SAN BERNARDINO NATIONAL FOREST
FUELS AND FIRE BEHAVIOR ASSESSMENT
2003

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FUELS ASSESSMENT:

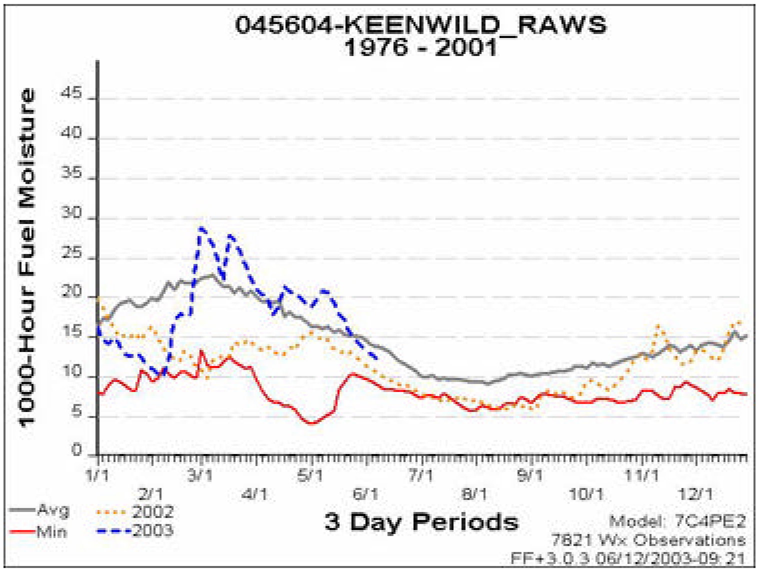
Vegetation consists of ponderosa pine, Jeffrey pine, Coulter pine, white fir, black oak, canyon live oak, chamise, manazanita, ceonothus, Pinion, juniper, sage, and grasses.

There is landscape-level mortality of 5-100% in the timber and chaparral over approximately 350,000 acres of the San Bernardino National Forest. Green trees that appear to be alive are in fact dead, and mortality is still increasing within many of these stands. 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.

A return of near normal winter and spring precipitation after several years of drought has resulted in grass crops that have not been seen in years. This has increased the volume and continuity of fine fuels, especially in the desert areas. This will add significantly to fire potential this year, as fine fuels are more available. The grasses at the lower elevations are dead but there is still a mix of green grasses at the higher elevations. I would expect these to die out by mid-July.

There is new growth in the chaparral along the coastal side of the mountain range; however I didn't observe any new growth on the desert side. Current fuel moistures for chaparral are at 80-90%, which is above the critical threshold of 60% (live fuels will burn like dead fuels at this threshold). These fuel moistures are expected to drop to critical levels or below around mid to the end of July. Fuel moistures in chaparral can continue to drop until dormancy around September-November where they level out until the spring.

The 1,000-hour fuels 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 hit an all time low in February 2003. It rose well above the 20-year average after rains in late February and March. Currently the fuel moisture level is below the 20-year average and is dropping. If trends continue we will probably see new record levels in the 1,000-hour fuel moistures starting in July.



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 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.

Potential for ignition in many of these homes is high in the event of a wildfire. 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 in the Oakland Hills Fire. Public and firefighter safety is of great concern in these areas, especially where it relates to structure protection and a safe working environment for crews.

