APPENDIX E – FUEL MODEL DEFINITIONS/PROCESS

Forest Service Manual(FSM) chapter 5105, defines fuel as combustible wildland vegetative materials, living or dead. FSM chapter 5150 on fuel management provides direction to evaluate, plan, and treat wildland fuel to control flammability and reduce resistance to control including mechanical, chemical, biological, or manual means including the use of prescribed fire, to support land and resource management objectives.

The objectives of fuels management are to:

1/ Reduce fire hazard to a level where cost effective resource protection is possible should a wildfire ignition occur. Fire hazard is the fire behavior potential (intensity and rate of spread) of a fire burning in a given fuel profile and its ability to be suppressed by fire forces.

2/ Reduce the potential fire severity.

The reason fire managers are concerned with fuels is that of the three elements that influence fire behavior- weather, topography, and fuels, the only element that can be manipulated is vegetation or fuels.

Throughout the analysis of the Beaver Creek Watershed, fuels conditions are identified that will contribute to high severity fire, damaging wildlife habitat, converting conifer stands to hardwood/shrubs. To keep this from occurring, fuels reduction projects need to be implimented. Without the implimentation of these projects, fire rehabilitation efforts are inevitable.

The following is a description of the components and the process involved in determining fire behavior potential and risk for the Beaver Creek watershed.

FUEL MODEL DEFINITIONS

The criteria for choosing a fuel model (Anderson, 1982) is based on the fact that fire burns in the fuel stratum best conditioned to support it. This means situations will occur where one fuel model represents rate of spread most accurately and another best depicts fire intensity. In other situations, two fuel conditions may exist, so the spread of fire across the area must be weighed by the fraction of the area occupied by each fuel. Fuel models are simply tools to help the user realistically estimate fire behavior.

Table 1.- Description of fuel models used in fire behavior as documented by Albini (1976)

Fuel model	Typical fuel complex	fuel loading 1hr	10hr	100hr	live	fuel bed depth
		----tons/acre----------				feet
Grass and grass-dominated						
1	Short Grass (1 foot)	0.74	0.00	0.00	0.00	1.0
2	Timber Grass and Understory	2.00	1.00	.50	.50	1.0

3 Tall Grass(2.5feet)	3.01	.00	.00	.00	2.5

Chaparral and Shrub Fields

4 Chaparral (6feet)	5.01	4.01	2.00	5.01	6.0
5 Brush (2 Feet)	1.00	.50	.00	2.00	2.0
6 Dormant Brush Hardwood Slash	1.50	2.50	2.00	.00	2.5
7 Southern Rough	1.13	1.87	1.50	.37	2.5

Timber Litter

8 Closed Timber Litter	1.50	1.00	2.50	0.00	0.2
9 Hardwood Litter	2.92	.41	.15	.00	.2
10 Timber (litter and understory)	3.01	2.00	5.01	2.00	1.0

Slash

11 Light Logging Slash	1.50	4.51	5.51	0.00	1.0
12 Medium Logging Slash	4.01	14.03	16.53	.00	2.3
13 Heavy Logging Slash	7.01	23.04	28.05	.00	3.0

The prediction of fire behavior has become more valuable for assessing potential fire damage to resources. A quantitative basis for rating fire danger and predicting fire behavior became possible with the development of mathematical fire behavior fuel models. Fuels have been classified into four groups- grasses, brush, timber, and slash. the differences in these groups are related to the fuel load and the distribution of the fuel among the size classes. Size classes are: 0-1/4", 1/4- 1", 1-3", and 3" and greater.

The criteria for choosing a fuel model includes the fact that the fire burns in the fuel stratum best conditioned to support the fire. Fuel models are simply tools to help the user realistically estimate fire behavior. Modifications to fuel models are possible by changes in the live/dead ratios, moisture contents, fuel loads, and drought influences. The 13 fire behavior predictive fuel models are used during the severe period of the fire season when wildfire pose greater control problems and impacts on land resources.

The following is a brief description of each of the 13 fire behavior fuel models.

GRASS GROUP

Fire behavior Fuel Model 1

Fire spread is governed by the very fine, porous, and continous herbaceous fuels that have cured or are nearly cured. Fires are surface fires that move rapidly through the cured grass. YVery little timber or shrub is present.

