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Fire and fuel hazard analysis in the Seeley Lake area Missoula County Montana

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A FIRE AND FUEL HAZARD ANALYSIS IN THE SEELEY LAKE AREA, MISSOULA COUNTY, MONTANA

by

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ABSTRACT

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A Fire and Fuel Hazard Analysis in the Seeley Lake Area, Missoula County, Montana

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Residential development in the forested regions of western Montana has created a large potential for diastrous wildfires, in terms of lives and property destroyed. This thesis documents the fire hazard associated with residential developments located within forested regions in the Seeley Lake area of northwestern Montana.

Ten study sites in the Seeley Lake area, consisting of each a residential development located within a heavily forested region, were selected. Data was collected within each of the ten study sites through establishment of a number of residential plots; consisting of a centralized residence, and the surrounding forest vegetation within a ten meter radius from the residence. All fire hazard data reported except fuel loading, originate from these 175 residential plots.

The study area was classified as being in either extreme or high potential fire hazard classes, utilizing Fischer's (1978) classification scheme. The potential fire behavior of the study area was determined to be high, utilizing rate of spread, fire reaction intensity, flame length, crowning potential, and fuel loads. The overall fire hazard potential for the Seeley Lake area is high, with the probability of a fast spreading, very hot, crown fire high.

The interface between the forest fuels and residential structures was documented showing that the forest fuels and residential structures were continuous with one another. There was little, if any, fuel break between the forest and residence. A large amount of slash adjacent to structures was common creating hazardous conditions. The access routes were documented. Fire frequencies were calculated from records and lightning is the major source of ignition. Wildfire safety guidelines and suggested fire hazard ameliorative treatments were discussed.

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CHAPTER I

INTRODUCTION

Increased residential development in the last decade of forested valleys in western Montana has greatly compounded the problem of fire hazard (Fischer and Books, 1977). With the proliferation of subdivisions and developments in forested areas, there has been a parallel increase in fuel build-up and fire hazard. These developments include not only secondary, residential homes or "cabins in the woods," but primary residential homes which are being built within fire-prone vegetation zones (Fischer and Books, 1977).

Wildfire is a natural phenomenon and is inevitable in western coniferous regions (Habeck and Mutch, 1973). Historical accounts of early explorations contain references to areas denuded by fire, and widespread forest fires in this century have been documented (Arno, 1976). Written records of fire before 1800 are rare, but charcoal in the soil, charred stumps, and fire scars in tree cross-sections provide evidence of a forest fire history predating the oldest living vegetation in the western coniferous forest (Arno, 1976). Therefore, it is generally accepted that most western Montana forests have evolved in the presence of repeated fires.

Contrary to this evolutionary concept, acknowledgement of the ecological importance of fire is relatively recent. Fire has usually been considered an external disturbance to an otherwise stable system, and only recently has fire been considered an internal perturbation of a general stable system (Lyon and Stickney, 1976).

Fire is an integral part of the western forest ecosystems (Mutch, 1970). Fire as a decomposer agent performs the function of rapidly recycling materials (Beaufait, 1971). Wildfires play an important role in developing and maintaining biologic diversity within a given landscape (Loucks, 1970). Diversity in turn is believed to provide stability to ecosystems. Forests which develop without periodic fire may be more heavily damaged by fungi or insects (Kozlowski and Ahlgren, 1974). Fire plays a role in seedbed preparation. Some plant species require heat treatment for germination or require mineral soil for germination. Commonly, there is an increase in available soil water following fire. Most important of all, fire plays a role in soil nutrient recycling. A large amount of nutrients are tied up in dead plant tissue. Fire, by decomposing the litter, is thereby releasing these trapped nutrients. But, fire intensity determines the amounts and kinds of nutrients recycled (Norum, 1976; Stark, 1977; Stark, 1979).

