SAN BERNARDINO NATIONAL FOREST
FUELS AND FIRE BEHAVIOR ASSESSMENT
2004

Submitted by: Carol Henson
Fire Behavior Analyst

This is a revision of the 2003 Fuels and Fire Behavior Assessment completed in June 2003. This revision is based on personal observations of the fire behavior while on the Old Fire, numerous interviews with fire suppression personnel, site visits to the San Bernardino National Forest, weather observations from local Remote Automated Weather Stations, photographs, fire progression maps, and various reports that came out after the 2003 wildfires.

I. VALIDATION OF 2003 FIRE BEHAVIOR PREDICTIONS

Only minor modifications were needed for fire behavior predictions. These are notable but insignificant in terms of implications for suppression. For example, predicted flame lengths for fuel models 2 and 4 were lower than observed but both predicted and observed fall into the category of extreme fire behavior. Another example is the predicted rates of spread for those fuel models were higher than observed rates of spread but both predicted and observed exceeded the production rates for all suppression resources. The predicted and observed spotting potential and spotting distances were correct.

During the Old Fire it was observed that standing dead trees with red needles on gentle slopes and/or light winds did not always react as expected. We expected that a surface fire would move up into the canopy and at a minimum torching would occur - that was not the case every time. Some timbered areas with dead standing trees appeared to have burned at a lower intensity not reaching the critical intensity needed to move up into the crown. In some of these areas the fire burned as if it were an understory burn. Perhaps there's a change in the physiology in the needles on the trees. We don't know what the foliar moisture was on living or standing dead trees, nor if the combustibility changed, but further research into this is needed.

Crown fire did occur in areas where there were high winds and/or steep slopes. Predominately these were passive and active crowning. There may have been areas with short independent crown fires but there were no direct observations of this.

II. 2004 FUELS ASSESSMENT

Vegetation consists of ponderosa pine, Jeffrey pine, Coulter pine, white fir, black oak, canyon live oak, chamise, manzanita, ceanothus, Pinion, juniper, sage, and grasses.

A large portion of the forest has not burned in well over 41 years and has missed an average of three to four fire cycles in the conifer stands. Even without the drought and mortality issues this is considered extremely hazardous conditions with old decadent brush, heavy fuel loadings, and densification of trees. Although the Grand Prix and Old Fires were large fires, 70% of the fires burned in chaparral and affected only 3-4% of the areas with timber mortality, leaving a large part of the Forest unburned.

There is new mortality in multiple areas, but for the most part it is within affected areas from last year. Many of the older standing dead trees (3 months or more) are losing needles but trees that have recently died are still holding onto their needles, and green trees that appear to be alive are in fact dead. You can see this across much of the Forest. There has been some new mortality in the pinion and chaparral.

North facing slopes where we normally find higher live fuel moistures are experiencing high mortality. I would best describe the timber mortality as standing heavy slash or a "vertical fuel model 13" though currently we are unable to model standing dead fuels. Standing and down dead fuel loadings could range up to several hundred tons per acre.

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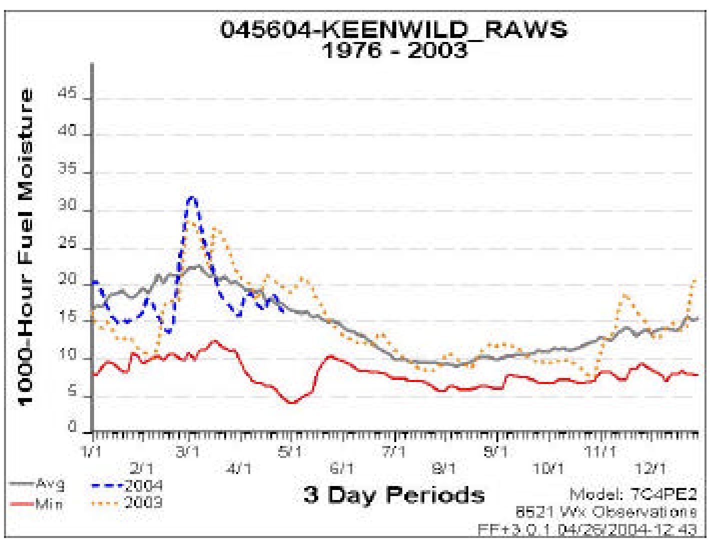
It's the 5th year that below normal rainfall has occurred in the area. Some areas did get a new grass crop but nothing like last years. This new grass crop has already curing out which is about a month ahead of normal, and will add to the volume and continuity of last year's grasses. This will add significantly to fire potential again this year.

Chamise is the only vegetation that is sampled for fuel moisture. Similar to 2003 there is some new growth in the chamise along the coastal side of the mountain range; however I again didn't observe any new growth on the desert side or at the higher elevations. Current fuel moistures for new growth in chamise are ranging around 92% at higher elevations and in areas outside of the marine influence. In the lower elevations with a marine influence the new growth fuel moistures are around 122-159%. The old growth is averaging around 75-80% in all areas. These samples are currently above the critical threshold of 60% (live fuels will burn like dead fuels at this threshold) but are expected to drop earlier than last year because of the record setting heat that we've been experiencing. Fuel moistures in chaparral can continue to drop until dormancy around September-November where they mostly level out until the spring. I observed that there was some flowering in the ceanothus but this should start peaking out soon.

The 1,000-hour fuel moistures for the San Bernardino NF are derived from data taken from the Keenwild Remote Automated Weather Station (RAWS). This RAWS is closer to an area where the marine influence could show higher fuel moisture levels than those found in the drier areas of the Forest. The 1,000-hour fuel moisture level for Keenwild has been mostly drier than the 28-year average. It spiked well above the average in late February through the first of March but dropped quickly with the record heat in March. The 1,000-hour fuel moistures have been near average since the first of April. I would expect the 1,000-hour fuel moisture to drop quickly with the record heat we experienced in April and continue dropping through the fire season to possible record levels.



As hazardous fuels reduction, thinning, and dead tree removal projects take place there will be an element of slash on the ground, though for a short time, which will increase the available and receptive fuels to any ignition.

Another fuel component in the area are the homes in the wildland urban interface/intermix of the communities within and outside of the Forest boundary. The potential for ignition of these homes from a wildfire depends on the home's exterior materials and design and the amount of heat to the home from the flames within the home ignition zone. Home ignition zones are areas that include the home and an area surrounding the home within 100 to 200 feet. Firebrand ignitions also depend on the home ignition zone either by igniting the home directly or igniting adjacent materials that heat the home to ignition.

