

# APPENDIX 3 - WILDFIRE ENVIRONMENT AND BEHAVIOR

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### 3. WILDFIRE: CURRENT ENVIRONMENT AND BEHAVIOR<sup>1</sup>

Describing the wildfire environment within the planning area provides an understanding of factors that influence *fire behavior*<sup>2</sup>.

#### 3.1 INTRODUCTION: DEFINING THE WILDFIRE PROBLEM

The Pioneer/Volcano planning unit is the most-at-risk area in the county. Situated between two major river drainages<sup>3</sup>, it is also one of the most populated areas of the county.

Many subdivisions are scattered throughout the area. Many of these subdivisions are served by sub-standard roads restricting the movement of firefighting resource and making large-scale evacuations challenging.

Upper Amador County has a rich history dating back to 1900 of periodic large fires that are wind driven. Fire history records show that periodic large fires burned within the planning unit and adjacent to it. All these fires occurred during a foehn wind event. These large fires occur roughly every twenty to thirty years in Amador County. Most of these wildfires occurred at a time when the area was less populated. The fact that these fires occur on a regular basis is cause for great concern.

Periodic large wildfires are not the only wildfire threat to humans and natural resources. Because of extensive human development in the unit and the unwillingness of some residents to comply with defensible space regulations, even relatively small fires can cause significant property damage and greatly complicate suppression efforts.

Unnaturally, heavy accumulations of forest fuels on steep slopes are typical within this planning unit. Large blocks of continuous forest fuels within and adjacent to the unit also increase the wildfire threat. It is this combination of terrain, fuels, weather, and human improvements that result in the Pioneer/Volcano Planning Unit's most-at-risk designation.

Other factors such as substandard roads, lack of or poor road and address signage, water supplies and building materials add to the wildfire threat in the planning unit. All the factors discussed above work together to create a potentially devastating fire environment.

Later in this section, there is a comparison between pre-European and post-European era fuel conditions. Changes in fuel quantities and distribution between two periods are dramatic. The volume and type of fuel in forests of today is much different today from pre-European time.

Many things that can be done to reduce much of this risk and assist emergency agencies more effectively deal with wildfire. This plan defines the wildfire problem, catalogs man-made hazards, and identifies ways of mitigating this problem through a partnership with the community and those responsible for protecting the public from wildfires.

### 3.2 PLANNING UNITS

Planning units like Pioneer/Volcano are a product of a Community Wildfire Protection Plan (CWPP) completed in 2005. This plan divides the county into nine planning units for the purpose of assessing relative risk from wildfire. Each planning unit represents a unique wildfire environment.

The follow table from the 2005 plan lists the factors used to make this assessment.

Table 1-Risk Factors by Fuel Modification Area<sup>4</sup> (Highest risk = 1, lowest = 7)

Risk factor	Assets at Risk	Weather	Slope	Residential Distribution	Hazardous Fuels Distribution	Ladder Fuel Distribution	Composite Score	Overall ranking
Plymouth	9	6	8	8	7	7	45	7
lone	8	8	9	4	8	8	45	7
Comanche	7	7	7	6	9	9	45	7
Jackson	4	5	6	3	6	6	30	6
Sutter/Amd.	5	4	4	5	5	5	28	5
Fiddletown	6	3	5	7	3	3	27	4
Pine Grove	3	3	2	1	2	2	13	2
Pioneer/Vol.	1	2	3	2	1	1	10	1
Upcountry	2	1	1	9	4	4	21	3

### 3.3 FIRE BEHAVIOR CHARACTERISTICS

Understanding the factors that affect wildfire behavior is important in understanding the threat from wildfire and how best to mitigate this threat. The following section describes these factors.

#### 3.3.1 SURFACE FIRES

On flat or moderate slopes in light fuels, fires usually burn on the surface of the ground. Surface fires may advance quickly with short or long *residence time*<sup>5</sup> and low to high heat output, and as such, they respond well to suppression. All things being equal, surface fires are

easy to manage and control. A manageable fire is one of the desired results of *fuel modifications*.<sup>6</sup>

Surface Fuel models are used to predict fire behavior. Each model describes a set of fire behavior outputs (flame length, rate of spread etc.). Surface fuel model descriptions are stylized vegetation types that can exhibit burning characteristics similar to that output by the fuel model assigned.

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### 3.3.2 CROWN FIRE POTENTIAL

Crown fires usually occur when there is a connection between the fuels on the surface and the crowns of the trees. This connection is usually brush and smaller trees. Called *ladder fuels*<sup>7</sup> these fuels also include man-made structures such as homes, barns, etc. The higher

the tree crowns from the surface fuels the less likely a crown fire will occur. One of the goals of fuel modification is to keep wildfires as surface fires by eliminating intermediate fuels and creating a safe separation between individual tree crowns.

Figure 1 - Crown fire (Power Fire 2004)



Crown fires occur when a fuel and/or weather conditions allow a wildfire to burn the tops (crowns) of trees. These fires usually spread rapidly and produce a lot of heat. When a crown fire occurs, it can cause *embers*<sup>8</sup> that are carried by convection and wind great distances from the main fires. These embers often cause new fires called *spot fires*<sup>9</sup> in advance of the main fire. Spot fires can cause the main fire to increase in size dramatically as these new fires expand and eventually merge with the main fire.