Fire behavior Fuel Model 2

Fire spread is primarily through cured or nearly cured grass where timber or shrubs cover one to two-thirds of the open area. These are surface fires that may increase in intensity as they hit pockets of other litter.

Fire Behavior Fuel Model 3

Fires in this grass group display the highest rates of spread and fire intensity under the influence of wind. Approximately one-third or more of the stand is dead or nearly dead.

SHRUB GROUP

Fire Behavior Fuel Model 4

Fire intensity and fast spreading fires involve the foliage and live and dead fine woody material in the crowns of a nearly continuous secondary overstory. Stands of mature shrubs, 6 feet tall or more are typical candidates. Besides flammable foliage, dead woody material in the stands contributes significantly to the fire intensity. A deep litter layer may also hamper suppression efforts.

Fire Behavior Fuel Model 5

Fire is generally carried by surface fuels that are made up of litter cast by the shrubs and grasses or forbs in the understory. Fires are generally not very intense because the fuels are light and shrubs are young with little dead material. Young green stands with little dead wood would qualify.

Fire Behavior Fuel Model 6

Fires carry through the shrub layer where the foliage is more flammable than fuel model 5, but requires moderate winds, greater than 8 mi per hour.

Fire Behavior Fuel Model 7

Fires burn through the surface and shrub strata with equal ease and can occur at higher dead fuel moistures because of the flammability of live foliage and other live material.

TIMBER GROUP

Fire Behavior Fuel Model 8

Slow burning ground fuels with low flame lengths are generally the case, although the fire may encounter small "jackpots" of heavier concentrations of fuels that can flare up. Only under severe weather conditions do the fuels pose a threat. Closed canopy stands of short-needled conifers or hardwoods that have leafed out support fire in the compact litter layer. This layer is mostly twigs, needles, and leaves.

Fire Behavior Fuel Model 9

Fires run through the surface faster than in fuel model 8 and have a longer flame length. Both long-needle pine and hardwood stands are typical. Concentrations of dead, down woody material will cause possible torching, spotting, and crowning of trees.

Fire Behavior Fuel Model 10

Fires burn in the surface and ground fuels with greater intensity than the other timber litter types. A result of overmaturing and natural events creates a large load of heavy down, dead material on the forest floor. Crowning out, spotting, and torching of individual trees is more likely to occur, leading to potential fire control difficulties.

LOGGING SLASH GROUP

Fire Behavior Fuel Model 11

Fires are fairly active in the slash and herbaceous material intermixed with the slash. Fuel loads are light and often shaded. Light partial cuts or thinning operations in conifer or hardwood stands. Clearcut operations generally produce more slash than is typical of this fuel model.

Fire Behavior Fuel Model 12

Rapidly spreading fires with high intensities capable of generating firebrands can occur. When fire starts it is generally sustained until a fuelbreak or change in conditions occur. Fuels generally total less than 35 tons per acre and are well distributed. Heavily thinned conifer stands, clearcuts, and medium to heavy partial cuts are of this model.

Fire Behavior Fuel Model 13

Fire is generally carried by a continuous layer of slash. Large quantities of material 3 inch and greater is present. Fires spread quickly through the fine fuels and intensity builds up as the large fuels begin burning. Active flaming is present for a sustained period of time and firebrands may be generated. This contributes to spotting as weather conditions become more severe. Clearcuts are depicted where the slash load is dominated by the greater than 3 inch fuel size, but may also be represented by a "red slash" type where the needles are still attached because of high intensity of the fuel type.

Fuel models identified and used in this analysis are in the following table.

Fuel Model	Acres	Percent
2	2,930	4%
5	1,145	2%
6	8,560	12%
8	900	1%
9	2,605	4%
10	52,900	76%
Non-Flammable	650	1%

WEATHER DATA

The following weather parameters were taken from the data collected at the Oak Knoll and Collins Baldy weather stations from 1976 through 1995. These parameters are representative of 90th percentile weather conditions.

