Fire and Fuels

Introduction

Fire has historically been the dominant disturbance factor in forests across the northern Rocky Mountains and has created the current mosaic patterns observed across the landscape. Most forests have evolved with the continual influence of fire. Forested communities and ecosystems depend on this type of disturbance regime for their continued perpetuation on the landscape (Habeck and Mutch 1973).

Natural historic fire regimes best illustrate fire disturbance patterns. A fire regime describes the frequency, predictability, and severity of fire in an ecosystem. Fires regimes can range from non-lethal to stand-replacing levels, typically becoming less frequent as severity increases.

Drought cycles and fuel availability have a considerable influence on fire regimes. Wildland fires often occur during the driest months of the year, typically July, August, and early September, and can have considerable effects to an area during drought periods. The quantity and type of fuels also affect fire behavior. Fire fuels are made up of dead woody debris and living vegetation. Fuel quantities can vary considerably, depending on the vegetation composition and recent fire history.

Pre-settlement wildland fires burned through the summer season until extinguished by fall precipitation. In the settlement period before 1941, wildland fire suppression efforts were often not successful and resulted in fires burning thousands to ten of thousands of acres. Suppression efforts since then have altered pre-settlement fire regimes and reduced the number of forested acres burned each year. The combination of fire suppression, fire exclusion, and natural disturbance processes has allowed fuels to accumulate in unmanaged timber stands. This situation currently exists in the Upper Swan Area.

An analysis of fire history in the Upper Swan Area was used to characterize historical fire regimes that typify this area and to determine to what extent fire suppression has altered these regimes and affected fuel accumulations.

Analysis Area

Spatial Bounds

The area evaluated for this Fire and Fuels Section includes the Upper Swan Analysis Area. The fire regime patterns in the Upper Swan are characteristic of those in the northern Rocky Mountain region. Elevation is moderate, ranging from 3800 to 8600 feet. Topography is a moderate relief landscape composed of valleys, ridgelines, and crests. The area has a mean slope of 25 percent with only 12 percent of the area having slopes greater than 40 percent. Most of the Upper Swan Analysis Area falls within the montane ecotone with lesser amounts in the lower subalpine ecotone. The western larch/lodgepole pine fire-initiated forest and the Douglas-fir fire-initiated and maintained forest are the major forest cover types within the Upper Swan Area.

Temporal Bounds

The length of time for effects in this cumulative effects analysis is approximately 10 years. This is based on the probable contract length for the proposed fuels reduction/forest health project, the timeframes for related activities, and the reasonably foreseeable action identified.

Data Sources, Methods, and Assumptions Used

The fire history analysis in the Upper Swan Area was based on the data collected between 1997 and 2002 for the Swan Lake Ranger District's Timber Stand Management Record System. Fire history and data collected for the Sixmile Watershed Analysis also supported the Upper Swan Analysis. Sixmile, though not an adjacent watershed, shares similar topographical, biophysical, and climatic characteristics. Local meteorological information was obtained from a WETS weather monitoring station in Condon, Montana, for dates after 1962 and from the National Weather Service Station in Kalispell, Montana for dates prior to 1962. Data gathered by the National Interagency Fire Management Integrated Database (NIFMID) evaluated fire ignition and suppression events and their associated causes from 1940 to the present.

Measurement Indicators

To focus the fire/fuels analysis and describe relevant effects, the following effects indicators have been used:

- Predicted rate of fire spread (chains/hour);
- Predicted flame length (feet);
- Type of predicted fire; and
- Acres of fuel reduction treatments.

Affected Environment

Historic and Current Fire Regimes

A fire regime is defined as the frequency, predictability, and severity of fire in any given ecosystem. An analysis of fire history in the Upper Swan Analysis Area was used to determine:

- Spatial and temporal distribution of fire disturbances.
- Mean fire intervals in areas with similar bio-physical and climatic characteristics.
- Whether fire suppression has affected primeval fire regimes.

Fire Regimes were assigned to each of the potential vegetation groups (PVGs) in the project area. The two predominant fire regimes that occur are as follows:

- Two mixed-severity regimes ranging from non-lethal under-burns to stand-replacing fires at mean intervals of 15 to 75 years, and
- A regime of infrequent stand-replacing fires at mean intervals of 100 to 340 years (Barrett, Arno, Key 1991).

Mixed-severity fire regime areas can experience the full range of severities during either a single event or consecutive events. Mixed-severity fire regime areas may experience fires of intermediate effects, often consisting of fine-grained spatial patterns resulting from a mosaic of varying severity. The mixed-severity fire regime in the project area is predominately of a moderately low frequency with moderate to high severity.

In contrast, stand-replacement fire regimes typically have lethal fires with less than 10 percent of the forested canopy cover remaining after the fire; in the project area, these are low frequency with high severity events.

The Integrated Scientific Assessment for Ecosystem Management in the Interior Columbia Basin and Portions of the Klamath and Great Basins (1996) analyzed individual sub-basin conditions across lands in parts of Idaho, western Montana and Wyoming, and northern Nevada and Utah. The assessment states, "Where important changes have occurred, mixed-severity fire regimes have tended toward lethal regimes and fire frequency has generally declined as a result of effective fire suppression". The threat of abnormally high severity fires is one of the primary risks to ecological integrity of much of the western forest types like those found in the project area.

Many western forests have undergone extraordinary changes during the 20th century. The evidence is unmistakable to most scientists, from repeat photography, fire-scar analyses, forest stand reconstructions, and pollen and charcoal studies. These changes are most profound in the dry, long-needle pine forests of the West, especially ponderosa pine. Among the changes are many fold increases in the density of trees and landscape-scale continuity of heavy fuels.

Today, in place of an open understory, we find thick brush, downed timber and many young trees; fires that start on the ground can spread quickly, and then climb through the branches of small trees, which create a “ladder” to the larger trees in the forest canopy.

