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Fuel Treatment Effects on Fire Behavior, Suppression Effectiveness, and Structure Ignition

Grass Valley Fire

San Bernardino National Forest



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Report submitted to

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Executive Summary

The Grass Valley Fire started at approximately 0508 on October 22, 2007 in the mountains of the San Bernardino National Forest in Southern California about 60 miles east of Los Angeles. Weather conditions were warm and dry. Santa Ana winds (strong, dry winds) had been blowing for two days. Live vegetation and dead fuels were very dry.

The fire spread to the south through wildland fuels and then transitioned to urban structural fuels where it destroyed or damaged approximately 199 structures. U.S. Forest Service, state, and local firefighters responded immediately after the initial report. Most of the final fire area burned on the first day. The fire was contained on the 26th of October. According to firefighters, suppression actions were substantially enhanced by fuel treatments in and adjacent to the fire.

A team was formed to assess effects of fuel treatments on:

- ◇ Fire behavior
- ◇ Fire effects
- ◇ Structure ignition
- ◇ Fire suppression
- ◇ Public safety and egress

Key Findings

- ◇ Fire behavior in fuel treatment areas was less rapid and less intense than in adjacent untreated wildland fuel and urban-structural fuel. The reduced spread rate and intensity allowed suppression forces to concentrate on protecting structures and on preventing additional fire spread to the south.
- ◇ Fuel treatments improved visibility enabling firefighters to engage the fire directly in places and to protect homes without jeopardizing their safety.
- ◇ The Mountain Area Safety Task Force coordinates hazard reduction efforts of all the organizations and agencies managing land, infrastructure, and emergency response in the Lake Arrowhead area. Their efforts greatly enhanced the safe evacuation of thousands of people due to previous dead tree removal. Removal of these dead trees reduced the amount of tree fall in roadways along main routes and also reduced ember production and associated spot fires.
- ◇ The Grass Valley Fire burned more intensely within the residential area than in adjacent wildland fuels. Mass ember production from structures ignited adjacent and downwind structures in many cases.

Introduction

The Grass Valley Fire occurred in the mountains just north of San Bernardino in Southern California (Figure 1). Within and adjacent to the fire is a residential area known as Lake Arrowhead. Located approximately 60 miles east of Los Angeles, the area is famous for recreation and destination resorts and contains many year round and vacation homes. The Mountaintop Ranger

District of the San Bernardino National Forest administers the core of the mountainous land base. Surrounding foothill lands have intermingled private and government ownership. Many parcels of private land occur within the National Forest. Private lands outside the National Forest contain a dense array of subdivisions.

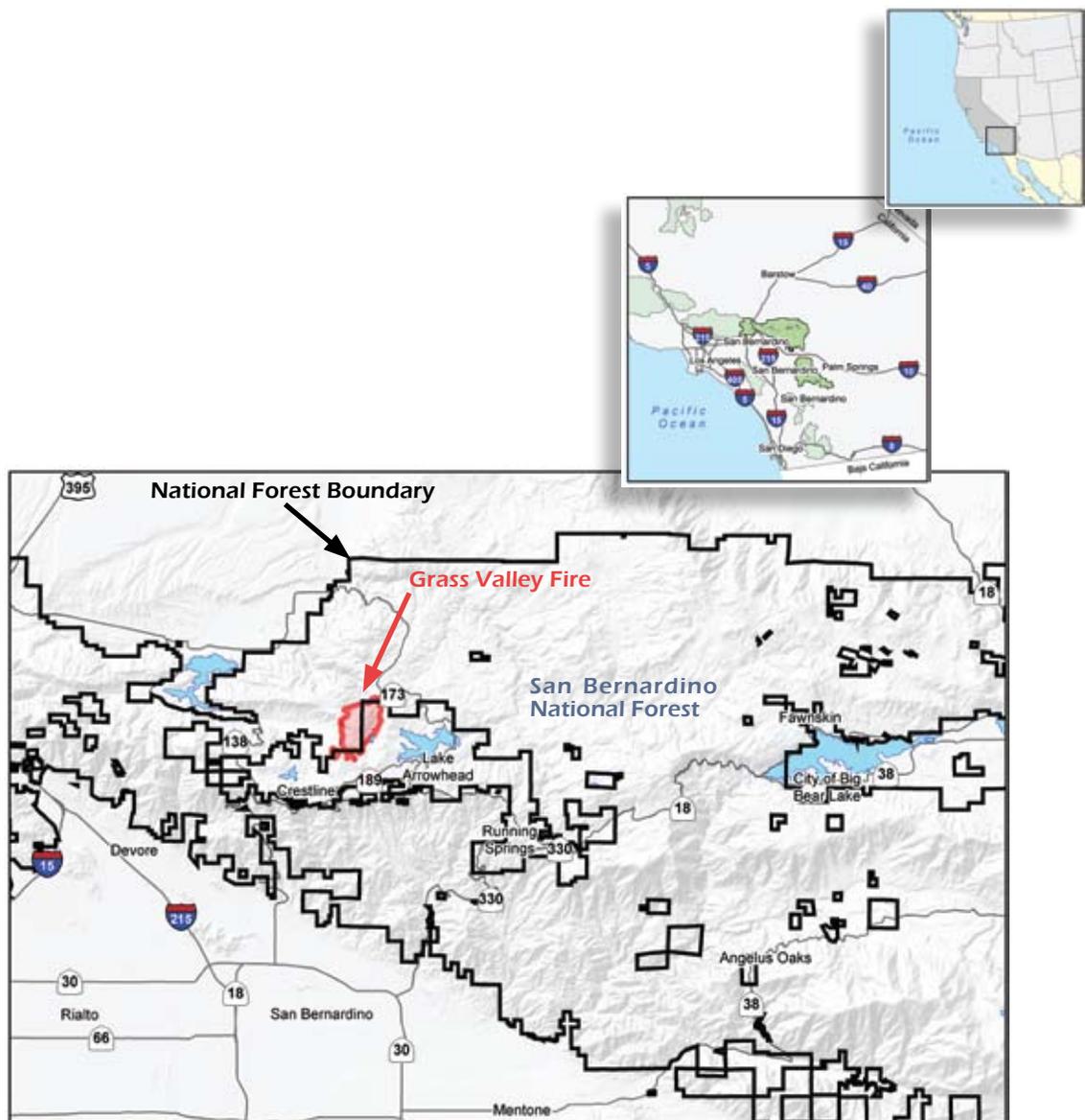


Figure 1. Vicinity map of the Grass Valley Fire.

The fire was reported at about 0508 on the 22nd of October. The fire origin was west of Lake Arrowhead, near Deer Lodge Park off the Grass Valley Road, north of the cul-de-sac on Edge Cliff Drive (Appendix A). The fire was driven to the south by dry Santa Ana winds of 20 to 30 miles per hour (Appendix B). About three fourths of the 1,242 acre fire burned on the first day spreading rapidly to the south through untreated wildland fuels and high density urban structures. Many residents throughout the area were evacu-

ated. Damage in urban areas was extensive with approximately 199 structures destroyed or damaged.

The fire burned onto National Forest System lands where recent hazard fuel treatments had been implemented (Figure 2). Suppression actions contained spread to the east and halted southerly spread by the end of the first day. Low fire intensity and spread rate in treated wildland fuels enabled fire-fighters to contain the fire north of Fairway Drive and Twin Peaks residential area.