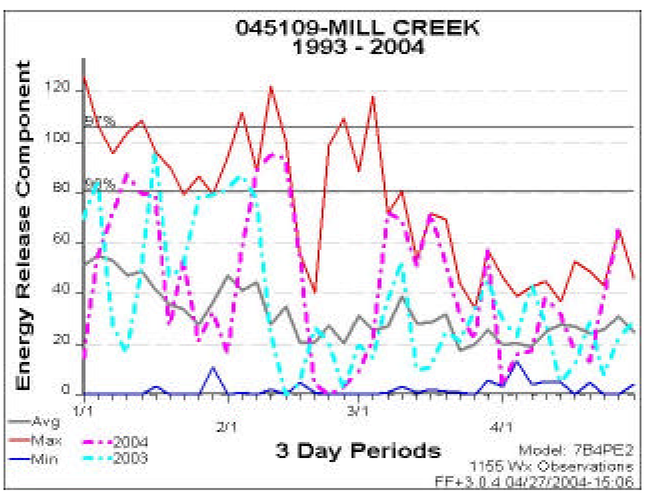
As observed in 2003 the potential for ignition in many of these homes is high. Fuel loadings in buildings are typically many times those in a forest, the heaviest likely fuel load in the forest is less than the lightest load for a structure. A great number of homes in the area have flammable roofs and wood siding, flammable vegetation close to the homes (including dead standing trees), firewood piles close to homes, dead leaves, needles, etc that contribute to the ignition potential. Due to the spacing of homes found in many of the communities, burning may be more characteristic of an urban conflagration than a typical wildland-urban interface fire, similar to what was observed last year during the 2003 wildfires in Southern California and in the 1991 Oakland Hills Fire. Public and firefighter safety is of great concern in these areas, especially where it relates to structure protection and safe working environments for crews.

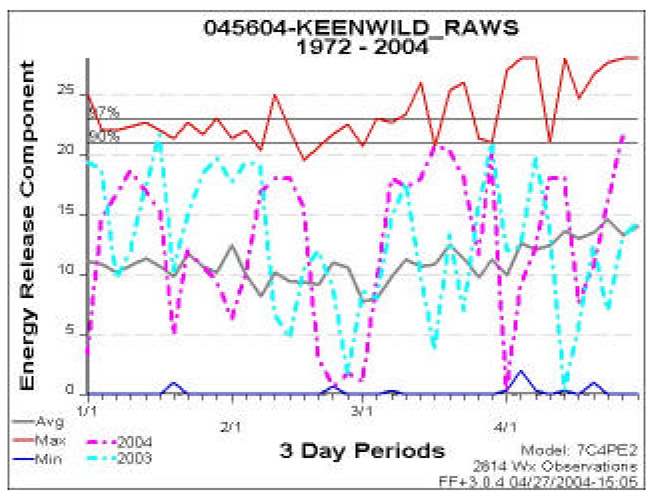
III. 2004 FIRE BEHAVIOR ASSESSMENT

Fire Danger - Energy Release Component (ERC):

The ERC is an estimate of the potential energy released in the flaming zone of the fire. The higher the ERC, the harder a fire will be to suppress. The ERC traces the seasonal trends in fire danger, rather than short-term fluctuations. As live fuels cure and dead fuels dry, the ERC values get higher, which provides a good idea of drought conditions. Wind is not a component of ERC.

The most recent ERC charts for 2004 show that most of the Forest is already at record levels and well above the 12-year average. If trends continue we should see record level ERCs throughout the summer.





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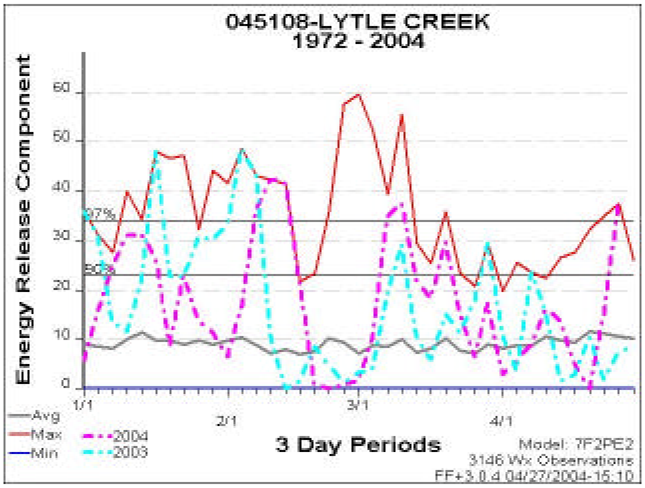