This wholesale transformation happened with reduction of grassy fuels by livestock grazing, which largely eliminated low-intensity surface fires, and with more proactive fire suppression after World War II. Climate also fostered continued fuel accumulation in two unusually wet decades from 1976 to 1995. During those decades, wildfires cleared relatively little fuel from the forests, while implementation of prescribed burning and fuels treatment fell farther behind (Befancourt et al 2003).

The majority of the project area is forested with few non-forested areas. There are some natural openings that would exclusively feature grass or shrubs, and there are a few rock outcroppings. Historically, approximately 72 percent of the project area would have had non-lethal or mixed fire regimes (Barrett 2002). Such fires acted as a natural thinning agent, reducing the encroachment of the less fire resistant species like Douglas-fir with some alpine fir and spruce. Infrequently, fire would kill the overstory trees when large amounts of forest floor biomass accumulated on the forest floor and provided increased intensity and fuel ladders. In the lower elevation portions of the analysis area, fire regenerated and maintained open park-like stands of predominantly larch with some Douglas-fir and ponderosa pine. In the higher elevation areas, the present timber stand conditions of even aged trees with more of a lodgepole pine component suggests that fires were more intense but less frequent (Arno 1980; Fischer and Bradley 1987). Historically, this has led to a mosaic of single-aged and multiple-aged groups of trees in the project area.

In the absence of fire for the past 80+ years, tree species such as the more shade tolerant Douglas-fir, alpine fir, and spruce have become well established as understory and have resulted in thick tree stocking in the timber stands being considered for commercial thinning under the action alternatives. Table 3-35 displays the historic and current fire regime percentages for the Upper Swan Analysis Area.

TABLE 3-35.
PERCENTAGE OF HISTORIC AND CURRENT FIRE REGIMES

	Non-Lethal	Mixed Severity-1	Mixed Severity-2	Lethal
Historic	31	20	21	28
Current	--	8	49	43

Current Condition Class Departures

The condition class departure is a function of the degree of departure from historical fire regimes resulting in alterations of key ecosystem components such as species composition, structural stage, stand age, and canopy closure. Current Condition Class Departures are defined in terms of the relative risk of losing one or more key components that define an ecological system based on five ecosystem attributes (Laverty and Williams 2000):

- Disturbance regimes (patterns and frequency of fire, insect, disease, etc),
- Disturbance agents,
- Smoke production,
- Hydrologic function, and
- Vegetative attributes (composition, structure, and resilience to disturbance agents).

The higher the number of condition class departures, the more the risk of losing key components of an ecological system if a wildland fire occurs. Condition Class Departures are categorized by the National Fire Plan as:

Class 1 - Maintenance: Fire regimes are within a historical range, and the risk of losing key ecosystem components is low. Vegetation attributes are intact and functioning within a historical range. No fire return intervals have been missed.

Class 2 – **Restoration:** Fire regimes have been moderately altered from their historical range. The risk of losing key ecosystems components is moderate. Fire frequencies have departed from historical frequencies by one fire or more return intervals. This results in moderate changes to one or more of the following: fire size, intensity and severity, and landscape patterns. Vegetation attributes have been moderately altered from their historical range.

Class 3 – **Conversion:** Fire regimes have been substantially altered from their historical range. The risk of losing key ecosystem components is high. Fire frequencies have departed from historical frequencies by multiple return intervals. This results in dramatic changes to one or more of the following: fire size, intensity, severity, and landscape patterns. Vegetation attributes have been substantially altered from their historical range (Laverty and Williams 2000). (NOTE: The Upper Swan Analysis Area has little Condition Class Departure 3 lands.)

Table 3-36 provides a summary of the historical average interval [mean fire interval (MFI)] between fires in the mixed-severity and stand-replacement fire regimes by potential vegetation group (PVG). The table also displays the current Condition Class Departure by vegetation type in the column labeled "Condition Class Departure" for timbered stands that have not been entered for timber management activities.

TABLE 3-36.
HISTORICAL AVERAGE INTERVAL BETWEEN FIRES IN THE UPPER SWAN ANALYSIS AREA

PVG and Fire Regime	Pre-1940 Stand MFIs (years)	Condition Class Departure
Warm-Dry MS-2		2
Range	69 to 87	
Mean	80	
Warm-Moist MS-2		2
Range	54 to 83	
Mean	73	
Cold-Dry MS-2		2
Range	59 to 67	

TABLE 3-36.
HISTORICAL AVERAGE INTERVAL BETWEEN FIRES IN THE UPPER SWAN ANALYSIS AREA

PVG and Fire Regime	Pre-1940 Stand MFIs (years)	Condition Class Departure
Mean	63	
Cold-Moist MS-2		2
Range	51 to 97	
Mean	80	
Cool-Moist MS-2		2
Range	44 to 97	
Mean	79	
Warm-Moist SR		1
Range	131 to 180	
Mean	156	
Cold-Moist SR		1 to 2
Range	97 to 148	
Mean	120, 125 MAFI**	
Cool-Moist SR		1 to 2
Range	83-119	
Mean	106, 147 MAFI*	

* MS-2 is mixed severity fire regime; SR is stand replacement fire regime.
**Multiple site Average Fire Intervals for ecologically similar types, i.e. PVG.

Forest Management

Although timber harvest and associated fuel treatments have not replicated wildland fire, they have replaced wildland fire as the dominant process that changes the patterns of vegetation and woody debris accumulations in the project area. Since the 1950s, approximately one-third of the Upper Swan Area has been regeneration timber harvested and fuels have been treated (prescribed burning and machine piling of slash with pile burning). These previously managed areas are considered to be in a Condition Class 1.

The forest management activities in the area have created fuel mosaics, which are breaks or changes in standing timber and surface fuel patterns. Along with road access, these fuel mosaics increase the success of initial attack, allow for effective fire suppression under the appropriate management response, and decrease the risk of high intensity stand-replacement wildland fire. The existing Forest Plan requires that all fires be suppressed (excluding areas covered under an approved Fire Management Guide or Plan) using the appropriate management response. The appropriate management response in the analysis area is suppression using aggressive initial attack actions to control a wildland fire with safety of the public and fire management personnel being the first priority, and sequentially the protection of property/natural resources.

