which many trees suffered crown scorch during an understory burn. This is manifested in the tree data as a decrease in crown ratio. Predicted crown weight for the scorched trees will be the same before and after the burn, because predicted crown weight depends only on dbh, and does not consider crown ratio. During the process of calculating the canopy load profile, crown weights from individual trees are distributed from the base of the crown to the tip of the tree. If the crown weight is held constant while the length of live crown has decreased due to scorching, the crown weight is distributed along a shorter length, so each foot in the profile receives a higher value. In order to avoid distorting the canopy weight profile, we developed a procedure to reduce the predicted post burn crown weight for a tree in proportion to the reduction in crown ratio between pre burn and post burn. The reduction is applied only to species and canopy position classes for which the crown weight equations lack a crown ratio term.

Data smoothing

Crown position class data (dominant, co dominant, intermediate, and suppressed) were collected by field crews at each visit. Since assignment of position class was subject to judgment by crews each year, there were cases where an individual tree's crown position class would decline or advance from one visit to the next. Crown position class affects calculation of crown weight for several important species in this study, dominant trees having calculated crown weight considerably higher than intermediate or suppressed trees of the same species, diameter, and height. We did not want to introduce "noise" into the database due to differences in field crews' judgment regarding crown position class. In order to stabilize crown position from visit to visit, we instituted a data processing rule wherein each tree's crown position class was locked at its initial class.

Year to year variation in crown base measurements also required some smoothing due to differences in application of measurement protocols or measurement error. There were many cases where a tree's measured crown base was lower in one or more of the follow-up visits than in the pre-treatment visit, something we felt was not biologically reasonable. In order to stabilize crown base measurements for individual trees from year to year, we instituted a set of data processing rules:

- A post-treatment crown base measurement can not be lower than pre-treatment;
- If one post-treatment crown base is less than pre-treatment, but another is higher, use the higher post-treatment crown base for both;
- A 15% difference threshold is required to detect a difference in crown base measurements, either pre-treatment to post-treatment, or between different post-treatment visits.

Table A3-1. Crown width equations for major species, trees >= 2" Dbh.

Item	Species	Dbh group	Posi	a	b	c	d	Model
LiveCrnWt	PP,JP		D,C	2.2812	1.5098	-3.0954		A
DeadCrnWt	PP,JP		D,C	2.8376	-3.7398			B
LiveCrnWt	PP,JP		I,S	-0.7572	2.216			C
DeadCrnWt	PP,JP		I,S	-2.5175	2.51			C
P1	PP,JP		D,C	0.5578	-0.04754			D
P2	PP,JP		D,C	0.6254	-0.05114			D
P1	PP,JP		I,S	0.6501	-0.1544			D
P2	PP,JP		I,S	0.8435	-0.1665			D
DP1	PP,JP	> 30"		0.004				G
DP1	PP,JP	<= 30"		-0.4345	1.4114			H
LiveCrnWt	DF	< 17	D,C	1.1368	1.5819			C
LiveCrnWt	DF	>= 17	D,C	1.0237	-20.74			E
DeadCrnWt	DF		D,C	0.01094				F
LiveCrnWt	DF	>2"	I,S	0.1508	1.8621			C
DeadCrnWt	DF	>2"	I,S	-1.928	2.353			C
P1	DF	> 36	D,C	0.224				G
P2	DF	>36	D,C	0.315				G
P1	DF	<= 36"	D,C	0.484	-0.02103			D
P2	DF	<= 36"	D,C	0.7289	-0.02332			D
DP1	DF	< 9		1	0			G
DP1	DF	>=9		0.8355	1.5893			H
LiveCrnWt	WF,RF		D,C	2.2812	1.5098	-3.0954		A
DeadCrnWt	WF,RF		D,C	2.8376	-3.7398			B
LiveCrnWt	WF,RF		I,S	-0.7572	2.216			C
DeadCrnWt	WF,RF		I,S	-2.5175	2.51			C
P1	WF,RF		D,C	0.5578	-0.04754			D
P2	WF,RF		D,C	0.6254	-0.05114			D
P1	WF,RF		I,S	0.6501	-0.1544			D
P2	WF,RF		I,S	0.8435	-0.1665			D
DP1	WF,RF	> 30"		0.004				G
DP1	WF,RF	<= 30"		-0.4345	1.4114			H
LiveCrnCt	IC			1.7273	2.8086			I
DeadCrnWt	IC			0.01063				F
P1	IC			0.6174	-0.02326			D
P2	IC			0.7562	-0.02411			D
DP1	IC			-0.01578	1.4673			H
LiveCrnWt	Oaks, TO			-0.3169	2.2774			D
DeadCrnWt	Oaks, TO			-2.4895	2.0374			D
P1	Oaks, TO			1.7936	0.5952	0.7239		J
P2	Oaks, TO			0.994	0.4229	0.652		J
DP1	Oaks, TO			-0.1424	0.7684	0.25	-0.473	K

Table A3-1. (cont).

