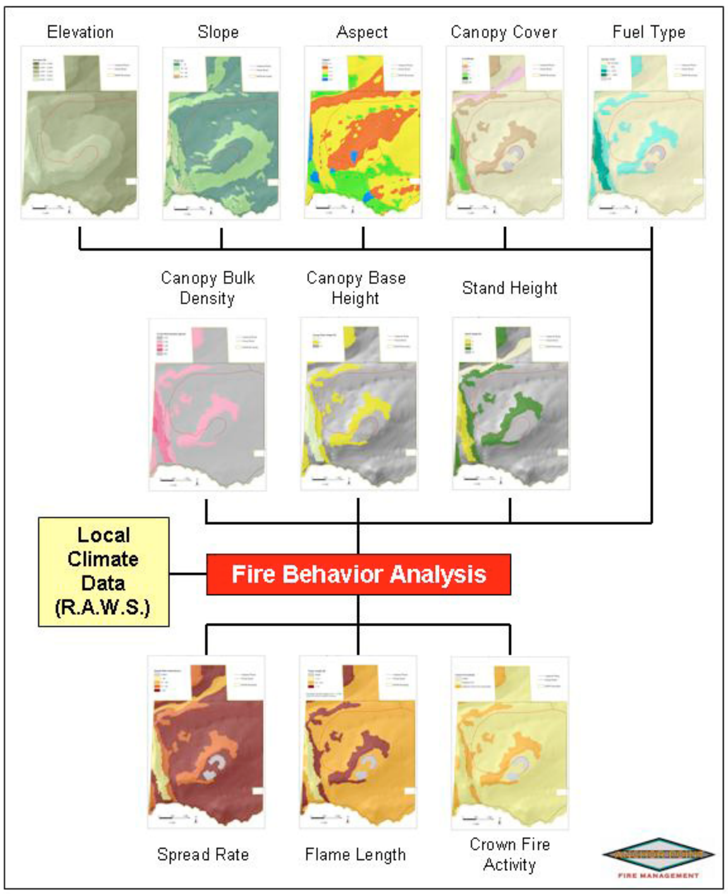
APPENDIX A

Fire Behavior Potential Analysis Methodology

PURPOSE

The purpose of this document is to describe the methodology used to evaluate the threat represented by physical hazards—such as fuels, weather and topography—to values at risk in the study area, by modeling their effects on fire behavior potential.

Figure 1. Flow Chart



The fire behavior potential analysis reports graphically the probable range of spread rate, flame length, and crown fire potential for the analysis area, based upon a set of inputs significant to fire behavior. The model inputs include aspect, slope, elevation, canopy cover, fuel type, canopy bulk density, canopy base height, stand height, and climate data. The model outputs are determined using FlamMap[1], which combines surface fire predictions with the potential for crown fire

1 Mark Finney, Stuart Brittain and Rob Seli., The Joint Fire Sciences Program of the Rocky Mountain Research Station (USDA Forest Service, Missoula, Montana), the Bureau of Land Management and Systems for Environmental Management (Missoula, Montana).

development. Calculations for surface fire predictions (rate of spread and flame length) are based on the USDA Forest Service's BEHAVE[2] model.

BEHAVE

The BEHAVE fire behavior prediction and fuel modeling system was employed to determine surface fire behavior estimates for this study. BEHAVE is a nationally recognized set of calculations used to estimate a surface fire's intensity and rate of spread, given certain conditions of topography, fuels, and weather. The BEHAVE modeling system has been used for a variety of applications, including prediction of an ongoing fire, prescribed fire planning, fuel hazard assessment, initial attack dispatch, and fire prevention planning and training. Predictions of wildland fire behavior are made for a single point in time and space, given simple user-defined fuels, weather, and topography. Requested values depend on the modeling choices made by the user.

Assumptions of BEHAVE:

- Fire is predicted at the flaming front
- Fire is free burning
- Behavior is heavily weighted towards the fine fuels
- Continuous and uniform fuels
- Surface fires

FlamMap

Anchor Point used FlamMap to evaluate the potential fire conditions in the fire behavior study area. The Grand Fire Protection District study area encompasses 94,282 acres (147 square miles). The study area for the fire behavior analysis covers approximately 127,878 acres (200 square miles). This area includes the study area and a 1-mile buffer in all directions. The inclusion of this buffer provides the user with an analysis of potential fire behavior on adjacent lands. From both a planning and tactical perspective, it is important to evaluate exposures beyond the area of interest. The study area is broken down into grid cells of 30-meters per side. Using existing vector and raster spatial data and field data, ArcGIS spatial analysis capabilities are used to calculate model inputs for each 30m cell. These values are input into FlamMap, along with reference weather and fuel moisture (long-term weather observations statistically calculated from the Porcupine Creek Remote Automated Weather Station (RAWS) information). The outputs of FlamMap include the estimated Rate of Spread (ROS) (from BEHAVE), Flame Length (FL) (from BEHAVE) and Crown Fire Activity for a fire in each 30m cell. The model computes these values for each cell in the study area independently, so the data in each cell is unaffected by adjacent cells.

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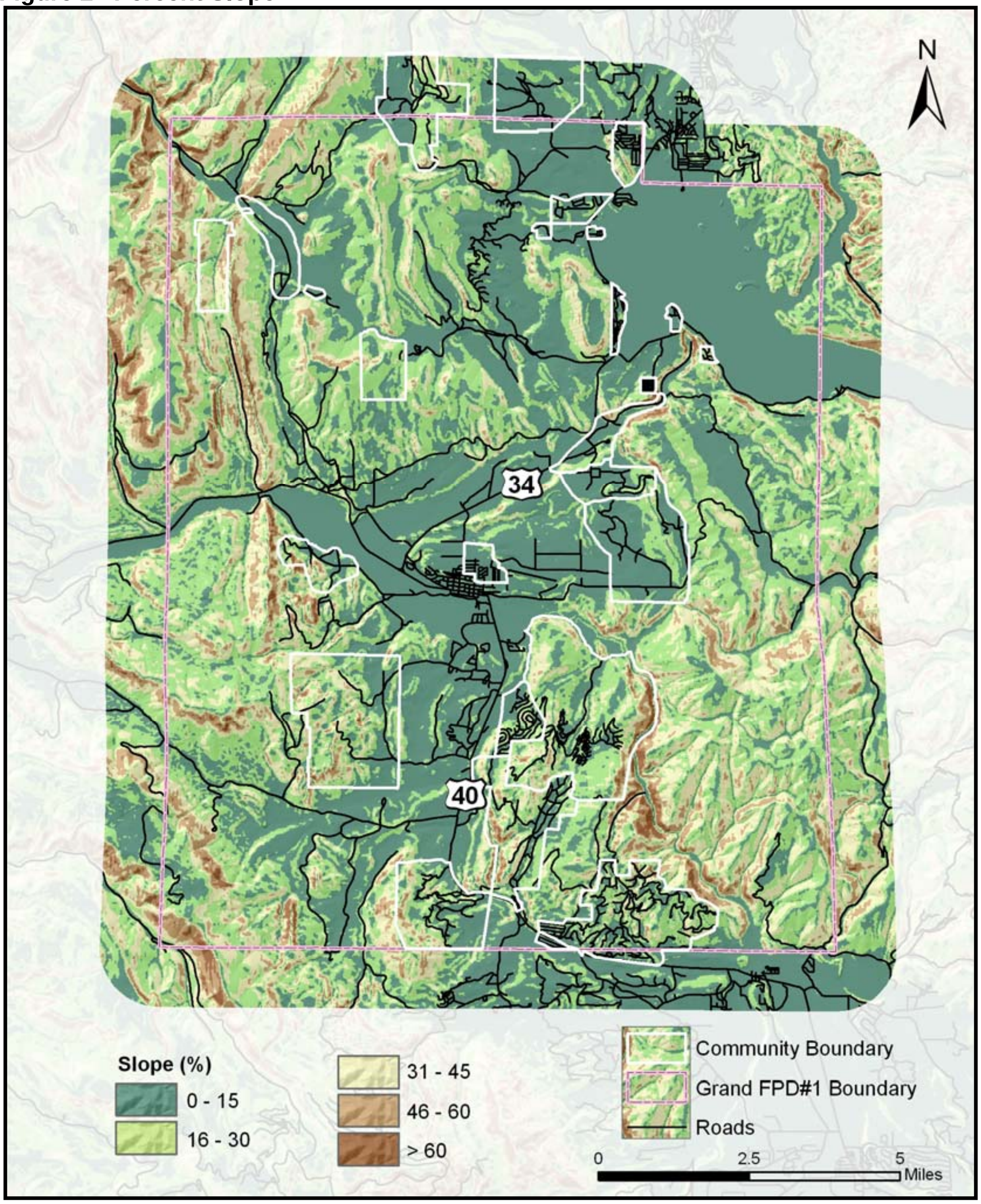
2 Patricia L. Andrews, producer and designer, Collin D. Bevins, programmer and designer, The Joint Fire Sciences Program of the Rocky Mountain Research Station (USDA Forest Service, Missoula, Montana) and Systems for Environmental Management (Missoula, Montana).