Much of the forest fuels in Pioneer/Volcano Planning Unit are Fuel Model #10 (see 3.4 *Description of Fuel through Fuel Models*). Most fuels within Sierra Nevada forests are characterized as Fuel Model #10. These forests have some live fuels in the surface layer, and an ample amount of dead branches and logs that fuel a more intense fire, creating fire suppression challenges. These fuels provide the opportunity for crown fires during normal bad fire weather conditions<sup>10</sup>.

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### 3.3.3 FIRE INTENSITY

Fire intensity refers to how hot a wildfire burns. Fire intensity varies throughout the life of a wildfire and at different locations within the fire. The three main factors affecting fire intensity are fuel, slope, and weather. Do not confuse fire intensity with fire severity. Fire intensity

describes heat production (energy release) while fire severity describes damage caused by the fire.

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#### 3.3.4 FIRE SEVERITY

Fire severity describes the resulting effects of a fire based on the amount of soil damage and tree mortality. Long flame lengths, large amounts of torching, crowning, high fire intensity, and high heat per unit area are all indicators of potentially severe fires

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#### 3.3.5 FLAME LENGTH

Flame length has the greatest impact on damage to structures and difficulty of control. This is because flame lengths longer than twelve feet increase the chance crown fires. In the pre-European Settlement era, flame lengths less than four feet were the norm and produce low intensity fires. Typically, fuel management goals aim for production of flame lengths less than four feet.

Slope also affects flame length - the steeper the slope the longer the flame length. This increase in length occurs as the flame is bent toward the slope pre-heating the fuels ahead of it. Thus, the fire burns with greater intensity creating a longer flame.

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#### 3.3.6 RATE OF SPREAD

The rate of spread refers to how fast the *leading edge*<sup>11</sup> a wildfire advances. Fast rate of spread makes controlling the fire more difficult and can increase the danger to the public and firefighters.

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#### 3.3.7 RESIDENCE TIME

The residence time is how long the leading edge of the fire burns in any one location. Residence time is useful in predicting tree mortality and soil damage.

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#### 3.3.8 HEAT PER UNIT AREA

Heat per unit area is defined as the total heat produced by flaming combustion in any one location. This does not include long *burn-out times*<sup>12</sup> and smoldering. This factor is especially important in determining soil heating and is a good predictor of potential root damage and *cambium*<sup>13</sup> heating, all indicators of fire severity. Smoldering produces the majority of smoke in a fire, but most fire behavior models do not include smoldering combustion.

## 3.4 GENERAL WILDFIRE ENVIRONMENT DESCRIPTIONS

### 3.4.1 TOPOGRAPHY

Topographic features such as slope, *aspect*,<sup>14</sup> and the overall form of the land have a profound effect on fire behavior. Topography directly and indirectly affects the intensity direction, and spread rate of wildfire. Fires burning in flat or gently sloping areas tend to burn more slowly and to spread in a wider ellipse than fires on steep slopes. Streams, rivers, and canyons tend to channel local *diurnal*<sup>15</sup> and general winds. These topographic features can accelerate the fire's speed and affect its direction, especially during *foehn*<sup>16</sup> wind events on the west side of the Sierra Nevada. Local winds are greatly affected by topography, which "bends the wind" as it flows around or over landforms.

Topography also causes daily upslope and down slope winds. The topographic features of aspect and elevation affect vegetation. The direction a slope is facing (aspect) influences fuel moisture. South and west facing slopes receive greater solar exposure thus reducing fuel moisture. Conversely, north and east facing slopes receive less solar radiation and tend to support vegetation with high fuel moistures.

The Pioneer/Volcano Planning Unit ranges from 2500 to 4200 feet in elevation with several large ridges running through it. These ridges are oriented east to west. This orientation makes the unit susceptible to wind driven wildfires under weather conditions that influenced past large fires in the county. The dominant aspects are south and north facing. The long exposure to the rays of the sun during the mid and late summer dries out the fuels on the south aspects making them prone to a fast rate of spread. (See *Plate 3 Shaded Relief Map*)

Many ridges in the unit have stands of conifers that add the potential for spot fires from embers cast off when trees crown. Ladder fuels are abundant in much of the unit creating the potential for crown fires during dry windy weather conditions. Steep canyons formed by the two rivers and several large streams in the center of the unit contribute to the rate of spread of wildfires, especially during foehn wind conditions.

### 3.4.2 WEATHER

This section describes common weather conditions and weather patterns that exist at the time the most damaging fires could occur, along with routine conditions during which serious fires may burn. When the temperature is high, relative humidity low, wind speed is high and/or originating from the east during foehn winds, conditions are very favorable for large, severe wildfires.

## WIND

Several wind conditions affect the planning unit. Daytime heating in the valley causes warm air to rise. This rising air creates upslope winds in the afternoon on most summer days. The reverse happens as the air at higher elevations cools during the night creating down slope winds. These are called diurnal winds. Wildland firefighters consider these wind direction changes when planning their fire suppression strategy.