Drought History

Studies indicate that severe single-year droughts occurred in the Northwest at least 10 times between 1940 and 1995, and have occurred in every decade (Barrett 1997, Karl and Koscielny 1982, Graumlich 1987, Meko, et al. 1993). Local meteorological information from a WETS weather monitoring station in Condon, Montana, indicates drought fire season years (in which fire suppression occurred within the analysis area) in 1967, 1972, 1973, 1984, 1988, 1989, 1991, 1994, 1996, 2000, 2001, 2003, and 2006.. This station was activated in 1962. The National Weather Service Station in

Kalispell, Montana (active since 1899) was used to correlate the drought fire season years prior to 1962 with the number of fire suppressions in the area. These drought years were 1940 and 1961.

Fire Ignitions and Suppressions since 1940

National Interagency Fire Management Integrated Database (NIFMID) identified 120 suppressed ignitions (82 lightning-caused and 38 human-caused) that occurred from 1940 though 2003 within the Upper Swan Area. Drought year dates were also cross-referenced with fire active dates recorded on the (NIFMID), the results were 34 lightning-caused and 19 human-caused ignitions during these more large fire-prone years. Of the total ignitions, 119 were promptly suppressed and averaged only 1.2 acres. The 2003 Crazy Horse Fire was the largest of the fires (lightning caused ignition) burning 11,000 acres.

Since 1970, there have been 38 human-caused fires. There appears to be a direct relationship between the increase of forest use and wildland-urban interface density with human-caused fire occurrence.

Fire Suppression Effects on Fire Intervals and Current Condition Class Departures

Before 1940 when effective fire suppression techniques are generally considered to have begun, a spreading wildland fire severe enough to change stand structure occurred once every 8.5 years within the project area on average. Wildland fire occurrence was two to three times more frequent within the mixed-severity fire regime than the stand-replacement regime. The large fire-free interval from 1930 to the present is more than seven times longer than the historical major fire interval. The spread of a typical moderate to severe large fire was on a west-to-east axis with a broadening north-south axis as it moved across the moderate relief landscape, while low to moderate fire spread was confined to a valley to ridgeline pattern. The mean slope for the Upper Swan Area is 30 percent, with 15 percent of the area containing slopes greater than 40 percent. The size of the historical mean major fire disturbance (greater than 100 acres) was approximately 11,756 acres within the analysis area and usually resulted in a full range of fire severities.

After comparing the mean fire intervals and current fire intervals for mixed-severity regimes in the Upper Swan Area, it appears that the warm-dry, warm-moist, cold-moist, and cool-moist PVGs would likely have experienced one spreading fire since 1940, and the cold-dry PVG would have had two spreading fires since 1940. Other studies suggest many stands with the mixed-severity fire regime have missed one or two fire cycles because of long-term fire suppression (Sneck 1977, Barrett et al. 1991, Barrett 1995). Therefore, effective fire suppression since 1940 has probably precluded one spreading fire at a minimum for all PVGs within the mixed-severity fire regime. This is indicative of a Condition Class Departure 2, which suggests that restoration activities be done in late-mid seral and late seral stands that are currently unmanaged.

The stand replacement regime fire intervals varied widely throughout the area, ranging from 16 to greater than 200 years long. The conservative approach is to compare the pre-fire effective suppression period mean average fire intervals (MAFIs) with current fire intervals for the cold-moist and the cool-moist PVGs. There is little disparity between them, so that suggests cold-moist and cool-moist PVGs in the Upper Swan Area are within historical range of fire regimes. Dendrochronological (tree-ring dating) research on fire-scarred trees in the Upper Swan Area indicates that on warm-moist PVGs, fires occurred more frequently before the mid-1700s with no large fires occurring since then. These results indicate that numerous stands were relatively old when either they experienced a stand-replacing fire following the "Little Ice Age" (e.g., 1910, 1917, 1919, 1926, and 1940) or after fire suppression became effective. This, too, suggests that current fire intervals for most warm-moist PVG stands are within their historical range. However, using a less conservative approach, comparing each PVG's MFI or MAFI with their respective current fire interval suggests that one spreading fire would have occurred in each PVG within the stand replacement fire regime since 1940.

Wildland Urban Interface

The Federal Register (January 4, 2001) supplied the three categories of WUI considered in the National Fire Plan. The WUI is defined as the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels. The Upper Swan Analysis Area only includes the Category 2 type of WUI called the Intermix Community, which is defined as follows:

> **Category 2 - Intermix Community:** The Intermix Community exists where structures are scattered throughout a wildland area. There is no clear line of demarcation (boundary). Wildland fuels are continuous outside of and within the developed area. The development density in intermix ranges from structures very close together to one structure per 40 acres. Fire protection districts funded by various taxing authorities normally provide life and property fire protection and may also have wildland fire protection responsibilities. Areas within the Upper Swan categorized as Category 2 include small cluster developments such as ranches, summer residences, hay meadows, timber production areas, ranch outbuildings, and other structures. Approximately 7285 acres of the Hemlock Elk Project Area is located within the WUI.

Although the amount of private ownership is finite within the analysis area, the current trend for development on private ownership is one of further subdivision and subsequent increase in population /dwelling-structure density. There is potential for development and increased private ownership within the PCTC sections currently for sale.

These areas encompass not only the sites themselves, but also the continuous slopes and fuels that lead directly to the sites. When wildland fire enters these areas, the suppression efforts require a large commitment of firefighting resources. During the fires of 2000, large portions of otherwise high-priority fires remained unstaffed because resources were committed to structure protection. Experienced fire managers know that the intermix area is one of the most dangerous environments in which to conduct fire suppression operations. Poor ingress and egress compromise firefighters' escape routes. Hazardous materials and other manmade materials produce toxic gases when burned and pose major threats to firefighters and the public. The high values at risk (homes, vehicles, domestic animals, etc.) can lead even the most seasoned wildland firefighters to take risks that he or she would not consider in the wildland environment.

