APPENDIX D - *Fire and Fuels*

The following is a description of the components and the process involved in determining fire behavior potential and risk for the Callahan Watershed.

FUEL MODEL DEFINITIONS

The prediction of fire behavior is 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 hour fuels), 1/4- 1" (10 hour fuels), 1- 3" (100 hour fuels), and 3" and greater (1000 hour fuels).

Table 1- Description of Fuel Models Used in Fire Behavior as Documented by Albini (1976)

FUEL MODEL Typical Fuel Complex	FUEL LOADING tons/acre				FUEL BED DEPTH in ft.
	1 Hr	10 Hr.	100 Hr.	Live	
GRASS AND GRASS-DOMINATED					
1-Short Grass (1 ft.)	0.74	0.00	0.00	0.00	1.0
2-Timber (Grass and Understory)	2.00	1.00	0.50	0.50	1.0
3-Tall Grass (2.5 ft.)	3.01	0.00	0.00	0.00	-
CHAPARRAL AND SHRUB FIELDS					
4-Chaparral (6 ft.)	5.01	4.01	2.00	5.01	6.0
5-Brush (2 ft.)	1.00	0.50	0.00	2.00	2.0
6-Dormant Shrub & Hdwd. Slash	1.50	2.50	2.00	0.00	2.5
7-Southern Rough	1.13	1.87	1.50	0.37	2.5
TIMBER LITTER					
8-Closed Timber Litter	1.50	1.00	2.50	0.00	0.2
9-Hardwood Litter	2.92	0.41	0.15	0.00	0.2
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	0.00	2.3
13-Heavy Logging Slash	7.01	23.04	28.05	0.00	3.0

The criteria for choosing a fuel model (Anderson, 1982) 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 continuous herbaceous fuels that have cured or are nearly cured. Fires are surface fires that move rapidly through the cured grass. Very 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.

CALLAHAN FUEL MODELS

EXISTING VEGETATION	FUEL MODEL	FUEL MODEL W/≥60% CC
Hardwood/Conifer	2	9
Douglas-Fir/M.C.	8	10
Ponderosa Pine/M.C.	9	11
Jeffrey Pine/M.C.	5	9
White Fir/M.C.	8	10
True Fir	8	10
Mountain Hemlock	8	8
Enriched Mixed Conifer	8	8
Riparian Tree	14	14
Pole, Harvested	12	12
Shrub, Harvested	5	
Shrub, Natural	6	
Grass/Forb	2	
Montane Meadow Shrub	14	
Montane Meadow Forb	14	

Fire Behavior Fuel Model 14 is virtually non-flammable due to wet conditions.

The models identified above are only for areas that were mapped in the EUI. The following are the fuel models identified for the remainder of the watershed. This modeling utilizes satellite imagery provided by Fruit Growers Supply Company. The imagery is converted to WHR vegetation types, from the WHR a crosswalk to fuel models has been done for this analysis.

WHR VEGETATION	FUEL MODEL
MCN4-6D	10
MCN-4M	8
MCN4P	8
MCN3M-D	6
MCN3S-P	2
MHC3M-D	9
MHC2M-D	5
MHC2M-D	2
JUN3P-M	6
MHW3M-D	9
MHW2-3P	2
SHG	S = 2, P = 5, M-D = 6
SHD-SHS	S = 2, P-D = 6
GSG	1
GSD	2
UNVEG	Nonflammable
WTR	Nonflammable

The percent of each fuel model identified in the watershed is shown in the following table.

FUEL MODEL	ACRES	PERCENT
1	5,975	5
2	21,020	18
5	16,955	15
6	14,635	13
8	25,370	22

9	4,100	4
10	23,105	20
12	1,685	1
14	1,520	1
Nonflammable	730	<1

WEATHER DATA

The following weather parameters were taken from the data collected from the Callahan weather station from 1976 through 1995. These parameters are representative of 90th percentile weather conditions.

FUEL MOISTURE	PERCENT
1 Hour	3-4
10 Hour	3
100 Hour	3-4
1000 Hour	5
Live Woody	80
Herbaceous	30
20 Foot Wind Speed	8 MPH

Conversion factors used to adjust 20' wind speed to midflame wind speed are:

FUEL MODEL	EXPOSURE	ADJUSTMENT FACTOR	MIDFLAME WIND SPEED
1	Full	.36	4
2	Partial	.25	3
4	Exposed	.55	6
5	Exposed	.42	4
6	Exposed	.44	4
8	Partial	.25	3
9	Partial	.25	3
10	Partial	.25	3
11	Exposed	.36	4
12	Exposed	.43	4
13	Exposed	.46	5

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 through 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.

