

Ventura County Fire Department
Validation of 100 Foot Clearance Requirement as it relates
to Firefighter Safety

Fire Behavior Analysis and Methodology
May 30, 2007

Introduction

Our task was to conduct a fire behavior analysis to validate Ventura County's requirement for 100 foot clearance or "defensible space" around structures as it relates to firefighter safety. Defensible space is defined as "an area either natural or manmade where material capable of causing a fire to spread has been treated, cleared, reduced, or changed to act as a barrier between an advancing wildland fire and resources (i.e. homes) or lives at risk". Adequate defensible space can provide a safer environment for firefighters when protecting structures.

Safe operational space for firefighting personnel was used as the criterion to validate clearance requirements. Safe operational space for firefighters utilizes the same guideline that is used for a wildland fire safety zone. A safety zone is defined as "a preplanned area of sufficient size and suitable location that is expected to prevent injury to fire personnel from known hazards without using fire shelters."

Sufficient size for a safety zone is a minimum of 4 times the height of a flame length. This guideline is considered a **minimum for radiant heat only**. The safety zone guideline assumes that there is no wind or slope. Convective heat from wind and/or terrain influences will increase this distance requirement. Areas with these influences would need greater distances than those recommended in this analysis to provide for firefighter safety.

The Upper Ojai and Bell Canyon areas of Ventura County were selected for this pilot project by Ventura County Fire Department. Historic weather patterns and wildland fuel conditions were analyzed to evaluate the hazardous fuel clearance requirements around structures needed to provide safe operational space for firefighters protecting structures in a wildland urban interface fire.

Fire Behavior Model

The fire behavior model utilized for this project was FlamMap, a fire behavior mapping and analysis program that computes potential fire behavior characteristics (spread rate, flame length, fireline intensity, etc.) over an entire landscape for constant weather and fuel moisture conditions. There is no temporal component to FlamMap. It uses spatial information on topography and fuels to calculate fire behavior characteristics at one instant.

FlamMap software creates raster maps of potential fire behavior characteristics (spread rate, flame length, crown fire activity, etc.) and environmental conditions (dead fuel moistures, mid-flame wind speeds, & solar radiation) over an entire landscape.

It incorporates the following fire behavior models:

- Rothermel's 1972 surface fire model
- Van Wagner's 1977 crown fire initiation model
- Rothermel's 1991 crown fire spread model
- Nelson's 2000 dead fuel moisture model

Data needed to run FlamMap includes landscape characteristics such as aspect, slope, and elevation; vegetation in the form of fuel models and canopy characteristics; fuel moisture data; and weather data. FlamMap assumes that the entire landscape is burning and predicts the fire behavior for every cell component of the landscape map under a single set of weather conditions. Thus, while FlamMap is not dynamic, it does allow easy comparison of fire behavior over large areas.

FlamMap has limitations and assumptions as do most models. An example of this is the slope contribution to fire behavior. It is expressed as a “wind” component and is added to an upslope or subtracted from a downslope midflame wind speed. Each twenty percent increase in slope is considered to be equivalent to about one mile/hour of wind. So, a forty percent slope would be equivalent to about two miles/hour of mid-flame wind speed. Topographic features such as steep slopes, narrow canyons, and saddles significantly influence fire behavior but this is not captured well in FlamMap.

Existing fire behavior models, including FlamMap, do not consider the complex physical processes that characterize real wildland fire behavior. It is critical to validate outputs with any model. Fuel model data and weather conditions from actual fires are used and adjusted to calibrate FlamMap outputs to more accurately simulate real fire behavior. Outputs for this project were calibrated and validated to previously observed fire behavior in the project areas. For this analysis, the 2005 Topanga Fire was used to validate the Bell Canyon area and the 1999 Ranch Fire was used to validate the Upper Ojai area.

FlamMap is designed for users familiar with fuels, weather, topography, wildfire situations and the associated terminology. Because of its complexity, only users with the proper fire behavior training and experience should use FlamMap when the outputs are used for making fire and land management decisions.

The outputs from FlamMap provide a reasonable representation of fire behavior across the landscape. Output values should be treated as approximations of fire behavior that can be interpreted relative to each other and not as absolute predictions of fire behavior. There are many potential outputs from FlamMap depending on assumptions and values entered when running the program. Based on expert knowledge and experience with fire behavior modeling, the layers produced are useful outputs for assessing fire hazard in Bell Canyon and Upper Ojai.