Forest community predisposition to fire is indicated by organic accumulation in excess of decomposition, a number of plant species with characteristics that enhance flammability, and regional weather patterns that provide both adequate ignition sources and fuel moisture conditions favorable for burning (Lyon and Stickney, 1976). Fires in western Montana usually occur during the summer dry season (July - August), with results that are best characterized as variable in both pattern and intensity.

Consequently, with the increased residential developments within the forested areas of western Montana, the problem of fire hazard is compounded. Since fire is a natural phenomenon in the western coniferous forest, people in residential developments within the forest have placed themselves in a potentially hazardous situation (Fischer and Books, 1977).

An analysis of the fire hazard associated with residential structures located within forested regions of the Seeley Lake area was done. The study emphasized the interface between forest fuels and homes. The specific location chosen for this study is the Seeley Lake area in northwestern Montana (113° 30' W, 47° 10' N). The study area is located in T 16 N, T 17 N, and R 15 W, Montana Principal Meridan. The Seeley Lake area (elevation 1250 meters) is a rapidly developing summer resort community, with a large portion of the residential development within densely forested areas. Located only 80 kilometers from Missoula, Montana, it is an ideal weekend, or even, bedroom community for those working in Missoula.

The principle objectives of this study were to: 1) document the residential build-up and forest fuel interaction: where the homes exist in direct, close relationship to the fuels; 2) quantify the fuel loadings surrounding home sites; 3) quantify the potential fire-spread rates and crowning potentials; 4) describe and document the access routes into and out of forested tracts supporting homes; 5) formulate a Seeley Lake area fire history; that is, natural fire frequencies; 6) relate forest development (succession) to fuel accumulations in the study area; and 7) formulate a set of wildfire safety guidelines.

CHAPTER II

LITERATURE REVIEW

The problem of forest fire hazard in residential developments is not unique to western Montana; similar problems have already occurred in other western states where there are bedroom communities within 50 to 80 kilometers radius of big cities, and recreation homes in forested areas. Studies addressing this problem have been done in California, Colorado, and Utah; the problem differs in each state. Colorado has been most notably successful in identifying and classifying fire-hazardous areas.

Hazard Classification

Fahnstock (1971), rated forest-fire hazard in residential developments in Colorado forests. He defined fire hazard classes in terms of vegetation and expected fire behavior. Fahnstock based his five hazard class ratings on crown coverage and ground fuel. The major criterion for defining three of the hazard classes is the likelihood of crown fire occurrence. A fourth class describes fuels that can support high intensity fires under some circumstances. The fifth class describes areas of zero hazard. Fischer (1978) modified Fahnstock's classes to fit the forests of western Montana.

The Colorado State Forest Service (CSFS) (1977), having the capability to identify, classify, and delineate potentially hazardous, wild fire areas, has made progress in applying comprehensive land-use planning to lessen the hazard and risk. At the ecosystem level, CSFS has formulated an "Ecosystem Guide for Mountain Land Planning" (Lynch, 1973), which identifies potential land-use problems in the planning process. The CSFS (1977), California State Forest Service (1971), and Utah State Forest Service (1978), each has produced guidelines and criteria for wild fire hazard areas, which includes criteria for identifying natural hazards, wild fire safety guidelines, standards for subdivisions and developments, and model wild fire hazard area control regulations.

Hulbert (1972), interviewed 300 people living in mountain homes and 20 developers of mountain subdivisions in Colorado. The results indicated a general feeling of unfounded, over confidence by most people toward the danger of forest fire. Seventy-five percent of the interviewees indicated that they thought the forest fire danger was low or only moderate in the mountains of Colorado. Three percent believed the danger was very low and that there was virtually nothing to worry about. Only one person in four indicated a concern for the forest fire problem.