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.” Next fuels in buildings include a variety of combustibles whereas forest fuels are exclusively cellulosic. Other factors to consider are moisture, which is very important during burning, is controlled within a building, but is determined in wildlands by environmental factors such as the sun, wind and precipitation. Radiation from an indoor fire is trapped inside the building whereas most radiation in a wildland fire escapes. Similarly, most convective heat is trapped in an indoor fire whereas it is lofted into the atmosphere in a wildland fire. Finally, oxygen is severely limited in an indoor fire whereas it is virtually unlimited in a wildland fire. (Information taken from "Community-Scale Fire Spread", Ronald G. Rehm, Anthony Hamins, Howard R. Baum, Kevin B. McGrattan, David D. Evans)

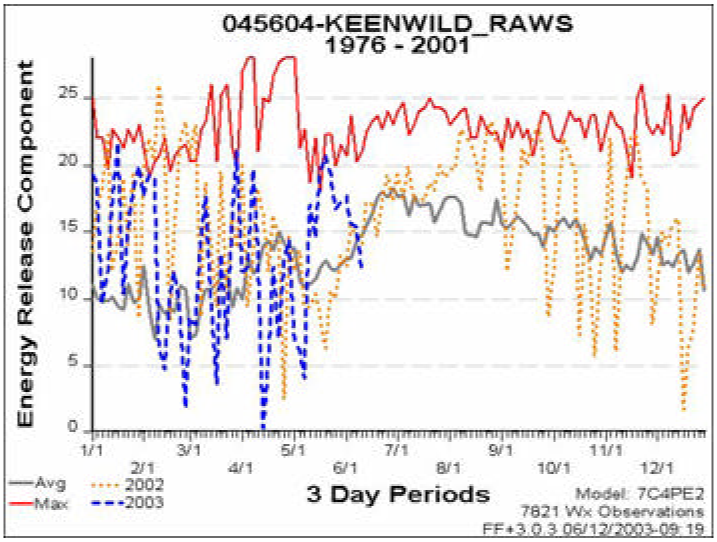
FIRE BEHAVIOR ASSESSMENT:

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 Keenwild RAWS graph shows that record ERC's were observed in mid-May, however the graph below shows that the ERC is dropping due to the cooler, damper weather we've experienced since May. The SCGACC Fire Season Outlook is forecasting warmer than normal temperatures and dry conditions, which are normal to the area. This has the potential to drive ERC's up to record or near record levels this summer.

Unfortunately the Keenwild graph does not display what the 90th or 97th percentile (i.e. 97th percentile = 3% worst weather conditions) is so there is no benchmark to see where we're at relative to those percentiles.



FIRE BEHAVIOR:

The combination of heavy mortality in the vegetation, heavy fuel loading, low live fuel moistures, low 1,000-hour fuel moistures, and the fire weather outlook of above normal temperatures all indicate a high potential for extreme fire behavior. There is a high potential for major fire runs to consume large acreage and threaten and destroy homes in a short period of time. Initial attack, especially aircraft, will be key to keeping a fire from transitioning from a surface fire to a crown fire. October/November is especially critical when the offshore winds are more prevalent.

Dry thunderstorm activity is not normal for the area so some moisture may be occur with the forecasted thunderstorms but any rainfall would be localized and provide no long term or widespread benefits.

Of concern would be multiple ignitions (lightning or arson) which could lead to drawdown of initial attack resources allowing fires to establish and grow before resources can get on scene.

Probability of ignition (PI) or spotting potential will depend on temperatures, relative humidities, shading, and receptive fuels. PI of 70% or greater indicates that spot fires are likely.

Grasses:

Grasses have increased in volume and continuity, especially in the desert areas. This will add significantly to fire potential in all areas this year, as more fine fuels are available to carry fire. Fire behavior in this vegetation will exhibit normal burning conditions in grass. Expect quick ignition and rapid rates of spread with flame lengths of 5-12 feet. Spotting distances around a 1/2-mile are possible. Fires will be too intense for direct attack at the head by crews with hand tools but they can take flanking action. Engines and dozers may be effective with flame lengths under 8 feet. Recommend a flanking action for fires with flame lengths greater than 8 feet.

Chaparral:

Fuel conditions in live chaparral are about normal for this time of year but as the season progresses expect live fuel moistures to drop at or below the critical threshold of 60% (around mid to the end of July). Fire behavior should burn moderately in chaparral until it meets that critical threshold around mid to the end of July.