Fire Behavior Inputs

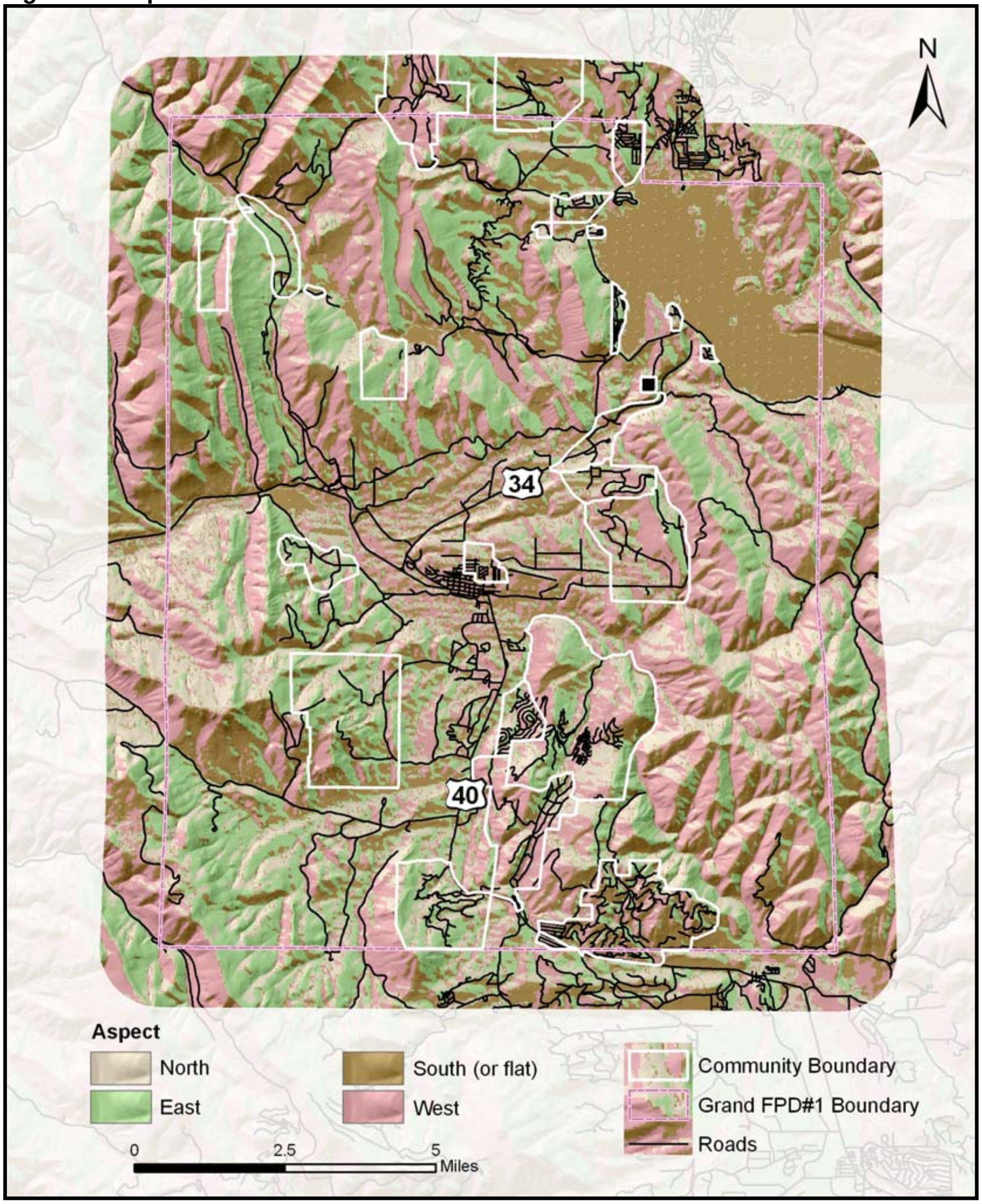
The major factors influencing fire behavior are fuels (type and coverage), weather, and topography (aspect, slope, and elevation). The following pages contain a brief explanation of each.

Figure 2. Percent Slope



Slopes are shown here as percent (rise/run x100). Steeper slopes intensify fire behavior and thus will contribute to a higher wildfire hazard rating. Rates of spread for a slope of 30% are typically double those of flat terrain, when all other influences are equal.

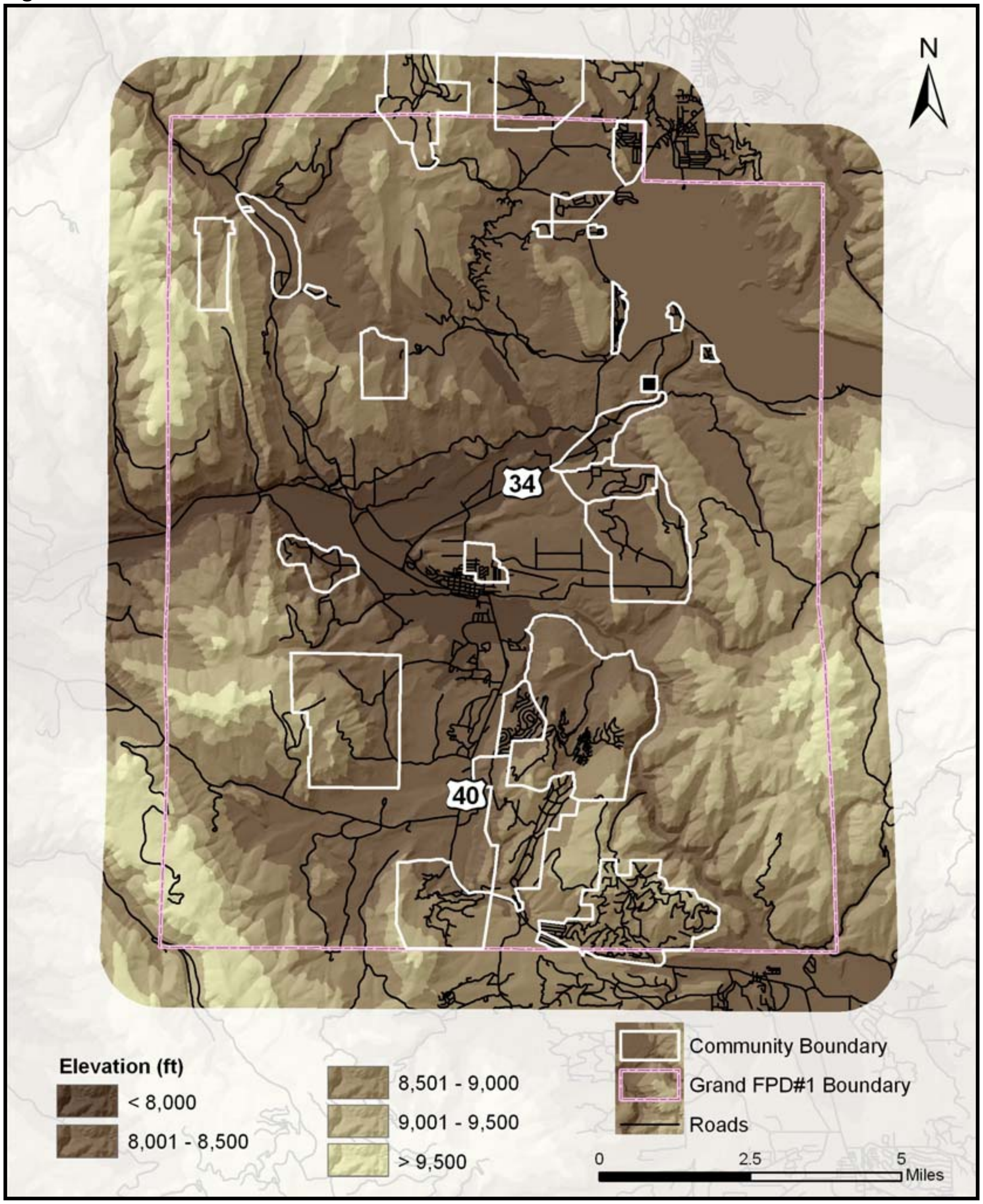
Figure 3. Aspect



Aspects are shown as degrees from north ranging from 0 to 360 according to their orientation. Aspects are influential in the type and quantity of vegetative fuels. Fuels on south facing slopes tend to be drier and more lightly loaded than fuels on north facing slopes, when all other influences are equal. Aspect also has an influence on plant species dominance.