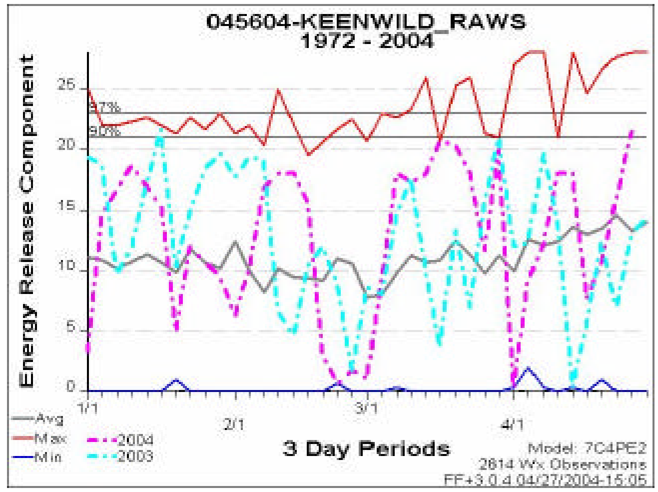

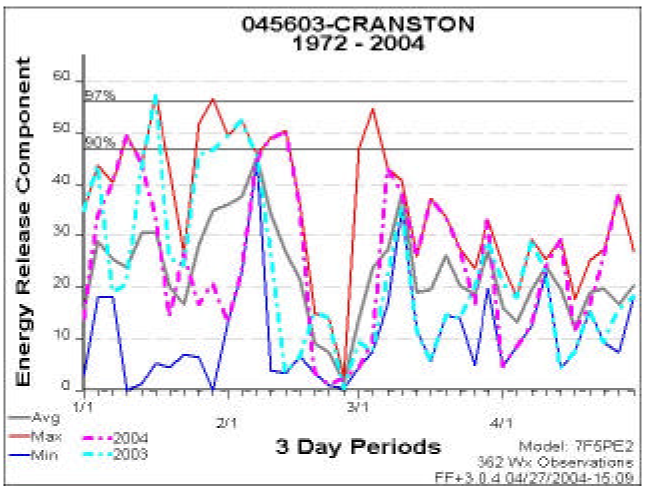

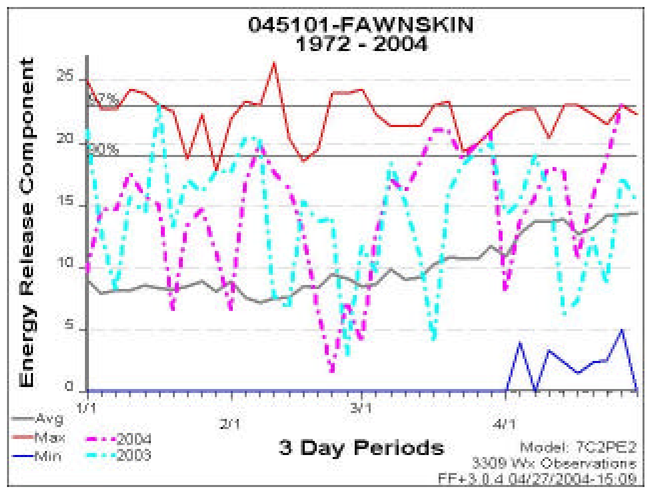

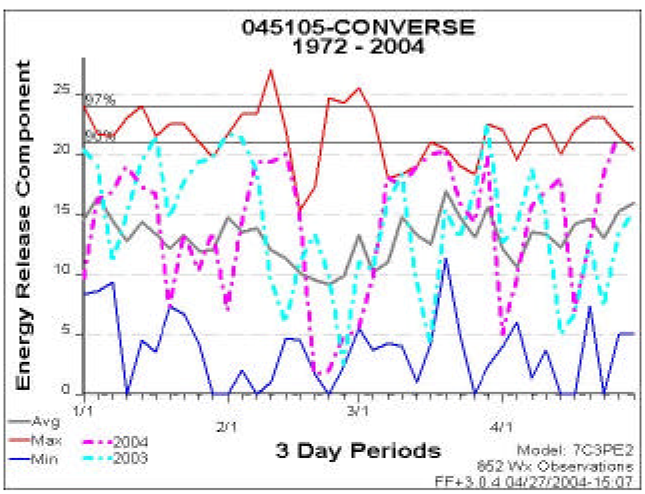

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Fire Behavior:

Heavy mortality in the vegetation, heavy fuel loadings, low live fuel moistures, low 1,000-hour fuel moistures, and the fire weather outlook of above normal temperatures in interior California all contribute to a high potential for extreme fire behavior again this fire season in areas not burned in the 2003 fires. Extreme fire behavior characteristics can include rapid rates of spread, intense burning, spot fires, crown fires, presence of fire whirls, and strong convection columns. All of these characteristics were observed on the Grand Prix and Old Fires in 2003, and can occur in 2004.

In 2003 all of the large fires (100-acres and larger) started in grass, chaparral, or a grass/chaparral mix and not in the timber. Two of the fires started with a northerly wind component (Lytle and Old Fires) and three fires started with a southerly wind component. These fires were typical of Southern California brush fires with steep slopes and/or high wind speeds, low relative humidity, high temperatures, and dry and/or dead vegetation all contributing to extreme fire behavior.

There is a high potential for major fire runs with rates of spread estimated at 2-miles an hour. Probability of Ignition (PI) or spotting potential will depend on temperatures, relative humidity, shading, and receptive fuels but a PI of 70% or greater indicates that spot fires are likely. Expect a PI of 70% or greater when relative humidity ranges from 0 – 24% with temperatures ranging from 70 – 109+ degrees, which is possible throughout the fire season. Short and long range spotting distances of 1-mile are possible.

Fire behavior observed in March 2004 in Santa Ana Canyon demonstrated that aggressive burning conditions exist now and will continue throughout the fire season. October and November are especially a concern due to the Santa Ana Winds that are more prevalent that time of year, though they can occur any time of the year.

Fires burning in the existing fuel conditions along with slope and/or wind will have a high resistance to control. Initial attack resources especially aircraft will be critical to the success in keeping fires small. In 2003 the San Bernardino National Forest had one hundred thirty five fires reported. There were five fires that burned more than 100 acres on the Forest. Initial attack resources were successful in keeping 96% of the fires below 100-acres.

As in 2003 multiple ignitions (lightning or arson) could lead to draw-down of initial attack resources or second alarm resources allowing fires to establish and grow before resources can arrive on scene.

Basic fire suppression tactics were effective in fighting the 2003 fires. Flanking the fires whether in the brush or timber was effective and safe. Taking advantage of the northerly wind, the firing operations along Highway 18 was effective and contributed to the success in saving a number of homes in the mountaintop communities.

Anticipated normal thunderstorm activity may provide some moisture in isolated areas but any precipitation would be localized and provide no long term or widespread benefits.

Grasses:

There was a small increase in the amount of grasses this year, however residual grasses from last year will contribute significantly to fire potential in all areas. Fire behavior in this vegetation will exhibit normal burning characteristics for cured and dead grass. Expect quick ignition and rapid rates of spread (2-miles an hour possible) with flame lengths over 5 feet. Long range spotting of around ½-mile is possible in this vegetation.

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Fires will be too intense for direct attack at the head of a fire by crews with hand tools but they can take flanking action. Engines and dozers may be effective in direct attack with flame lengths under 8 feet but recommend a flanking action once flame lengths exceed 8 feet.

Chaparral:

Fire behavior in chaparral during the escaped prescribed burn in Santa Ana Canyon in March 2004 was extremely aggressive for this early in the year. Fire exhibited rapid rates of spread, short range spotting, and flame lengths in excess of 35 feet. Live fuel moistures have gone up since then but expect fire behavior to burn from moderate to extreme as live fuel moistures begin to drop.

As the season progresses live fuel moistures will drop at or below the critical threshold of 60% (live fuels burn as if they are dead at this level) by June/July which is earlier than last year. Typical of Southern California brush fires expect aggressive burning, rapid rates of spread (around 2-miles an hour possible) with flame lengths exceeding 17 feet, especially in areas where fuels, slope, and wind are aligned. Spotting distances of up to a mile are possible. In the dead standing chaparral rates of spread and intensities can exceed these predictions. There are no models for standing dead vegetation or for predicting the fire behavior associated with it.