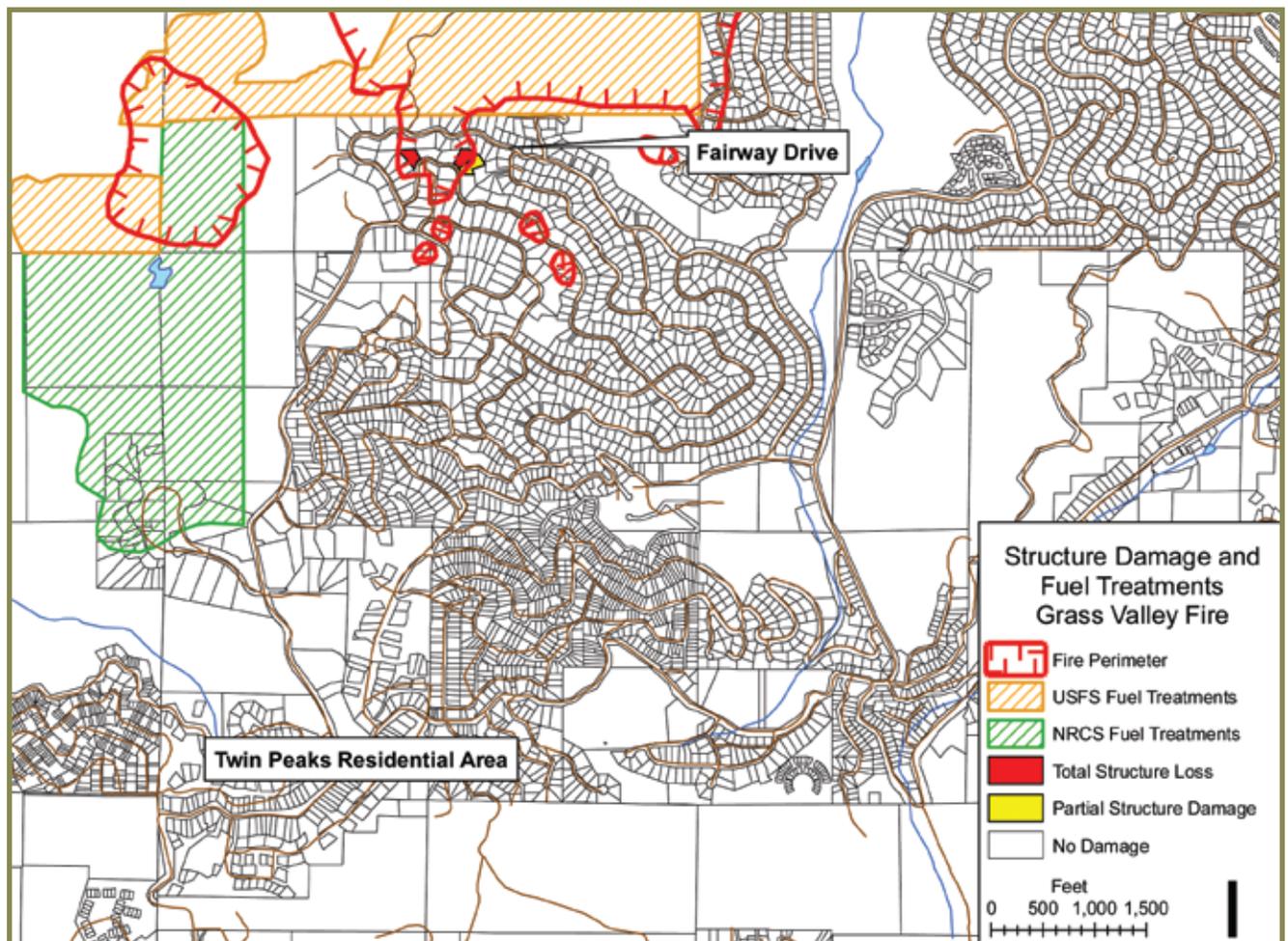


Figure 2. Vicinity map for the southern portion of the fire. Note the location of the fuel treatments and residential areas.

Background

In 2002, major tree mortality broke out caused by a combination of overly dense stands of trees, drought stress, insects, and disease (Figure 3). The Forest Service and other collaborators recognized the need for hazard fuel reduction. Support for this program was greatly enhanced by

reaction to the Old Fire, which occurred in October, 2003. This fire occurred in the San Bernardino National Forest including the area surrounding Lake Arrowhead and Crestline and burned 970 structures and 91,281 acres with high intensity fire.



Figure 3. Aerial view of beetle killed trees around Lake Arrowhead in 2003.

The Mountain Area Safety Task Force (MAST) was established to coordinate hazard reduction efforts of all the organizations and agencies managing land, infrastructure, and emergency response in the Lake Arrowhead area and other mountain communities. This group has prioritized hazard fuel treatments, developed grant applications, and commissioned area assessments to

determine treatment needs. MAST has emphasized area and linear fuelbreaks adjacent to urban areas in forested fuels. Substantial treatments on private lands have been funded and implemented with emphasis on dead tree removal. MAST continues to collaboratively promote and plan actions to protect communities, evacuation routes, and communication sites.

Assessment Objectives and Methodology

Objectives

Provide a clear description of:

- ◇ Fire environment
- ◇ Fire chronology
- ◇ Fuel treatments implemented prior to the fire

Evaluate the effects of fuel treatments on:

- ◇ Fire behavior
- ◇ Fire effects
- ◇ Structure ignition
- ◇ Fire suppression
- ◇ Public safety and egress

Methodology

Facts and circumstances regarding the Grass Valley Fire were determined by ground and air reconnaissance, photos, videos, interviews, and review of written documentation. Many interviews were conducted with local residents, specialists, and subject matter experts to confirm information. Team members installed plots to gather data for fire behavior, modeling, and analysis used to support conclusions about the effectiveness of fuel treatments.

Description of Fire Environment

Fuel and Topography

Wildland fuel types within and adjacent to the fire perimeter include oak-shrub with surface litter and long and short-needle pine with understory trees. Deciduous black oaks provided a break in canopy continuity of the pine. In addition, a complex fuel mosaic existed within the subdivision areas which included homes and related structures,

household items and debris, wildland fuel as described above, and ornamental shrubs. Roughly one fifth of the fire area is within the Forest Service Tunnel 2 fuel treatment. Other fuel treatments were present but much smaller in size (Table 1).

Treated and Untreated Areas Within the Grass Valley Fire Perimeter	Acres
USFS Fuel Treatments (Tunnel 2 and other)	249
USFS Untreated	577
NRCS/San Bernardino County Fuel Treatment (Edge Cliff Dr)	11
NRCS Fuel Treatment (California Fish and Game)	20
NRCS Fuel Treatment (Krause-Hall)	68
Forest Care Fuel Treatment (Deer Lodge Park)	15
Untreated Private	302
Total	1,242

Table 1. Fuel treatments and acres

The layers of vegetation in the forest/woodland types created a continuous fuel ladder from surface into canopy fuel (Figure 4). The overstory consists of sparse black oak and a mix of Coulter, sugar, and Jeffery pine, with big-cone Douglas fir in the lower

elevations and drainages. The understory consists mostly of dense suppressed white fir. Interior live oak and incense cedar were scattered throughout the fire area. Additionally, there were areas of chaparral with manzanita as the dominant species.