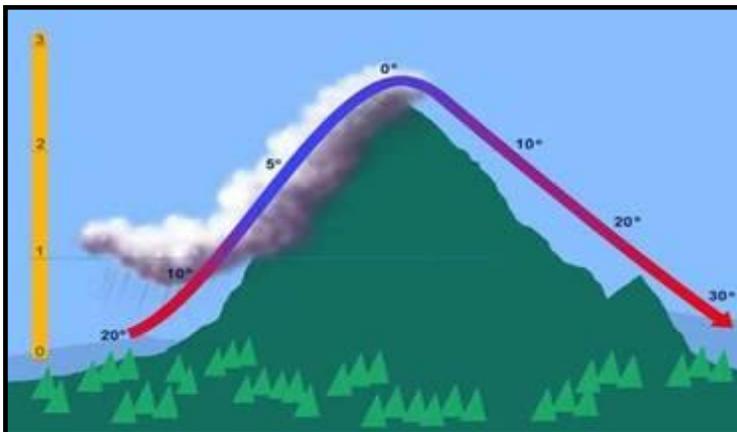
A wind condition often referred to as the marine flow can affect fire behavior in the planning unit. Marine flow is the wind (and cooling) that occurs when cooler offshore air pushes into the central valley. This happens when the Pacific High Pressure system weakens and can create strong westerly winds for short periods.

Normal prevailing winds during the fire season are out of the southwest. These winds can at times be quite strong.

Frontal systems moving through the area can also create difficult and dangerous fire conditions. Of particular concern are frontal systems associated with thunderstorms. CAL FIRE has suffered its greatest number of fatalities when two conditions exist - light fuels (grass fires) and thunderhead clouds overhead.

Finally, foehn winds, which flow from the north and east, can cause extreme fire conditions and erratic fire behavior. Amador County is affected by foehn winds differently depending where one is located.

Figure 2 Foehn Wind Event



In the lower elevations, foehn winds are from the north. In the upper elevations, winds are from the northeast or east.

Foehn winds are a special type of local wind associated with mountain systems, particularly in the Western United States. In most mountainous areas, local winds are observed that blow over the mountain ranges and descend

the slopes on the leeward side. If the down-flowing wind is *warm and dry*, it is called a *foehn* wind. The development of a foehn wind requires a strong high-pressure system on one side of a mountain range and a corresponding low-pressure system or trough on the other side. Such pressure patterns are most common to the *cool months*; therefore, foehn

winds are more frequent in the period from September through April than in the summer months.

Occasionally during late summer and fall, foehn winds will develop and affect fire behavior in Amador County. This type of foehn is related to a cold, dry, usually stagnated high-pressure air mass restricted by mountain barriers. If a low-pressure center or trough is located on the opposite side of the barrier, the strong pressure gradient will cause air to flow across the mountains. Since the mountains block the flow of surface air, the airflow must come from aloft. The air above the surface high-pressure system is subsiding air and is therefore dry and potentially quite warm. On the leeward side of the mountains, surface air is forced away by the strong pressure gradient, and it is replaced by the air flowing from aloft on the windward side and descending to the lowland on the leeward side. Surface wind speeds of 40 to 60 miles per hour are common in foehn flow of this type, and speeds up to 90 miles per hour have been reported. The wind often lasts for 3 days or more, with gradual weakening after the first day or two. Sometimes, it stops very abruptly.

High-pressure areas composed of cool air masses frequently stagnate in the Great Basin of the Western United States during the fall, winter, and spring months. Depending on its location, and the location of related Lows or troughs, a Great Basin High may create foehn winds which move eastward across the northern and central Rockies, westward across the Oregon and Washington Cascades and the northern and central Sierra Nevada, or southwestward across the Coast Ranges in southern California. A combination of high pressure over the State of Washington and low pressure in the Sacramento Valley causes north winds in northern California. Brief foehn wind periods, lasting 1 or 2 days, may result from migrating Highs passing through the Great Basin.

Fires occurring during foehn wind events burn with greater intensity and are very difficult to control. In 1961, the Rancheria fire began under a normal summer weather pattern that pushed the fire eastward and upslope during its initial stage. A rapidly developing foehn wind event reversed the direction of the fire and drove it down slope into Sutter Creek and Lone. Fortunately, this type of wind driven fire is relatively rare. However, these fires:

- Exhibit extreme fire behavior
- Have a high potential to destroy hundreds of structures and other infrastructures
- Have a high potential for loss of life
- Have a high potential to adversely affect downstream values
- Cause major degradation of ecosystem and loss of key elements of ecosystem
- Can significantly reduce local government revenues for several years due to loss of property taxes
- Can significantly reduce visual enjoyment of large areas of the view shed for many years
- Are very expensive to control

- Can adversely affect downstream values

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## TEMPERATURE

Normal summer temperatures in Amador County range between 80 and 107. Temperature affects fire behavior in two ways. Hot dry air dries forest fuels by reducing the fuel moisture in both live and dead forest fuels. The sun's rays preheat forest fuels, especially those on south and west facing (aspect) slopes. This preheating makes the fuels burn more intensely.

The Mt. Zion remote weather station has recorded summer air temperatures as high as 107 degrees. High temperature combined with wind dry forest fuels very quickly.

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## HUMIDITY

Humidity greatly affects wildfire behavior. How humid the air is varies during the day. Generally, the humidity rises at night and drops during the daylight hours. Usually, humidity decreases as the summer progresses. Low humidity draws moisture from forest fuels thus increasing the fire danger. Fuel moisture impacts fire behavior by causing fuels to ignite easier and burn hotter. The affect of dry air and humid air on moisture content is described by the class of the fuel. These classes are:

**Table 2 - Fuel Moisture Classes**

Fuel Class	Description
1 hour fuels	Fuels that are less than ¼ inch in diameter
10 hour fuels	Fuels that range in diameter from ¼ to 1 inch in diameter
100 hour fuels	Fuels that range from 1 to 3 inches in diameter
1000 hour fuels	Fuels that range from 3 to 8 inches in diameter

These fuel moisture classes define the number of hours to lose or gain two-thirds of the moisture content of the surrounding air. In practical terms, this means that if it rains for a short time in the late summer followed by dry weather, the 1-hour fuels are burnable in a little more than one hour from the rain event. In the same scenario, the 10, 100, and 1000 fuels have not had time to take on additional moisture and are still very flammable. Wind also affects the moisture content of forest fuels. Dry hot wind accelerates the drying process.