1 Hour Fuel Moisture	3-4%
10 Hour Fuel Moisture	4-5%
100 Hour Fuel Moisture	4%
1000 Hour Fuel Moisture	7-8%
Live Woody	80%
Herbaceous	30%

20 Foot Wind Speed 9-12 Miles Per Hour

Conversion factors used to adjust 20' windspeed to midflame windspeed are:

Fuel Model	**Exposure**	**Adjustment Factor**	**Midflame Windspeed**
1	Full	.3	64
2	Partial	.2	53
4	Exposed	.5	56
5	Exposed	.4	24
6	Exposed	.4	44
8	Partial	.2	53
9	Partial	.2	53
10	Partial	.2	53
11	Exposed	.3	64
12	Exposed	.4	34
13	Exposed	.4	65

Conversion factors used are taken from the NFES 1981 S-390 Fire Behavior Field Guide. Table 4A: Wind Adjustment Factors.

FIRE BEHAVIOR POTENTIAL

To determine Fire Behavior Potential Classes, each fuel model is run through the BEHAVE program. This program uses fuel model, slope, and weather parameters to predict fire behavior and resistance to control for fire suppression purposes. The 90th percentile weather from the most representative weather station was used to model late summer afternoons, typical of late July thru early September.

Three slope classes are used, consistent with the slope classes used in the LMP geologic hazard classification (0-34%, 35-65%, and >65%). All fuel models were run through each of the three slope classes, to determine increases in fire behavior with increased steepness of terrain.

The output of this is a rating of Low, Moderate, or High fire behavior based on flame lengths, which are good indicators of fire line intensity and resistance to control, and/or rate of spread (ROS), which is also a good indicator of resistance to control.

Using the CONTAIN model of BEHAVE, it was determined whether or not a fire with Low Flame Lengths could be contained by the initial attack forces. These runs indicated that given, typical responce times, terrain, fuels, and available forces, a Low rating had to have a ROS <30 chains per hour, for containment to be accomplished during initial attack.

FIRE BEHAVIOR POTENTIAL CLASSES

Low- Flame lengths <4' and ROS <30 chains per hour
Fires can generally be attacked at the head or flanks by firefighters using handtools. Handline should hold the fire.

Moderate- Flame lengths 4-8'
Fires are too intense for direct attack at the head of the fire by firefighters using handtools. Handline cannot be relied on to hold the fire. Equipment such as dozers, engines, water and/or retardent dropping aircraft can be effective.

High- Flame lengths >8'
Fires may present serious control problems, such as torching, crowning, and spotting. Control efforts at the head of the fire will be ineffective.

These are the acres associated with each Fire Behavior Class in the watershed.
High- 37,000 acres (53% of the watershed)
Moderate- 27,000 acres (39% of the watershed)
Low- 4,900 acres (7% of the watershed)
Non-Flammable- 650 acres (1% of the watershed)