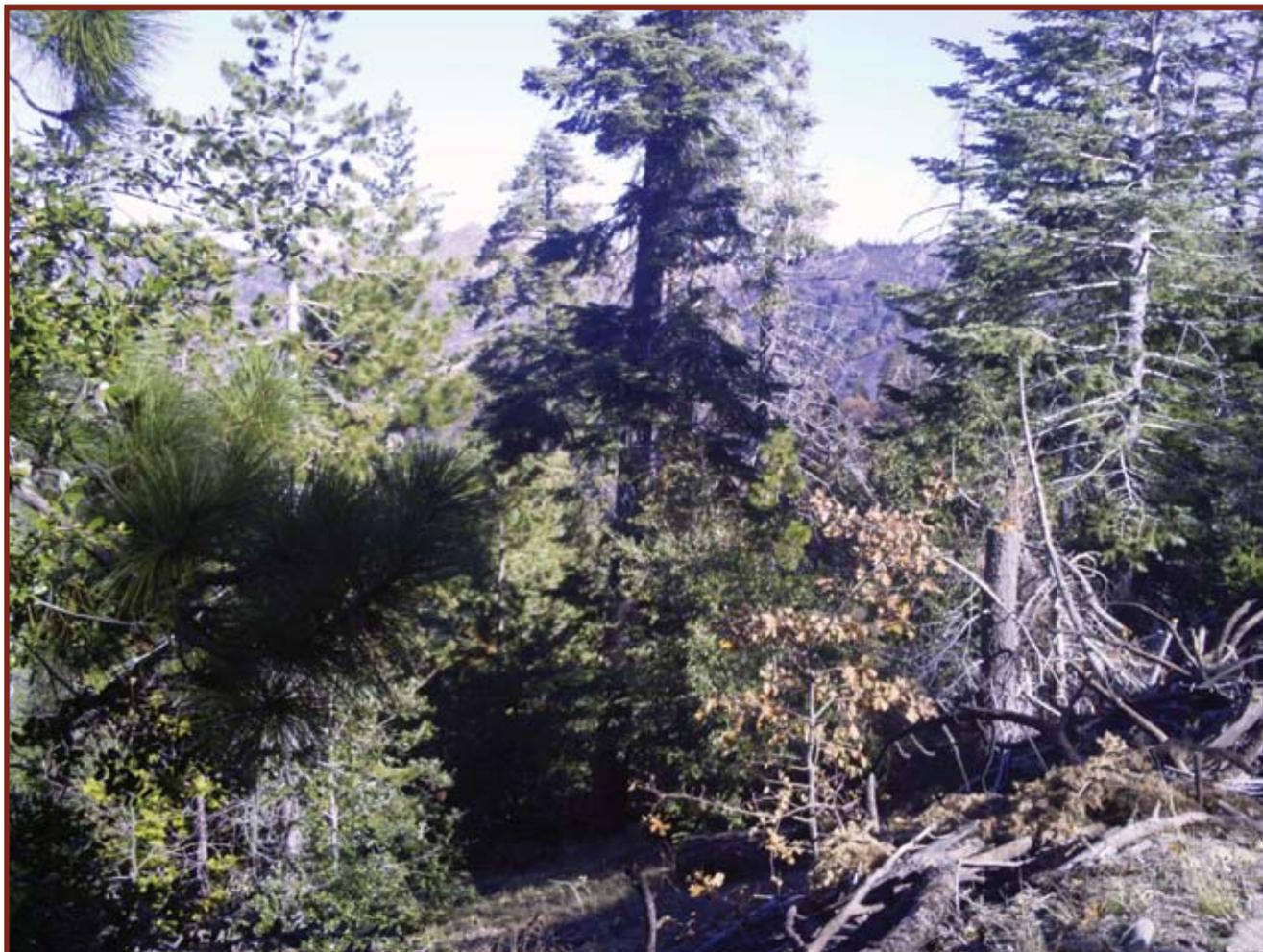


Figure 4. Typical conditions in stands which had not received fuel treatment.

Where vegetation and fuel management activities have been implemented, trees and shrubs were less dense (Table 2). These areas

were dominated by large over-story oak and pine with smaller areas of widely-spaced chaparral.

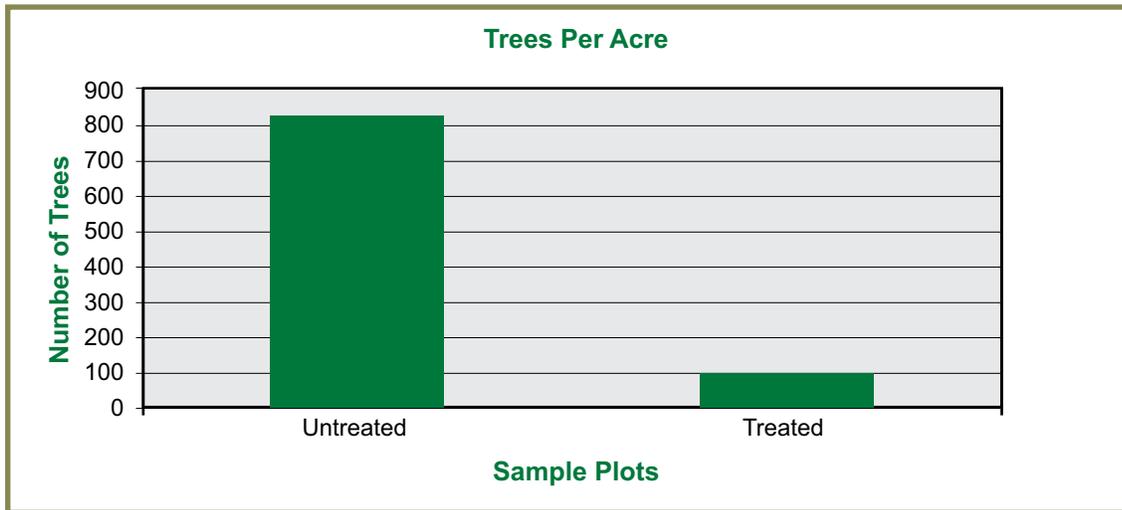


Table 2. Trees per acre in treated and untreated areas based on sample plots taken immediately after the fire within the fire perimeter. This quantifies the difference in tree density between treated and untreated areas.

Surface fuel in the managed stands consisted of pine needles and oak leaves with light to moderate loading (Figure 5). The

topography within the fire perimeter varies from gentle (<10%) to steep (>60%).

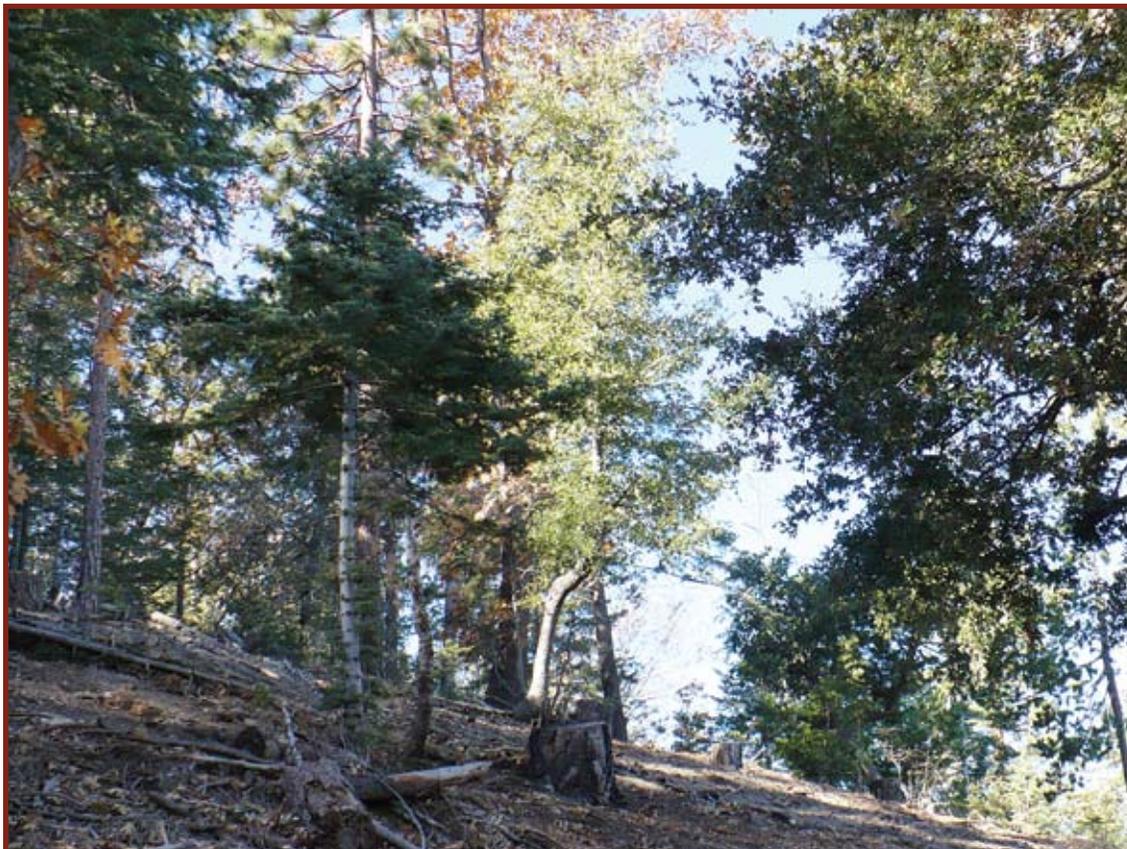


Figure 5. Typical conditions in stands which had received fuel treatment.

Fire Weather and Fire Danger

The Lake Arrowhead vicinity is typically warm and dry during the summer and fall months. October of 2007 was unusually dry, as recorded by the four Remote Automated Weather Stations (RAWS) in the area. The large dead fuel moisture (3"-9" diameter) was 8% and the live woody fuel moistures were 56% which further indicates a very dry season. On October 22nd, the minimum relative humidity was 8%, one of the lowest

recorded for the 2007 fall season. The Rock Camp RAWS, located approximately 1/2 mile northeast of the ignition point, recorded average northerly wind speeds of 18 mph with gusts up to 34 mph (Appendix B). October 22nd set a record for the highest wind speeds during the month of October over the past 13 years. Firefighters observed winds in the fire area gusting in excess of 40 mph.

Fire Behavior Chronology

The fire started October 22, 2007 at approximately 0508 in grass and brush. The Rock Camp RAWS recorded a north wind averaging 18 mph with gusts up to 29 mph for the first hour of initial attack (Appendix B).

Strong northeast winds pushed the fire down and cross-slope into the Grass Valley Creek drainage. According to dispatch logs, the first engine on scene, USFS E-11, reported 5 acres and moderate rate of spread at 0526 and a need for law enforcement to initiate evacuation.

At 0534, the Initial Attack Incident Commander, Randy Clauson, requested a mandatory evacuation of Deer Lodge Park, reporting the potential of a fire larger than 1,000 acres. "One of my worst fears was a north wind fire in the Grass Valley Creek drainage" (Randy Clauson, Initial Attack Incident Commander).