Fires will be too intense for direct attack at the head and may not be effective. Recommend flanking action for crews, engines, dozers, and aircraft.

Timber (Living/Dead trees):

Expect a surface fire in the timber to burn with moderate to rapid rates of spread. Passive crowning (torching - one tree or a group of several trees has fire moving from the ground up into the canopy) is likely when ladder fuels are present even when there is little slope and/or wind. If ladder fuels are not available, and there is little slope and/or wind, expect the fire to carry in the surface fuels as a surface fire. Direct attack at the head may be possible when there's little slope and/or wind. If 20-foot wind speeds are below 7 mph on flat ground or gentle slopes then moderate to long range spotting distances of up to 1/2-mile are possible. The same spotting distances are possible with little or no wind on slopes less than 50%.

Active crown fire (the surface and canopy fuels are involved – this phase is dependent on heat from burning surface fuels) and independent crown fires (the fire burns in the canopy without aid from a supporting surface fire) are possible when there are ladder fuels, continuous canopy, and strong winds and/or steep slopes. If a surface fire establishes on slopes >50% and/or wind speeds >7 mph occurs an active crown fires is probable, which can move into an independent crown fire. Independent crown fires rarely occur though, and are normally short lived. Short and long range spotting is possible.

Fuel moisture sampling of foliar moisture in the timber has not been taken but my estimates are that we're seeing levels well below 100% for living green trees. Live foliar fuel moisture levels at 125% and below can exhibit extreme fire behavior including crowning, spotting, and potential for development of a plume dominated fire. These conditions are explosive and are extremely dangerous conditions for the firefighters.

If initial attack resources, especially aircraft, arrive on scene quickly enough a fire may be contained before it establishes as an intense surface fire then transition up into the crowns. Firefighters need to recognize and be aware of the transition from a surface fire to a crown fire.

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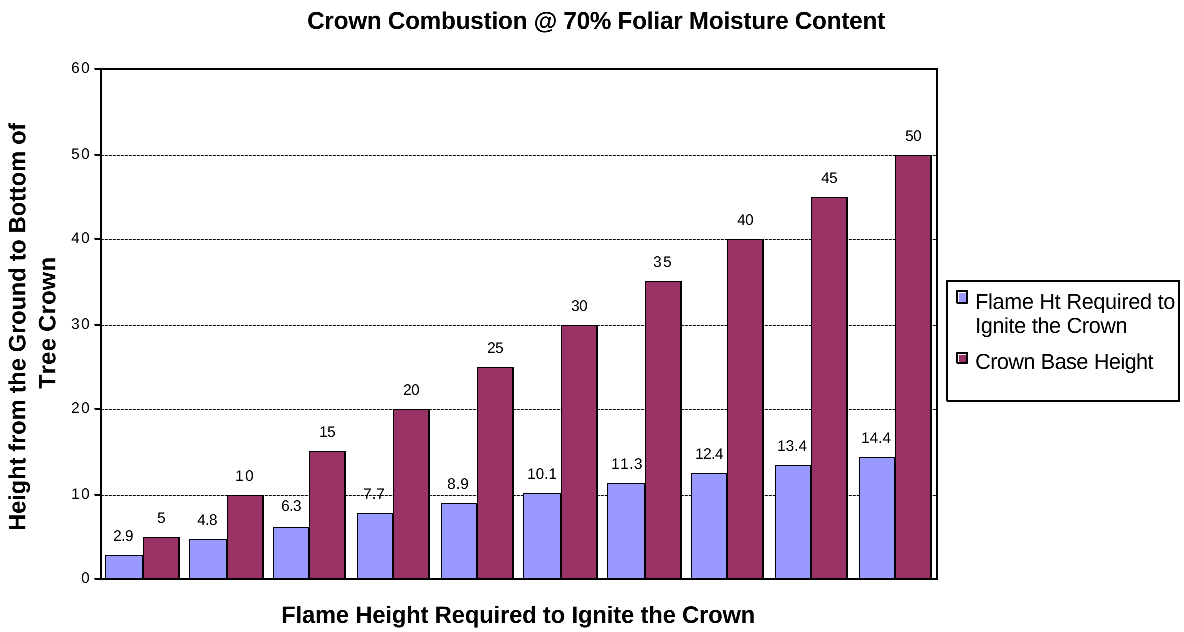
There are a number of areas where needles have dropped from the dead trees creating breaks in the canopy. Active or independent crown fires that move into these areas will transition back to a surface fire until other opportunities for crown fire arise with ladder fuels, tightly spaced canopy closure, steep slopes and/or high winds occur.

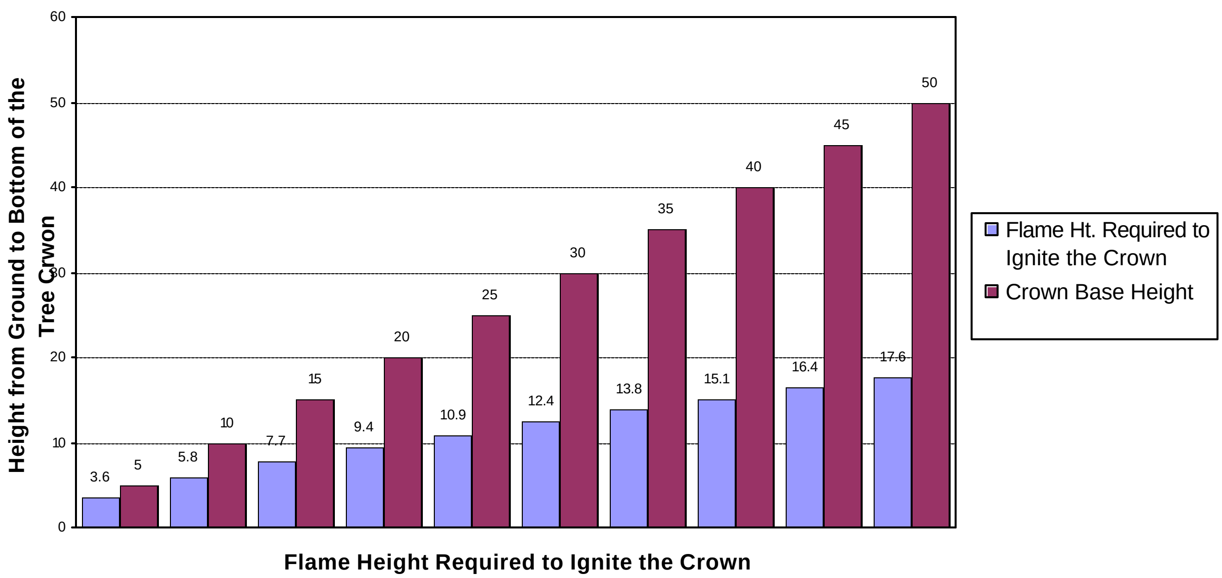
Suppression resources should not place themselves ahead of a crown fire for structure protection. Firefighters may be able to find a safe anchor point toward the back of a fire and start flanking with safety zones in close proximity.