Rate of Spread and Crowning Potential

Fahnstock (1970), characterized forest fire fuels and fire behavior in terms of conditions that are recognizable in the field and essentially independent of specialized technical knowledge. He devised a set of dichotomous keys to identify and describe forest fuels in terms of crowning potential and rate of spread. The crown fire potential is estimated by combining two of the factors necessary for crown fires, the intensity of surface fires which initiates crowning and the capability of the overstory to sustain a crown fire. Brown (personal communication, 1979) revised Fahnstock's Crowning Potential Key to include the contribution of large fuel combustion behind the fire front.

Fuel Appraisal and Inventory

Fischer (1979) produced a system to appraise down and dead forest fuels using a series of photographs. The photographs are accompanied by a description of the fuel loading, fire potential rating, and stand information for each stand. These photographs are arranged according to forest cover type and are designed for easy use by a layperson.

A detailed field method of inventorying of downed woody material was devised by Brown (1974) and modified by Oberheu (1977) to include litter, grass, forbs, duff, and shrubs as potential forest fire fuels. The information (fuel loading data) gathered from this technique can be used to predict rates of fire spread and intensity. Albini (1976) used Rothermel's (1972) fire spread model to develop a set of nomographs for estimating rate of spread, reaction intensity, and flame length for a variety of "typical" fuel complexes, under variable conditions.

Fire History

Arno (1976) documented the fire frequencies, intensities, and influences on stand structure and composition on the Bitterroot National Forest in west-central Montana. The results show that fire was historically a major force in ecosystem development and maintenance, but that it has been reduced to a minor influence during the past fifty years, likely due to modern organized fire suppression.

Sneck (1977) documented the fire history and the role of fire in the *Larix occidentalis*/*Pseudotsuga menziesii** forest of the Coram Experi-

*Nomenclature used follows Hitchcock and Cronquist (1973).

mental Forest in northwestern Montana. Sneck's results clearly implicate fire as a major factor creating diversity and mosaics of forest vegetation on similar sites. Both Arno's and Sneck's studies used the technique of analyzing fire scars in the annual growth rings of surviving trees, for determining fire history (frequency) in coniferous forests of the Mountain West.

Gabriel (1976) studied fire history of Pinus contorta-dominated forests in the area of the Bob Marshall Wilderness, Flathead National Forest, Montana. Gabriel found evidence that fire in this wilderness has been rather frequent in the past centuries and that it burned at various intensities.

Davis, Clayton, and Fischer (1980) summarized the available information on fire as an ecological factor for forest habitat types that occur on the Lolo National Forest, Montana. The Lolo National Forest habitat types were grouped into ten "fire groups" based primarily on fire's role in forest succession. For each fire group information on the relationship of major tree species to fire, forest fuels, the natural role of fire, fire and plant succession, and fire management considerations was presented in their report. This report will be used as background information on fire history for the habitat types in the Seeley Lake study area.