Classification	North	East	South	West
Range	315-45	45-135	135-225	225-315

Figure 4. Elevation



Elevations within the study area range from approximately 8,300′ to over 13,000′. As elevation increases, environmental conditions, fuel species, and characteristics change.

Fuel Models and Fire Behavior

Fire behavior fuel models are a set of numbers that describe fuels in terms that a fire behavior model, in this case FlamMap, can use. There are seven characteristics used to categorize fuel models:

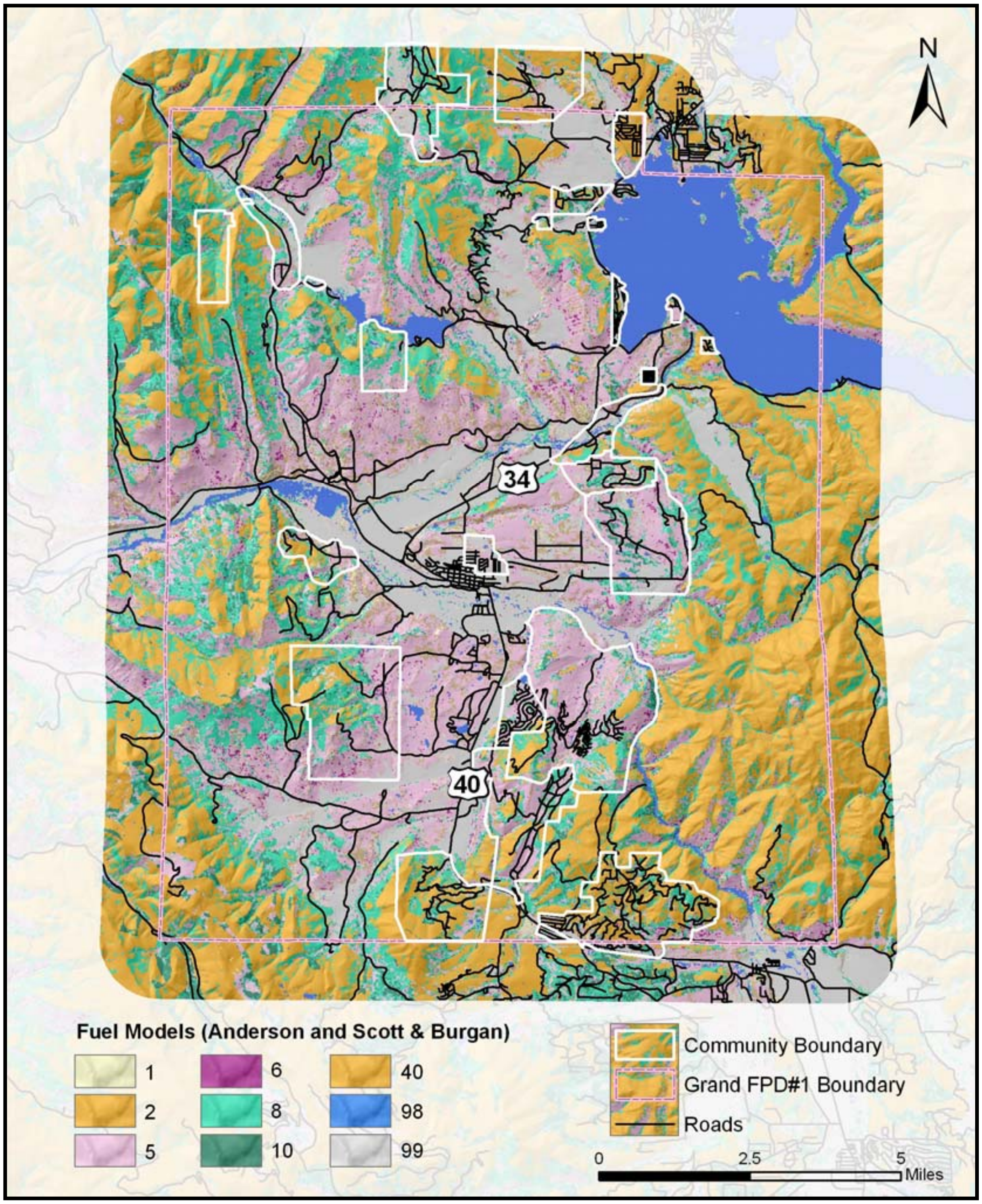
- Fuel Loading
- Size and Shape
- Compactness
- Horizontal Continuity
- Vertical Arrangement
- Moisture Content
- Chemical Content

Each of the major fuel types present in the study area are described below, in terms of the characteristics that coincide with that fuel model. Fuel model descriptions are taken from Anderson's *Aids to Determining Fuel Models for Estimating Fire Behavior*[3]*,* a national standard guide to fuel modeling, unless otherwise noted. **Vegetation for the project area may or may not be specifically listed in the description**. Plant species are only an aid to help visualize the characteristics of the model. The photos are taken from the project area and show where the local vegetation fits in. A table showing a range of surface fire behavior under moderate burning conditions based on the **BEHAVE** system is also included.

The study area is represented primarily by nine fuel models (FM): FM 1, 2, 5, 6, 8,10, and 40. Other fuel models exist, but not in quantities sufficient to significantly influence fire behavior in the Wildland Urban Interface. Fuel models 98, and 99 in the map legend indicate areas of insignificant combustibility such as water, rock, sand, etc. Fuel model 40 is a custom fuel model to describe standing dead stands of conifers with the needles still on (standing red-needle MPB trees). **Figure 5** displays the fuel types graphically for the study area.

3 Anderson, Hal E., Aids to Determining Fuel Models for Estimating Fire Behavior, National Wildfire Coordinating Group, NFES 1574, April 1982.

Figure 5. Grand FPD Fuel Models



FUEL MODEL 1

Figure 6. Short Grass

Characteristics

Grasslands and savanna are represented along with stubble, grass-tundra, and grass-shrub combinations.

Common Types/Species

Annual and perennial grasses are included in this fuel model.

Fire Behavior

Fire spread is governed by the fine, very porous, and continuous herbaceous fuels that have cured or are nearly cured. Fires in this fuel model are surface fires that move rapidly through the cured grass and associated material. Very little shrub or timber is present—generally less than one third of the area.

FUEL MODEL 1

Rate of spread in chains/hour
(1 chain=66 ft) (80 chains/HR = 1 MPH)

Fine Dead Fuel moisture %	Mid-flame Wind Speed: 2.0	4.0	6.0	8.0	10.0	12.0
2.0	28.8	92.9	203.6	362.4	570.1	665.6
4.0	22	71.1	155.7	277	345.1	345.1
6.0	19.4	62.4	136.8	243.4	270.1	270.1
8.0	16.7	53.9	118.1	198.7	198.7	198.7
10.0	11	35.6	64.8	64.8	64.8	64.8
12.0	0	0	0	0	0	0

****Moderate Weather inputs from Porcupine Creek RAWS with 10% slope were used for all tables****

Flame Length in Feet

Fine Dead Fuel moisture %	Mid-flame Wind Speed: 2.0	4.0	6.0	8.0	10.0	12.0
2.0	3	5.1	7.3	9.6	11.8	12.7
4.0	2.4	4.1	5.9	7.8	8.6	8.6
6.0	2.2	3.8	5.5	7.1	7.5	7.5
8.0	2	3.4	4.9	6.3	6.3	6.3
10.0	1.4	2.4	3.2	3.2	3.2	3.2
12.0	0	0	0	0	0	0

FUEL MODEL 2

FIGURE 7. Open canopy trees with grass understory

Characteristics

Fire spread is primarily through the fine herbaceous fuels, either curing or dead.