FUEL MODEL DATA TABLE Page 1

	F.M.	ASP	ELEV	1 HR	WIND	R25	R55	R75	F25	F55	F75	H@25	H@55	H@75
1	1	ALL	<4000	3	3	59	111	168	4	5	6	HIGH	HIGH	HIGH
2	1	ALL	>4000	4	4	81	128	179	4	5	6	HIGH	HIGH	HIGH
3	5	S&W	<4000	3	4	28	40	53	7	8	9	MOD	HIGH	HIGH
4	5	S&W	>4000	3	5	49	65	82	9	10	11	HIGH	HIGH	HIGH
5	5	E	<4000	4	4	27	38	51	7	8	9	MOD	HIGH	HIGH
6	5	E	>4000	5	5	47	62	79	9	10	11	HIGH	HIGH	HIGH
7	5	N	<4000	5	4	26	37	49	6	8	9	MOD	HIGH	HIGH
8	5	N	>4000	6	5	45	60	76	8	10	11	HIGH	HIGH	HIGH
9	6	S&W	<4000	3	4	39	55	73	7	8	9	HIGH	HIGH	HIGH
10	6	S&W	>4000	4	5	45	59	75	7	8	9	HIGH	HIGH	HIGH
11	6	E	<4000	4	4	35	49	65	7	8	9	HIGH	HIGH	HIGH
12	6	E	>4000	5	5	40	54	68	7	8	9	HIGH	HIGH	HIGH
13	6	N	<4000	5	4	31	45	59	6	7	8	HIGH	HIGH	HIGH
14	6	N	>4000	6	5	37	49	62	6	7	8	HIGH	HIGH	HIGH
15	8	S&W	<4000	3	2	1	2	3	1	1	2	LOW	LOW	LOW
16	8	S&W	>4000	4	3	2	3	4	1	1	2	LOW	LOW	LOW
17	8	E	<4000	4	2	1	2	3	1	1	1	LOW	LOW	LOW
18	8	E	>4000	5	3	1	2	3	1	1	1	LOW	LOW	LOW
19	8	N	<4000	5	2	1	2	3	1	1	1	LOW	LOW	LOW
20	8	N	>4000	6	3	1	2	3	1	1	1	LOW	LOW	LOW
21	9	S&W	<4000	3	2	4	9	14	2	3	4	LOW	LOW	MOD
22	9	S&W	>4000	4	3	6	10	14	3	3	4	LOW	LOW	MOD
23	9	E	<4000	4	2	4	8	12	2	3	4	LOW	LOW	MOD
24	9	E	>4000	5	3	5	9	13	2	3	4	LOW	LOW	MOD
25	9	N	<4000	5	2	4	7	11	2	3	3	LOW	LOW	LOW
26	9	N	>4000	6	3	5	8	12	2	3	3	LOW	LOW	LOW
27	10	S&W	<4000	3	2	5	10	15	4	6	7	MOD	MOD	MOD
28	10	S&W	>4000	4	3	7	11	16	5	6	7	MOD	MOD	MOD
29	10	E	<4000	4	2	5	9	14	4	6	7	MOD	MOD	MOD
30	10	E	>4000	5	3	7	11	15	5	6	7	MOD	MOD	MOD
31	10	N	<4000	5	2	5	9	13	4	5	7	MOD	MOD	MOD
32	10	N	>4000	6	3	6	10	14	5	6	7	MOD	MOD	MOD

FIRE RISK

Historical records indicate lightning and human caused fires have been common in the watershed. Little precipitation (May to September) and high summer temperatures allow fuels to dry, which allows for ease and spread of wildfire ignitions.

There are numerous fire risks within and adjacent to the watershed. Several year round occupancies, both day use and overnight campgrounds, recreational use, travel corridors, and a powerline that crosses the lower portion of the watershed, all contribute to the possibility of a wildfire occurrence from human causes.

The greatest risk of fire starts is from the occurance of lightning. Thunder storms are common throughout the summer months in and near the watershed. Lightning, erratic winds and usually precipitation accompany these storms, the latter which limits the actual number of ignitions.

The Forest's fire history data base indicates that the watershed had 473 fire starts from 1922-1994. Using this information and the vegetative composition of the watershed, determines the general fire risk assessment.

It is important to realize that risk is not the probability of a fire occurring, but the probability of when a fire will occur. In this watershed, the fire **will** occur.

A mathmatical formula is used to derive a risk value. Included in the formula are the number of starts, number of years of historical information, and number of acres involved. The values in the formula are:

x = Number of starts recorded for the area from the fire start data base (473).
y = Period of time covered by the data base (for this analysis, 72 years).
z = Number of acres analyzed (displayed in thousands 69,690 = 69.69).

$\{(x/y)10\}/z$ = Risk rating

$\{(473/72)10\}/69.69 = 0.94$

The value derived corresponds to a likelihood of fire starts per 1000 acres per decade. The following are the risk ratings and range of values used to determine the risk.

Low Risk = 0-0.49 This projects one fire every 20 or more years per thousand acres.

Moderate Risk = 0.5-0.99 This projects one fire every 11-20 years per thousand acres.

High Risk = $\geq$ 1.0 This level projects one fire every in 0-10 years per thousand acres.

The rating of 0.94 falls into a moderate risk, although it is very close to being a high risk. This rating indicates that the average number of fire starts for this watershed are .94 per 1000 acres per decade, or 65 fires per decade, or an average of 6.5 fires per year.