Methodology:

The following describes the methodology that was used for the analysis.

The first step was to gather available GIS data used to create the model input. Such data included digital elevation models (DEMs), fire history, parcels, color aerial photograph imagery, etc. Sources for each piece of GIS data varied and were downloaded from various agency websites or existing local agency databases.

Fuel Modeling

In order to develop the fuel model layer required to run FlamMap, a vegetative cover layer was needed. The vegetative and man-made cover was mapped using normal color aerial imagery that was supplied by Ventura County. The areas of interest were designated by 1-mile diameter circles. Within these circles, areas of more detailed interest were designated by parcel boundary outlines. Both areas were mapped twice; once using imagery acquired prior to the most recent fire and once using 2005 imagery. The Upper Ojai area, also called the Ranch Fire area, was mapped using 1999 and 2005 imagery. The Bell Canyon, also called the Simi area, was mapped using 2001 and 2005 imagery.

Vegetation within the Upper Ojai and Bell Canyon areas was mapped to minimum 5-acre polygons. The areas within and adjacent to the more detailed parcel boundary areas were mapped to minimum 1-acre polygons. A few polygons may be slightly smaller than 1-acre. In the Bell Canyon area, the more detailed mapping locations extended beyond the circled area and were included in the mapping. Areas of similar vegetation that extended beyond the circle boundaries were mapped to the edge of the vegetation cover type. In a few cases, where the vegetation type extended a great distance beyond the circle boundary, discernable breaks in the vegetation were used as the polygon boundary.

Each polygon was assigned a percentage of each of seven cover types, including:

1. Conifer (concov) which includes pines, firs, and other evergreen trees (this vegetation type was not found in the analysis area and was excluded);

2. Hardwood (hwdcov) which includes primarily oaks but may include other native deciduous trees;
3. Shrub (shbcov) which includes chaparral, manzanita, chemise, sagebrush or other native shrub species;
4. Grasses and forbs (frbcov) which includes low growing ground covers;
5. Agriculture (agrcov) which includes plowed row crops and orchards;
6. Landscaping (orncov) which includes any vegetation near homes that is green, maintained, and irrigated, such as lawns and ornamental trees and shrubs; and
7. Barren (barrencov) which includes cleared areas, structures, roads, and rock outcrops.

Each cover type was assigned a value in five-percent increments. The value was based on visible cover of each type in each image. The precision of visual cover estimation is plus or minus ten percent. Nearly every polygon was assigned at least a minimum of five-percent barren cover to account for small open areas not visible in the imagery. The percentage of barren cover is greater in polygons with larger percentages of shrub and/or grasses/forbs cover to account for the typical open spaces in these cover types. Structures are designated as barren because fire behavior models do not model structure fires.

Landscape files

Landscape files incorporated all of the input layers into a single file read by FlamMap. They consisted of a series of GIS raster, or grid, layers that have been converted to ASCII file types. For each of the four scenarios (two areas with two scenarios each), a landscape file was created with an elevation layer (in feet), a slope layer (in degrees) derived from the DEM, an aspect layer (in degrees) also derived from the DEM, the fuel model layer, and a canopy cover layer. Since there is no continuous conifer forest on the landscapes in the study, there are no canopy characteristics to input into the model runs (as the fire behavior models do not treat hardwood canopy the same way as conifer canopy). Thus, the canopy cover layer was created as a homogenous layer with zero percent canopy cover across the entire study region. Input layers for Stand Height, Crown Base Height, and Crown Bulk Density were not included, nor were layers of Duff Loading and Coarse Woody fuels. The distance units were set to Feet because the projection of the original data was State Plane, and the latitude was set at 34 degrees.

Each polygon was also assigned a fuel model code for use in the fire behavior modeling software. Fuel models were assigned using the digitized vegetative mapping and cover type, aerial imagery, a field visit to Bell Canyon and Upper Ojai, and General Technical Reports (GTR) INT-122 "Aids to determining fuel models for estimating fire behavior" and GTR-153 "Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model."

Fuel model selections were based on what fuel type might carry a fire (such as grass, grass-shrub, shrub, timber (oak) litter, and/or timber (oak) understory), the

amount of vegetation, the moisture of extinction (dry climate vs. humid climate), and expected fire behavior. The fuel models are described in terms of both expected fire behavior and vegetation.