Common Types/Species

Open shrub lands and pine stands or scrub oak stands that cover one third to two thirds of the area may generally fit this model. Such stands may include clumps of fuels that generate higher intensities and that may produce firebrands. Some Pinyon-juniper may be in this model.

Fire Behavior

These are surface fires where the herbaceous material—in addition to litter and dead/down stemwood from the open shrub or timber overstory—contributes to the fire intensity.

FUEL MODEL 2

Rate of spread in chains/hour
(1 chain=66 ft) (80 chains/HR = 1 MPH)

		Mid-flame Wind Speed					
Fine Dead Fuel moisture %		2.0	4.0	6.0	8.0	10.0	12.0
	2.0	12.2	33.6	66.4	109.8	163.3	226.4
	4.0	10	27.6	54.6	90.3	134.3	186.2
	6.0	8.9	24.6	48.7	80.4	119.6	165.9
	8.0	8.2	22.7	44.8	74	110.1	152.6
	10.0	7.3	20.2	39.8	65.8	97.9	135.8
	12.0	5.7	15.8	31.2	51.6	76.7	106.4

Flame Length in Feet

		Mid-flame Wind Speed					
Fine Dead Fuel moisture %		2.0	4.0	6.0	8.0	10.0	12.0
	2.0	4.2	6.8	9.3	11.7	14	16.3
	4.0	3.6	5.8	7.9	10	12	13.9
	6.0	3.3	5.3	7.3	9.2	11	12.8
	8.0	3.2	5	6.9	8.7	10.4	12.1
	10.0	2.9	4.6	6.3	7.9	9.5	11.1
	12.0	2.4	3.7	5.1	6.5	7.8	9

FUEL MODEL 5

Figure 8. Young Shrub Stands with Primarily Live Fuels

Characteristics

This model consists of continuous stands of low brush. Generally, heights do not exceed six feet. The stands will have a grass or scattered grass understory. Usually shrubs are short and almost totally cover the area.

Common Types/Species

Young, green stands with no dead wood would qualify: Laurel, Vine maple, Alder, or even chaparral, Manzanita, or Chamise. Mountain grasses are also associated with this type.

Fire Behavior

The fires are generally not very intense because surface fuel loads are light, the shrubs are young with little dead material, and the foliage contains little volatile material. Fire is generally carried in the surface fuels that are made up of litter cast by the shrubs and the grasses or forbs in the understory. Cured leaves retained on shrubs can cause greater intensities.

FUEL MODEL 5

Rate of spread in chains/hour
(1 chain=66 ft) (80 chains/HR = 1 MPH)

Fine Dead Fuel moisture %	Mid-flame Wind Speed 2.0	4.0	6.0	8.0	10.0	12.0
2.0	7.5	17.5	29.8	43.7	59.2	75.9
4.0	5.8	13.6	23	33.9	45.8	58.8
6.0	3	6.9	11.8	17.3	23.5	30.1
8.0	2.4	5.7	9.7	14.2	19.2	20.1
10.0	2.4	5.5	9.4	13.8	18.6	18.8
12.0	2.3	5.3	9	13.2	17.4	17.4

Flame Length in Feet

Fine Dead Fuel moisture %	Mid-flame Wind Speed 2.0	4.0	6.0	8.0	10.0	12.0
2.0	3.7	5.4	6.9	8.2	9.5	10.6
4.0	2.9	4.3	5.5	6.5	7.5	8.4
6.0	1.6	2.3	3	3.5	4.1	4.6
8.0	1.3	1.9	2.5	3	3.4	3.5
10.0	1.3	1.9	2.4	2.9	3.3	3.3
12.0	1.2	1.8	2.3	2.8	3.2	3.2

FUEL MODEL 6

FIGURE 9. Dormant Brush

Characteristics

Shrubs in Fuel Model 6 are older than, but not as tall as, the shrub types of Fuel Model 4. They also do not contain as much fuel as FM 4.

Common Types/Species

This model covers a broad range of shrub conditions. Fuel situations to be considered include intermediate stands of Chamise, chaparral, oak brush, low Pocosin, Alaskan spruce taiga, and shrub tundra. Even hardwood slash that has cured can be considered. Pinyon-juniper shrub lands may be represented but may over-predict rate of spread except at high winds, such as 20 mi/h (32 km/h) at the 20-foot level.

Fire Behavior

Fires carry through the shrub layer where the foliage is more flammable than fuel model 5, but this requires moderate winds, greater than 8 mi/h (13 km/h), at mid-flame height. Fire will drop to the ground at low wind speeds or at openings in the stand.

FUEL MODEL 6

Rate of spread in chains/hour
(1 chain=66 ft) (80 chains/HR = 1 MPH)

		Mid-flame Wind Speed					
Fine Dead Fuel moisture %		2.0	4.0	6.0	8.0	10.0	12.0
	2.0	16.4	36.7	60.9	88.1	117.8	149.5
	4.0	13.4	30	49.8	72	96.3	122.2
	6.0	11.4	25.5	42.3	61.2	81.8	103.9
	8.0	10.1	22.5	37.4	54.1	72.2	91.7
	10.0	9.1	20.5	34	49.2	65.7	83.4
	12.0	8.5	19	31.5	45.5	60.9	77.3

Flame Length in Feet

		Mid-flame Wind Speed					
Fine Dead Fuel moisture %		2.0	4.0	6.0	8.0	10.0	12.0
	2.0	4.8	7	8.8	10.4	11.9	13.3
	4.0	4.1	6	7.6	9	10.3	11.4
	6.0	3.7	5.3	6.7	8	9.1	10.2
	8.0	3.4	4.9	6.2	7.3	8.4	9.4
	10.0	3.2	4.6	5.8	6.9	7.9	8.8
	12.0	3.1	4.4	5.6	6.6	7.6	8.4

FUEL MODEL 8

Figure 10. Riparian and Lodgepole Stands

Characteristics

Hardwoods that have leafed out support fire in the compact litter layer. This layer is mainly needles, leaves, and occasionally twigs, because little undergrowth is present in the stand. Amounts of needle and woody litter are also low.

Common Types/Species

Closed canopy stands of short-needle conifers or hardwoods. Representative conifer types are White pine, Lodgepole pine, spruce, fir and larch.

Fire Behavior

Fires in this fuel model are slow burning and low intensity, burning in surface fuels. Fuels are mainly needles and woody litter. Heavier fuel loadings from old dead and down trees or branches can cause flare-ups. Heavier fuel loads have the potential to develop crown fires in extreme burning conditions.

FUEL MODEL 8

Rate of spread in chains/hour
(1 chain=66 ft) (80 chains/HR = 1 MPH)

Fine Dead Fuel moisture %	Mid-flame Wind Speed					
	2.0	4.0	6.0	8.0	10.0	12.0
2.0	1.1	2.2	3.8	5.6	7.6	9.5
4.0	0.9	1.8	3.1	4.5	6.2	6.5
6.0	0.7	1.5	2.6	3.8	4.7	4.7
8.0	0.6	1.3	2.2	3.3	3.7	3.7
10.0	0.6	1.2	2	3	3.1	3.1
12.0	0.5	1.1	1.8	2.7	2.7	2.7

Flame Length in Feet

Fine Dead Fuel moisture %	Mid-flame Wind Speed					
	2.0	4.0	6.0	8.0	10.0	12.0
2.0	0.9	1.3	1.6	1.9	2.2	2.5
4.0	0.8	1.1	1.4	1.7	1.9	2
6.0	0.7	1	1.2	1.5	1.6	1.6
8.0	0.6	0.9	1.1	1.3	1.4	1.4
10.0	0.6	0.8	1	1.2	1.3	1.3
12.0	0.5	0.8	1	1.2	1.2	1.2

FUEL MODEL 10

Figure 11. Mixed Conifer Stands

Characteristics

This model is represented by dense stands of over-mature ponderosa pine, Lodgepole pine, mixed-conifer, and continuous stands of Douglas-fir. Heavy down material is present in all stand types. There is also a large amount of dead/down woody fuels. Reproduction may be present, acting as ladder fuels. This model includes stands of budworm-killed Douglas-fir, closed stands of Ponderosa pine with large amounts of ladder and surface fuels, and stands of Lodgepole pine with heavy loadings of downed trees. This model can occur from the foothills through the sub-alpine zone.