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### 3.4.3 HYDROLOGY

The *hydrology*<sup>17</sup> of an area defines the flow of water across and through the land. Lakes, ponds, streams, wetlands, and springs are just a few examples of features that contribute to the hydrology of an area. The presence of these features tends to increase the humidity of a local site and can make it more resistant to the effects of fire. In the case of ponds and lakes, their availability as water sources for suppression is also important.

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### 3.4.4 VEGETATION AND FUELS

Vegetation varies by size, height, and density, and combined with other flammable material on the site, it provides the fuel that feeds wildfire. The volume and distribution of fuels, the *moisture content*,<sup>18</sup> and the arrangement of fuels greatly influence resulting fire behavior.

Fuel is anything that can burn including grass, shrubs, and trees, as well as fences, decks, furniture, cars, and houses. These can be described either as fuel models (as described in section 3.5), or in terms of sizes and volumes: light fuels (consisting of grass, dry leaves, and kindling-size twigs), medium fuels (shrubs and fences), or heavy fuels (logs, trees, or homes). The distribution of the volume and sizes of fuels in any one space, along with the moisture content and arrangement of fuels, greatly influence resulting fire behavior.

*See Appendix 4 for more information on local vegetation types and their fire ecology.*

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### 3.4.5 WILDLIFE

Wildlife in the Sierra Nevada includes animals, plants, insects, other invertebrates, and fish. The variety of animals in the Sierra Nevada is extensive. A recent assessment indicates the presence of about 400 animal species in the region.<sup>19</sup> They include amphibians (25 species), reptiles (32), birds (230), and mammals (112). In addition, there are 40 kinds of fish with 26 species represented.<sup>20</sup> Over 50% of the native plant species (more than 2,700 species) found in California occurs in the Sierra Nevada.<sup>21</sup> These include 405 *endemic*<sup>22</sup> species, i.e., found only in the Sierra Nevada. These wildlife species all depend on the environment around them to provide the food, water, and shelter they need to survive.

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### 3.4.6 THREATENED AND ENDANGERED SPECIES

California has a large number of threatened and endangered species. While most biologists acknowledge that fire plays a role in the environment in which these species live, little is known about the relationship of these species to fire. Their response to fire of varying intensities, frequencies, and seasons is also not well understood; even less the effects of potential hazard reduction treatments on rare species. The planning and implementation of projects may be hindered because of this lack of knowledge.

### 3.5 FUEL: DESCRIPTION OF FUEL THROUGH FUEL MODELS

A fuel model describes the fuels available to a fire. Models are based on the amount, distribution, and continuity of vegetation. These models are used by fire managers to predict how fires will burn. Information regarding fuel volumes and fire behavior descriptions is available from the publication *How to Predict the Spread and Intensity of Forest and Range Fires*.<sup>23</sup>

Fuel models also describe the structure of the fuel. Fuel structure largely determines the fuel that will support the wildfire. For example, understory is more important than overstory. The amount and distribution of smaller-diameter fuels are a significant factor in fuel models. This is because these materials generally spread wildfires.

The amount of dead vegetation and the ratio of live-to-dead material also help determine the fuel model. Dead vegetation has less fuel moisture than live vegetation and carries flames more readily.

Fuel models may be delineated by several methods, from drawing polygons on maps, to field surveys and samples, to defining spectral bands on satellite imagery.

The following table illustrates the relationship between Sierra Nevada typical fuel models and vegetation types. The vegetation types are broad classifications of vegetation communities. These vegetation types and their fire ecology are discussed in detail in Appendix 4.

**Table 3 - Relationship between Sierra Nevada Vegetation Types and Typical Fuel Models.**

Vegetation Type	Typical Fuel Model <sup>24</sup>
Grassland and Dry Meadows	Fuel Model 1
Chaparral	Fuel Model 4,6
Montane Chaparral	Fuel Model 5
Foothill Woodland	Fuel Model 2, 8
Ponderosa Pine and Mixed Conifer	Fuel Model 9, 10
Upper-Elevation Fire Forests	Fuel Model 8, 10
Lodge pole-Meadow-Aspen	Fuel Model 8.9
Sagebrush-Bitterbrush	Fuel Model 5

The dominant fuel models in the Pioneer/Volcano Planning Unit are Fuel models 10, 6, 5, and 1 with 10 being the most dominate. The wide distribution of fuels in fuel model 10 throughout the planning unit suggests the potential for large damaging

fires. Additionally, the potential for significant property damage following small fires is also evident.