After the threshold is met expect aggressive burning, extreme rates of spread with flame lengths of 17-37 feet are possible, especially in areas where fuels, slope, and wind are aligned. Spotting distances of up to 1 mile can be expected. These are typical conditions for brush fires, however in standing dead chaparral there will be rates of spread and intensities that exceed the predictions made above. There are no models for standing dead vegetation or for predicting the fire behavior associated with it.

Direct attack at the head of these fires is not safe as fires are too intense. Control efforts at the head may not be effective. Anchoring a fire and flanking is recommended.

TIMBER:

Crown fire potential -

Crown fire potential is extremely high. This will range from passive crowning (also called torching, is one in which individual or small groups of trees torch out), to an active crown fire (is one in which the entire surface/canopy fuel complex becomes involved - the crowning phase remains dependent on heat from the surface fuels for continued spread), and possibly to an independent crown fire (is one that burns in canopy fuels without aid of a supporting surface fire). Independent crown fires occur rarely and are short lived requiring a combination of steep slope, high windspeed, and low foliar moisture content which exists on the San Bernardino.

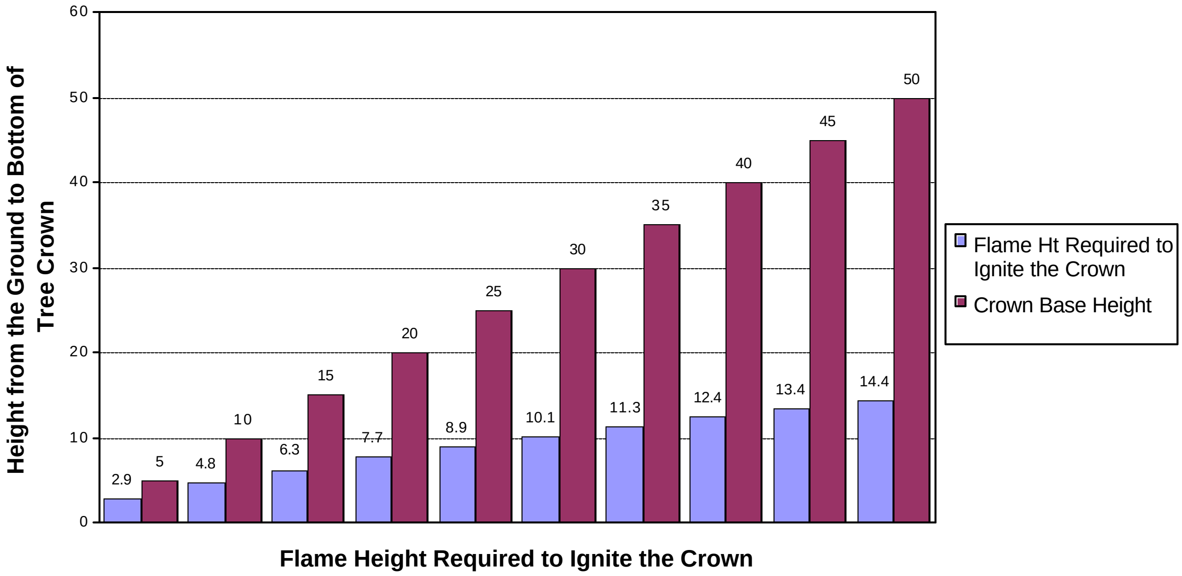
Crowning potential in dead trees:

There's a 100% probability of crown fires occurring in dead standing trees.