Fuel models selected for the project included:

Non-burnable	Grass	Brush	Timber (Oak) Understory	Timber (Oak) Litter
91	1	4	161	182
99	2	5	165	186
	102	6		
	104	145		
	107	147		

A fuel model 91 consists of land covered by urban and suburban development including structures and ornamental vegetation used in landscaping. Ornamental vegetation and structures do support fire spread but at this time it is not possible to model fire behavior in ornamental vegetation or structures. A non-burnable fuel model 99 is bare ground such as a plowed field with little to no vegetation available to burn.

Weather and fuel moistures

The second step was to gather weather and fuel moistures data to create the model input. FireFamily Plus software was used to examine local climatology for weather, wind, and fuel moisture inputs to FlamMap. This data is available at <http://famweb.nwcg.gov/weatherfirecd/>.

The Cheeseboro Remote Automated Weather Station (RAWS) was used to gather actual RAWS weather and fuel moistures for the 2005 Topanga Fire scenario and we created a second weather and fuel moisture file to mimic potential worst-case conditions (97th percentile) for the post Topanga Fire scenario.

A combination of RAWS data (Ojai, Casitas, and Temescal) was utilized in the Upper Ojai area to makeup a Special Interest Group (SIG) in FireFamily Plus for two reasons. First, the study area is not well-represented by any one station. Second, the short length of the records at two of the stations provided a small overall database, and errors or anomalies in the data would have been amplified if only one of those stations had been used. The SIG was used to determine the 97th percentile thresholds for weather and fuel moisture to mimic potential worst-case conditions. Additionally, data from a Ventura County Air Pollution Control District (VCAPCD) RAWS in Ojai provided actual weather data for the 1999 Ranch Fire scenario. This data was analyzed outside of FireFamily Plus since there were formatting issues with this data and the software program.

There are three main parameters that must be set for the FireFamily Plus calculations. First, the analysis length was set to one day. This allows for the actual worst date value to be displayed, as opposed to a moving average window. Second, the data years were set to match the years of data available from the stations. Third, the annual filter was set as either a five-week window from the end of September through October (for the 97th percentile predictive runs) or to the actual fire dates for the two actual fire runs. The final use for FireFamily Plus was to determine times corresponding to the coldest and warmest hours of the day, from which a diurnal graph was created for each site.

Winds

Wind speeds captured in the RAWS did not match winds observed on the fireline. RAWS collects wind gusts based on a 10-second average, and are not built to accommodate the sustained, northeast or east winds that occur during a Santa Ana wind event. Thus, winds for FlamMap runs were difficult to duplicate in the FireFamily Plus software. Wind gusts can produce extreme influences on fire behavior affecting safety of firefighters. It was determined that wind speeds observed on the Topanga and Ranch Fires, rather than modeled winds should be used for modeling those fires.

Interviews conducted by telephone with Ventura County Fire Department personnel on the Topanga Fire confirmed that winds 50 mph or higher were experienced by firefighters on the ground. In addition, a published report from Los Angeles City Fire Department personnel on the scene of the Topanga Fire during initial attack reported “20 - 30 mph winds with gusts up to 50 mph.”

On the Ranch Fire, the Ventura County Fire Department reported that winds were “25 mph with gusts up to 30-mph when the 911 call came in at 7:49 PM. The Operations staff and the Fire Behavior Analyst reported that winds were in excess of 70-mph during the first night of the incident.” Personal interviews with U.S. Forest Service fire personnel that had worked on the Ranch Fire confirmed that 60+ mph winds were experienced by firefighters on the ground.

We utilized observed wind speeds in creating FlamMap outputs for each of the fire scenarios in Bell Canyon and Upper Ojai areas. For the 2005 and 2006 scenarios we used the 97th percentile FireFamily Plus wind speed outputs since this is the best data available for planning purposes.

Fuel moisture

Fuel moistures were calculated in FireFamily Plus for the Ojai area. The observed fuel moistures were below the minimum input parameters for FlamMap for 1-hour, 10-hour, and 100-hour, so the fuel moisture inputs for the 1999 run and the 2006 run were identical as they are the lowest possible fuel moisture values allowed by the model. For the Bell Canyon area, the fuel moistures were based on the actual recorded fuel moisture for the 2005 Topanga Fire run and the 97th percentile fuel moisture for the predictive 2006 Bell Canyon run.