The Fire Behavior Prediction System describes fire behavior in these fuel models as follows:

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#### 3.5.1 SHORT GRASS – FUEL MODEL #1

*“The fine, very porous, and continuous herbaceous fuels that have cured or are nearly cured govern fire spread. Fires are surface fires that move rapidly through the cured grass and associated material. Very little shrub or timber overstory is present, generally less than 1/3 of the area. Both annual and perennial grasses are included; grasslands and savannas are represented along with grass-shrub combinations that meet the above area constraint.”*

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#### 3.5.2 SAGEBRUSH AND BITTERBRUSH /MONTANE CHAPARRAL - FUEL MODEL #5

*“Fire behavior is not normally explosive. Rates of spread are quite fast, but flame lengths are low (usually under five feet) and heat output minimal. 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. 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.”*

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#### 3.5.3 DORMANT BRUSH FUEL MODEL #6

*“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. A broad range of shrub conditions is covered by this model. 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, like 20 mi/h (32 km/h) at the 20-foot level.”*

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#### 3.5.4 CONIFER FOREST WITH DEAD, DOWNED LOGS - FUEL MODEL #10

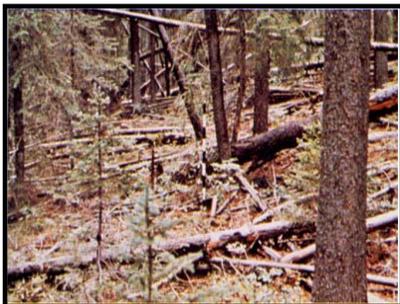


Figure 3 Typical Fuel Accumulation in Fuel Model 10

*“The fires burn in the surface and ground fuels with greater intensity than the other timber litter models. Dead down fuels include greater quantities of 3-inch or larger limb wood resulting from over-maturity or natural events that create a large load of dead material on the forest floor. Crowning out, spotting and*

torching is more frequent in this fuel situation, leading to potential fire control difficulties”

## CHARACTERISTICS OF FUEL MODELS

**Table 4 – Summary of Fuel Models**

Fuel Model	Typical Fuel Complex	Fuel Loading (Tons/Acre)				Fuel Bed Depth (ft)	Moist Extinction Dead Fuels (%) <sup>25</sup>	ROS* Chains/Hour	FL* (ft)
		1 Hr.	10 Hr.	100 hr.	Live				
1	Short Grass	0.74	0.00	0.00	0.00	1.0	12	78	4
2	Timber	2.00	1.00	0.50	0.50	1.0	15	35	6
3	Tall grass	3.01	0.00	0.00	0.00	2.5	25	104	12
4	Chaparral	5.01	4.01	2.00	5.01	6.0	20	75	19
5	Brush	1.00	0.50	0.00	2.00	2.0	20	18	4
6	Dormant brush	1.50	2.50	2.00	0.00	2.5	25	32	6
7	Southern rough	1.13	1.87	1.50	0.37	2.5	40	20	5
8	Closed timber litter	1.50	1.00	2.50	0.00	0.2	30	2	1
9	Hardwood litter	2.92	0.41	0.15	0.00	0.2	25	8	3
10	Timber	3.01	2.00	5.01	2.00	1.0	25	8	5
11	Light logging slash	1.50	4.51	5.51	0.00	1.0	15	6	4
12	Medium logging slash	4.01	14.03	16.53	0.00	2.3	20	13	8
13	Heavy logging slash	7.01	23.04	28.05	0.00	3.0	25	14	11

\*Rate of spread (ROS) and flame length (FL) are represented under fine fuel moisture of 8%, a mid-flame wind speed of 5 mph and live fuel moisture, if present, of 100% (Anderson 1982)

As stated in section 3.2, Surface Fires, surface fuel models are used to predict fire behavior. The California Department of Forestry and Fire Protection (CAL FIRE) developed a fuel assessment methodology for the California Fire Plan<sup>26</sup>. This methodology is called *Fuel Ranking*. This method assigns ranks based on expected fire behavior for unique combinations of topography and vegetative fuels under a given severe weather condition (wind speed, humidity, and temperature). The fuel ranking procedure makes an initial assessment based on the fuel model(s) present in a given area. It then raises the rank based on the amount of ladder fuels and/or crown fuel present to arrive at a fuel rank. In addition to the 13 fuel models in the table above, CAL FIRE includes six other fuel models: plantation, desert, urban, agricultural, water, and rock/barren. There are four fuel ranks (predicted fire behavior) derived from this method: non-fuel, moderate, high, very high.

Plate 23 - Fuel Rank indicates that most of the fuels within the Pioneer/Volcano Planning Unit are either very high or high. The dominant fuel rank in the planning unit is high.

## 3.6 FIRE HISTORY

The fire history of an area is a description of the time, space, and cause of fires. In fire jargon, “risk” is often associated with fire history because this term describes the events that cause a fire to start (i.e., ignitions).

The fire history of an area is important because it illustrates the potential for future fires. Large fires often repeat themselves; thus, it is useful to understand burning patterns over time. An area’s fire history also portrays ignition patterns that can target effective prevention programs. For example, if there is a history of frequent fires along a well-traveled route, roadside vegetation management may be in order. Additionally, fire history discerned through fire scars on tree rings may indicate the way fires have changed over time, in both frequency and intensity. This may point to appropriate goals for future fuel conditions.

The last time a large fire burned in the Pioneer/Volcano Planning Unit was in 1924 (See *Plate 4*). Since 1924, large fire has been excluded from this area. The result of this exclusion is an unnatural accumulation of forest fuels throughout much of the unit.

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### 3.6.1 FIRE CAUSED BY LIGHTNING

Lightning caused fires are common in the summer and fall. They are less common in the spring. Most lightning strikes occur between 4000 and 7000 feet elevations. Lightning caused fires usually are not a significant threat because at these elevations they are usually accompanied by moisture. However, on rare occasions, lightning occurs without moisture. When this happens, the fires caused by lightning can pose a threat to resources, life, and property. Wide spread dry lightning storms cause large numbers of fires that can overwhelm the resources of fire protection agencies.