Home Ignitability

Recent research (Cohen 2000a) addresses home ignitibility, or the potential for a home to ignite, in the WUI. Cohen concludes that homes ignite via one of two processes, direct flame contact with the structure and lofted firebrands landing on a receptive fuel, such as a house. The Structure Ignition Assessment Model (SIAM) developed by Cohen (1995) and results from the International Crown Fire Modeling Experiment (Alexander et al. 1998) generally concur that a flaming front at a distance of 40 meters or more from a structure does not deliver sufficient heat energy to ignite the exterior of a home. However, lofted firebrands, such as those experienced in the 2000 Cerro Grande Fire in New Mexico, ignited surface fires on homes while leaving green needles on trees around the home (Cohen 2000b). Highly ignitable homes can ignite during wildland fire without fire spreading near the structure. This occurs when firebrands are lofted downwind from fires. The firebrands subsequently collect on and ignite flammable home materials (such as roofs) and adjacent flammables (such as woodpiles, decking, or landscaped vegetation). Firebrands resulting in ignitions can originate from wildland fires that are a distance of one kilometer or more (Cohen 2000a). Cohen concludes:

> "Because homeowners typically assert their authority for the home and its immediate surroundings, the responsibility for effectively reducing home ignitability can only reside with the property owner rather than wildland agencies."

Because of the problems and complexities associated with the Intermix Community, resource mangers and fire managers find it desirable to exclude, to the extent possible, wildland fire from these areas and may use limited, carefully controlled, prescribed fire treatments or, more commonly, mechanical treatments to reduce fuels in such areas. The purpose of these fuel treatments is to provide firefighter safety and minimize future loss of property and natural resources. Sociopolitical and logistic constraints may preclude or limit prescribed fire use near residences (Kalabokidis and Omi 1998, DellaSalla, et al. 1995). Limitations to use of prescribed fire within the WUI include public attitudes toward smoke, fear of escaped fire, negative visual effects of burns, and limited windows of opportunity in conditions dry enough to achieve fuel reduction objectives while still insuring containment near homes.

Forest Fuels and Fire Behavior

The greatest effect of fire suppression and exclusion in unison with other natural disturbance processes has allowed biomass to accumulate in most unmanaged timber stands. The bulk of the biomass currently occupying the analysis area is in the form of dead standing and downed trees and shrubs, as well as live shade-tolerant true firs, spruce, lodgepole pine, and Douglas-fir. The combination of dead fuel and continuous live vegetation from the forest floor to the upper forest canopy creates a complex of fuel that, when ignited under severe fire conditions, would leave little or no surviving above-ground vegetation.

Fuels, weather, and topography influence fire behavior. Fuels are the only factor that management can modify. Fuels are made up of the various components of vegetation (live and dead) occurring on a site. These components include litter and duff layers, the dead-downed woody material, grasses and forbs, shrubs, regeneration, and timber. Various combinations of these components define the major fuel groups of grass, shrub, timber, and slash. The differences in fire behavior among these groups are basically related to the fuel load and its distribution among the fuel particle-size classes. Fuel load and depth are critical fuel properties for predicting whether a fire will ignite, its rate of spread, and its intensity. The relationship of fuel load and depth segregates the 13 fuel models into two distinctive orientations, with two fuel groups in each. Grasses and shrubs are vertically-oriented fuel groups, which rapidly increase in depth with increasing load.

Fuel component characteristics contribute to fire behavior properties. Fuel loading, size class distribution of the load, and its arrangement (compactness or bulk density) govern whether an ignition will result in a sustaining fire. Horizontal continuity influences whether a fire will spread or not and how steady the rate of spread will be. Loading and its vertical arrangement will influence flame size and the ability of a fire to torch into the overstory. With the proper horizontal continuity in the overstory, the fire may develop into a crown fire. Fuel moisture content has a substantial impact upon fire behavior affecting ignition, spread, and intensity.

Wildland fires would still occur and may escape initial attack during severe fire conditions. The intensity of these fires would be dependent upon weather, fuels, and topography. When burning conditions are less than severe, fires may be of low to moderate severity and result in only moderate or no damage to overstory trees. If downed fuels are present, tree mortality can occur even during moderate burning conditions. Fuels, weather, and topography combine to determine how hot and fast a fire burns. Fuel conditions are described by quantity, arrangement and size and used as one of the inputs in the BEHAVE computer model to determine flame height and rate of spread for a wildfire. Behave runs based on an average bad day.

Fuel Models and Fire Behavior: Fuel models are a tool to help the user realistically estimate fire behavior. Each fuel model is described by:

- The fuel load and the ratio of surface area to volume for each size class.
- The depth of the fuel bed involved in the fire front.

- Fuel moisture, including that at which the fire will not spread (called the moisture of extinction).

These are based on Albini's (1976) paper "Estimating Wildfire Behavior and Effects." The criteria for choosing a fuel model includes the fact that the fire burns in the fuel stratum best conditioned to support the fire. The 13 fuel models for fire behavior estimation are for the severe period of the fire season when wildland fires pose greater control problems and impacts on land resources.

The nine surface Fire Behavior Fuel Models listed below best represent the landscape fuel mosaic for the area analyzed and are described in terms of vegetation, expected fire behavior, and acreage. Fire Behavior Fuel Model 1 (mountain grasslands or private pastureland), Fire Behavior Fuel Model 3 (marshgrass) and the riparian shrub portion of Fire Behavior Fuel Model 5 are volatile under severe fire conditions if untreated. The private pastureland is usually treated by grazing and/or harvesting for hay production. These sites would not readily burn under normal summertime weather conditions and can serve as anchor points for fuelbreaks and firebreaks. There are acres in the analysis area that are assigned a zero for Fire Behavior Fuel Model (ponds, lakes, large rock outcroppings, and gravel pits) and may function as fuelbreaks. The reference material used in the description and design of the Fire Behavior Fuel Models for the project is Anderson (1982).

