Fuel Modification Installation and Maintenance Program

University Hills
San Bernardino, CA
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Report Introduction
We have prepared this report for the San Bernardino City Fire Department (SBFD). The report is a vegetation wildfire analysis, to justify the landscaping performance of the fuel modification installation and maintenance program for the University Hills planned community. The study takes into consideration many factors such as the vegetative fuels, topography, weather, and wind/structure placement alignments during a wild fire burning towards the development from the surrounding perimeter areas. The report will show the severity level in which a wild fire under these factors could impact the proposed development and why fuel modification is one of the major fire protection features for a residential development.

The fire behavior analysis in this report projects fire behavior results based on a worst case scenario for this development. By using the worst case scenario fire conditions, we expect that future fires with less extreme factors than we are projecting would produce reduced fire behavior spread and intensity. We used a scientific approach to describe a fire hazard assessment and expected wildland fire behavior results. Our computer projections simulate a fire burning within the native vegetative fuels directly outside the boundaries of the fuel modification zones because the entire fuel modification zone is replanted and permanently irrigated. This report will also demonstrate how code conforming fuel modification zones will do their part to help protect the future community.

The report describes how the development meets or exceeds requirements set forth in the Foothill Fire Zone Building Standards (Chapter 15.10 of the San Bernardino Municipal Code), Building Safety Enhancement Area Building Standards (Chapter 15.11 Municipal Code), Chapter 19.15 (City Of San Bernardino Development Code), and City Fire Code (MC-1130).
General Geographic Description

The proposed 404-acre development is located in a Hazardous Fire Area in the City of San Bernardino. The project will be located north of the California State University San Bernardino campus on the opposite side of Badger Hill. The development project is at the bottom of a large flat valley that is slightly sloping south, away from the San Bernardino Mountains towards the base of Badger Hill.
The development will be bordered by combustible vegetation mostly on the north and west sides. The south side of the development will mostly be considered to built-out due to the Devils Canyon Diversion Levees, a Reservoir, large irrigated slopes, and an existing development located on the extreme south-east side. The land which will be developed will be relatively flat with slight undulations. The site currently is covered with low growing highly combustible plant species listed on the mandatory removal list, which is shown on the fuel modification plan. All existing on-site vegetation will be removed.

(Figure 1) On the south bottom left is the Levee. Bottom center is a reservoir. The south middle will be large re-landscaped areas. On the extreme right is an existing residential development. Badger hill completely separates the development and the University.
Fire History
The property burned in the recent “Old Waterman” fire in 2003. The site contained mostly northern mixed chaparral and sage scrub, prior to the recent Old Waterman fire.

Fuel Modification Program
The Fuel Modification Maintenance Program (FMMP) described in this report meets San Bernardino Fire Department (SBFD) minimum fuel modification code requirements. The codes enforced by the SBFD for fuel modification were developed to handle the exact type of wildland fuels that will be interfacing with this future development. The future community will be entirely bordered by fuel modification zones on all sides of the development. In many locations, landscaped areas extend well beyond the fuel modification zones, out towards the wild land areas.

The FMMP also requires regular and annual maintenance responsibilities by the LLMD. The requirement to do maintenance will reside in the communities CC and R’s rules and regulations recorded documents. The fuel modification on-going maintenance requirements will be on the fuel modification plans for inspection by SBFD and for use by the landscape maintenance company. The developer will distribute the approved plans and maintenance requirements directly to the LLMD at the required FMMP maintenance turnover meeting. The SBFD shall be present at the maintenance turnover.

Zone Configuration
Irrigated Zone “A”.
This Zone is to be located on a graded area at the top or base of a slope. The zone is the last 10 to 20 feet of private homeowner’s flat yards adjacent to the ridge or toe of slope and is directly adjacent to the LLMD “B” fuel modification zone. Zone“A” is maintained by the homeowner and/or the LLMD, only non-combustible construction is allowed within Zone “A”. No tree canopies are allowed within 10 feet of structures when the tree is within a fuel modification zone. The objective is to prevent spread of fire to or from a structure. Vegetation shall be maintained to prevent a path for fire to reach the structure.