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### 3.6.2 NATIVE AMERICAN PERIOD FIRE HISTORY

Prior to European settlement, Sierra forests were more open and park-like than today. This is because Native Americans inhabiting this area periodically burned the forest in the fall to improve game hunting and other purposes. While the severity of these annual fires varied greatly, researchers estimate that the fire frequency ranged between 5 and 25 years. The pre-European Sierra forests were likely to have large widely spaced trees with patches of young trees. More of the area was covered by wildflowers, grasses, and hardwoods. These species were more fire-tolerant.

### 3.6.3 EUROPEAN SETTLEMENT FIRE HISTORY

During European settlement, logging, primarily of the largest, oldest trees, became common, with subsequent changes in forest structure and fuel volumes. As the European population grew, there was an increased desire for fire protection. At the turn of the last century, forest policy in national forests was influenced following several large fires that burned nearly 5 million acres in Montana and Idaho in 1910. By the mid-twenties national forest policy was to control all fires before they reached 10-acres in size. The idea was to control all fires before they became large and destructive. In 1935, this policy was amended to include the “first burning period” policy. This policy declared that fires exceeding ten acres be extinguished before 10 a.m. of the next day. Clearly, the intent was to keep fires small. These federal forest fire policies were adopted by the then California Division of Forestry (CAL FIRE today) and are still in effect today.

### 3.6.4 RECENT FIRE HISTORY

During the last century, fire history has changed dramatically. Forest fuels have changed through modern cultural practices of timber harvesting, mining, and grazing. Fire control in the Sierra Nevada has been extremely effective, particularly since the 1930s where today less than 2% of fires get larger than ten acres. However, these 2% cause most of the damage.

The SNEP report<sup>27</sup> compared historic *fire-return intervals*<sup>28</sup> and present patterns, resulting in the following table.

Table 5 - Fire Return Intervals for Sierra Nevada Vegetation Types

Forest Type	Fire Return Interval (Years)	
	Historic (Pre-1900)	Present
Red Fir	26	1,644
Mixed conifer-fir	12	644
Mixed conifer-pine	15	185
Ponderosa Pine	11	192
Blue Oak	8	78

The following set of maps<sup>29</sup> (Plates 5 – 10) dramatically shows the occurrence of large wild-fires within Amador County during successive twenty-year intervals starting in 1900 and continuing to 2009. When most of these fires occurred the population of the county was much smaller than today.

## 3.7 FIRE HAZARD

The term “hazard” is usually used in the fire community in relation to topography and *fuel complex*<sup>30</sup> (the volume type, condition, arrangement, and location of fuels).<sup>31</sup> After several decades of successful fire-suppression efforts and reduced forest management, the Sierra

Nevada has an increasing problem of loss from wildfire. Fuel loads have increased to unnatural levels, and land-use patterns place valuable resources at risk from unnaturally intense wildfires. Fire hazard is influenced by past disturbances. The history of fire or management activities greatly alters the hazard for better or worse by changing the overall moisture of the site, as well as the volume and spatial arrangement of the fuels. This history is characterized by three fire management eras: the time before human occupation when lightning was the only ignition source, the era of Native American occupation when fire was used extensively, and the era after European Settlement when fire was largely curtailed and suppressed (as discussed in the Fire History section).<sup>32</sup>

### 3.7.1 HAZARD ASSESSMENT

CAL FIRE’s Fire and Resources Assessment Program developed a method to identify and prioritize projects that reduce damage from large wildfires. This method, fuel hazard ranking, *predicts fire behavior during severe weather conditions*. Projects identified by the fuel ranking method become part of the California Fire Plan. A detailed description of this method is included in the appendix.

Plate 13-Fire Threat map on the last page of this appendix displays the predicted fire behavior for the planning area.

### 3.8 FIRE REGIME

Fire regime is a measurement of fire’s historic and natural occurrence in the landscape. It includes the season, frequency, distribution, and intensity of wildfires. There is great variation in each of these factors. Each vegetation type has its own fire regime. There are five fire regimes generally accepted nationwide.<sup>33 34</sup>

The five fire regimes are based on average number of years between fires combined with the severity of the fire on the dominant overstory vegetation. These five regimes include:

**Table 6 - Fire Regimes**

Regime	Frequency (Years)	Severity
I	0-35	low (surface fires most common) to mixed severity (less than 75% of the dominant overstory vegetation replaced);
II	0-35	high (stand replacement) severity (greater than 75% of the dominant overstory vegetation replaced)
III	35-100+	mixed severity (less than 75% of the dominant overstory vegetation replaced)

IV	35-100+	high (stand replacement) severity (greater than 75% of the dominant overstory vegetation replaced)
V	200+	high (stand replacement) severity

Fire regime is a measurement of fire’s *historic and natural* occurrence in the landscape. It includes the season, frequency, distribution, and intensity of wildfires. There is great variation in each of these factors. Each vegetation type has its own fire regime. There are five fire regimes generally accepted nationwide.<sup>35 36</sup>

Plate11-Fire Regimes shows the fire regime most common in the Pioneer/Volcano Planning Unit is Fire Regime I.

### 3.8.1 FIRE CONDITION CLASS

Condition class describes the difference in fire regime between pre- and post-European settlement. Usually where the condition class indicates the absence of fire for an unnaturally long period of time, the fire risk to both the environment and human improvements is high. Condition class does not relate directly to fire hazard but is designed to better predict the effects from a fire, specifically, fire-related risks to ecosystems.