Firefighters on scene reported that spotting contributed to fire spread in the wildland fuels. Wildland firebrands consisting of leaves, needles, and small twigs which ignited from surface fire, were lofted into the air by convection and transported down wind where they landed and ignited new fires in advance of the main fire.

According to dispatch logs and interviews with firefighters, the first home to burn on the east flank of the fire occurred on the north end of Brentwood Drive. This home was located directly above a steep south facing slope.

Shortly after the first home ignition, the fire burned into a dense residential area at Trinity Drive and the streets above. The close proximity of homes to one another, along with wind and slope alignment, contributed to rapid fire spread from house-to-house. At 1141, the Incident Commander notified dispatch that approximately 75 to 100 structures were destroyed.



Figure 6. Typically in the subdivisions, the homes were burning and the adjacent vegetation was not. (Photo by Brett Snow, San Bernardino Sun)

Once a home ignited and was fully involved, it exposed other adjacent structures to damaging radiant and convective heat (Figures

6 and 7). Burning homes also produced a tremendous amount of embers which were lofted and carried downwind.



Figure 7. Flammable roofs were vulnerable to embers. (Photo by Eric Reed, San Bernardino Sun)

Wood decks, overhanging vegetation, firewood, lumber, and other flammable material located immediately adjacent to houses ignited readily when embers landed on them (Figure 8). Small spot fires in these materials spread quickly to the adjacent house.



Figure 8. Spot fire igniting flammable material on deck of a structure. (Photo by Eric Reed, San Bernardino Sun)

Structure firefighting efforts were difficult due to dense smoke, house-to-house ignitions, limited access, and other unsafe conditions as homes were burning on both sides of roads simultaneously.

By 1300, David Kelly, Initial Attack Operations Section Chief, was able to get out to the Tunnel 2 fuelbreak to check the fire behavior through the treated area. At that time it was a very low intensity surface fire with predominately two foot flame lengths. According to Kelly, “It was a relief to see the type of fire behavior in the fuelbreak so our fire resources could concentrate on the east side in the community.”

By 1500, the fire had moved into the south end of the Tunnel 2 fuel treatment

area. By 1700, the fire had burned to its final perimeter (Figure 9) to the south along the boundary of the Tunnel 2 fuel treatment area. A retardant line and helicopter drops secured the southwest portion of the fire at the edge of the Tunnel 2 fuel treatment area.

A spot fire about one-third of a mile to the southwest of the main fire was detected about 2200 on 10/22/07. Action was deferred until the next day because the spot was in a treated area and exhibited very low fire intensity. In addition, priority for firefighting resources was in the residential area. The west flank of the fire exhibited low intensity spread on the 24th and 25th. Indirect lines were constructed and burned out to establish the final fire perimeter on the west.

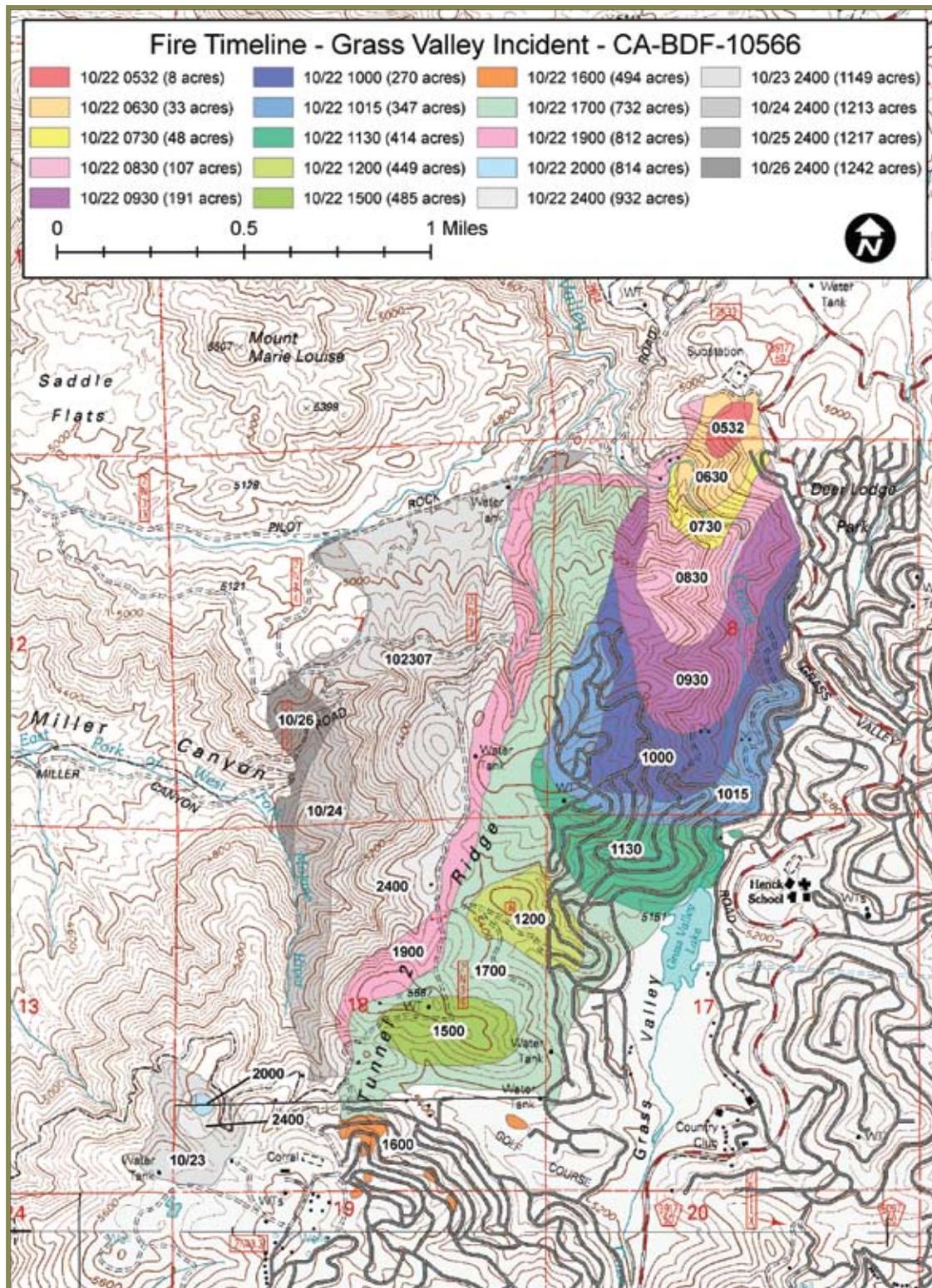


Figure 9. Approximate progression of the Grass Valley Fire (as recalled by firefighters) from its start in the northeast corner on October 22nd to the final expansion of the perimeter on the west, ending on October 26th at 2400.



Figure 10. View from area of origin (yellow triangle) looking south into the Grass Valley drainage. Note minimal crowning on north aspects.