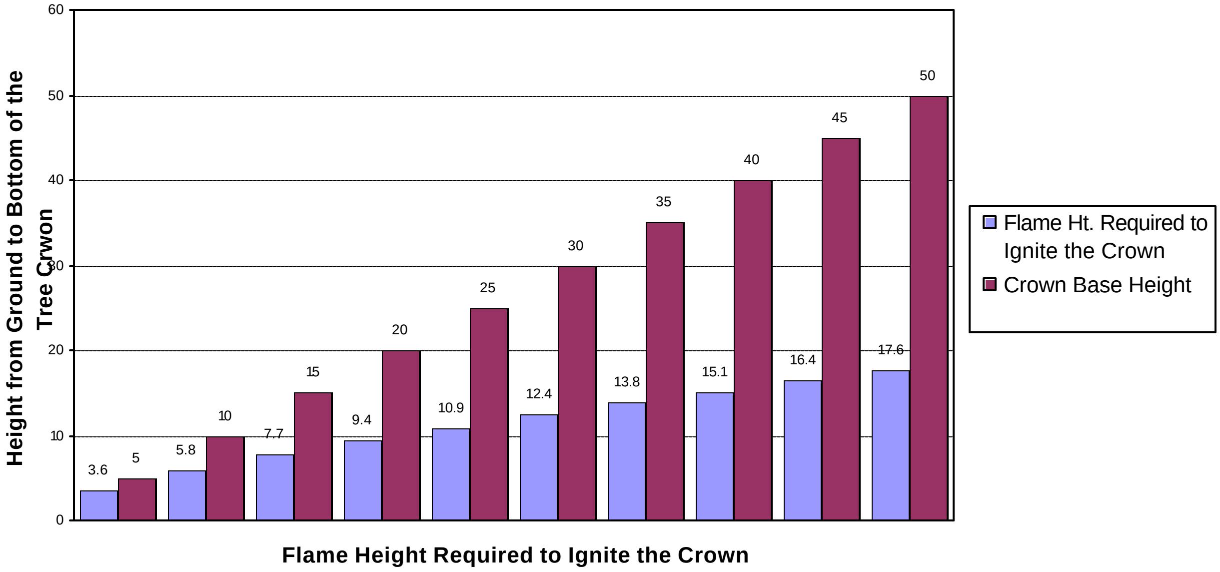
Crowning potential in live trees:

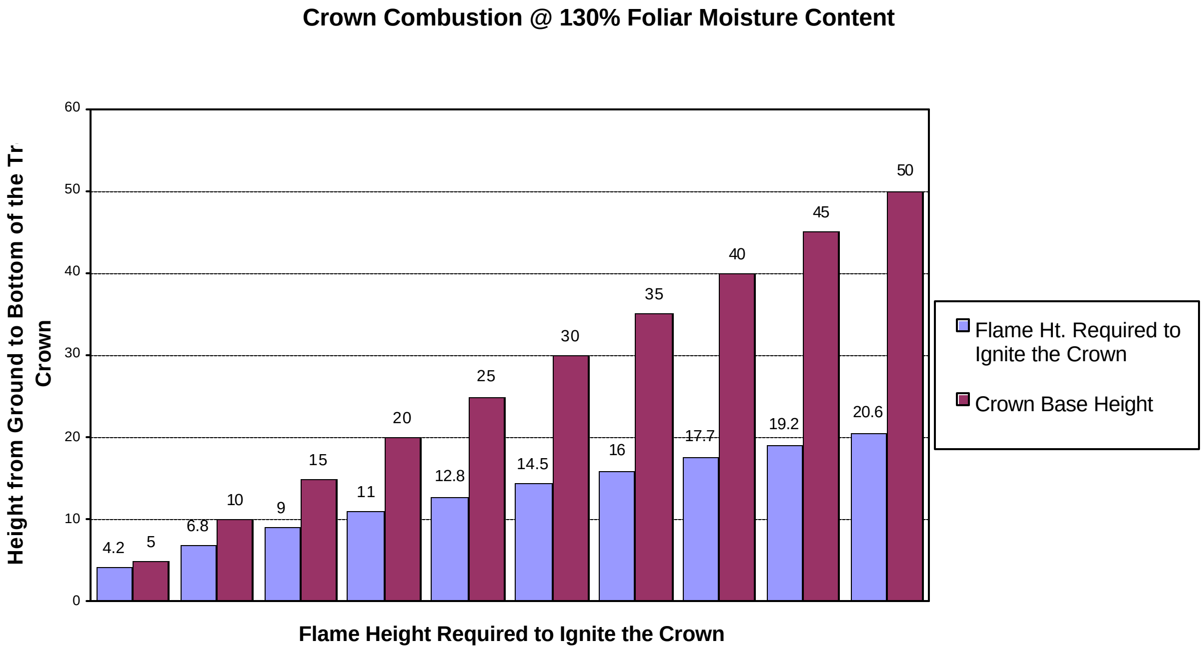
In order for transition to occur from a surface fire to a crown fire a critical surface fire intensity must be attained. The critical surface intensity for crowning is dependant on the crown base height and foliar moisture content. The crown fire initiation is based on a crown fire theory described by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