Common Types/Species

Many types of vegetation can occur in this model, but primary species are Spruce/fir, Ponderosa pine, and Lodgepole pine.

Fire Behavior

Fire intensities can be moderate to extreme. Fire moves through dead, down woody material. Torching and spotting are more frequent. Crown fires are quite possible.

FUEL MODEL 10

Rate of spread in chains/hour
(1 chain=66 ft) (80 chains/HR = 1 MPH)

Fine Dead Fuel moisture %	Mid-flame Wind Speed 2.0	4.0	6.0	8.0	10.0	12.0
2.0	3.2	7	11.6	17.1	23.1	29.7
4.0	2.8	6.2	10.3	15.2	20.5	26.4
6.0	2.6	5.6	9.4	13.8	18.7	24
8.0	2.4	5.2	8.8	12.9	17.4	22.4
10.0	2.3	5	8.3	12.2	16.6	21.3
12.0	2.2	4.8	8	11.7	15.9	20.4

Flame Length in Feet

Fine Dead Fuel moisture %	Mid-flame Wind Speed 2.0	4.0	6.0	8.0	10.0	12.0
2.0	3.5	5	6.3	7.5	8.7	9.7
4.0	3.2	4.5	5.7	6.8	7.8	8.8
6.0	2.9	4.2	5.3	6.3	7.3	8.2
8.0	2.8	4	5	6	6.9	7.7
10.0	2.7	3.8	4.8	5.8	6.6	7.4
12.0	2.6	3.7	4.7	5.6	6.4	7.2

FUEL MODEL 40

Figure 12. Mountain pine beetle infected Lodgepole stands

Characteristics

This custom model was created to capture Mountain pine beetle (MPB) infested Lodgepole pine stands. The model has most of the characteristics of FM 8 with some modifications to better represent the effects of MPB on the stand. The 1 hour fuels are increased, to account for needle fall, as is the fuel bed depth. The Canopy Bulk Density has been reduced to better represent the loss of red needles. This is an attempt to model an average condition. In reality, some trees lose needles more quickly and some retain them longer. Trees are also in different stages of decline, depending on when they were infected.

Common Types/Species

Primary species is Lodgepole pine.

Fire Behavior

Fire intensities can be moderate to extreme. Surface fires will have larger flame lengths and higher rates of spread with the continuous red needle layer. Transition from surface fire to torching and crowning is more likely because the needles on the trees are dead and more receptive. Some needles stay on the tree for several years and continue to create high potential for crown fire. Trees that have dropped some of the needles are more prone to torching than crowning.

FUEL MODEL 40

Rate of spread in chains/hour
(1 chain=66 ft) (80 chains/HR = 1 MPH)

Fine Dead Fuel moisture %	Mid-flame Wind Speed					
	2.0	4.0	6.0	8.0	10.0	12.0
2.0	3.8	8.3	14	20.5	27.7	35.6
4.0	3.4	7.4	12.4	18.1	24.6	31.6
6.0	3.1	6.7	11.2	16.5	22.3	28.7
8.0	2.9	6.2	10.4	15.3	20.7	26.6
10.0	2.7	5.9	9.9	14.4	19.6	25.1
12.0	2.6	5.6	9.4	13.8	18.6	24

Flame Length in Feet

Fine Dead Fuel moisture %	Mid-flame Wind Speed					
	2.0	4.0	6.0	8.0	10.0	12.0
2.0	3.9	5.5	7	8.3	9.6	10.7
4.0	3.5	5	6.3	7.5	8.6	9.7
6.0	3.2	4.6	5.8	7	8	9
8.0	3	4.3	5.5	6.6	7.6	8.5
10.0	2.9	4.2	5.3	6.3	7.2	8.1
12.0	2.8	4	5.1	6.1	7	7.9

REFERENCE WEATHER USED IN THE FIRE BEHAVIOR POTENTIAL EVALUATION

The weather inputs for FlamMap were created by using weather data collected at the Porcupine Creek Remote Automated Weather Station (RAWS).

Porcupine Creek Site Information

Latitude (dd mm ss)	40 ° 05' 52 " N
Longitude (dd mm ss)	106 ° 40 ' 47 " W
Elevation (ft.)	8,880

Weather observations for a twenty-two year period (1985-2007) from the Porcupine Creek Remote Automated Weather Station (RAWS) were used to calculate these conditions. The average conditions class (16th to 89th percentile) was calculated for each variable (1 hour, 10 hour, and 100 hour fuel moisture, woody fuel moisture, herbaceous fuel moisture, and wind speed) using Fire Family Plus. This weather condition class most closely represents an average fire season day.

The extreme conditions class was calculated using 97th percentile weather data. In other words, the weather conditions on the most severe fire weather days (sorted by Spread Component) in each season for the twenty-two year period were used for this analysis. It is reasonable to assume that similar conditions exist on at least three to five days of the fire season during an average year. In fact, during extreme years such conditions may exist for significantly longer periods. Even these calculations may be conservative compared to observed fire behavior. The following values were used in **FlamMap**:

Average Weather Conditions	
Variable	**Value**
20 ft Wind speed up slope	17 mph
Herbaceous fuel moisture	101%
Woody fuel moisture	122%
100-hr fuel moisture	14%
10-hr fuel moisture	10%
1-hr fuel moisture	6%

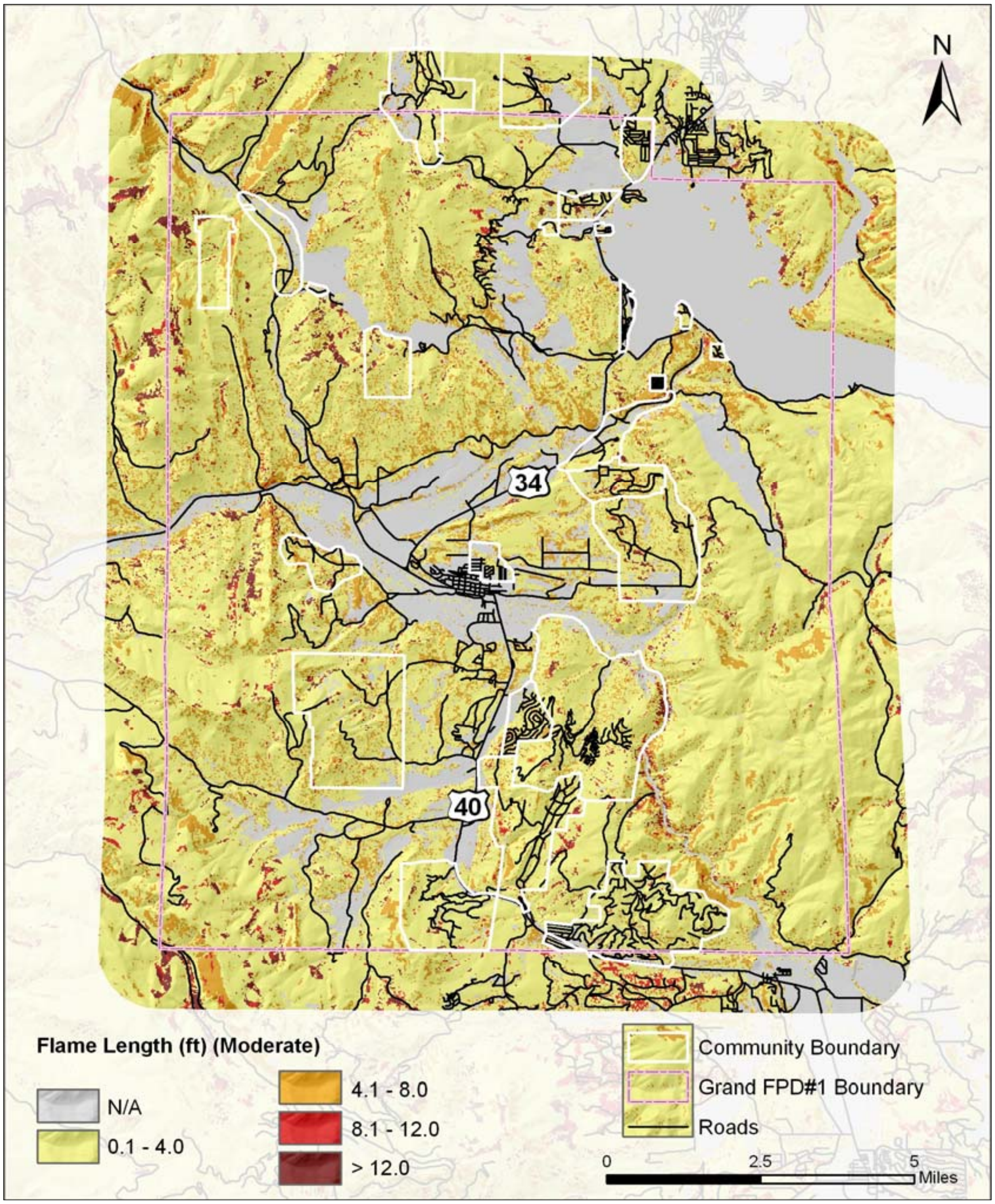
Extreme Weather Conditions	
Variable	**Value**
20 ft Wind speed up slope	30 mph
Herbaceous fuel moisture	42%
Woody fuel moisture	91%
100-hr fuel moisture	12%
10-hr fuel moisture	6%
1-hr fuel moisture	4%