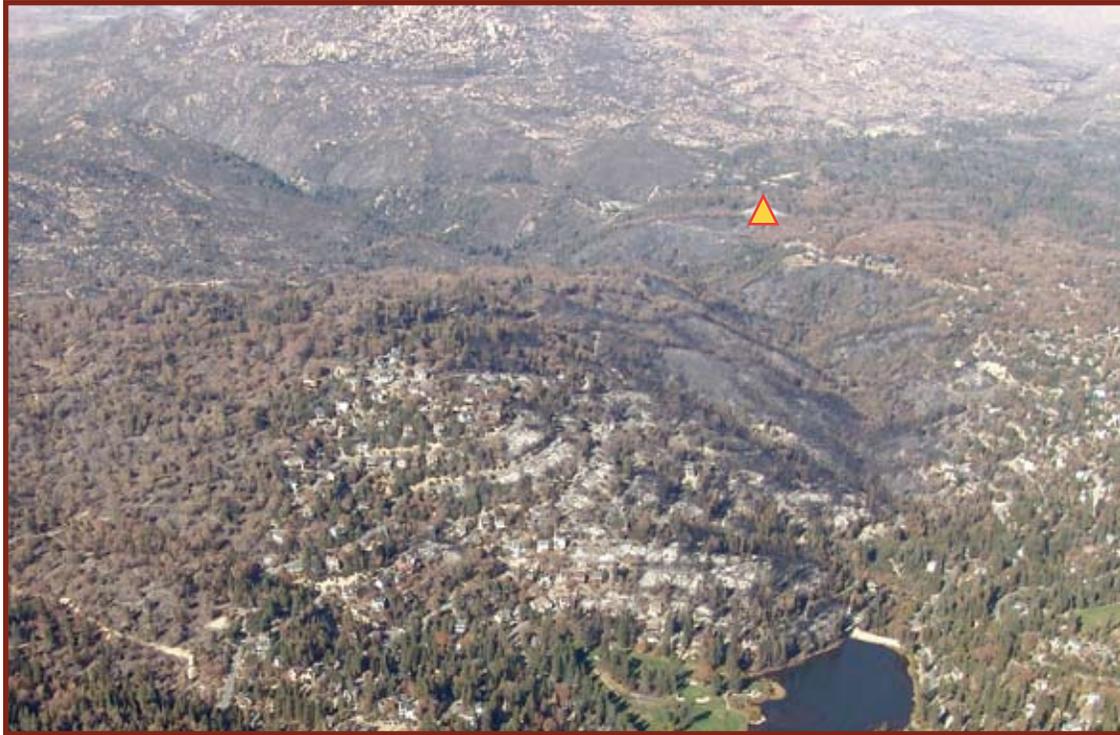


Figure 11. Grass Valley Creek drainage, looking north. Note the fully consumed tree crowns on south and southeast facing slopes. Triangle is approximately the point of origin.

Some of the homes on Trinity Drive and Merced Lane received embers or direct flame contact and radiant heat from wild-land fire. These homes were on a north facing aspect in the path of the fire, located on a steep slope above untreated private

land. The area below these streets had substantially higher tree densities than treated areas. Fuels directly below these homes had continuous vertical and horizontal arrangement of white fir with tight canopy spacing (Figure 13).



Figure 12. Consecutive burned homes where streets were aligned with the wind are indicated by the arrow.

Figure 13. Typical fuels below homes on Trinity Drive and Merced Lane.



On the ground inspections revealed that pieces of sheathing, siding, and other burning matter were carried downwind.

Firebrand production from burning structures was substantial in both quantity and size (Figure 14).

Figure 14. Large firebrand that drifted onto a resident's property.



Post-fire visual examination indicated a lack of substantial fire effects on the vegetation and surface fuels between burned homes. Lack of surface fire evidence in surrounding vegetation provides strong evidence that house-to-house ignitions by airborne firebrands were responsible for many of the

destroyed homes. Much of the tree canopy burned only in the area directly adjacent to the burning homes. This was the result of radiant and convective heat from burning structures. See Cohen and Stratton (2008) for a detailed explanation of home ignition and spread on the Grass Valley Fire.

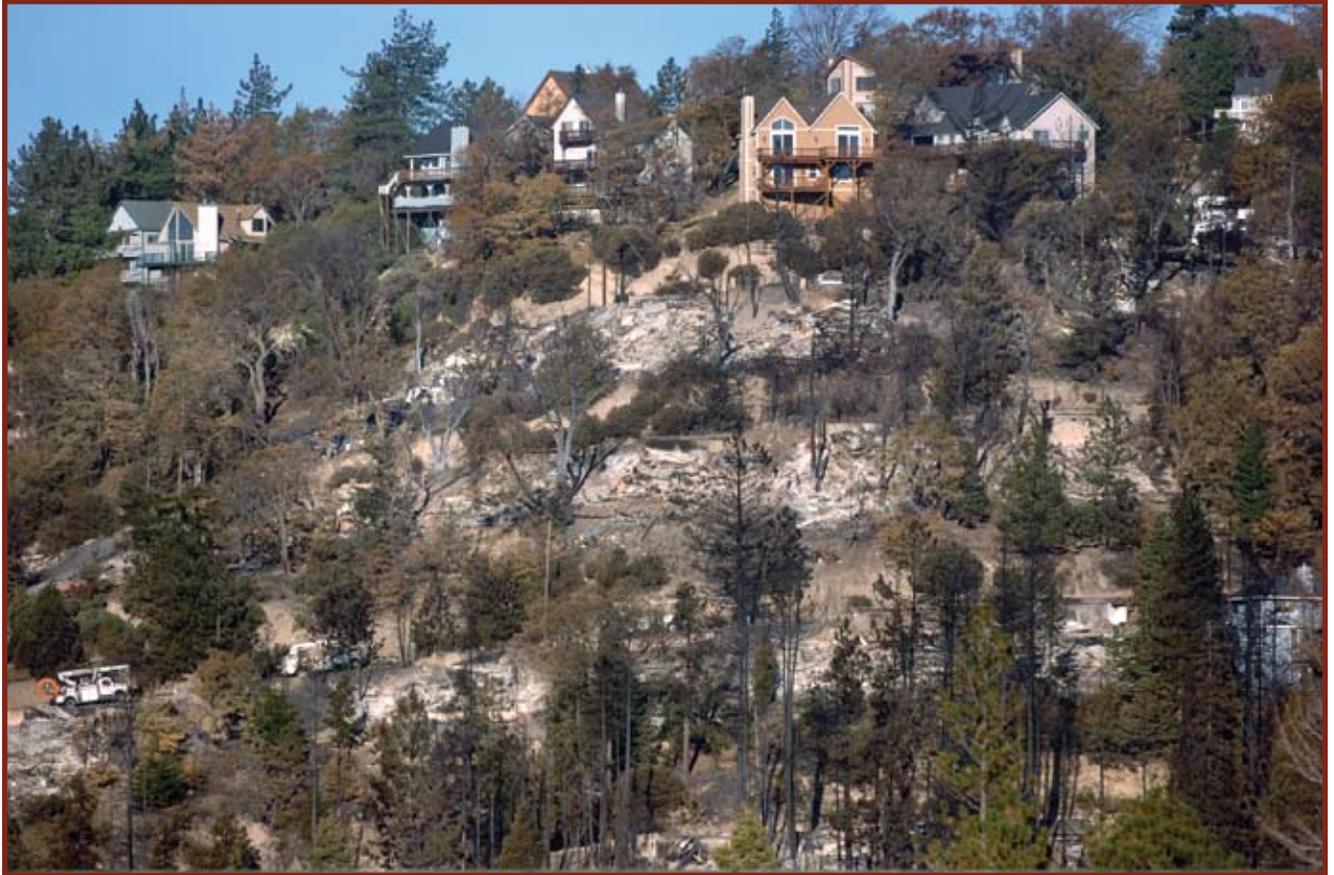


Figure 15. Trees directly adjacent to homes were burned, while trees more distant from homes were not burned. This indicates that homes, not the vegetation, were the primary fuel by which the fire spread. (Photo by Eric Reed, San Bernardino Sun)



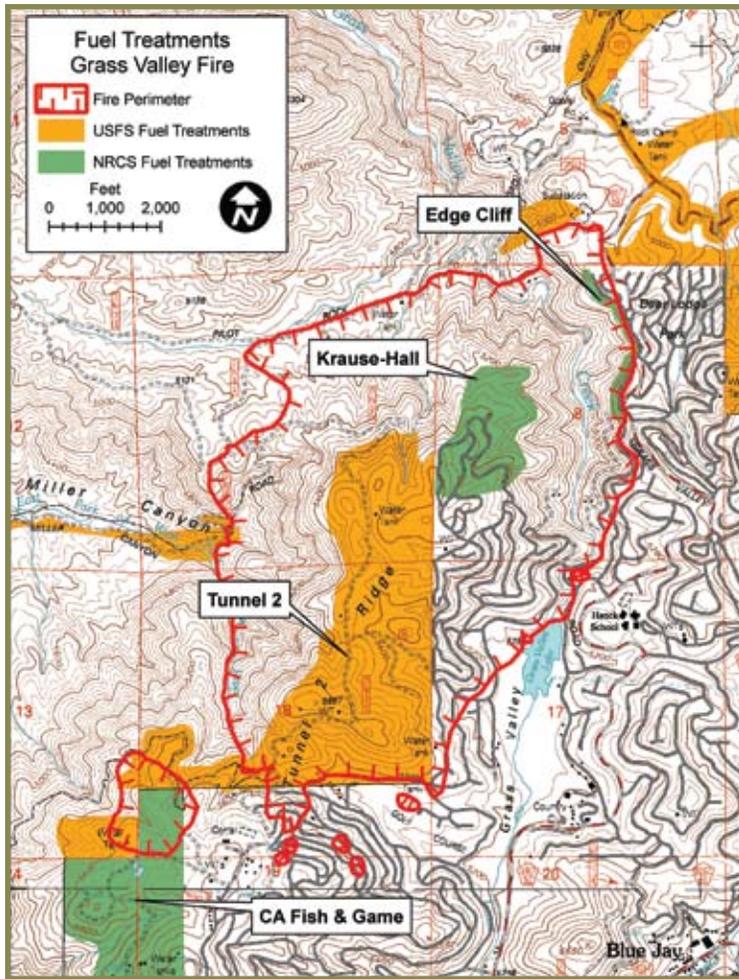
Figure 16. Note the unburned vegetation adjacent to the burned structure. The scarring on the tree indicates the tree caught fire from the structure and not the reverse.