Crown Combustion @ 70% Foliar Moisture Content



Crown Combustion @ 100% 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.
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.
E. Topography
    1) Steep slopes dramatically increase potential. Heads up during strong down drafts in areas with thunderstorm activity that can push fire downhill. Also in plume dominated fires.

F. Atmospheric conditions

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

Initial attack resources will be instrumental in keeping fire out of the crowns. If initial attack resources, especially aircraft, can arrive on scene early and take safe action 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.

Passive crowning (torching) is likely in many areas. Wind and slope will dictate whether an active crown fire occurs. If 20-foot wind speeds are below 7 mph on flat ground or gentle slopes then moderate spotting distances of up to 1/2-mile are possible. The same could be said with little or no wind on slopes less than 50%.

If a surface fire establishes and slopes >50% and/or wind speeds >7 mph occurs an active crown fires is probable, which can move into an independent crown fire. Fuel moisture sampling of foliar moisture in the timber has not been taken but my estimates are that we're seeing levels below 100% for living green trees. Live foliar fuel moisture levels at 125% and below 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.

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.

PLUME DOMINATED FIRE:

A plume-dominated fire is not as predictable as a wind driven fire as it creates it's 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.
⇒ 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.

The potential for a plume-dominated fire is extremely high; 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.

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:

A rapidly spreading wildland fire coupled with highly ignitable homes can cause many homes to burn simultaneously. This multistructure involvement 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.

For example, significant fire runs destroyed over 650 structures during the 1990 Painted Cave fire in Santa Barbara, most of them within two hours of the initial fire report. The 1993 Laguna Hills fire in southern California ignited and burned nearly all of the 366 homes destroyed in less than five hours. A description by an observer of the Oakland Hills Fire in 1991 said "homes were being ignited one by one by the pine trees which were exploding like three-month-old Christmas trees. The transfer of fires from trees to decks to roof gutters filled with dead pine needles caused one house after another to burn like one match in a matchbook lighting the next match".

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 factor in this situation.

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 Watchout Situations, 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", training, 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, WIND GUSTS, FIREWHIRLS, AND TURBULENCE. SAFETY ZONES IN THESE AREAS WOULD HAVE TO BE MUCH LARGER.**