Thirty percent herbaceous fuel moisture was used for all four runs. This moisture level is utilized by the new dynamic fuel models. FlamMap allows for lower than thirty percent but the model won't accurately calculate fire behavior with values lower than thirty percent. Thirty percent is considered dead fuel in FlamMap.

Sixty percent woody live fuel moisture was used for each of the 97th percentile scenarios since worst-case conditions were used. This is a critical threshold in live fuel moistures for these areas. The 2005 Topanga Fire live fuel moistures were sixty two percent (Topanga Fire Final Narrative). The 1999 Ranch Fire fuel moisture level of live fuels were around the sixty percent critical level.

Validation

The third step was to validate the FlamMap outputs. We calibrated FlamMap by validating the model outputs against the observed and documented fire behavior.

Interviews were conducted with personnel on the 2005 Topanga Fire and the 1999 Ranch Fire. Personal observations of weather and fire behavior were collected from Ventura County Fire Department, Los Angeles City Fire Department, and the U.S. Forest Service, Los Padres National Forest fire suppression personnel. In addition, available written reports from the departments were also used.

Fire behavior observations of the Topanga Fire included:

Flame lengths to 100 feet were observed, especially in areas where slope, fuel, and wind were aligned. Oak understory and litter had flame lengths around 15 - 30 feet, grass typically had flame lengths around 30 - 50 feet, and brush had the highest flame lengths of 60 feet and above (Nestor, et al, and the Topanga After Action Report).

Fire behavior observations of the Ranch Fire included:

Flame lengths of over 100 feet were observed. Oak understory and litter had flame lengths around 15 – 30 feet, grasses had flame lengths of 20 – 90 feet, and brush had the highest flame lengths of over 100 feet (Cross, Blair, et al, and actual raw video footage obtained from Blair, Cross).

Winds

Winds tend to be one of the most sensitive components of the fire behavior models; in that small changes in wind speed or direction can have a significant effect on model outputs. Downslope winds, such as those that occur during Santa Ana events, cannot be modeled accurately. Thus, models do not accurately account for the level of flammability present in the vegetation, and tend to calculate shorter flame lengths than observed on fires burning during Santa Ana winds. Removal of the wind direction or wind vector component in the FlamMap runs produced flame lengths comparable to observed fire behavior during the

actual fire events. Given this validation result, the wind vector was removed from the final FlamMap runs to allow for the most accurate depiction of observed and expected fire behavior in the fuels and topography present in the study areas.

Fuel Models

There are a number of fuel models that could have been selected for each of the grass, shrub, and timber types in Upper Ojai and Bell Canyon. Comparisons of fuel models were made in FlamMap to find fuel models that best depicted actual vegetation and the observed fire behavior that occurred during the Topanga and Ranch Fires.

Final Analysis:

The analysis validates that a **minimum** of 100 feet of clearance is required for firefighters to safely engage in structure protection actions in areas with high amounts of grass, moderate to high amounts of grass/brush mix, moderate to high amounts of broad leaf litter, and high amounts of oak understory (see attached maps that spatially display FlamMap outputs). It is important to point out again that the final results of this report are for radiant heat only.

The analysis also demonstrated that the physical location of a structure in relation to moderate to heavy vegetation, topography, and wind creates varying needs for clearance; in some cases three times the current 100 feet minimum clearance is needed as shown in the attached maps.

In areas where vegetation is light, such as areas with defensible space or grazing, the flame lengths dropped to levels more acceptable for firefighter safety. On the attached maps these areas were incorporated into the 0 – 25 foot flame length category.

As expected, the areas that were modeled as “non-burnable” (fuel models 91 and 99) did not burn. Areas mapped as fuel model 91 may still experience structural losses and extreme fire behavior that threaten firefighters during an actual wildland fire. On the attached maps these areas were incorporated into the 0 – 25 foot flame length category.

There is a marked reduction in flame lengths in areas where wildfire had previously burned as shown in the attached Bell Canyon 2006 and Upper Ojai 2006 maps compared to the 1999 Ranch and 2005 Topanga Fire maps. However, as vegetation re-establishes and grows in those areas, fire behavior is likely to equal or exceed levels observed during the Topanga and Ranch Fires.

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