Fuel Treatments

USFS Tunnel 2 Fuel Treatment

The Mountaintop Ranger District of the San Bernardino National Forest in collaboration with MAST, recognized the need for forest health improvement and fuel treatments. In response to this need, a hazard fuel reduction plan was developed. The treatment plan for the National Forest was developed by taking a district wide look at the forest and woodland areas adjacent to urban and other facilities. Sites were

selected where high fuel hazards existed and where an area fuel treatment could be implemented that would be large enough to change fire behavior from crown fire to surface fire, reduce flame lengths, spotting, and improve forest health. The largest of the Forest Service area treatments was Tunnel 2. Other Forest Service treatments were located in smaller areas along community boundaries in the area. (Figure 17)



Local managers recognized the critical importance of prioritization and location of fuel treatments. Planners considered the hazard reduction effect of recent wildfires which had burned about 25% of the area. They also recognized that, in the short term, given the operational and funding capabilities, treatments could only reduce hazard on a small portion of the other 75% of the area. The Tunnel 2 treatment was located on the National Forest boundary area between the high density wildland urban communities of Lake Arrowhead and Twin Peaks. These communities were embedded in very hazardous fuels adjacent to Forest Service lands to the northwest (Figure 18).

Figure 17.
Fuel Treatment Map



Figure 18.
Home embedded in dense vegetation in the Lake Arrowhead area.

Managers defined acceptable fire behavior for this area as “flame lengths of four feet or less under 90th percentile weather conditions.”¹ Flame lengths of four feet or less are generally recognized as safe for direct attack by firefighters on the ground (Andrews and Rothermel 1982). Areas treated to the “four foot flame length” standard have proved to be effective in changing fire severity and increasing effectiveness of fire suppression resources. In many cases, fire behavior has been observed to transition from a crown fire to a surface fire when the fire entered the treatment area (Murphy, Sexton, and Rich 2007; Finney, McHugh, and Grenfell 2005).

Fire behavior modeling and expert judgment provided estimates of surface fuel, ladder fuel, and tree canopy conditions which would result in the desired level of fire behavior (Appendix C). Treatment actions which achieved this objective included removal of dead, dying, and diseased trees, thinning, pruning, chipping, and burning to reduce surface litter and woody fuel loading as well as ladder and canopy fuel. More conifers than oaks were removed and more understory trees than overstory trees were removed. This left widely spaced oak-dominated woodland with discontinuous surface fuels.



Figure 19. Crews working in Tunnel 2 fuelbreak.

It should be recognized that Tunnel 2 fuel treatment prescription did not seek to stop fire spread. The treatment objectives were to reduce crowning potential and ember production. A prescription designed to stop fire spread would have directed the removal of almost all trees and shrubs for at least 1/2 mile (spot fires were observed on the Grass Valley Fire that originated from embers lofted 1/4 to 1/2 mile upwind) and all surface fuel for as much as 100 yards.

¹90th percentile weather conditions occur on ten percent of the days of the fire season and are the top ten percent for severe fire danger.

Fuel Treatments on Private Lands

Natural Resources Conservation Service (NRCS) and San Bernardino County Fire accomplished many hazard reduction projects on private land including Krause-Hall and Edge Cliff Drive. Forest Care, a program that assists homeowners in reducing fire risk, helped many landowners reduce fuels on their property. Forest Care is administered by the non-profit San Bernardino National Forest Association. The program is offered through the cooperation of the California Department of Forestry and Fire Protection and is funded through a U.S. Forest Service grant. Through Forest

Care, homeowners are offered assistance in thinning trees and removing undergrowth to make their property more fire resistant while meeting state and local regulations for fire clearances.

In addition, Southern California Edison began a program to remove dead, dying, and diseased trees in 2003. By October of 2007, more than 186,000 trees had been removed. The primary objective for these private land treatments was to remove hazard trees associated with the 2002 beetle kill outbreak.



Figure 20. Large dead tree removal on private property.

These dead trees posed a risk of falling on roadways, homes, power lines, and other structures. In addition, once ignited they cast embers to ignite spot fires in wildland fuel and structures. Removal of these trees lessened the risk to firefighters working in and around the structures.

Some of these private land treatments also disposed of small trees, shrubs, and surface fuels in order to reduce potential fire intensity and spread rates. One worker described conditions on Edge Cliff Drive as 6 to 10 foot manzanita with 10-12 inch

bases, scrub oak, full oak trees, downed pine, and a fuel load so heavy you couldn't walk through it (Figure 21). Treatments placed along roadways such as Edge Cliff, were intended to make public evacuations safer while improving visibility and access for firefighters. This was accomplished by cutting some of the trees and shrubs and disposing of some of the surface fuels. Some of this material was burned, some was chipped and scattered to inhibit post-treatment herbaceous fuel growth and some was hauled off-site.



Figure 21. Conditions in Edge Cliff fuelbreak before treatment.

Fire Behavior in Fuel Treatments

USFS Tunnel 2 Fuel Treatment

Fire behavior within the Tunnel 2 treatment area during the Grass Valley Fire exhibited lower flame lengths, slower rate of spread, less transition to crown fire, and less spotting than

outside the treatment area. Fire personnel noted that the reduced fire behavior allowed fire resources to concentrate on evacuating other sides of the fire.



Figure 22. Tunnel 2 Fuel Treatment – aerial view, looking north. Yellow line depicts approximate unit boundary. Red arrow indicates direction of wind and fastest fire spread.



Figure 23. Tunnel 2 fuelbreak with low scorch heights and patches of unburned fuel.

Post-fire examination of incomplete litter and duff consumption, observations of patches of unburned fuel, and comparatively low scorch heights on trees (Figure 23) supported the firefighter accounts.

Insect and drought stress caused tree mortality after Tunnel 2 treatment was completed resulting in small concentrations of standing dead and down fuel. Due to these conditions, there were isolated areas within the Tunnel 2 project where torching occurred.

Included in a portion of the Tunnel 2 fuel treatment was a portion of a Spotted Owl Protected Activity Center (PAC). Fuel treatment occurred in this area (Appendix C). This portion of the PAC experienced surface fire due to a combination of factors, including fuel treatment, high wind, and moderate slope, which kept the fire on the ground until it hit the top of the slope where it entered the tree crowns. The rest of the untreated PAC, which was on private property, received almost complete mortality from crown fire.



Figure 24. Tunnel 2 treatment area boundary is shown in white. Portions of the treatment area burned with higher intensity (in yellow oval).

Fuel Treatments on Private Lands

Observations from home owners and initial attack resources describe fire behavior in the area of the county hazard fuels reduction project along Edge Cliff Drive as a low intensity surface fire. Post-fire photos and interviews support these conclusions (Figures 25 and 26. “The Edge Cliff fuel break definitely saved lives” (Peter Brierty, San Bernardino County Fire Department). “It

is my opinion that the lives of my children and husband, as well as our many neighbors, were saved by the intended practical application of this fuels reduction treatment” (Ginny Jablonski, resident, Edge Cliff Drive). It is clear that the residents and local firefighters believed the treatments provided a margin of safety in this fire situation.



Figure 25. Note location of Edge Cliff Drive (red arrow) and the fuel break below the road (white polygon).



Figure 26. Hazard fuel reduction project along Edge Cliff Drive. Note limbed trees.



Figure 27. Krause-Hall treatment area burned with low intensity due to flat terrain, open roads, and a driving wind.

Krause-Hall and California Fish & Game Treatments

The primary objective for both the Krause-Hall and California Fish and Game area fuel projects were removal of dead, down, and diseased trees. A secondary effect from this treatment was reduction of surface fuels and removal of some small groups of trees on the skid trails in these areas. However, throughout the majority of these areas there was little

change in live tree canopy characteristics. Fire burned through the Krause-Hall treatment area (Figure 27) at approximately 1000. This area was relatively flat with discontinuous fuel due to many open skid trails and roads. Post-fire photo observations indicate low fire intensity as the fire moved through this treatment area.



Figure 28. California Fish and Game treatment area, where a spot fire occurred. Notice shorter clumps of white fir are scorched, while large over-story fuel remained un-scorched.