CHAPTER III

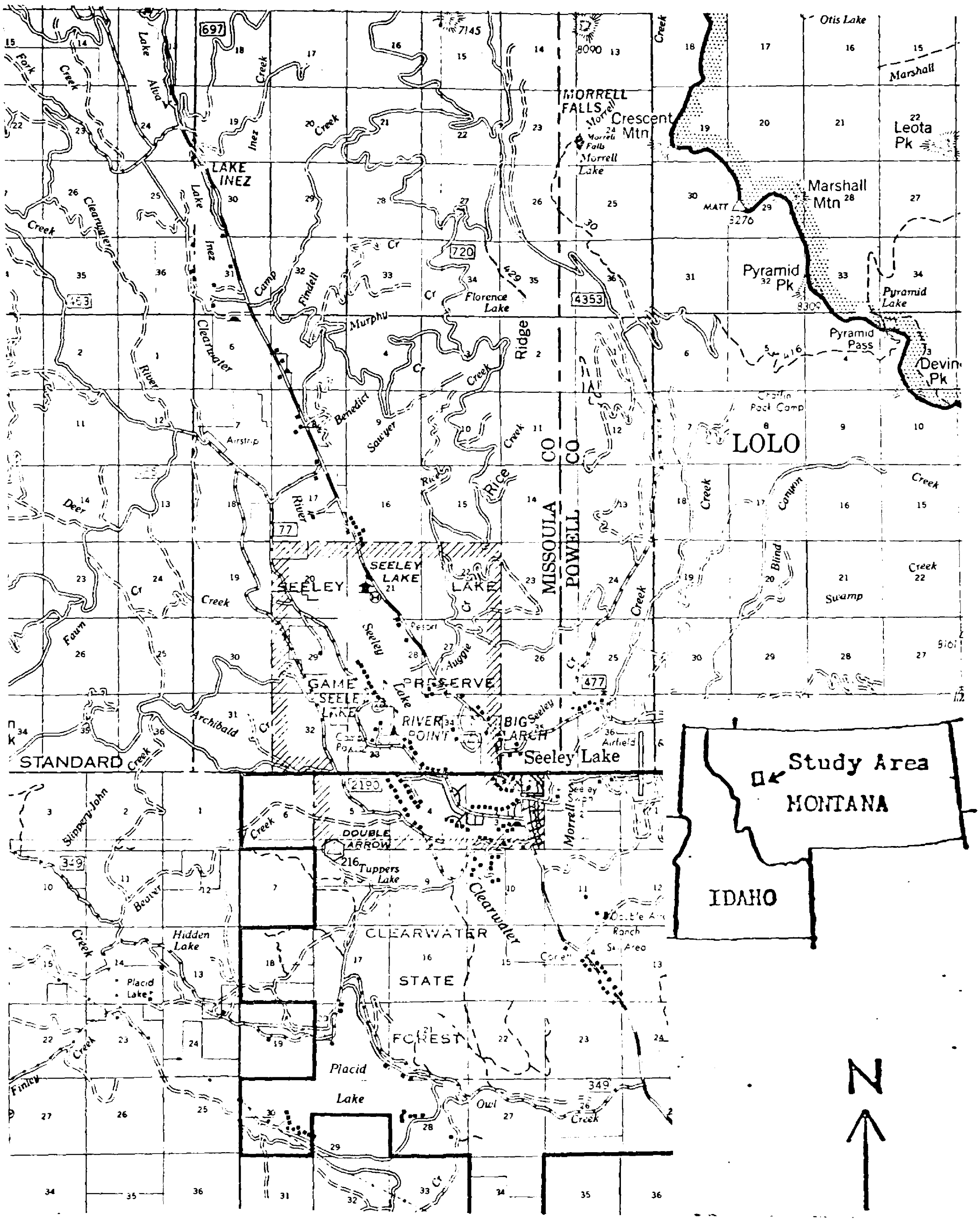
DESCRIPTION OF THE STUDY AREA

Geography

The study area encompasses the town of Seeley Lake, Montana and adjacent areas of residential subdivisions. These include private lands, state leased tracts, and U.S.D.A. Forest Service (USDA-FS) leased lands (Figure 1). Seeley Lake (1250 meters) is situated in the upper Clearwater River Valley, of northwestern Montana, approximately 80 kilometers from Missoula, Montana. Directly to the north is the Clearwater/Swan drainage divide; the Swan River Valley is to the north. Both valleys comprise part of a trench bounded by parallel mountain ranges. To the west are the Mission Mountains, and to the east lie the Swan Range. A chain of lakes are located in the two valleys, with Seeley, Swan, Placid, and Holland Lakes being the larger of these. The Lolo National Forest borders the area to the west and east, with the Clearwater State Forest bordering the southern portion of Seeley Lake as show in Figure 1.

Elevation of the study area ranges from 1200 meters to 1500 meters. The Mission Mountains begin adjacent to the northern extremity of the Swan Valley, and rise steadily southward, attaining an elevation of 3010 meters at McDonald Peak adjacent to the upper end of the Clearwater Valley. From the Swan and Clearwater Valleys the slopes of the Mission Mountains rise gradually and are heavily forested on the lower slope positions. On the east side of the Swan Valley the Swan Range rises abruptly and maintains a high ridge line throughout, rarely dropping below 2000 meters and rising to 2852 meters at Holland Peak.