Irrigated Zone “B”.
The Zone begins at the homeowners property line at the toe or ridge of a slope and extends 50 to 150 feet further outward away from the structures towards the native vegetation. The area is cleared, replanted with higher fire resistive plants, and permanently irrigated with only plants listed on the precise planting plans that SBFD approved. Plants are originally installed conforming to approved plant types and code required horizontal and vertical spacing arrangements. See the fuel modification plan for more details. Zone “B” is maintained by the LLMD.

For Both Zones:
- No highly combustible plant species allowed within the zones (see the fuel modification plan)
- Horizontal and vertical plant spacing specifications are required
- Dead and dying material removed regularly
- Only non-combustible construction is allowed

The fuel modification maintenance code provisions are copied onto the fuel modification plans. Notes on the fuel modification plans detail the maintenance requirements.
**Thinning Zone C:**
The C Zone extends an additional 50-70 feet beyond Zone B; the remaining vegetation is to be thinned 50%. For this project, the vegetation will be thinned (maintained by the LLMD) a minimum of 50 feet beyond Zone B surrounding the developed areas except for portions of the North and North East sides of the project which will maintain an extended 150’ plus Zone B.

“A” and “B” Zone Example

“A”, “B” and “C” Zone Example
**Wildland Interface Fuel Types**

The type and amount of fuels on the open slopes surrounding the future development are generally:

- Native grasses from 1-2’in height. 40%
- Sage scrub shrubs 3- 4’ in height. 40%
- Chaparral tree-form shrubs from 4-15’ in height. 10%
- Trees (Oak, Elderberry, Riparian willow species) 10%

These fuels (except for the Oak and Willow species) are considered highly combustible in the native setting and could be analyzed for their fire performance based on many factors.

(Figure 2) BEHAVE Sage/Buckwheat shrub fuel model So Cal 18 is present in the photo and will surround the fuel modification zones. (We will calculate the fire spread using a worst case fuel model 4.)


Fuel Model Runs
The BEHAVE, Computer Fire Behavior Prediction and Fuel Modeling System is the most accurate method for predicting wildland fire behavior. The BEHAVE fire behavior computer modeling system is utilized by wildland fire experts nationwide. The fuel models in the computer program, are also referenced from the book titled, “Aids to Determining Fuel Models for Estimating Fire Behavior.” The fuel models were designed to aid in determining fuel types and are used in calculating and estimating fire behavior. We used BEHAVE to measure the intensity of a fire moving towards this development.

The fire model describes the fire behavior only within the flaming front of the fire. The primary moving force in the fire is dead fuel less than ¼” in diameter. These are the finest fuels that carry the fire. Fuels larger than ¼” contribute to fire intensity, but not necessarily to fire spread as much as the fine fuels. The BEHAVE fire model describes a wildfire spreading through surface fuels, which are the burnable materials within 6’ of the ground and contiguous to the ground.

This type of modeling will demonstrate that the FMMP is the best fire defense system for the University Hills development. The Modeling will show that the structures are significantly further away than the most extreme flame lengths and intensity that would be produced. Instead of estimating with the exact fuel model inputs for calculating fire behavior, we will use worst case scenario fuel model inputs to ensure a further safety cushion in the computer fire behavior calculations and result analysis.

BEHAVE Fuel Model Run Locations
We entered BEHAVE input run data for two wind patterns since wild fires are mostly wind driven events. We measured fire coming from the North-East (Santa Ana wind) and a fire coming from a normally prevailing South-West wind. The width of the fire is determined by the distance away from the development and the wind speed. Generally, the faster the wind speed results in a more narrow burn area during high winds.

Our computer projections simulate a fire burning within the native vegetative fuels directly outside the boundaries of the FMMP zones because the entire fuel modification zone is replanted and permanently irrigated. A fire may only burn towards a portion of the development. If a fire was to begin at the most easterly portion of the north side in a Santa Ana wind event, the fire could spread across the north side perimeter all the way to the west side. The 150 foot wide irrigated zone is designed to keep the measured fuels fire outside of the perimeter of the irrigated zone.