Fire spotted into the California Fish and Game treatment area and was first discovered around 2200. The spot burned with low intensity and severity, creating a patchy surface fire, where short dense clumps of white-fir varied from little to full scorch. Evening burning conditions and flat terrain reduced fire intensity. Most of the overstory

vegetation remained unscorched (Figure 28). Action on this spot was deferred until the next morning because it exhibited very little fire behavior and suppression priorities were higher elsewhere. Interviews with fire personnel, photos, and observations support these conclusions.



Figure 29. Typical conditions with high density fuel on steep slopes with intermingled homes. Look closely behind the trees to see more homes.

Fuel Treatments on Private Lands

The reduction of large diameter dead trees from urban lots did little to reduce fire behavior once homes ignited. Many homes within the fire perimeter were less than

fifty feet apart. Homes were built on steep slopes, many were 3 storied with multiple levels of wooden decks (Figure 29).

Fire Suppression Effectiveness, Structure Ignitions, and Public Safety/Egress

USFS Tunnel 2 Fuel Treatment

The effectiveness of initial attack on the Grass Valley Fire was improved by the Tunnel 2 fuel treatment area. When the fire moved into that treated area, the fire behavior shifted to a low intensity surface fire. Surface fire and low flame lengths, two feet or less, were observed by the Operations Section Chief. This allowed firefighting resources to concentrate on the protection of structures and secure a control line on the east flank of the fire.

Firebrands, lofted by an area of crown fire activity, resulted in many spot fires from south

of the fuel treatment boundary. The spot fires were contained by rapid suppression actions. Slower fire spread in the treatment area allowed more time for public evacuations.

The location of the Tunnel 2 treatment area reduced fire behavior as the fire spread south-southwest, allowing suppression forces time and safety to contain spot fires before they were able to spread throughout the homes southwest of Fairway Drive.

Fuel Treatments on Private Lands

These areas received substantial spotting and direct surface fire when the fire came out of the Grass Valley Creek drainage. Private land treatments added to the effect of the Tunnel 2 fuel treatment area in slowing the fire spread and intensity and allowing suppression resources to focus attention elsewhere of higher priority.

Fire personnel noted that visibility was improved where trees and brush had been removed. Improved visibility enabled firefighters to observe the fire location and intensity in relation to egress and values at risk. The treatments allowed fire fighters to enter residential areas that otherwise would have been avoided due

to safety concerns. Treatments also reduced fire intensity and spread rate allowing fire fighters to more rapidly suppress ignitions.

Significantly fewer trees fell on roadways and powerlines because of the fuel treatments which had removed hazard trees before the Grass Valley Fire. Reduced treefall enabled rapid safe public evacuations and firefighter access. The Southern California Edison dead tree removal program was specifically credited by firefighters with improving access for fire suppression forces, especially those that arrived later in the day.

Summary

The Grass Valley fire spread to the south, driven by strong winds aligned with the canyon in extremely dry untreated wildland fuels that crowned and spotted until it transitioned to urban structure fuels.

Fire spread rates through area wildland fuel treatments on private and Forest Service was comparatively slower than on untreated lands. Greater density of trees on steeper south facing slopes had stand replacement fire behavior. Structure fires, driven by winds aligned with the streets, spread more rapidly than adjacent wildland fuels, producing mass ember spotting and intensity that ignited other structures.

People throughout the area were evacuated more safely due to previous dead tree removal coordinated by MAST. Fire spread was slower through wildland fuels that had been treated on Forest Service lands. Suppression actions contained spread to the east and by the end of the first day had essentially stopped further southerly spread. Due to the low fire intensity in the wildland fuels that had been treated to the west, fire spread was stopped with just a dozer line connecting roads on the western flank of the treated area.

Fire spread was less intense in the Tunnel 2 fuel treatment area allowing suppression forces to concentrate on controlling the spread of fire in urban areas.

Three factors contributed most to treatment effectiveness:

1. Placement and prioritization was based on an integrated landscape look at hazardous fuels and terrain, fire weather and history, access, egress, and communities at risk.

2. Effective treatments were planned and implemented on specific fire behavior objectives.
3. Treatments along roads, power lines, and urban areas all contributed to enhancing suppression actions and enabling safe evacuation of the public.

Older homes in the Lake Arrowhead area are constructed of flammable materials including wood shake roofs. Dense vegetation often surrounds many of these older homes. These structures are not only at risk from wildfire, but are at risk for house-to-house ignition. Where trees and shrubs were removed prior to the fire, suppression forces were able to engage the fire and protect homes. In some places where vegetation had not been removed, suppression forces were unable to safely engage the fire or protect structures.

Southern California Edison had done work along its power lines to remove dead trees and top live trees to keep them away from the lines. This had two benefits during the Grass Valley Fire. First, the removal and trimming lowered the probability of tree damage to the lines which could have blocked or slowed evacuations. Second, the power service remained on to the community through the incident.

Recent collaborative fuel treatments reduced fire behavior, specifically rate of spread and intensity, allowing residents to evacuate and firefighters to enter the initial attack area. Other fuel treatment areas encountered by the fire allowed fire fighters to concentrate on perimeter containment and structure protection.

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USFS Pacific Southwest Region