Figure 1: Study area location map.



Numerous tributary streams flow at right angles to the main axis of the Swan Valley and drain both the Mission and Swan Mountains. These streams have deeply dissected the mountain masses, producing deep sided valleys with sharply contrasting north and south slopes.

Climate

The climate of Seeley Lake is strongly affected by Pacific air masses. During the winter relatively warm moist air masses move inland from the Pacific Ocean following the prevailing storm track along the Canadian border. These air masses lose much of their moisture over the Cascade Mountains and the mountains of northern Idaho and extreme northwestern Montana, but enough remains to yield large amounts of precipitation to the lower elevations as these air masses intercept the main ranges of the Rocky Mountains, namely the Missions and Swans. Precipitation in western Montana is lowest during July, August, and September, with the highest amounts occurring in the winter and late spring (Table 1).

Along with increased precipitation, the Pacific air masses moderate temperature extremes, especially during the winter. While very cold, arctic air masses frequently occur on the plains east of the Continental Divide, only occasionally do these layers of cold air arise over this mountain barrier to invade the northwestern Montana valleys. Therefore, the climate of the west side of the Divide is buffered by the moderating influence of the Pacific Ocean and presence of the mountain barrier against extreme temperature fluctuations.

Table 1 summarizes available precipitation data for the Seeley Lake area. The average temperature and precipitation values are based on a record of approximately forty years, obtained from the Seeley Lake Ranger Station.

TABLE 1. Climatic Summary for Seeley Lake Ranger Station (elevation 1250 meters).

Month	Average Temperature	Average Precipitation
January	-7.3°C*	7.18cm*
February	-3.5	4.73
March	-1.3	3.95
April	4.4	3.55
May	9.3	5.08
June	12.9	6.83
July	16.8	2.58
August	16.0	2.53
September	11.4	3.60
October	6.6	3.78
November	-0.3	5.70
December	-5.2	6.78
Annual	5.0°C	55.70cm

*For conversions to English from Metric, see Appendix B.

Between November and March most of the precipitation is in the form of snow. Through much of the winter, as much as 76 centimeters (30 inches) or more of snow on the ground is not unusual.

The lower moisture during mid-summer, combined with summer lightning storms and dry forest fuels, has lead to regular occurrence of forest fires in this part of northwestern Montana (Habeck, 1980).

Geology

The uplifting of the Mission and Swan ranges has created the Swan Valley. Both mountain ranges are composed of Precambrium Belt Series rocks. The east slopes of the Missions are composed predominately of argillite and quartzite, whereas the west slope of the Swans is mainly composed of impure argillite limestone.

During the Pleistocene the Seeley Lake area was entirely filled with glacial ice. A branch of the large glacier that filled the Flathead Valley to the west came over the top of the low northern end of the Mission Range and flowed down the Swan Valley as far south as Clearwater Junction. The floor of the valley is completely covered by glacial till left when the ice melted at the end of the last ice age about 10,000 years ago. The chain of lakes along the two valleys occupies basins scooped out by the moving ice, then dammed by debris dumped when the ice melted.

Thus, the major surface parent materials of the study area range from various forms of glacial till to residual rock material both of which may be calcareous or not to varying degrees. In addition, there are areas of alluvial silts and clays along the Clearwater River.

Soils

Soils in the study area were formed in materials weathered from sandy glacial alluvium or glacial outwash fans (Stem, personal communication, 1980). These soils are poorly drained sandy loams. In a typical profile, the surface layer is light brownish gray sandy loam, 2.5 centimeters (1 inch) thick. The subsurface layer is pinkish gray loamy fine sand, 7.5 centimeters (3 inches) thick. The subsoil is pinkish gray loamy sand, 66 centimeters (26 inches) thick. The substratum is pinkish gray loamy coarse sand to 152 centimeters (60 inches) (Stem, personal communication, 1980).