The north perimeter side of the development also provides for re-landscaped areas often twice the distance of the fuel modification zone. This is a benefit due to the irrigation and different type of plants introduced in these areas.
Wind Patterns and Structure Alignment
We entered the two most extreme wind patterns and speeds relating to wildfires into the BEHAVE model. All other lesser wind patterns and wind speeds normally produce less fire intensity based on a fire in wildland fuels. The two most extreme wind patterns/wildland fuel alignments are:

1. 90 mph northeast Santa Ana wind.
2. A rare 30 mph dry southwest on-shore, normally prevailing wind.

(Figure 3) We used BEHAVE to calculate a North-East Santa Ana wind directed fire affecting the north east side of the development. The south side of the development is not as subjected to a north east wind driven fire except for ember reception.

(Figure 4) We used a South-West wind directed fire that is affecting the West and South perimeter sides of the development.
Fire Behavior (BEHAVE) Outputs:

The North Development Perimeter Side / North-East Santa Ana Wind

(Figure 5) BEHAVE So Cal Fuel Model 18 fuels are present on the slight slopes down up to the future development. The east side of the development is subject to the worst case fire weather. (We will calculate the fire spread using a worst case fuel model 4 below.)

(Figure 6) This is the north side of the development in the background. BEHAVE Fuel Model So Cal 18 present.
(Figure 7) This is a photo of the extreme north-east side of the development showing the existing built-out development and the fuels interfacing with the north and east side. BEHAVE Fuel Model So Cal 18.

North-East Wind Exposure Fire Behavior
BEHAVE Calculation inputs for computer fire runs:

- 90 mph N/E down slope wind
- BEHAVE Fuel Model 4

Flame Length (feet) 122
Rate of Spread 38 MPH
Spotting Distance 7.3 Miles

Note: Fire Behavior models are estimates only, based on fire experience and observations. Actual fire behavior may vary. As winds in this area can be, and have been, very severe, worst case estimated wind speeds were used and the estimated worst-case vegetation types and heights were used. The SBFD requested that a 90 mph wind speed be used for this particular site.
(Figure 8) This is the west side interface of the development. BEHAVE Fuel Model So Cal 18. 
(We will calculate the fire spread using a worst case fuel model 4.) Notice the Levee acting as a 
large cement firebreak off in the distance.

(Figure 9) This is a typical photo of the south side of the development. BEHAVE Fuel Model 
So Cal 18. Notice the tip of the Levee on the right and the smaller hill next to Badger Hill.
(Figure 10) Badger Hill fuels. A road is at the toe of the slope which assists in defending a downhill south-west wind driven fire. BEHAVE Fuel Model So Cal 18.

**South West Wind Exposure Fire Behavior**

BEHAVE Calculation inputs for computer fire runs:

- 30 mph N/E down slope wind
- BEHAVE Fuel Model So Cal 18 Sage/Buckwheat

**Rate of Spread (ft/min)** 146  
**Fireline Intensity** 10,359  
**Flame Length (feet)** 23.7

*Note: Fire Behavior models are estimates only, based on fire experience and observations. Actual fire behavior may vary. As winds in this area can be, and have been, very severe, worst case estimated wind speeds were used and the estimated worst-case vegetation types and heights were used.*
**BEHAVE Input Data:**

<table>
<thead>
<tr>
<th>Model</th>
<th>1 hour Fuel Moisture</th>
<th>10 Hour Fuel Moisture</th>
<th>100 Hour Fuel Moisture</th>
<th>Live Woody Moisture</th>
<th>20' Windspeed Upslope</th>
<th>Air Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM-4</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>55%</td>
<td>90 mph</td>
<td>95 degrees f</td>
</tr>
</tbody>
</table>

**BEHAVE Output Results:**

<table>
<thead>
<tr>
<th>Model</th>
<th>Flame length</th>
<th>Rate of Spread</th>
<th>Spotting Distance Downwind</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM-4</td>
<td>122’</td>
<td>38 mph</td>
<td>7.3 miles</td>
</tr>
</tbody>
</table>

The worst case Santa Ana wind condition fire will be a rapidly spreading fire. Estimated vegetation burnout time for the fire at any one structure would probably be less than 10 minutes. However, residual fire can be present for over an hour. Fires can spread due to spotting of burning embers downwind from the main body of the fire.
BEHAVE Calculation Results Analysis

Reduced BEHAVE Input Factors:
The above calculations were projected for fuels within the areas immediately adjacent to the fuel modification zone. A 90 mph wind speed is very rare event. A 60 mph wind speed is rare and happens limited times each year also.