Bernard Bahro

Hugh Safford

Jerry McGowan

Mario Chocooj

USFS Adaptive Management Services Enterprise Team

Dave Kerr

Scott Dailey

San Bernardino County Fire Department

George Corley

Peter Brierty

Scott Turknette

Daniel Elliot

Others

Northern California Team 2

Dr. Jack Cohen

USFS Rocky Mountain Research Station

Brett Fay

USFS Intermountain Region

Tom Iraci

USFS Pacific Northwest Region

Rick Stratton

Systems for Environmental Management

Glenn Barley

Cal Fire-Forest Care

Jim Williamson

Local resident

Ron Bench

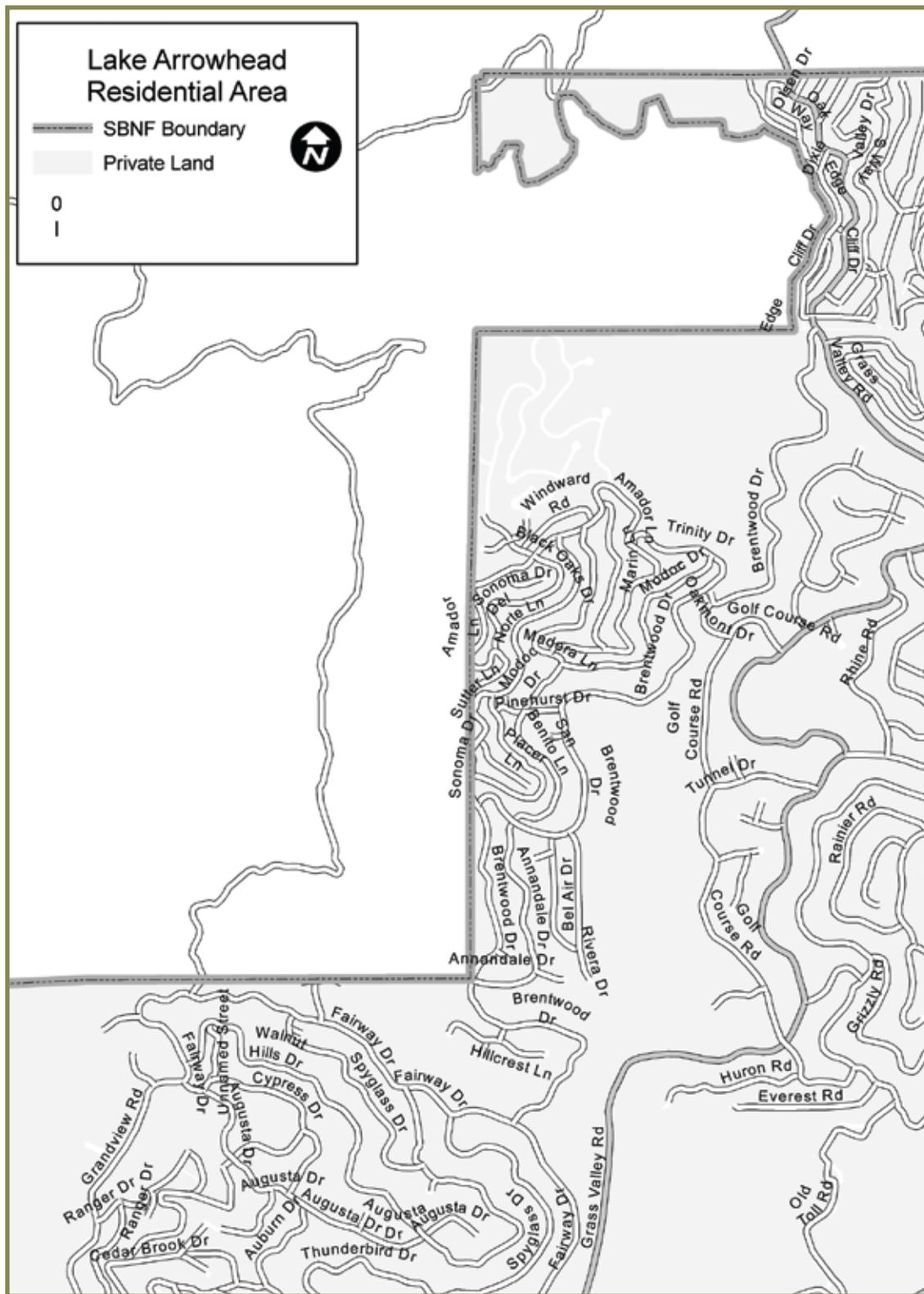
Local resident

Ginny Jablonski

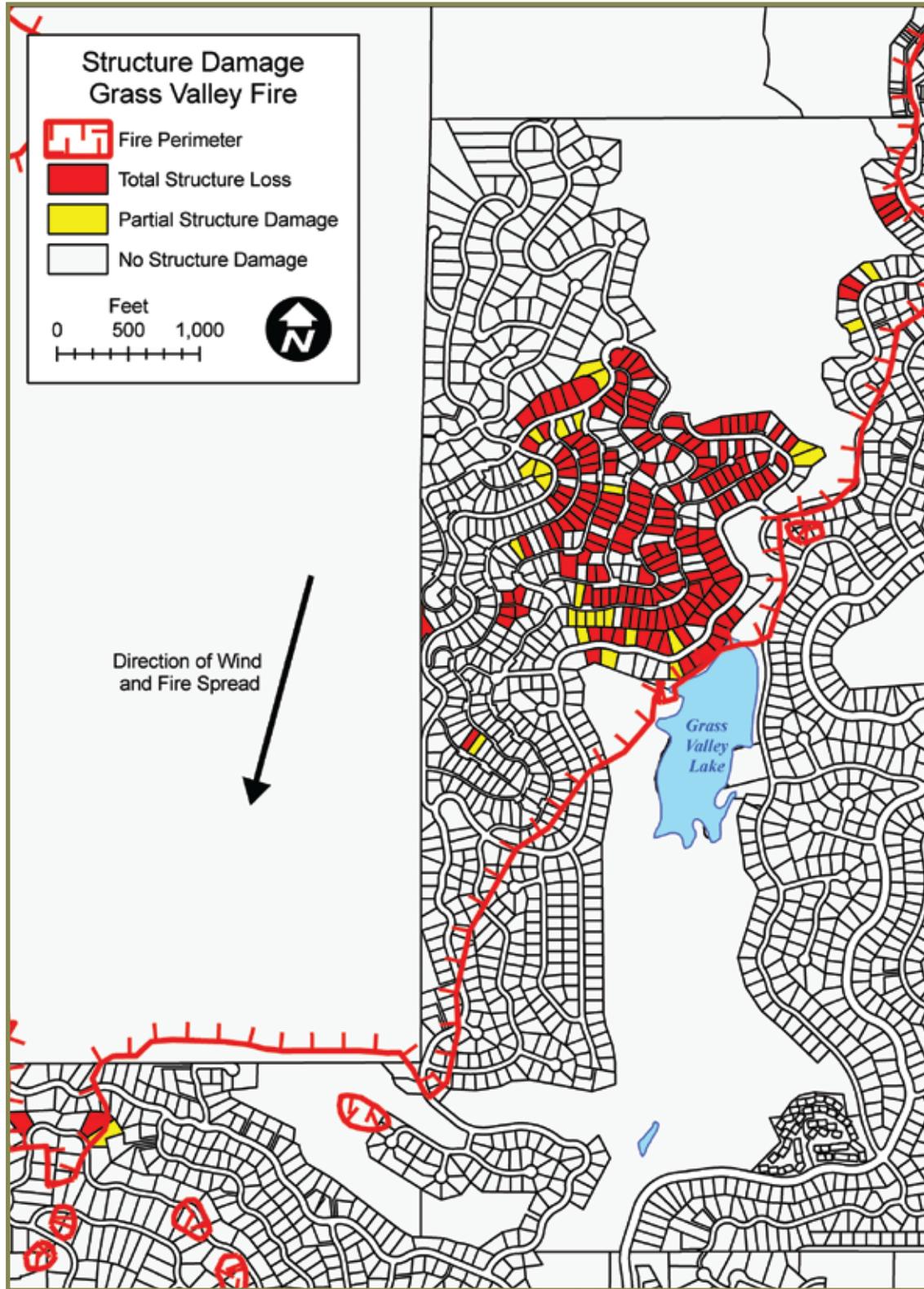
Arrowhead Communities Fire Safe Council

Appendix A: Maps

Lake Arrowhead Residential Area



Structure Damage Grass Valley Fire



Appendix B: Fire Weather/Fire Danger

Wind and Gust Speeds and Direction

Time	October 22nd			October 23rd		
	Average Wind Speed MPH	Gust Speed MPH	Direction Degrees	Average Wind Speed MPH	Gust Speed MPH	Direction Degrees
1:00 AM	16	33	15	10	23	336
2:00 AM	18	33	7	9	19	336
3:00 AM	16	32	14	11	21	357
4:00 AM	16	31	12	9	19	351
5:00 AM	18	27	8	11	19	5
6:00 AM	18	29	13	13	20	9
7:00 AM	16	29	13	11	21	8
8:00 AM	16	29	7	12	20	352
9:00 AM	18	30	2	10	22	342
10:00 AM	17	29	10	13	23	351
11:00 AM	14	34	341	12	23	330
12:00 AM	12	28	345	12	24	343
01:00 PM	13	26	342	12	24	1
02:00 PM	15	27	331	12	24	348
03:00 PM	13	32	336	12	21	331
04:00 PM	12	24	318	9	21	338
05:00 PM	10	19	352	7	18	325
06:00 PM	11	24	12	3	12	327
07:00 PM	10	20	3	4	11	3
08:00 PM	13	22	3	5	9	350
09:00 PM	14	24	349	5	8	50
10:00 PM	12	25	0	7	13	327
11:00 PM	11	20	4	3	8	192
12:00 PM	9	20	7	5	9	189

Appendix C: Forest Service Fuel Treatment Prescriptions

Fuels Reduction Treatment Level Guidelines and Desired Condition

Arrowhead and Big Bear Ranger Districts, San Bernardino National Forest

Treatment Level 1

This treatment level was applied adjacent to urban development and on roads/ridges at a width of approximately 100 feet.

Fuels Reduction Objective:

- ◇ Four foot or less flame length under 90th percentile weather conditions.

Desired Condition:

- ◇ Twenty foot spacing between crowns of individual or clumps of trees.
- ◇ Canopy base height averages 15 feet or greater.
- ◇ Twenty percent or less shrub canopy cover.
- ◇ All recent dead standing and down trees are removed.
- ◇ Litter and fine fuel loading less than 1-3 tons per acre.

Treatment Level 2

This treatment level was applied adjacent to level one treatments at a width of approximately 200 feet.

Fuels Reduction Objective:

- ◇ Eight foot or less flame length under 90th percentile weather conditions.

Desired Condition:

- ◇ Ten to twenty foot spacing between crowns of individual or clumps of trees.

- ◇ Canopy base height averages 10 feet or greater.
- ◇ Thirty five percent or less shrub canopy cover.
- ◇ All recent dead standing and down trees are removed within 100 feet of level 1 areas. All recent dead standing and down trees are removed beyond 100 feet of level 1 areas except those needed to minimally meet Forest Plan Standard for snags and down logs.
- ◇ Litter and fine fuel loading less than 3-5 tons per acre.

Spotted Owl Protected Activity Center Treatment Level

This treatment level was applied in this Spotted Owl Protected Activity Center, which was within the Tunnel 2 fuelbreak

- ◇ Remove all standing dead.
- ◇ Remove trees less than 10" DBH that provide ladder to the overstory canopy.
- ◇ Leave all live trees greater than 10" DBH
- ◇ Prune all remaining trees to approximately 8' above the ground
- ◇ Pile and burn slash from activity fuels
- ◇ Desired condition for litter and fine fuel loading is 5-7 tons/acre

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