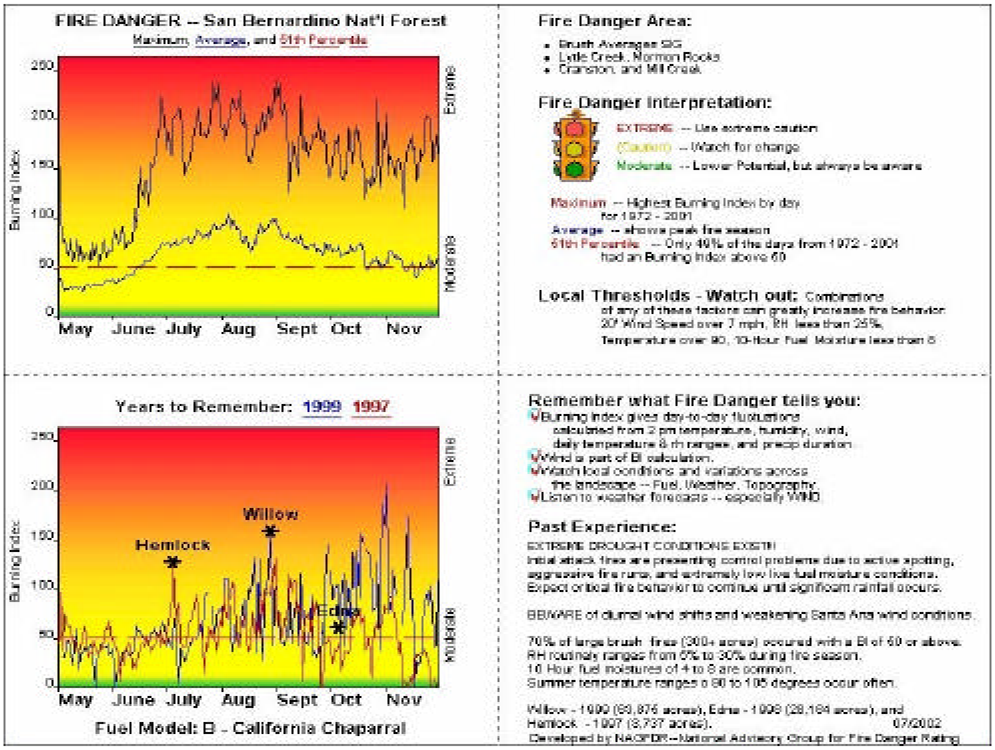
TRIGGER POINTS:

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, and critical burning conditions.

Forest pocket cards:



Fuel Model: B - California Chaparral

Fire Danger Area:

- Brush Averages SIG
- Lytle Creek, Mormon Rocks
- Cranston, and Mill Creek

Fire Danger Interpretation:

EXTREME -- Use extreme caution
(Caution) -- Watch for change
Moderate -- Lower Potential, but always be aware

Maximum -- Highest Burning Index by day
for 1972 - 2001
Average -- shows peak fire season
51th Percentile -- Only 49% of the days from 1972 - 2001
had an Burning Index above 60

Local Thresholds - Watch out: Combinations of any of these factors can greatly increase fire behavior:
20' Wind Speed over 7 mph, RH less than 25%,
Temperature over 90, 10-Hour Fuel Moisture less than 8

Remember what Fire Danger tells you:

✓Burning index gives day-to-day fluctuations calculated from 2 pm temperature, humidity, wind, daily temperature & rh ranges, and precip duration.
✓Wind is part of BI calculation.
✓Watch local conditions and variations across the landscape -- Fuel, Weather, Topography.
✓Listen to weather forecasts -- especially WIND.