Grass Group

Fire Behavior Fuel Model 1 (mountain grasslands and private pastureland) - Fire spread is governed by the fine, very porous, and continuous grasses and herbaceous fuels that have cured or are nearly cured. Fires are surface fires that move rapidly through contiguous cured grass and associated material if untreated. Very little shrub or timber is present, generally less than one-third of the area.

Fire Behavior Fuel Model 2 (post timber harvest stands; nonstocked and seedling) - Fire spread is primarily through the fine herbaceous fuels, either curing or dead. These are surface fires where the herbaceous material, in addition to the little and dead-down stemwood from the open shrub or timber overstory, contribute to the fire intensity. Open shrublands or low brush and pine 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.

Fire Behavior Fuel Model 3 (riparian marshgrass) - Fires in this fuel are the most intense of the grass group and display high rates of spread under the influence of wind. Wind may drive fire into the upper heights of the grass and across standing water. Stands are tall, averaging about 3 feet, but considerable variation may occur. Approximately one-third or more of the stand is considered dead or cured and maintains the fire. These areas in the analysis area are usually discontinuous and separated by expanses of water greater than 30 feet (e.g., wet meadows and adjacent to beaver pond areas). Rate of spread is only applicable to contiguous marshlands.

Shrub Group

Fire Behavior Fuel Model 5 (sapling stands and riparian shrub) - 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. The riparian shrub portions of this fuel model in the analysis area are usually intermingled with riparian marshgrass and separated by expanses of water greater than 30 feet.

Timber Litter Group

Fire Behavior Fuel Model 8 (closed timber litter) - Slow-burning ground fires with low flame lengths are generally the case, although the fire may encounter an occasional "jackpot" or heavy fuel concentration that can flare up. Only under severe weather conditions involving high temperatures, low humidities, and high winds do the fuels pose fire hazards. Close canopy stands of short-needle conifers or 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 (Refer to representative Photo Guides for Appraising Down Woody Fuels).

Fire Behavior Fuel Model 8/10 Mosaic and 10 (timber litter and understory) - The fires burn in the surface and ground fuels with greater fire intensity than the other timber litter models. Dead and down fuels include greater quantities of three-inch or larger limbwood resulting from overmaturity or natural events that create a large load of dead material on the forest floor. Crowning out, spotting, and torching of individual trees are more frequent in this fuel situation, leading to potential fire control difficulties. Any forest type may be considered if heavy downed material is present; examples are insect or disease-ridden stands, windthrown stands, overmature situations with deadfall, naturally thinned stands, and aged light thinning. These types may have a well-developed vertical or ladder fuel component.

Logging Slash Group

Fire Behavior Fuel Model 11 (Pre-Commercial Thinning, 4 to 15 years old) - Fires are fairly active in the slash and herbaceous material intermixed with the slash. The spacing of the rather light fuel load, shading from overstory, or the aging of the fine fuels can contribute to limiting the fire potential. Thinning operations in mixed conifer stands are considered.

Fire Behavior Fuel Model 12 (Pre-Commercial Thinning, 0 to 3 years old) - 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 fuels is encountered. The visual impression is dominated by slash and much of it is less than three inches (7.6 cm) in diameter. The fuels total less than 35 tons per acre (15.6 t/ha) and seem well distributed. This fuel model is represented by heavily thinned conifer stands.

Analysis Methods - Fire Behavior Modeling

Fire behavior modeling is performed to estimate a number of fire behavior characteristics. There are three main categories of input to fire behavior modeling;

1. Weather,
2. Fuels and
3. Topography.

Weather is classified and discussed in more detail in the climatology section later in this report. Historic weather information is used as an input to estimate fire behavior. Fuels are classified as surface fuels and crown fuels. Surface fuels are described with a fire behavior fuel model number (Anderson 1982). Crown fuels are described by canopy bulk density (the foliage contained per unit crown volume), canopy base height (the average height from the ground to the lowest living foliage), and canopy fuel load (the volume of canopy fuel load) (Scott and Reinhardt 2001). Crown fuels are important for determining crown fire characteristics, such as whether a fire can transition from the ground to the tree crowns. The topography input related to fire behavior is percent slope. Slope can effect how a fire burns. Fires generally burn with more intensity and faster spread rates when burning on steeper slopes.

There are several outputs available with fire behavior modeling. The outputs of most concern for this project include rate of fire spread, flame length, type of fire, torching index and crowning index. Fire behavior characteristics are used to estimate resistance to control. This is defined as the relative difficulty of constructing and holding a control line as affected by resistance to line construction and by fire behavior (National Wildland Coordinating Group Handbook 3, 2004).

The rate of spread indicates how fast a fire will move. The flame length is important to fire suppression techniques. If flames are over 4 feet, suppression with hand crews is generally unsuccessful. If flame lengths are over 8 feet, mechanized equipment is not considered effective.

The type of fire is also very important to estimate how successful suppression efforts will be, or resistance to control. Fire scientists and managers recognize three general types of wildland fire depending on the fuel stratum in which the fire is burning.

Ground Fire

A ground fire is one that burns in ground fuels such as duff, organic soils, roots, rotten buried logs, etc. Ground fires are generally ignited by surface fires. Ground fires have very low spread rates. For these reasons, ground fires are not predicted or further discussed in this analysis because they would be secondary to and in association with a surface fire.

Surface Fire

A surface fire is one that burns in the surface fuel layer, which lies immediately above the ground fuels but below the canopy, or aerial fuels. Surface fuels consist of needles, leaves, grass, dead and down branch wood and logs, shrubs, low brush, and short trees. Surface fire behavior varies widely depending on the nature of the surface fuel complex. Surface fires are generally easier to contain than any type of crown fire.

Crown Fire

A crown fire is one that burns in the elevated canopy fuels. Canopy fuels normally consumed in crown fires consist of the live and dead foliage, lichen, and very fine live and dead branchwood found in the forest canopy. We generally recognize three types of crown fire: passive, active and independent.