(Note: Strong winds at 20 ft will feel significantly less noticeable on the skin at ground level. For example, a “gentle breeze” on the skin may constitute an 11 MPH 20-foot wind, adding one of the components necessary for extreme weather conditions.)

Fire Behavior Analysis Outputs

Crown fire activity, rate of spread, and flame length are derived from the fire behavior predictions. The following maps graphically display the outputs of **FlamMap** for both average and extreme weather conditions.

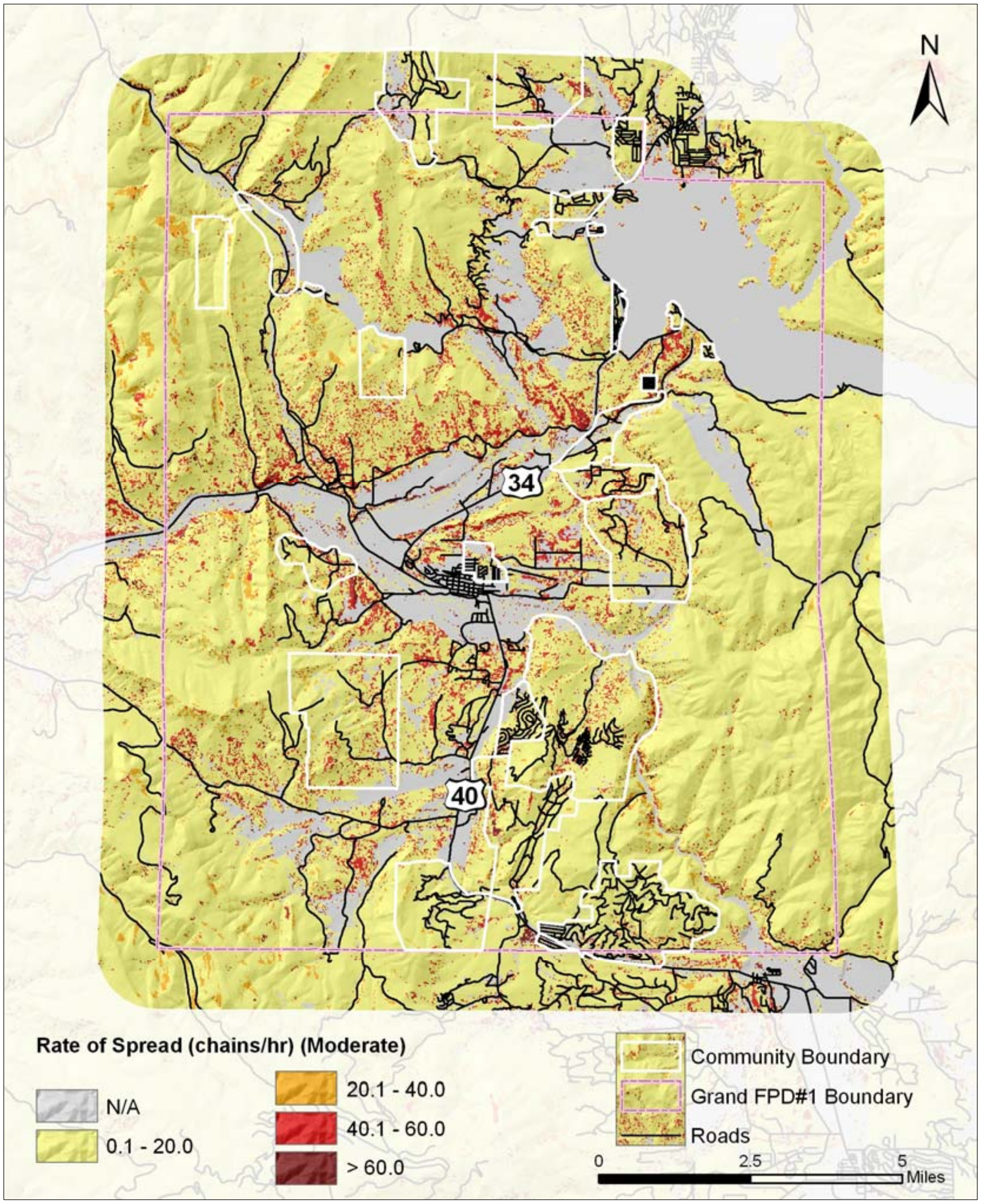
Figure 13. Flame Length Predictions (Moderate Weather Conditions)



Flame length values are generated by the **FlamMap** model and classified in the four categories based on standard ranges: 0-4 feet, 4.1-8 feet, 8.1-12 feet and 12.1-60 feet. Flame lengths of 4 feet and less are acceptable for direct attack by hand crews. Flame lengths of 8 feet and less are suitable for direct attack by machinery. With flame lengths of greater than 8 feet, indirect attack and aerial attack are the preferred methods.

Figure 14. Flame Length Predictions (Extreme Weather Conditions)

Figure 15. Rate of Spread Predictions (Moderate Weather Conditions)



(1 chain=66 ft) (80 chains/HR = 1 MPH)

Spread rate values are generated by the **FlamMap** model and classified into four categories based on standard ranges: 0-20 ch/h (chains/hour), 20.1-40 ch/h, 40.1-60 ch/h, and greater than 60 ch/h. A chain is a logging measurement that is equal to 66 feet. One mile equals 80 chains. 1 ch/h equals approximately 1 foot/minute or 80 chains per hour equals 1 mile per hour.