Crowning potential:

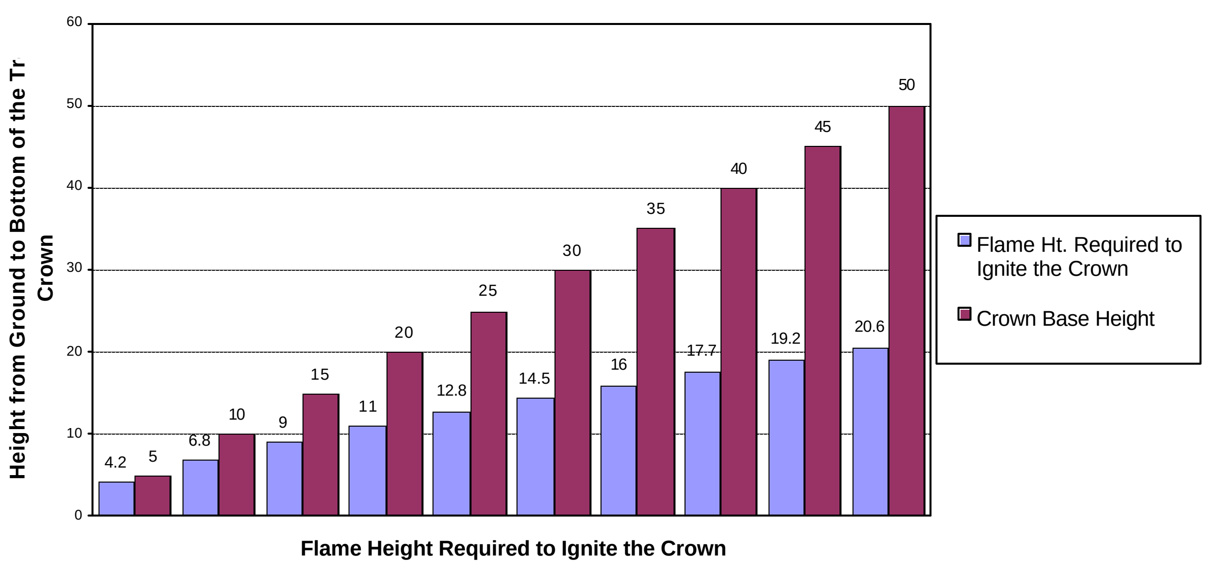
In order for transition to occur from a surface fire to a crown fire, critical surface fire intensity must be attained. The critical surface intensity for crowning is dependant on the crown base height and foliar moisture content. The crown fire initiation is based on a crown fire theory described by Van Wagner. Below are charts for minimum flame heights for initiation of crown combustion versus height to live crown base based on foliar moisture content.



Crown Combustion @ 100% Foliar Moisture Content



Crown Combustion @ 130% Foliar Moisture Content



Common denominators of crown fires and important conditions leading to crown fires:

A. Crown conditions

1) Spacing in close proximity is more susceptible to spreading crown fires. (20 feet or less between crowns is a good indicator.)

2) Stocking levels greater than 100 tress per acre create closer spacing, therefore higher potential.

3) Crown closure of 75% or more also indicates a high potential.

4) Ladder fuels

5) Crown height. The lower the crown height the greater the potential. Crown height is also referred to as height to live crown base.

6) Chemical content.

B. Surface conditions

1) Loading - heavy fuel loading, especially in 0-3" diameter, substantially adds to the ability to crown. Discontinuous fuels with heavy loading can provide the same effect as continuous fuels.

C. Weather - Winds

1) Strong winds are needed to carry the fire in the crowns, especially on flat ground. However, crowning can occur in plume-dominated fires under low windspeed conditions.

2) Heads up during strong down drafts in areas with thunderstorm activity that can push fire downhill. Also possible in plume dominated fires.

D. Moisture content

1) Low fine fuel moisture of less than 5% indicates the ease of burning. There can be a lot of dead fuels in the crowns.

2) Foliar moisture - low foliar moisture makes crowns more susceptible. 80-90% foliar moisture is an important threshold for crowning. This moisture level is for live green needles only. Dead trees foliar moisture will act as 1-hour fuels subject to change with relative humidity.

E. Topography

1) Steep slopes dramatically increase potential.

F. Atmospheric conditions

1) Low moisture content in the lower atmosphere can be another factor.

2) Atmospheric instability.

Plume Dominated Fire:

The potential for a plume-dominated fire is possible; this is primarily due to the heavy dead fuel loading over the landscape and the potential for crown fire. Plume dominated fires can include crowning or can be caused by crowning when wind or slope are no longer pushing the fire. These conditions are explosive and the most dangerous for firefighters. This is the event that took 6 firefighter's lives in the 1990 Dude Fire.

A plume-dominated fire is not as predictable as a wind driven fire as it creates its own environment. They are associated with relatively low windspeeds and the development of strong convection columns. The Haines Index is used to measure atmospheric stability, which can help forecast the potential for a plume dominated fire event. We don't use the Haines Index here in California as upper air soundings that are available are from the coast. This marine influence would affect the index (Ron Hamilton).

Common characteristics of a plume dominated fire:

⇒ Unusually large fires or rapid growth.
⇒ Fire spread is a function of the fire itself, not the wind.

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- ⇒ Upper level winds at 10,000-feet below 20 mph.
- ⇒ Convection column is well developed, sometimes reaching 20,000+ feet.
- ⇒ Strong updrafts during rapid growth and strong downdrafts after air cools in the upper atmosphere causing air to descend rapidly (column collapse) causing strong downdrafts.
- ⇒ Spotting is not long distance but can be profuse in all directions.
- ⇒ Whirlwinds are typical around the perimeter.

Recommendations for this event would be to pull firefighters out to safety zones until conditions change. A lookout should be placed a great distance from the fire to observe the column for characteristics leading to the column building and then collapsing.