Passive. A passive crown fire, also called torching, or candling, is one in which individual or small groups of trees torch out, but a solid flame is not consistently maintained in the canopy. These can encompass a wide range of fire behavior, from the occasional tree torching out, to a nearly active crown fire. The increased radiation to surface fuels from passive crowning increases flame front spread rate, especially at the upper end of the passive crown fire range. Embers lofted during passive crowning can start new fires downwind, making containment more difficult and increasing the overall rate of fire growth. Passive crowning is common in many forest types, especially those with an understory of shade-tolerant conifers.

Active. An active crown fire is a crown fire in which the entire fuel complex becomes involved, but the crowning phase remains dependent on heat released from the surface fuels for continued spread. Active crown fires are characterized by a solid wall of flame extending from the fuelbed surface through the top of the canopy. Greatly increased radiation and short-range spotting of active crown fires lead to spread rates much higher than would occur if the fire remained on the surface. Medium and long-range spotting associated with active crowning leads to even greater rates of fire growth. Containment of active crown fires is very difficult.

Independent. An independent crown fire is one that burns in canopy fuels without aid of a supporting surface fire. Independent crown fires occur rarely and are short-lived, requiring a combination of steep slope, high wind speed, and low foliar moisture content. Many apparently independent crown fires may actually be active crown fires in which the canopy phase is momentarily pushed ahead of the surface phase under the influence of steep slope or strong wind.

Few cases of independent crown fire have been documented. Independent crown fires are not addressed because they occur so rarely and because no model of their behavior is available.

Climatology

Weather information was obtained from http://famweb.nwcg.gov/weatherfirecd/ for the Condon Remote Automated Weather Station for the time period from 1986 to 2006. The computer program, Fire Family Plus version 3.0.1.0 (USDA Forest Service 2002), was used to summarize the weather data. Table 3-37 shows the percentile weather used for fire behavior calculations (Project File Exhibit I-5).

TABLE 3-37

PERCENTILE WEATHER BY ENERGY RELEASE COMPONENT (ERC)

(The table below displays fuel moistures and windspeed characteristics used to model fire behavior on days when 90th percentile ERC conditions are reached)

Fuel Characteristics	Modeled conditions at 90 Percent ERC
1 Hour Fuel Moisture	4
10 Hour Fuel Moisture	5
100 Hour Fuel Moisture	10
1000 Hour Fuel Moisture	23
Herbaceous Fuel Moisture	48
Woody Fuel Moisture	86
20 Foot Wind Speed	5

Energy Release Component (ERC), a number related to the available energy per unit area within the flaming front at the head of a fire, was used to categorize weather. The Energy Release Component is often used for planning and estimating the relative fire danger on any given day. 90h percentile ERC would only be expected to occur on approximately 10 percent of the fire season days. The 90th percentile ERC weather conditions were calculated to be used as inputs when modeling fire behavior.

Fuel moisture is the amount of moisture in a piece of fuel relative to its oven dried weight. Fuel moistures are displayed in six categories based on type of fuel (live or dead) and size class. The size classes for dead fuels are as follows:

- 1 hour fuels are 0 to 0.25 inch in diameter
- 10 hour fuels are 0.25 to 1 inch in diameter,
- 100 hour fuels are 1 to 3 inches in diameter, and
- 1000 hour fuels are 3+ inches in diameter.

Dead fuels are classified in this manner because different sizes of fuels take different amounts of time to gain or lose moisture, thus the number of hours associated with each (Anderson 1982). Live fuels are classified as either herbaceous or woody, depending on the type of plant.

Twenty foot wind speed is the speed of the wind measure 20 feet above the vegetation. It is important to note that 20 foot winds are often three times the strength of the wind we feel on the ground in a forested area. For example, in a moderately dense conifer stand it would take a 20 mph 20 foot wind to produce a 6 mph eye level wind (National Wildland Coordinating Group Handbook 3, 2004). Eye level winds are often referred to as mid-flame winds because these are the winds that most directly effect surface fires. Mid-flame wind speeds are calculated from 20 foot winds by using a wind adjustment factor (National Wildland Coordinating Group Handbook 3, 2004). When a forested stand density is reduced through removal of trees, the potential mid-flame wind speeds increase. This was considered and adjusted when estimating fire behavior in post fuel reduction treatment areas.

Environmental Consequences

This section describes the direct, indirect, and cumulative effects of the proposed treatments on the Fire and Fuels resource. To focus the fire/fuels analysis and describe relevant effects, the following effects indicators are used:

- Predicted rate of fire spread (chains/hour);
- Predicted flame length (feet); and
- Type of predicted fire; and
- Acres of fuel reduction treatments.

Proposed silvicultural treatments for each alternative were categorized into two fuel treatment codes. The two types represent fuels and stand conditions in areas proposed for mechanical treatments. Although no treatments are proposed in Alternative A (No Action), fire behavior is still displayed by stand group in order to provide a comparison in similar stand groups for the no action and action alternatives.

Table 3-38 displays the silvicultural treatments and how they correlate to the fuel treatment code used to compare the changes in fire behavior for each alternative:

TABLE 3-38
SILVICULTURAL TREATMENTS AND THEIR CORRELATION TO FUEL TREATMENT CODES

Silvicultural Treatment	Fuel Treatment Codes
Clearcut with Reserves, Patch Clearcut with Reserves, Seed Tree with Reserves	1
Thin from Below – Commercial, Sanitation, Thin From Below – Non-Commercial, Salvage Harvest	2
Fire Type	**Fire Behavior Descriptor**
Active	Crown fire
Passive	Surface fire with torching of individual, or groups, of trees
Surface	Surface fire

Alternative A - No Action
Direct and Indirect Effects

Under Alternative A, no fuel treatment would occur. In the absence of disturbance, fuel conditions would generally persist or fuel loadings would increase throughout the project area. The overall result would be a continuation of current fuel loadings with an increased fire hazard over time. Although no treatments are proposed in Alternative A, fire behavior is still displayed below in Table 3-39 in order to provide a comparison for Alternative A and the action alternatives.