Figure 16. Rate of Spread Predictions (Extreme Weather Conditions)

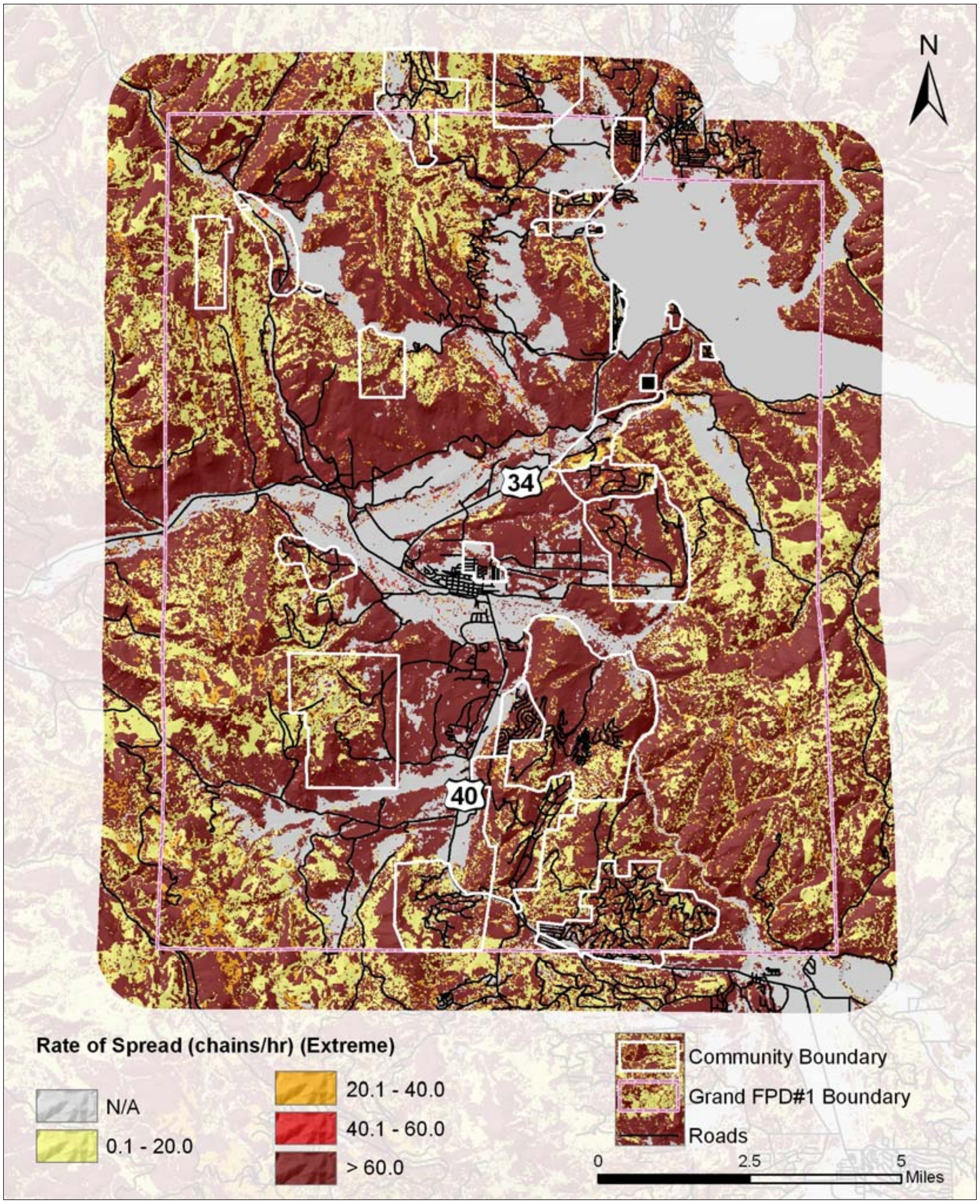
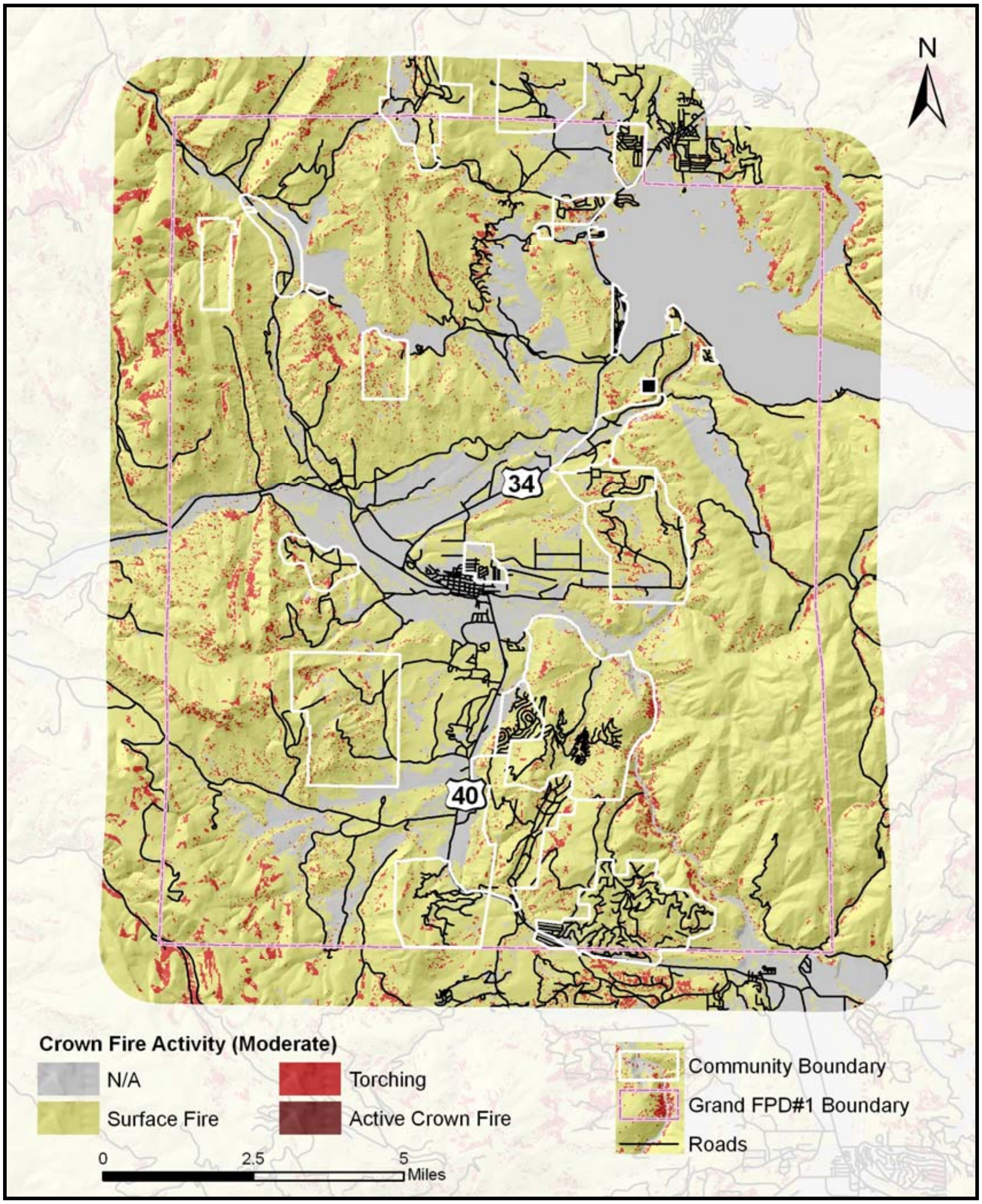
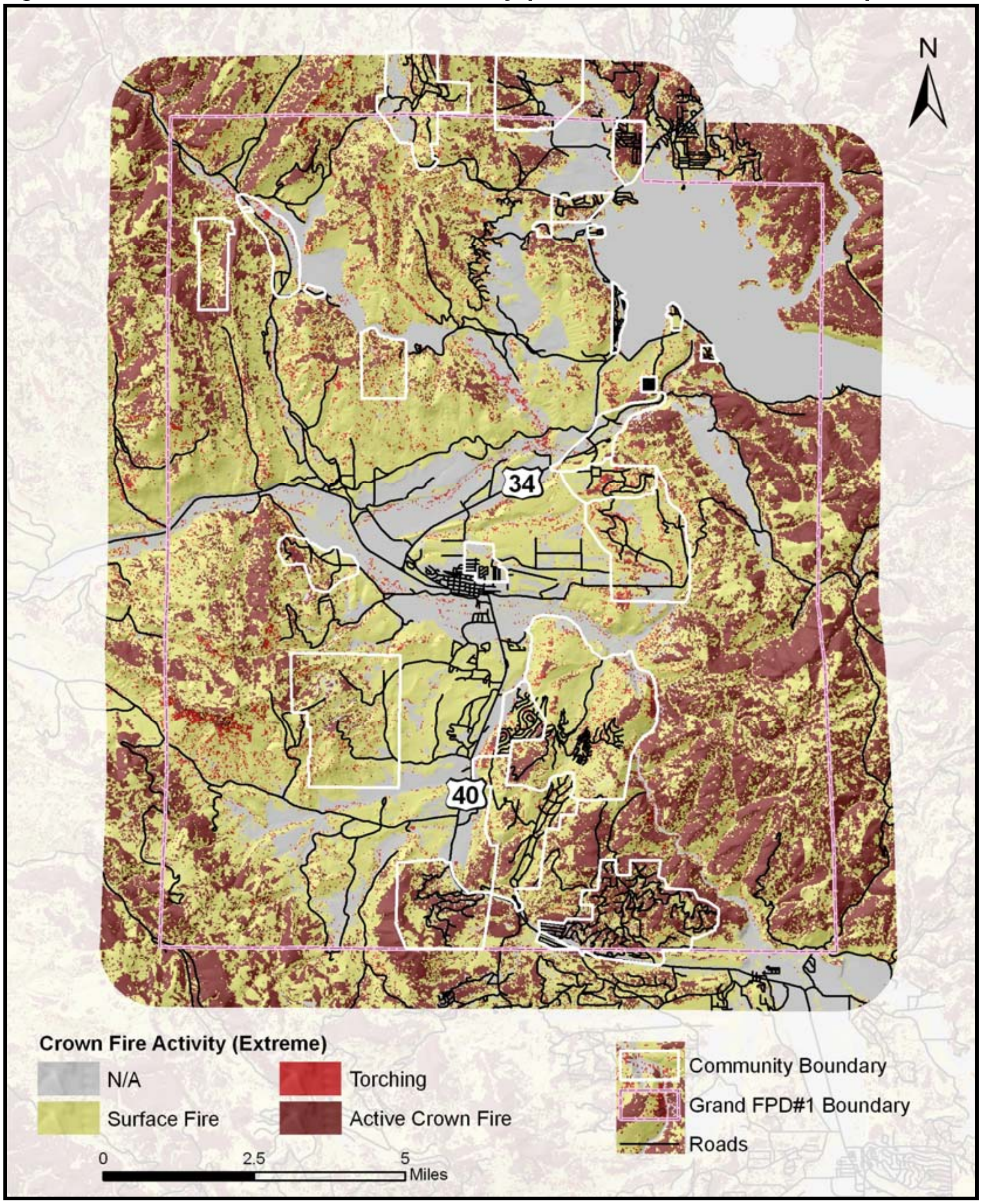