- We calculated fuel model runs in the same northern interface locations with a 60-mph Santa Ana wind speed. The results showed an overall flame length and fire intensity reduction of approximately 30%.

Irrigated “B” Zone Factors:
The above calculations were projected for fuels within the areas immediately adjacent to the fuel modification zone. We additionally calculated fuel model runs for fuels within the maintained fuel modification zones, and the results showed an overall fire intensity reduction of:

- 90% reduction in the irrigated zone.
  (This is due to the removal of highly combustible species being cleared, replanted, and permanently irrigated with only plants listed on the approved plans. Plants are originally installed and maintained conforming to code required horizontal spacing arrangements.)

BEHAVE demonstrates that flames and fire intensity is significantly reduced within the fuel modification zone.

Additionally, the proposal exceeds the minimum code requirements because the entire distance of required fuel modification zones are irrigated when compared to a code conforming designed fuel modification program for other developments that includes the dry thinning zones.

The future structures will not ignite from the direct effects of fire regarding flame impingement and radiant heat. Any structure even those further away in other developments are subjected to firebrand embers. Fuels measured directly outside the fuel modification zones do not have sufficient flame lengths or radiant and convective heat energy to reach the future structures to the point of ignition when the new California Building Code Chapter 7A requirements are met.

Structure Ignition Assessment Model (SIAM).
The following is information regarding a valid structure assesment model used by the fire service and professionals throughout the nation. The author of the model is one of the most well respected wildland fire professionals in the world. A USDA-Forest Service research study and report entitled the “Structure Ignition Assessment Model (SIAM)” by Jack D. Cohen, Intermountain Fire Science Laboratory, Missoula, Montana has helped to validate how much distance is required to keep structures from igniting due to wildland fire radiant heat. SIAM research further suggests that for reducing structure ignitions from radiant and convective heat sources, vegetation management (fuel treatment) beyond some relatively short (100 feet) distance from a structure built of non-combustible materials has little significant benefit for reducing flame generated ignitions. Vegetation management cannot be practically extensive enough to significantly reduce airborne firebrand ignitions landing on combustible roofs or other fuelbeds on privately controlled land around a home. Future structures will be set back even further from the intensity of a fire burning outside the limits of the fuel modification zone. Fire suppression efforts combined with the fuel modification zone protection and the latest known building construction practices will ensure the best possible outcome for a safe development.
Building Construction Material Requirements
Shall be in accordance with the latest version of the SBFD adopted Fire Code in effect at the time of building permit application, including local amendments.

The construction of all structures throughout the development:
- CBC Chapter 7A requirements for Attic Venting and Roof Construction requirements.
- Class “A” roof coverings and assemblies.
- No cornice or eave venting allowed.
- All Building Chapter 7A requirements apply.

Report Summary
This development is designed using the most recently developed codes. We used BEHAVE to measure the intensity of a fire moving towards this development, and flame lengths and fire intensity is ultimately reduced by the installation and maintenance of the FMMP.

Based on the scientific fire behavior analysis, exterior portions of future structures will not ignite from the exterior fire exposure from a wildland vegetation fire. This is primarily because the fire energy is too far away from the structures due to the low plant densities within the fuel modification zones and the most recent construction feature requirements.

The codes enforced by the SBFD for fuel modification were developed to handle the exact type of fuels that are interfacing with this future development. The fuel modification zones designed for this development meet the minimum code requirements and surrounding the majority of the project exceeds the minimum standards. The use of the standard “A”, “B”, and “C” Zone design is only utilized on the boundary of the project adjacent to the Levee and low fuel Reservoir and the hang-glider port. All of the areas not utilizing the “C” Zone have extended “B” Zones, (permanently irrigated) which provides additional protection.

We recommend approval of the Fuel Modification Maintenance Program.

Acknowledgements and references:


3. 3-30-06: Draft Fire Protection Plan; Paradise Hills