TABLE 3-39
EFFECTS INDICATORS FOR ALTERNATIVE A

Fuel Treatment Code	Rate of Spread (chains/hour)	Flame Length (feet)	Fire Type
1	12	7	Passive
2	12	7	Passive

Continued Dense Understory and Ladder Fuel: Large-diameter Douglas-fir and larch in most of the ponderosa pine/Douglas-fir type forest stands would continue to lose vigor due to competition from dense understories of shade-tolerant tree species. This would perpetuate a denser understory. This understory also would serve as ladder fuel that would permit a surface fire to expand into the canopy, thereby killing many of the existing large-diameter trees that would have otherwise survived a ground fire. Insects and disease have existed in the past and would continue in the foreseeable future within the project area. It can be anticipated that fuel build-up would continue due to tree mortality from these sources.

Historically, stand-replacing fires were less common in the ponderosa pine/Douglas-fir type forest types, where frequent moderate intensity fires maintained a mosaic pattern of vegetation with an overstory component of large diameter trees. If a stand-replacing fire were to occur in the Upper Swan Area today, the overstory trees that remain could be killed and the burned areas would likely regenerate to lodgepole pine. However, the largest threat of stand-replacing fires in the lower elevations is to private property, homes, public safety, and firefighter safety throughout the landscape.

Alternatives B, C, and D
Direct and Indirect Effects

Vegetation Treatments

The proposed fuel reduction techniques focus on reducing the potential for crown fires and high intensity surface fires in treatment units, and thus reducing the resistance to control. Thinning of trees would reduce the crown density. By removing understory trees it would also increase the canopy base height, making it more difficult for crown fire initiation. The thinning would primarily focus on removing the smaller trees and species that are less resistant to fire, leaving larger, fire resistant (seral) species where possible. The proposed surface fuel treatment would reduce the amount of surface fuels to lower potential flame lengths. This would decrease the resistance to control and also reduce the likelihood of crown fire initiation. Table 3-40 describes the effects of some fuel treatment principles.

TABLE 3-40.
FUEL TREATMENT PRINCIPLES

Principle	Effect	Advantage
Reduce surface fuels	Reduces potential	Improves control flame length, reduces torching
Increase canopy base height	Requires longer flame to start torching	Reduces torching length
Decrease crown density	Reduces potential for crown fire	Makes tree-to-tree less likely crown fire
Retain larger trees	Increases proportion of trees with thicker bark, taller crowns	Increases tree survival

Adapted from Agee, J. K. 2002. Fire behavior and fire-resilient forests. In: Fitzgerald, S. A., ed. Fire in Oregon's forests: risks, effects, and treatment options. Portland, OR: Oregon Forest Resources Institute: 119.126.

Table 3-41 below displays, by alternative, the number of acres treated within each "Fuel Treatment Code" defined in Table 3-38 The action alternatives reduce the rate of spread from 12 chains per hour with no treatment (under the No Action Alternative) to rates of spread of 3 chains per hour. In addition, the table demonstrates considerably shorter predicted flame lengths in the action alternatives.

TABLE 3-41
EFFECTS INDICATORS FOR ALTERNATIVES B, C, AND D

Fuel Treatment Code	Alt B Acres Treated by Treatment Code	Alt C Acres Treated by Treatment Code	Alt D Acres Treated by Treatment Code	Rate of Spread (chains/hour)	Flame Length (feet)	Fire Type
1	203	203	0	3	1	Surface
2	475	475	602	3	1	Surface

To further reduce hazardous fuel conditions that existed prior to or created by timber harvest activity, effects would vary based on the number of acres treated and the hazardous fuels reduction prescribed. In general, the more acres of effective fuel reduction treatment, the better the alternative would be at reducing fuel hazard and subsequent fire behavior characteristics.

Table 3-42 summarizes the number of acres treated by hazardous fuels reduction activity by alternative.

TABLE 3-42
FUEL REDUCTION TREATMENTS BY ALTERNATIVE

Fuel Treatment (Acres)	Alt. A (Acres)	Alt. B (Acres)	Alt. C (Acres)	Alt. D (Acres)
Whole Tree Yard/Excavator Pile/Chip/Burn	0	465	465	592
Whole Tree Yard/Excavator Pile/Chip/Lop and Scatter	0	10	10	10
Whole Tree Yard/Excavator Pile/Burn	0	203	203	0
Hand Piling and Pile Burning	0	61	61	61
Whole Tree Yard/Excavator Pile/Chip/Burn	0	465	465	592
Total Acres of Fuel Treatment	**0**	**739**	**739**	**663**
Fuel Reduction **within** the WUI	0	321	321	300
Fuel Reduction **outside** the WUI	0	418	418	363

Effective Fuel Reduction Zones (FRZs)

Nearly all treatment areas proposed by all action alternatives are linked to previously treated stands or natural fuelbreaks. This helps to create larger, more effective treatment areas. These fuelbreaks are important to either slow the spread or reduce the intensity of wildland fire, thus increasing the effectiveness of suppression efforts to protect values at risk.

The fuel treatment areas adjacent to the intermix community are designed to protect primarily private and government structures and improvements; secondarily, they are designed to protect NFS land resource values. Wildland fire can threaten a structure in three ways:

1. Direct exposure from flames,
2. Radiated heat, and
3. Airborne firebrands.

The treatments proposed are meant to decrease the probability that airborne firebrands could reach structures. This would be of particular concern when viewing both long-range and short-range spotting potential of forested areas adjacent to developed areas.

Treatments proposed would also reduce the potential of direct exposure from flames and radiated heat by creating a “defensible space” around a property or structure. Defensible space refers to that area between a structure and an oncoming wildland fire where the vegetation has been modified to reduce the wildland fire threat and to provide an opportunity for firefighters to effectively and safely defend the structure. Fuels can be treated in a relatively small area immediately adjacent to structures to reduce exposure to flames and radiant heat. Some evidence suggests that fuel reduction within 40 meters of a structure can substantially reduce ignitions from direct exposure to flames or radiant heat (Cohen 1999). These stands would likely be managed into the future to maintain fire resistant tree species, light surface fuels, and no ladder fuels. This would provide an effective fuel reduction area to reduce the potential of the short range and long range spotting threat associated with those stands during wildland fire.