Urban Interface:

Rapidly spreading wildland fire coupled with highly ignitable homes can cause many homes to burn simultaneously. As seen in 2003 this multi-structure involvement, in addition to suppressing the wildland fire, can overwhelm fire protection capabilities and, in effect, result in unprotected residences. Severe wildland urban interface fires can destroy whole neighborhoods in a few hours—much faster than the response time and suppression capabilities of even the best equipped and staffed firefighting agencies.

Structure protection may not be possible. Sizing up each situation and triaging structures will be extremely important before committing to any structure protection. Fire behavior will be influenced not only by forest fuels but also by the extreme intensities of burning structures. Expect extreme fire behavior conditions with the potential of homes being a carrier of fire.

Hazardous materials, electric and gas lines, and propane tanks will also be a concern in this situation.

Vulnerable communities:

- The communities north of Interstate 10 and east of the Old Fire including Crafton Hills, Yucaipa, Redlands, Angelus Oaks, Forest Falls, and Mountain Home Village have potential to experience similar fire behavior as those in San Bernardino, Lytle Creek, Rancho Cucamonga, and Devore during the Old Fire. The biggest threat would be fire(s) starting up in Santa Ana Canyon, upper Deep Creek, Mill Creek Canyon, or Banning Canyon and being pushed down into the communities by Santa Ana winds.

  The communities of Angelus Oaks, Forest Falls, Mountain Home Village, and the eastern side of Big Bear would also be threatened by fire(s) starting south from below and pushed by a southwesterly flow up through Santa Ana Canyon. Old decadent 41+ year old chaparral, in addition to dead and dying vegetation, create ideal conditions for fire to make major runs into these communities.

- The Community of Arrowhead is fairly protected from major fire runs similar to what happened in 2003 (8 miles in one burn period) because it's surrounded on three sides (west, south, and east) by the 2003 Old Fire and the 2000 Willow Fire. One threat of a major fire run from the west does exist in Miller Canyon in the event of a strong west wind. Grass Valley Creek off of Highway 173 may also present a problem during a Santa Ana wind.

  In addition, fire starting within or nearby the community pushed by strong winds and/or steep slopes has potential to take out homes within neighborhoods due to structure spacing and old decadent 41+ year old drought stressed or dead wildland vegetation tight intermixed with the homes. There are areas where strong winds and/or slopes could push the fire into the crowns of trees due to tight canopy spacing. A lot of good work has gone into the Arrowhead area which should help firefighters in the event a fire starts within the community or fire comes into the community from Miller Canyon or Grass Valley Creek.

- The communities of Running Springs, Arrowbear, and Green Valley Lake have potential for fire spread to come from below off of Highway 330 with southwesterly winds. If fire gets established in these areas it can then move quickly into Fawnskin and Big Bear. Fire also has the potential to start within or nearby these communities and make runs with a strong wind and/or steep slopes. Little or no fuel reduction work has been done in these communities. Old decadent 41+ year old vegetation, in addition to the dead and dying vegetation, extends throughout the area and is intermixed with the communities.

- The communities of Fawnskin, Big Bear City, and Big Bear have potential from the fire establishing itself on the west side of Deep Creek into Bear Creek and Siberia Creek with a southwesterly flow and running up onto the mountaintop east of Butler Peak. The southwesterly winds would push the fire into the communities on the west side. Fire also has the potential to start within or nearby these communities and make runs with a strong wind and/or steep slopes. Little or no fuel reduction work has been done in these communities.

  Big Bear, Fawnskin, and Big Bear City also have potential of fire moving from desert pushed by Santa Ana winds and/or slope into the mountaintop communities. These fires would be burning in desert chaparral and pinion-juniper for the most part, though there is a timber component. There would be rapid rates of spread with a strong northerly wind component and/or steep slopes, especially in areas where there's been mortality in the chaparral and pinion-juniper. The canopy spacing in the timbered areas are not as tight so fire would most likely be carried by the surface fuels with some isolated torching.

- The communities of Idyllwild, Pine Cove, and Mountain Center have potential for major runs coming from the Highway 74 area below. There have been a several fires that have burned below these areas in the last 35-years which has left light and flashy fuels that lead up to the edge of these communities. The difference now is that there's a large component of dead and dying vegetation that didn't exist when these fires burned. As in most mountain communities homes are tightly spaced with little or no defensible space. Old decadent 41+ year old vegetation, in addition to the dead and dying vegetation is intermixed with the homes and extends throughout the area. There's also potential for fire to start within or adjacent to these communities and make runs with strong winds and/or steep slopes. There has been some limited fuel reduction work needed in the community of Idyllwild.

IV. SAFETY

As in every fire situation firefighters need to follow the basics. The 10 Standard Firefighting Orders must be followed - we don't break them and we don't bend them. As well as the 18 Watch out Situations, LCES, and the 9 Urban Interface Situations

Review the "Structure Protection Checklist" in the Incident Response Pocket Guide, the NWCG Publication "Improving Firefighter Safety in the Wildland Urban Intermix", and appropriate job hazardous analysis.

Safety Zones:

A safety zone should be large enough so that the distance between the firefighters and flames is **at least four times the maximum flame height in all directions per firefighter**. **THIS IS FOR RADIANT HEAT ONLY. THERE ARE NO STUDIES FOR CONVECTIVE HEAT GENERATED FROM SLOPE,**

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WIND GUSTS, FIREWHIRLS, AND TURBULENCE. SAFETY ZONES IN THESE AREAS WOULD HAVE TO BE MUCH LARGER.

Trigger Points for extreme fire behavior:

Extreme fire behavior trigger points developed using the Forest Pocket Cards are:

- ⇒ Relative humidity below 25%
- ⇒ 20-foot winds at 7 mph and greater
- ⇒ 1,000-hour fuels below 8% are considered explosive conditions.
- ⇒ Burning Index of 50 - large fires occur on the Forest at this level

Fire behavior associated with these trigger points include quick ignition, aggressive burning conditions, spot fires that occur often and spread readily, moderate to long range spotting distances, extreme fire behavior probable.

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V. FIRE BEHAVIOR MODEL INPUT

Assessment comments:

Fire behavior calculations provided are based upon general conditions and are worst case conditions. The predictions provided are best estimates based on assumptions and are not and cannot be site specific. These predictions are intended to provide general indications of fire behavior potential only. Adjustments must be made for site-specific fire behavior for your location. They assume that fires are free burning with no suppression action being taken.