Figure 17. Predictions of Crown Fire Activity (Moderate Weather Conditions)



Crown fire activity values are generated by the **FlamMap** model and classified into four categories based on standard ranges: Active, Passive, Surface, and Not Applicable. In the surface fire category, little or no tree torching will be expected. During passive crown fire activity, isolated torching of trees or groups of trees will be observed and canopy runs will be limited to short distances. During active crown fire activity, sustained runs through the canopy will be observed that may be independent of surface fire activity.

Figure 18. Predictions of Crown Fire Activity (Extreme Weather Conditions)



Fire Behavior Modeling Limitations and Interpretation

This evaluation is a prediction of likely fire behavior, given a standardized set of conditions and a single point-source ignition in every cell (each 30 x 30 meter area). It does not consider cumulative impacts of increased fire intensity over time and space. The model does not calculate the probability a wildfire will occur. It assumes an ignition occurrence for every cell. These calculations may be conservative (under predict) compared to observed fire behavior.

This model can be conceptually overlaid with the Community Wildfire Hazard Ratings (WHR) or other values at risk identification to generate current and future “areas of concern,” which are useful for prioritizing mitigation actions. This is sometimes referred to as a “values layer.” One possibility is to overlay the fire behavior potential maps with the community hazard map, in order to make general evaluations of the effects of the predicted fire behavior in areas of high hazard value (areas where there are concentrations of residences and other man-made values). However, one should remember that the minimum mapping unit used for fire behavior modeling is one acre, and therefore, fine scale fire behavior and effects are not considered in the model. Additionally, weather conditions are extremely variable and not all combinations are accounted for. The fire behavior prediction maps are best used for pre-planning and not as a stand-alone product for tactical planning. If this information is used for tactical planning, fire behavior calculations should be done with actual weather observations during the fire event. For greatest accuracy, the most current Energy Release Component (ERC) values should be calculated and distributed during the fire season to be used as a guideline for fire behavior potential.

Flame Length

Figures 13 and 14 display the flame length predictions for the two weather scenarios. Flame length is a proxy for fire intensity. It is important to note flame length is considered to be the entire distance from the base of the flame to the tip, irrespective of angle, and not simply the flame height above the ground. It is possible in high wind conditions to have very intense flames (high flame lengths) which are relatively close to the fuel bed. The legend boxes display flame length in ranges which are meaningful to firefighters. Flame lengths of four feet and less are deemed low enough intensity to be suitable for direct attack by hand crews, and therefore represent the best chances of direct extinguishment and control. Flame lengths of less than eight feet are suitable for direct attack by equipment such as bulldozers and tractor plows. Flame lengths of eight to 12 feet are usually attacked by indirect methods and aircraft. In conditions where flame lengths exceed 12 feet, the most effective tactics are fuel consumption ahead of the fire by burnouts, or mechanical methods. Although indirect fire line and aerial attack are also used for fires with flame lengths of greater than 12 feet, as flame lengths increase the effectiveness of these tactics decrease and their use is generally designed to slow rates of spread and reduce fire intensity, especially in areas where values at risk are concentrated.

Rate of Spread

Figures 15 and 16 show the predicted rates of spread for the moderate fire weather and extreme fire weather scenarios respectively. Rates of spread are expressed in chains/hour (CPH). A chain is a unit of measure commonly used by loggers and firefighters. It is equal to 66 feet. Therefore, one mile equals 80 chains. Rates of fire spread are influenced primarily by the wind, slope grade, fuel type/continuity, and fuel sheltering from the wind. Fire is the only force of nature which moves faster uphill than downhill. When all other factors are equal, fire moves twice as fast uphill on a slope of 30% than it does on flat terrain. In areas where high to extreme rates of spread are predicted (ROS of >40 CPH or ½ mile per hour) it is possible fires could spread faster than humans can escape, creating extremely dangerous conditions for firefighters and evacuating residents. High rates of spread also make suppression efforts less effective and increase the tactical complexity of the incident.

Crown Fire Activity

The Crown Fire Activity maps (**Figures 17 and 18**) display the potential for fires to move from the surface into the canopy of trees. The likelihood of progression from the surface into the aerial fuels is displayed in four categories. N/A refers to areas where surface fires are unlikely to develop, due to the lack of combustible fuels. These would include any area lacking a combustible fuel bed such as rock, ice, snow fields, water, sand, or some urban landscapes. The surface fire category covers areas where fires are expected to be limited to the surface fuels and lack the energy to initiate and sustain vertical development into the aerial fuels. Areas where grass fuels without overstory plants are dominant fall into this category regardless of the energy produced by the fire, due to the lack of overstory. Areas covered by the torching category are expected to experience isolated combustion of the tree crowns in individual trees and groups of trees. In other words, individual or relatively small clusters of trees will be completely involved, but these fires lack the energy to initiate sustained horizontal movements (referred to as “runs” by fire fighters) through the crowns. The active crown fire category includes areas where sustained horizontal movements through tree crowns are expected. This category can be further subdivided into dependent or independent crown fire. Dependent crown fires rely on the presence of surface fires to support aerial burning. Independent crown fires develop when aerial burning is sustained without the need for associated surface fire. Independent crown fires are rare and are associated with the most extreme fire behavior conditions. Current fire behavior models do not have the ability to predict independent crown fire development. All crown fires, regardless of whether they are dependent or independent, represent extreme fire behavior conditions, and are notoriously resistant to typical methods of suppression and control.

Most communities show little torching and no crowning under moderate conditions. This is to be expected, as many of the communities are in the open. Also, in the Lodgepole stands, the wind is reduced due to the sheltering effect of the tight tree canopy. However, given the intermix of red trees and green trees it is likely that there would be more group torching then single tree torching.

Under extreme conditions, all of the red trees show active crown fire but not the green ones. It is important to realize that the model does not show the affect of one cell on another. **When a large area of red trees is crowning it is highly probable that the green trees adjacent to them will begin to crown as well.**