There are three condition classes for each fire regime – low (FRCC<sup>37</sup> 1), moderate (FRCC 2), and high (FRCC 3). These classes represent the departure from the natural fire regime. Condition class FRCC1 is considered to be within the historical pre-European fire regime. Moderate and high condition classes are outside the historic and natural fire regime and represent areas experiencing dramatic increases in fire behavior, intensity, severity, and fire size.<sup>38</sup>

Where the condition class departs from the class, vegetation characteristics are changed. For example if fire burned every 3-10 years in the pre-European era and now burn every 50-70 years, it can be expected that the volume of forest fuel will be much greater today. Fuels will also be more continuous. This change in fuels conditions will create more intense fires that are likely to kill trees that have survived fires for centuries. Fires are likely to be larger and risk of losing key parts of the ecosystem greater.

Years of highly effective fire suppression have excluded widespread low- to moderate-severity fires. As a result, the *structure*<sup>39</sup> and *composition*<sup>40</sup> of most Sierra Nevada vegetation types, especially in low- to middle-elevation forests, are affected. Forest stands are denser consisting of mainly small- and medium-size trees. These trees are often shade tolerant and *fire-sensitive*<sup>41</sup> tree species.

Fuel management projects can restore the vegetation type and structure through prescribed fire and/or other types of management techniques in a spatial distribution that can mimic the

effect of historic and natural fire regimes. Thus fuel management can move a condition class to one more closely resembling pre-European settlement, regardless of recent fire history.

The condition classes in the planning area are mostly Class 3, based on a fire regime of I and a recent fire history showing an interval of 200 to over 300 years. The following map shows Condition Classes for the planning area. See *Plate 12 Condition Class*.

### 3.9 FIRE THREAT

“Fire threat can be used to estimate the potential for impacts on various assets and values susceptible to fire. Impacts are more likely to occur and/or be of increased severity for the higher threat classes. Fire Threat is derived from a combination of fire frequency (how often an area burns) and expected fire behavior under severe weather conditions. Fire frequency is derived from 50 years of fire history data. Fire behavior is derived from fuels and terrain data. These data inputs are also catalogued within CERES<sup>42</sup> and available via the CDF-FRAP web site. Detailed documentation is under development and will be posted on the FRAP web site.”<sup>43</sup> Plate 13 on the last page of this appendix displays fire threats for the planning area.

#### 3.9.1 CHANGING FUELS IN THE WILDLAND URBAN INTERFACE

The above information and assessments provide a context and history of the changing fire environment. Many recognize that the changing fire environment, along with increasing urbanization and human use of the Sierra Nevada, have created conditions where human life and property, as well as key ecosystem components, are at increasing risk from the effects of high-intensity wildfires.<sup>44</sup>

Before the mid-1800s, fires generally were frequent and mostly of low to moderate intensity, from lower-elevation blue oak woodlands through upper-montane red fir forests.<sup>45</sup> Fire exclusion, logging, grazing, forest clearing, and urbanization have combined to alter fire regimes that are now quite different from their historical character. These modified fire regimes have corresponding modified ecosystems, often with increases in vegetation density and accumulation of forest litter and duff that support a larger proportion of high-intensity fires than occurred under historical conditions.<sup>46</sup> The problems were created over a long time, and they will not likely be solved rapidly. The use of shaded fuelbreaks and other fuel reduction efforts along the interface can reduce these fire risks.<sup>47</sup> This plan provides a list of projects designed to mitigate the potential damage from wildfire.