Fire behavior potential modeling is done in order to estimate the severity and resistance to control that can be expected, when a fire occurs during what is considered the worst case weather conditions. Late summer weather conditions are referred to as the 90th percentile weather data, which is a standard used when calculating fire behavior (90th percentile weather is defined as the severest 10% of the historical fire weather, i.e., hot, dry, windy conditions occurring on mid afternoons during the fire season). The modeling incorporates fuel condition, slope class, and 90th percentile weather conditions in calculating projections on flame lengths and rates of spread. A **low** rating indicates that fires can be attacked and controlled directly by ground crews building fireline and will be limited to burning in understory vegetation. A **moderate** rating indicates that hand built firelines alone would not be sufficient in controlling fires and that heavy equipment and retardant drops would be more effective. Areas rated as **high** represent the most hazardous conditions in which serious control problems would occur i.e., torching, crowning, and spotting, control lines are established well in advance of flaming fronts with heavy equipment and backfiring may be necessary to widen control lines.

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 response 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 <30chs/hr
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 retardant 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 - 18,850 acres (17% of the watershed)
Moderate - 58,500 acres (51% of the watershed)
Low - 30,900 acres (27% of the watershed)
Nonflammable - 5,970 acres (5% of the watershed)

FUEL MODEL DATA TABLE

Fuel Model	Aspect	1 HR	Wind	R25	R55	R75	F25	F55	F75	H@25	H@55	H@75
2	S&W	3	3	28	48	69	6	8	9	MOD	HIGH	HIGH
2	E	4	3	25	*44	63	6	7	9	MOD	HIGH	HIGH
2	N	5	3	24	*41	59	5	7	8	MOD	HIGH	HIGH
5	S&W	3	3	29	45	63	7	9	10	MOD	HIGH	HIGH
5	E	4	3	27	43	60	7	8	10	MOD	HIGH	HIGH
5	N	5	3	26	41	58	7	8	10	MOD	HIGH	HIGH
6	S&W	3	3	29	45	63	6	8	9	MOD	HIGH	HIGH
6	E	4	3	26	*41	57	6	7	8	MOD	HIGH	HIGH
6	N	5	3	24	*37	51	5	7	8	MOD	HIGH	HIGH
8	S&W	3	2	1	2	4	1	1	2	LOW	LOW	LOW
8	E	4	2							LOW	LOW	LOW
8	N	5	2							LOW	LOW	LOW
9	S&W	3	2	4	9	14	2	3	4	LOW	LOW	MOD
9	E	4	2							LOW	LOW	LOW
9	N	5	2							LOW	LOW	LOW
10	S&W	3	2	7	13	19	5	7	8	MOD	MOD	HIGH
10	E	4	2	6	12	18	5	7	8	MOD	MOD	HIGH
10	N	5	2	6	11	17	5	6	7	MOD	MOD	**HIGH
12	S&W	3	3	13			9			HIGH	HIGH	HIGH
12	E	4	3	12			8			HIGH	HIGH	HIGH
12	N	5	3	11			8			HIGH	HIGH	HIGH
14	S&W	10	3	3	N/A	N/A	1	N/A	N/A	LOW	LOW	LOW
14	E	12	3	3	N/A	N/A	1	N/A	N/A	LOW	LOW	LOW
14	N	14	3	3	N/A	N/A	1	N/A	N/A	LOW	LOW	LOW

* Fire behavior potential is based on rate of spread rather than flame length.
** Enhanced fire behavior potential (slope >60% and crown closure >70%).

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 the watershed. Many year-round residences, agricultural and industrial endeavors, many dispersed camp sites, recreational use, travel corridors, and powerlines, all contribute to the possibility of a wildfire occurrence from human causes.

The greatest risk of fire starts is from the occurrence 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 Klamath National Forest fire history data base indicates that the portion of the watershed within the Forest boundary had 355 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 mathematical 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 (355).
y = Period of time covered by the data base (for this analysis, 72 years).
z = Number of acres analyzed (displayed in thousands 61,550 = 61.55).

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

$\{(355/72)10\}/61.55 = 0.80$

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 0.80 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 .80 per 1000 acres per decade, or 49 fires per decade, or an average of 5 fires per year.