Item	Species	Dbh group	Posi	a	b	c	d	Model
LiveCrnWt	SP,WP			0.0947				L
DeadCrnWt	SP,WP			2.6076	-4.397			B
P1	SP,WP			0.5497	-0.0345			D
P2	SP,WP			0.9138	-0.0978			M
DP1	SP,WP			1.0077	-0.4556			N
LiveCrnWt	LP		D,C	0.02238	0.1233	-2		O
DeadCrnWt	LP	<= 10"	D,C	0.025	-0.025			P
DeadCrnWt	LP	> 10"	D,C	0.235				Q
LiveCrnWt	LP	<= 7.5"	I,S	0.5				Q
DeadCrnWt	LP	<= 7.5"	I,S	0.5				Q
LiveCrnWt	LP	> 7.5"	I,S	0.6				Q
DeadCrnWt	LP	> 7.5"	I,S	0.6				Q
P1	LP			0.4933	-0.01167			R
P2	LP			0.7767	-0.01464			R
DP1	LP	> 20"		0.139				G
DP1	LP	<= 20"		1.3527	-0.7585			N
LiveCrnWt	MA			-0.7881	2.4839			C
DeadCrnWt	MA			-2.3938	2.2937			C
P1	MA			1.6013	0.3591	1.309		J
P2	MA			1.0357	0.2263	1.3567		J
DP1	MA			-0.0632	0.7214	0.25	-0.4655	K

Model Forms

A	Y = Exp(a * Log(Dbh) + b * Log(R) + c)
B	Y = Exp(a * Log(Dbh) + b)
C	Y = Exp(a + b * Log(Dbh))
D	Y= a * Exp(b * Dbh)
E	Y = a * Dbh ^ 2 + b
F	Y = a * Dbh ^ 3
G	Y = a
H	Y = a + (b / Dbh)
I	Y = Exp(a * Log(Dbh * R) - b)
J	Y= 1/ (a + b * Dbh ^ c)
K	Y = a + (b * Dbh ^ c) - (d * Log(Dbh))
L	Y = a * Dbh ^ 2 * R
M	Y=a + b * Sqrt(Dbh)
N	Y= a * Dbh ^ b
O	Y = a * Dbh ^ 3 + b * (Dbh ^ 2 * R) + c
P	Y=(a * Dbh - b) * LiveCrnWt
Q	Y = a * LiveCrnWt
R	Y = a + b * Dbh

Item definitions:

LiveCrnWt	total weight of live crown components, lbs
DeadCrnWt	total weight of dead crown components, lbs
P1	proportion of live crown weight in foliage
P2	proportion of live crown weight in twigs 0 to ¼" diameter

DP1	proportion of dead crown weight in twigs 0 to ¼" diameter

Species Codes:

PP	pinus ponderosa
JP	pinus Jefferyi
DF	pseudotsuga Menziesii
WF	abies concolor
RF	abies magnifica
IC	calocedrus decurrens
Oaks	quecus species
TO	lithocarpus densiflorus
SP	pinus Lambertiana
WP	pinus monticola
LP	pinus contorta
MA	arbutus Menziesii

Appendix 4. Photos

Figure A.4-1. Relatively dense pre-treatment conditions in the Kingsbury Project, dense unit (KBd).

Figure A.4-2. Relatively open pre-treatment conditions in the Kingsbury Project, open unit (KBo).

Figure A.4-3. Partially-treated conditions with residual woodchip material in the Dollar5 hand thinned unit (DH).

Figure A.4-4. Partially-treated conditions with residual slash material in the Dollar5 mechanically thinned unit (DM).

Figure A.4-5. Dense, small diameter white fir in WRD 20-09.

Figure A.4-6. Low canopy base height in BLK 1-4.

Figure A.4-7. Shrub patch in WRD 20-16.

Figure A.4-7. High fuel loading of down woody debris in MCK 13-3.