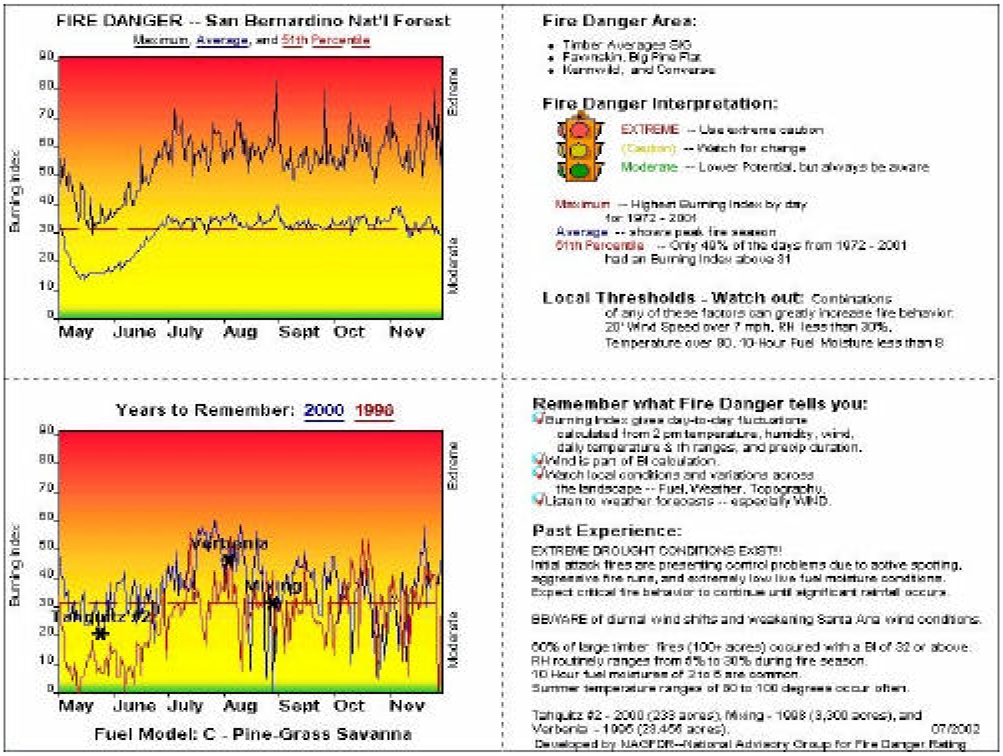
Past Experience:

EXTREME DROUGHT CONDITIONS EXIST!!
Initial attack fires are presenting control problems due to active spotting, aggressive fire runs, and extremely low live fuel moisture conditions.
Expect critical fire behavior to continue until significant rainfall occurs.

BEWARE of diurnal wind shifts and weakening Santa Ana wind conditions.

70% of large brush fires (300+ acres) occured with a BI of 60 or above.
RH routinely ranges from 6% to 30% during fire season.
10 Hour fuel moistures of 4 to 8 are common.
Summer temperature ranges o 90 to 105 degrees occur often.

Willow - 1999 (63,876 acres), Edna - 1998 (28,184 acres), and
Hemlock - 1997 (8,737 acres). 07/2002
Developed by NAGFDR--National Advisory Group for Fire Danger Rating



Fuel Model: C - Pine-Grass Savanna

Fire Danger Area:

- Timber Averages SIG
- Fawnskin, Big Pine Flat
- Kennwild, and Converse

Fire Danger Interpretation:

EXTREME -- Use extreme caution
(Caution) -- Watch for change
Moderate -- Lower Potential, but always be aware

Maximum -- Highest Burning Index by day
for 1972 - 2001
Average -- shows peak fire season
51th Percentile -- Only 49% of the days from 1972 - 2001
had an Burning Index above 31

Local Thresholds - Watch out: Combinations of any of these factors can greatly increase fire behavior:
20' Wind Speed over 7 mph, RH less than 30%,
Temperature over 80, 10-Hour Fuel Moisture less than 8

Remember what Fire Danger tells you:

✓Burning index gives day-to-day fluctuations calculated from 2 pm temperature, humidity, wind, daily temperature & rh ranges, and precip duration.
✓Wind is part of BI calculation.
✓Watch local conditions and variations across the landscape -- Fuel, Weather, Topography.
✓Listen to weather forecasts -- especially WIND.

Past Experience:

EXTREME DROUGHT CONDITIONS EXIST!!
Initial attack fires are presenting control problems due to active spotting, aggressive fire runs, and extremely low live fuel moisture conditions.
Expect critical fire behavior to continue until significant rainfall occurs.

BEWARE of diurnal wind shifts and weakening Santa Ana wind conditions.

60% of large timber fires (100+ acres) occured with a BI of 32 or above.
RH routinely ranges from 6% to 30% during fire season.
10 Hour fuel moistures of 2 to 6 are common.
Summer temperature ranges of 80 to 100 degrees occur often.