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- <sup>1</sup> Much of the information appearing in this section was taken from original material provided by Carol Rice, Wildland Resource Management. It was modified to apply to the Pioneer/Volcano Planning Unit.
- <sup>2</sup> Fire Behavior: The combination of fire spread, heat output, flame length intensity, etc. as the fire responds to weather, topography, types of fuels, etc.
- <sup>3</sup> Mokelumne and Consumes Rivers
- <sup>4</sup> Fuel Modification Area is synonymous with Planning Unit
- <sup>5</sup> Residence Time: How long the flaming front burns in any one location.
- <sup>6</sup> Fuel Modification: The management of fuels for fire safety. Examples include prescribed burns and creation of firebreaks.
- <sup>7</sup> Ladder Fuels: Materials such as shrubs or small trees connecting the ground to the tree canopy or uppermost vegetation layer. In forests, this allows fire to climb upward into trees.
- <sup>8</sup> Embers: Small glowing or smoldering pieces of wood or other organic debris, often dispersed ahead of a fire, also known as firebrands
- <sup>9</sup> Spot Fire: A smaller fire outside the boundary of the main fire (usually ahead of the direction the fire is traveling), started by airborne sparks or embers.
- <sup>10</sup> Normal bad fire weather refers to the normal weather experienced during the peak of fire season
- <sup>11</sup> Leading Edge: The foremost part of a fire that is guiding the fire in the direction of travel.
- <sup>12</sup> Burn-Out Time: The length of time in which flaming and smoldering phases occur in a given area or for the whole fire.
- <sup>13</sup> Cambium: The growing layer of a tree, located between the bark and wood of the stem.
- <sup>14</sup> Aspect: The direction that a slope faces (as in north, south, east, or west).
- <sup>15</sup> Diurnal: Belonging to or active during the day.
- <sup>16</sup> Foehn Events: A wind that blows warm, dry, and generally strong, creating extremely dry fuel and dangerous fire potential.
- <sup>17</sup> Hydrology: A science that deals with the waters of the Earth including movement, distribution, seasonal patterns, and conservation.
- <sup>18</sup> Moisture Content: The dry weight of a material, such as wood or soil, compared to the wet weight of the same material. It is not unusual for live material to have moisture content greater than 100% because it could contain more water than solid material by weight.
- <sup>19</sup> Graber, D.M. (1996). "Status of Terrestrial Vertebrates." *Sierra Nevada Ecosystem Project, Final Report to Congress, Volume II, Assessments and Scientific Basis for Management Options*. Davis: University of California, Centers for Water and Wildland Resources.
- <sup>20</sup> Moyle, P.B., R.M. Yoshiyama, and R.A. Knapp (1996). "Status of Fish and Fisheries." *Sierra Nevada Ecosystem Project, Final Report to Congress, Volume II, Assessments and Scientific Basis for Management Options*. Davis: University of California, Centers for Water and Wildland Resources.
- <sup>21</sup> Shevock, J.R. (1996). "Status of Rare and Endemic Plants." *Sierra Nevada Ecosystem Project, Final Report to Congress, Volume II, Assessments and Scientific Basis for Management Options*. Davis: University of California, Centers for Water and Wildland Resources.
- <sup>22</sup> Endemic: A plant that is native to a certain limited area and found nowhere else.
- <sup>23</sup> Rothermel, Richard C. (1983). General Technical Report INT-143, published by the USDA Forest Service Intermountain Forest and Range Experiment Station.
- <sup>24</sup> There is a wide variety of fuel volume, structure, and size class distribution within vegetation types; fuel models should be determined by site-specific conditions. Fuel models can be classified by comparing photographs of fuel models with on-site conditions (Anderson 1982), by using expert opinion to translate vegetation types to fuel models, or by using a "key" provided in Rothermel (1983). Anderson, Hal E. (1982). "Aids for determining fuel models for estimating fire behavior." Res. Pap. INT-305. Ogden, UT. Intermountain Forest and Range Experiment Station. 26 pp.
- <sup>25</sup> Moisture of extinction: The fuel moisture content at which a fire will not spread, or spreads only sporadically, and in a non-predictable manner.
- <sup>26</sup> A plan required by the California Board of Forestry which is a road map to reduce the risk of wildfires.
- <sup>27</sup> Sierra Nevada Ecosystem Project (1996a) An assessment of the Sierra Nevada ecoregion which was requested by Congress in 1992.
- <sup>28</sup> Fire Return Interval: A period of time between fires in a specific region or area.

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- <sup>29</sup> Data source is CALFIRE Fire and Resource Assessment Program (FRAP)
- <sup>30</sup> Fuel Complex: The volume type, condition, arrangement, and location of fuels.
- <sup>31</sup> Husari et al. 2006.
- <sup>32</sup> Stephens, S.L., and N.G. Sugihara (2006). "Fire management and policy since European settlement." In: Sugihara, N.G., J. van Wagtenonk, K.E. Shaffer, J. Fites-Kaufman, and A.E. Thode, editors. *Fire in California's Ecosystems*. Berkeley: University of California Press. Pp. 431–443.
- <sup>33</sup> Hardy, K.M., C.C. Schmidt, J.M. Menakis, and N.R. Samson (2001). "Spatial data for national fire planning and fuel management." *International Journal of Wildland Fire* 10: 353–372.
- <sup>34</sup> Hann, W.J., and D.L. Bunnell (2001). "Fire and land management planning and implementation across multiple scales." *Int. J. Wildland Fire* 10: 389–403.
- <sup>35</sup> Hardy, K.M., C.C. Schmidt, J.M. Menakis, and N.R. Samson (2001). "Spatial data for national fire planning and fuel management." *International Journal of Wildland Fire* 10: 353–372.
- <sup>36</sup> Hann, W.J., and D.L. Bunnell (2001). "Fire and land management planning and implementation across multiple scales." *Int. J. Wildland Fire* 10: 389–403.
- <sup>37</sup> Fire Regime Condition Class website (October 2006), Definition, [www.frcc.gov](http://www.frcc.gov).
- <sup>38</sup> Fire Regime Condition Class website, Definition, (October 2006), [www.frcc.gov](http://www.frcc.gov)
- <sup>39</sup> Structure: The composition of a forest or vegetation type, specifically looking at the density, cover, size or diameter, and arrangement.
- <sup>40</sup> Composition: The percentage of each species that comprise a given area.
- <sup>41</sup> Fire-Sensitive: A species of tree that is more susceptible to fire damage. Sensitivity may be due to thin bark or easily ignitable foliage.
- <sup>42</sup> CERES is an information system developed by the [California Natural Resources Agency](http://www.ceres.ca.gov) to facilitate access to a variety of electronic data describing California's rich and diverse environments.
- <sup>43</sup> California Department Of Forestry And Fire Protection. (2005) Fire And Resource Assessment Program. "Metadata Record: Fire Threat." [frap.cdf.ca.gov/data/frapgismaps/output/fthreat\\_map.txt](http://frap.cdf.ca.gov/data/frapgismaps/output/fthreat_map.txt).
- <sup>44</sup> Biswell (1989); California Spotted Owl Federal Advisory Committee (1997); SNEP (1996a).
- <sup>45</sup> Skinner and Chang 1996.
- <sup>46</sup> Skinner and Chang 1996.
- <sup>47</sup> Husari et al. 2006.