To reduce threat of ignition from firebrands, fuels need to be reduced both near and at some distance from the structure. Firebrands that result in ignitions can originate from wildland fires that are at a distance of 1 kilometer or more (Cohen 1999). However, firebrands pose a greater threat the closer the fire is to the structures and other existing resources.

Implementation of action alternatives would result in modifying the behavior of a wildland fire and would increase the likelihood that fire suppression efforts would be successful in containing the fire at a small size.

Alternatives B, C, and D
Cumulative Effects

The Cumulative Effects Worksheet (Project File Exhibit I-2) considers and describes proposed activities in addition to the past, current, and reasonably foreseeable activities listed at the beginning of this Chapter in Tables 3-1 and 3-2. Those activities that cumulatively contribute indiscernible effects on fuel conditions are not included in this section. Those activities that cumulatively affect the fuels conditions are discussed below.

Intermediate harvest, underburning, whole-tree yarding, and yarding of unmerchantable material combined with slashing ladder fuels, excavator piling, and chipping activities, and non-commercial fuel reduction treatments, would continue to reduce fuels and the associated risk of wildland fire. Regeneration harvest would move stands to a Condition Class 1 and from Fuel Models 8 and 8/10 to Fuel Model 2/5 initially. These stands would then trend to a Fuel Model 5 in 5 to 10 years. Pre-Commercial Thinning would also help to create healthy, vigorous stands of trees composed of a desirable mixture of tree species. Where such activity occurs in the WUI, slash treatments such as chipping or hand/pile and burning is recommended for to reduce the short term potential for increase in increased fire risk due to increased ground fuel from thinning slash. Stands treated would be more resistant to insects and disease, be able to better withstand low-to moderate intensity wildland fires over time, and may be machine or hand piled as needed. The overall cumulative trend would be a continued improvement in forest health conditions as management moves stands towards desired future conditions.

Past Activities

A portion of the NFS lands within the Hemlock Elk Project Area have been harvested in some manner (See Forest Vegetation Section). Timber harvest has also occurred on private lands in the project area. Most of this past activity is on private timber lands; some on small private holdings. These past activities have broken up the fuel connectivity on a landscape scale. Some of the recent regeneration harvests still function as effective fuel reduction areas. Even in areas where an intermediate harvest occurred, the crown connectivity has been altered enough to affect the sustainability of crown fire within these stands. Past treatments can make an area more defensible for fire suppression activities for decades.

Firewood cutting has an annual effect on forests 200 feet adjacent to roads open year round and seasonally. Larch and Douglas-fir are the preferred species; however, due to the high demand and scarcity of available area, lodgepole pine and any other dead species are removed. This activity has the potential to reduce coarse down woody material, snags, and fuel up to 200 feet from roads. It is difficult to know how many acres have been affected by this activity. Removing the dead fuel component creates a corridor of defensible area necessary for successful suppression activities. In areas of heavy firewood collection, the removal of dead wood breaks up horizontal and vertical fuel continuity; this action combined with the fuel-free road surface would assist in successful suppression operations.

Private land development has been occurring for the last century in the analysis area; however, it has been most intense in the last two decades. The vegetative conditions on small private land are highly variable and range from grassland to dense old forest. The effect of private land development has been to convert some forested land to low density forest or grassland and roads. There has been a recent response to fire prevention education involving effective fuel reduction within some of these private in-holdings. Although in most cases, the desire of the landowners has been to maintain a forested setting, on one or more aspects, in the immediate vicinity of dwellings and structures that is contiguous with forested public lands. In many cases, small private forested areas have not been managed and forests have become densely stocked stands with large quantities of dead trees. These sites are highly vulnerable to insect and disease outbreaks and wildland fire.

Reasonably Foreseeable Activities

Firewood cutting is anticipated to continue along seasonal and yearlong open roads. This activity has the potential to reduce course down woody material, snags, and fuel up to 200 feet from roads. This removal of dead standing and downed wood would reduce the amount of fuel left on NFS lands. Firewood gathering contributes to the overall effort to reduce fuels in the WUI.

Plum Creek Timber Company has plans for two vegetation management projects totaling about 800 acres (Grizzly Meadow Commercial Thin and Stoner Lake Pre-Commercial Thin) within the analysis area. The anticipated change in the fuel and fire behavior characteristics would be similar to the post treatment scenarios described in this analysis.

Private in-holdings in the Hemlock Elk Project Area have been developed in the recent past with an increase in the number of residences adjacent to the project area. The probable development trend would be to expect further home construction within the limits of county zoning practices (Project File Exhibit Q-1). It is reasonable to foresee that some additional home development may occur on private lands within the project area with likely consequences being the removal of some additional vegetation on private lands to accommodate new landowner’s objectives. The presence of more dwellings elevates the importance of fuel reduction to reduce the potential loss of life and property.

Other foreseeable actions include noxious weed control, road maintenance, administrative road use, public recreational use, and gathering small forest products for personal use. These activities are not expected to contribute to, or inhibit, efforts to achieve desired stand conditions.

Regulatory Framework and Consistency

Action Alternatives B, C, and D are consistent with the following Forest Plan Fire Management Direction (Appendix G, LRMP 2001) and fire and fuels direction for all affected management areas:

- Implement prescribed fire to maintain healthy, dynamic ecosystems that meet land management objectives.
- Integrate an understanding of the role fire plays in regulating stand structure into the development of silvicultural prescriptions.
- Planned ignition prescribed fire may be utilized to reduce hazards from activity-caused fuel concentration and to maintain or enhance vegetative components or wildlife habitat (Forest Plan, pp. III-74).