Adjustments to outputs:

Based on observations from last year's extreme fire behavior I have divided the rates of spread outputs on Fuel Models 2 and 4 by two to reflect actual fire behavior in the narrative above.

I did not increase the flame lengths to match flame lengths observed last year. Flame lengths over 11-feet are all considered extreme with fireline intensities exceeding 1,000 Btu/ft/sec.

Methodology used for the tables below:

Spot calculations were linked to Direct runs for all outputs. Values used include elevation differences from ridge to valley of 800 feet and a horizontal distance from ridge to valley of 0.5 miles. Ridgetop winds were used.

Estimated average slope of 35%, which was used for all Direct runs for the following tables.

Variables used for PI include temperatures of 90-100 degrees F., 1-hour fine fuel moisture, and no shading.

Assuming a receptive fuelbed exists you can expect:

1-hour fine fuel moistures of 2 = 100% PI
1-hour fine fuel moistures of 3 = 90% PI
1-hour fine fuel moistures of 4 = 80% PI
1-hour fine fuel moistures of 5 = 70% PI

Various midflame wind speeds are used 1, 3, 5, 7, 9.

Fuels moistures for 10-hour fuels were 1 more than the 1-hour and 2 more for the 100-hour fuels.

Live fuel moisture of 60% was used.

Fuel models used for this assessment include the standard FBPS Fuel Models 2, 4, 5, 6, 8, 9, 10, 11, 12, and 13. I did not consider the custom chaparral models developed by Riverside Fire Lab for this assessment.

These fuel models are characterized for input into a fire model for the best estimate of fire behavior. They are tuned to the fine fuels that carry a fire at the time of year when fires burn well.

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Fuel model descriptions in the assessment area include:

FUEL MODEL	DESCRIPTION
2	Grass - Annual and perennial grasses with open shrub lands and pine stands that cover 1/3 to 2/3 of the area. There is a live fuel component that can influence fire behavior. Sage is included in this model.
4	Shrub - Stands of mature shrubs, 6 ft. or more tall though height depends on local conditions. Dead woody material in the stands significantly contributes to fire intensity. There is a live component.
5	Shrub - Green, low shrub fields within timber stands or without overstory are typical. Regeneration shrublands after fire or disturbance. Live fuel moisture component can influence fire behavior.
6	Shrub - The shrubs are older than a FM5. This model covers a broad range of conditions. Live fuel moisture component can influence fire behavior. Pinion-juniper is in this model.
8	Timber - Closed canopy stands that have compact litter layer. This layer is mainly needles, leaves, and occasionally twigs because little undergrowth is present in this stand. Live fuel moisture is not a significant component in influencing fire behavior in these stands for surface fires.
9	Timber - Closed stands of long-needles pine like Ponderosa pine. Concentrations of dead-down woody material. Live fuel moisture is not a significant component in influencing fire behavior for surface fires. However, live fuel moisture related to foliar moisture is critical as it makes timber stands more susceptible to crown fires.
10	Timber - Any forest type can be considered if heavy down material is present; examples are insect or disease ridden stands, wind-thrown stands, overmature situations with deadfall, and ages light thinning or partial-cut slash. Live fuel moisture is a component.
11	Slash - Light partial cuts or thinning operations in mixed conifer stands and hardwood stands. Used for areas where activity is taking place. No live fuels.
12	Slash - Heavily thinned conifer stands, clearcuts, and medium or heavy partial cuts are represented. Used for areas where activity is taking place. No live fuels.
13	Slash - Large quantities of material. Clearcuts and heavy partial-cuts in mature or overmature stands. The total load may exceed 200 tons per acre. Used for areas where activity is taking place. No live fuels.

Models do not exist for any standing dead fuels. The best description that I can give for the standing dead trees are a "vertical fuel model 13", this however does not fit the model.

Submitted by: Carol Henson
Fire Behavior Analyst

Fire behavior tables:

THE BEHAVE SYSTEM BURN SUBSYSTEM FIRE1 PROGRAM: VERSION 4.4 -- FEBRUARY 1997

DEVELOPED BY: THE FIRE BEHAVIOR RESEARCH WORK UNIT INTERMOUNTAIN FIRE SCIENCES LABORATORY MISSOULA, MONTANA

ASSUMPTIONS, LIMITATIONS, AND APPLICATION OF MATHEMATICAL MODELS USED IN THIS PROGRAM ARE IN:
Andrews, Patricia L. "BEHAVE: Fire behavior prediction and fuel modeling system--BURN subsystem, Part 1", INT-GTR-194, 1986,
Andrews, Patricia L., and Chase, Carolyn H. "BEHAVE: Fire behavior prediction and fuel modeling system--BURN subsystem, Part 2", INT-GTR-260, 1989

FUEL MODEL ------------ 2 – TIMBER (GRASS AND UNDERSTORY)

RATE OF SPREAD, CH/H

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	17.	35.	67.	112.	169.
3.0	15.	31.	60.	100.	151.
4.0	14.	29.	55.	92.	138.
5.0	13.	27.	51.	86.	129.

FLAME LENGTH, FT

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	5.1	7.0	9.4	11.9	14.4
3.0	4.6	6.4	8.6	10.9	13.2
4.0	4.3	6.0	8.0	10.2	12.3
5.0	4.1	5.7	7.6	9.7	11.7

MAXIMUM SPOTTING DISTANCE, MI

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	.1	.2	.3	.5	.6
3.0	.1	.2	.3	.4	.6
4.0	.1	.2	.3	.4	.6
5.0	.1	.2	.3	.4	.5

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FUEL MODEL 4 -- CHAPARRAL, 6 FT

RATE OF SPREAD, CH/H

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	46.	94.	160.	238.	327.
3.0	43.	88.	150.	223.	306.
4.0	40.	84.	142.	211.	289.
5.0	38.	79.	135.	201.	275.

FLAME LENGTH, FT

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	17.4	24.3	30.9	37.1	42.9
3.0	16.4	23.0	29.3	35.2	40.6
4.0	15.7	21.9	27.9	33.5	38.8
5.0	15.1	21.0	26.8	32.2	37.2

MAXIMUM SPOTTING DISTANCE, MI

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	.1	.3	.6	.8	1.0
3.0	.1	.3	.5	.8	1.0
4.0	.1	.3	.5	.7	1.0
5.0	.1	.3	.5	.7	.9

Submitted by: Carol Henson
Fire Behavior Analyst

FUEL MODEL ------------ 5 – BRUSH, 2 FT (60 CM)

RATE OF SPREAD, CH/H

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	14.	30.	51.	76.	104.
3.0	14.	29.	49.	72.	99.
4.0	13.	28.	47.	69.	95.
5.0	13.	27.	45.	67.	92.