The historic disturbance regime for the watershed was dominated by fire. Natural fires were ignited by lightning. Fires were also ignited by American Indians. American Indians ignited fires to enhance acorn production and facilitate gathering in the oak woodland communities, to improve bear grass quality for basket making in meadows and improve seed production of grasses, to improve travel, and to facilitate hunting. The vegetation in all the plant communities developed and adapted as a result of this disturbance regime. The following is a description of the historic fire regime by vegetation community.

Hardwood Conifer - Prior to Euro-American settlement, this low elevation community was dominated by large (>30" dbh) widely spaced (30-60') ponderosa and sugar pine. Clumps of pine would occur on better soils and in small size classes, but would be usually be thinned by fire. Oregon white oak was the dominant hardwood. With the influence of frequent fire it would be thinned, the understory opened, and trees would develop with the first limbs found several feet above the ground. These stands were probably burned by Native Americans semi-annually or as necessary to encourage production and ease harvesting of acorns. Fire returns were from 1-15 years.

Ponderosa Pine Mixed Conifer - Trees occurred in all size classes, mostly in small even-aged patches. Understories consisted mostly of perennial grasses and forbs, with scattered pockets of shrubs. Low intensity, either creeping or fast moving ground fires maintained a mosaic of open understories and regenerated pine stands. Abundant perennial grass cover in the open understories and annual pine needle cast provided fuel for these fires. Openings in the overstory were also created following outbreaks of insects and disease or blowdown, followed by high intensity fire. This allowed for shrub and tree seedling regeneration. Fire returns were from 4-18 years.

Jeffrey Pine Mixed Conifer - These harsher sites limited understory and conifer development. Lightning ignited fires occurred and were spread usually by wind events through understory litter and vegetation. Fire returns were from 5-20 years.

Douglas-Fir Mixed Conifer - This community consisted of Douglas-fir, ponderosa pine, sugar pine, white fir, and incense cedar. The historic fire regime maintained stands in even-aged patches of trees, with greater components of fire tolerant species. Sites with dense canopies influenced by low intensity fires were maintained with a fairly open understory, with scattered grasses and forbs. Exposed sites with less dense canopies had a shrub understory consisting mostly of snowbrush ceanothus and greenleaf manzanita. Fire returns were from 8-20 years.

White Fir Mixed Conifer - This community was much smaller than it occurs today. Much of the area presently identified as this community was occupied by fire adapted conifer species. White fir was limited to cooler, moister, more firesafe sites, fire occurrence was variable, with longer return intervals allowing for establishment and maintenance of fire sensitive conifers. With a dense canopy, understory vegetation was limited. Openings created by insect and disease or blowdown followed by fire were soon occupied by dense regeneration or shrubs such as snowbrush and manzanita. Fire returns were from 9-40 years.

True Fir - This community consisted of large patches of even-aged trees, many in larger size classes (greater than 24" dbh). Red fir dominated, with many of the same shrub species that currently exist. With fewer large scale disturbances, only a few large shrub dominated openings existed. Fire crept and smoldered through these stands throughout the summer, burning with higher intensity only during the hottest summer days in heavy fuels created by insects, disease, and blowdown. These areas were cleared by fire and seed rain perpetuated stand regeneration. Fire returns were from 8-40 years.

Mountain Hemlock - This tree species is a fire avoider. The presence of mountain hemlock indicates a fire return of 200-400 years. Fire returns of approximately 200 years were likely in stands occurring with lodgepole pine. Stands of pure mountain hemlock develop after a long fire free period (300-400 years).

Enriched Mixed Conifer and Unique Species - Many of these species react to fire much the same as mountain hemlock. Fire intervals historically were long or occurred with very low intensity. The presence of lodgepole pine indicates a fire return of <200 years.

Riparian Tree - Species occurring in riparian tree areas are adapted to frequent fire intervals and historically were burned at regular intervals. Many of these species depend on fire to remove dead material and rejuvenate the health and growth of these plants and trees. Lightning fires backed down into these areas and Native Americans burned through these areas. Fire intervals ranged from 5-20 years.

Shrub, Natural - This community developed as a result of disturbances such as high intensity fires. On harsh sites and southwest aspects this community persisted as a fire disclimax community. On better sites, i.e., north and east aspects, shade tolerant conifers grew up through the shrubs and reoccupied the sites. Fire intervals ranged from 5-20 years.

Montane Meadow Shrub
Shrub fields associated with wet meadows were burned regularly by lightning and Native American ignited fires. These areas would burn in the late summer or early fall. They were most susceptible during periods of drought. Fire intervals ranged from 5-30 years.