Tahquitz #2 - 2000 (233 acres), Mixing - 1998 (3,300 acres), and
Verbenia - 1996 (23,456 acres). 07/2002
Developed by NAGFDR--National Advisory Group for Fire Danger Rating

SUPPORTING INPUT:

Assessment comments:

Fire behavior calculations provided are based upon general 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.

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 due to the live component in those models. 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.

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.

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)

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

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

===================================
MAXIMUM SPOTTING DISTANCE, MI
===================================
 1-HR  I      MIDFLAME WIND, MI/H
 MOIS  I
       I   1.0   3.0   5.0   7.0   9.0
 (%)   I---------------------------------------------
       I
 2.0   I    .1    .2    .3    .5    .6
       I
 3.0   I    .1    .2    .3    .4    .6
       I
 4.0   I    .1    .2    .3    .4    .6
       I
 5.0   I    .1    .2    .3    .4    .5
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FUEL MODEL 4 -- CHAPARRAL, 6 FT

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

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

===================================
MAXIMUM SPOTTING DISTANCE, MI
=================================
 1-HR  I      MIDFLAME WIND, MI/H
 MOIS  I
       I   1.0   3.0   5.0   7.0   9.0
 (%)   I---------------------------------------------
       I
 2.0   I    .1    .3    .6    .8   1.0
       I
 3.0   I    .1    .3    .5    .8   1.0
       I
 4.0   I    .1    .3    .5    .7   1.0
       I
 5.0   I    .1    .3    .5    .7    .9
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FUEL MODEL ------------ 5 – BRUSH, 2 FT (60 CM)

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

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

=================================
MAXIMUM SPOTTING DISTANCE, MI
=================================
 1-HR  I      MIDFLAME WIND, MI/H
 MOIS  I
       I   1.0   3.0   5.0   7.0
 (%)   I------------------------------
       I
 2.0   I    .1    .2    .3    .4
       I
 3.0   I    .1    .2    .3    .4
       I
 4.0   I    .1    .2    .3    .4
       I
 5.0   I    .1    .2    .3    .4
```

****

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

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

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

==================================
MAXIMUM SPOTTING DISTANCE, MI
==================================
 1-HR  I      MIDFLAME WIND, MI/H
 MOIS  I
       I   1.0   3.0   5.0   7.0
 (%)   I--------------------------------
       I
 2.0   I    .1    .2    .3    .4
       I
 3.0   I    .1    .2    .3    .4
       I
 4.0   I    .1    .2    .3    .4
       I
 5.0   I    .1    .2    .3    .4
```

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

```
==================================
RATE OF SPREAD, CH/H
==================================
 1-HR  I      MIDFLAME WIND, MI/H
 MOIS  I
       I   1.0   3.0   5.0   7.0   9.0
 (%)   I------------------------------------------------
       I
 2.0   I   1.    2.    4.    5.    7.
       I
 3.0   I   1.    2.    3.    5.    7.
       I
 4.0   I   1.    2.    3.    4.    6.
       I
 5.0   I   1.    2.    3.    4.    5.

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

====================================
MAXIMUM SPOTTING DISTANCE, MI
==================================
 1-HR   I      MIDFLAME WIND, MI/H
 MOIS   I
        I   1.0   3.0   5.0   7.0   9.0
 (%)    I---------------------------------------------------
        I
 2.0    I    .0    .1    .1    .1    .2
        I
 3.0    I    .0    .1    .1    .1    .2
        I
 4.0    I    .0    .1    .1    .1    .2
        I
 5.0    I    .0    .1    .1    .1    .2
```

****

FUEL MODEL ------------ 9 – TIMBER

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

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

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

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

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

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

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

****

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

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


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


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

FUEL MODEL ------------ 12 – MEDIUM LOGGING SLASH

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

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

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

****

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

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

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

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

5.0     I    .1    .2    .3    .5    .6
```