FLAME LENGTH, FT

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	5.3	7.5	9.5	11.4	13.2
3.0	5.1	7.1	9.1	10.9	12.6
4.0	4.9	6.9	8.8	10.5	12.2
5.0	4.7	6.7	8.5	10.2	11.8

MAXIMUM SPOTTING DISTANCE, MI

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0
2.0	.1	.2	.3	.4
3.0	.1	.2	.3	.4
4.0	.1	.2	.3	.4
5.0	.1	.2	.3	.4

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FUEL MODEL ------------ 6 – DORMANT BRUSH, HARDWOOD SLASH

RATE OF SPREAD, CH/H

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	18.	37.	61.	89.	120.
3.0	16.	33.	54.	79.	107.
4.0	14.	30.	49.	72.	96.
5.0	13.	27.	45.	65.	88.

FLAME LENGTH, FT

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	5.1	7.2	9.1	10.8	12.4
3.0	4.7	6.6	8.3	9.9	11.4
4.0	4.4	6.1	7.7	9.2	10.5
5.0	4.1	5.7	7.2	8.6	9.8

MAXIMUM SPOTTING DISTANCE, MI

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0
2.0	.1	.2	.3	.4
3.0	.1	.2	.3	.4
4.0	.1	.2	.3	.4
5.0	.1	.2	.3	.4

FUEL MODEL ------------- 8 – CLOSED TIMBER LITTER

RATE OF SPREAD, CH/H

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	1.	2.	4.	5.	7.
3.0	1.	2.	3.	5.	7.
4.0	1.	2.	3.	4.	6.
5.0	1.	2.	3.	4.	5.

FLAME LENGTH, FT

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	1.0	1.3	1.6	1.9	2.2
3.0	.9	1.2	1.5	1.8	2.1
4.0	.8	1.1	1.4	1.7	1.9
5.0	.8	1.0	1.3	1.5	1.8

MAXIMUM SPOTTING DISTANCE, MI

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	.0	.1	.1	.1	.2
3.0	.0	.1	.1	.1	.2
4.0	.0	.1	.1	.1	.2
5.0	.0	.1	.1	.1	.2

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FUEL MODEL ------------- 9 – TIMBER

RATE OF SPREAD, CH/H

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	5.	9.	16.	25.	37.
3.0	4.	8.	14.	22.	33.
4.0	4.	7.	13.	20.	29.
5.0	3.	6.	11.	18.	27.

FLAME LENGTH, FT

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	2.5	3.4	4.4	5.5	6.5
3.0	2.2	3.1	4.0	5.0	5.9
4.0	2.1	2.8	3.7	4.6	5.4
5.0	1.9	2.6	3.4	4.2	5.0

MAXIMUM SPOTTING DISTANCE, MI

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	.0	.1	.2	.3	.4
3.0	.0	.1	.2	.3	.4
4.0	.0	.1	.2	.3	.3
5.0	.0	.1	.2	.2	.3

FUEL MODEL ------------- 10 – TIMBER (LITTER, UNDERSTORY)

RATE OF SPREAD, CH/H

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	6.	11.	18.	26.	35.
3.0	5.	10.	16.	24.	33.
4.0	5.	9.	16.	23.	31.
5.0	5.	9.	15.	22.	29.

FLAME LENGTH, FT

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	4.7	6.4	8.0	9.5	11.0
3.0	4.5	6.0	7.6	9.0	10.4
4.0	4.3	5.7	7.2	8.6	9.9
5.0	4.1	5.5	6.9	8.3	9.5

MAXIMUM SPOTTING DISTANCE, MI

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	.1	.2	.3	.4	.5
3.0	.1	.2	.3	.4	.5
4.0	.1	.2	.3	.4	.5
5.0	.1	.2	.3	.4	.5

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FUEL MODEL ------------- 11 – LIGHT LOGGING SLASH

RATE OF SPREAD, CH/H

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	4.	7.	11.	15.	19.
3.0	3.	6.	10.	13.	17.
4.0	3.	6.	9.	12.	15.
5.0	3.	5.	8.	11.	14.

FLAME LENGTH, FT

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	3.1	4.1	5.0	5.7	6.4
3.0	2.9	3.8	4.6	5.3	5.9
4.0	2.7	3.5	4.3	4.9	5.5
5.0	2.5	3.3	4.0	4.6	5.2

MAXIMUM SPOTTING DISTANCE, MI

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	.1	.1	.2	.3	.4
3.0	.1	.1	.2	.3	.4
4.0	.0	.1	.2	.3	.3
5.0	.0	.1	.2	.3	.3

Submitted by: Carol Henson
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FUEL MODEL ------------- 12 – MEDIUM LOGGING SLASH

RATE OF SPREAD, CH/H

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	9.	16.	24.	32.	41.
3.0	8.	15.	22.	29.	37.
4.0	7.	13.	20.	26.	33.
5.0	7.	12.	18.	24.	31.

FLAME LENGTH, FT

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	7.6	9.9	11.9	13.7	15.2
3.0	7.0	9.2	11.0	12.6	14.0
4.0	6.6	8.6	10.2	11.7	13.1
5.0	6.2	8.0	9.6	11.0	12.3

MAXIMUM SPOTTING DISTANCE, MI

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	.1	.2	.4	.5	.7
3.0	.1	.2	.4	.5	.6
4.0	.1	.2	.3	.5	.6
5.0	.1	.2	.3	.5	.6

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FUEL MODEL ------------- 13 – HEAVY LOGGING SLASH

RATE OF SPREAD, CH/H

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	11.	20.	29.	39.	49.
3.0	10.	18.	26.	35.	44.
4.0	9.	16.	24.	32.	41.
5.0	9.	15.	22.	29.	37.

FLAME LENGTH, FT

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	10.0	13.0	15.5	17.7	19.8
3.0	9.3	12.1	14.4	16.5	18.4
4.0	8.7	11.3	13.5	15.4	17.2
5.0	8.2	10.6	12.7	14.5	16.1

MAXIMUM SPOTTING DISTANCE, MI

1-HR MOIS (%)	MIDFLAME WIND, MI/H 1.0	3.0	5.0	7.0	9.0
2.0	.1	.3	.4	.5	.7
3.0	.1	.2	.4	.5	.6
4.0	.1	.2	.4	.5	.6
5.0	.1	.2	.3	.5	.6

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