Permeability is moderately rapid and the available water capacity is moderate. The potential rooting depth is about 152 centimeters. The surface runoff is very slow and the water erosion hazard is slight (Stem, personal communication, 1980).

General Vegetation of the Area

The study area falls within the lower subalpine zone, (*Abies lasiocarpa* series) (Pfister *et al*., 1977). All upland forests of the study area are potentially dominated at climax by *Abies lasiocarpa*. There exist basically three different habitat types in the study area, *viz*., *Abies lasiocarpa*/*Clintonia uniflora* (ABLA/CLUN), *Abies lasiocarpa*/*Vaccinium caespitos um* (ABLA/VACA), and *Abies lasiocarpa*/*Linnaea borealis* (ABLA/LIBO).

Abies lasiocarpa/*Clintonia uniflora* habitat type is prominate on the west side of Seeley Lake and along the Clearwater River. It is a relatively moist, warm habitat type within the *Abies lasiocarpa* series. ABLA/CLUN occurs from the lower mountain valley at about 1000 meters elevation up to 1700 meters, in northwestern Montana. *Abies lasiocarpa* is the indicated climax throughout the habitat type. Its major associates in seral forests found in the study area are *Larix occidentalis*, *Picea engelmannii*, *Pinus contorta*, and *Pseudotsuga menziesii*, in order of decreasing abundance. Major components of the forb layer are *Clintonia uniflora* (indicator species of this habitat type), *Arnica latifolia*, *Galium triflorum*, *Chimaphilia umbellata*, *Cornus canadensis*, *Tiarella trifoliata*, *Pyrola secunda*, and *Goodyera oblongifolia*. The shrub layer is represented by *Linnaea borealis*, Lonicera utahensis, Rubus parviflorus, and Vaccinium globulare. The epiphytes are well developed in this habitat type. Species of Bryoria, Alectoria, Hypogymnia, and Parmeliopsis are the most abundant components of this structural group (McCune, 1979).

Abies lasiocarpa/Vaccinium caespitosum is the prominant habitat type for the east side of Seeley Lake and the area in which the town itself of Seeley Lake is located. These sites occur largely at moderate elevation on well drained benchlands and frosty basins where cold air accumulates. Pinus contorta presently is the sole dominant conifer in all stands sampled, although Abies lasiocarpa and Picea engelmannii are common in the understory. Most forests of this type are less than 150 years old; therefore, actual climax status of the study areas cannot be established (Pfister et al., 1977). Thus, Pinus contorta may be considered the persistent seral dominant of this habitat type. Undergrowth consists of a dense mat of Vaccinium caespitosum, Vaccinium scoparium, Calamagrostis rubescens, and Linnaea borealis. Bryoids are also well developed in this habitat type.

Abies lasiocarpa/Linnaea borealis is the third habitat type present in the study. It is found on a bench east of the town of Seeley Lake and belonging to the Double Arrow subdivision. It occurs on relatively moist north-facing slopes and benches at elevations of 1500 meters to 2100 meters. The dominant trees of the seral forests are Pinus contorta, Pseudotsuga menziesii, and Abies lasiocarpa. Picea engelmannii, Pinus ponderosa, and Larix occidentalis are also found in the forests but are only minor components. The shrub layer is composed of Linnaea borealis, Lonicera utahensis, Vaccinium globulare, and Amelanchier alnifolia. The herb layer consists of Calamagrostis rubescens, Arnica latifolia, and

Pyrola secunda. The epiphyte layer is similar to that found in the other habitat types of the study area.

CHAPTER IV

METHODS

Selection of Study Sites

A group of ten (10) study sites located in the vicinity of Seeley Lake, were selected on the basis of their presence within forested portions of this resort region; each of the ten study sites support residential developments. The study sites selection (Figure 2) were not chosen at random; an effort was made to sample a representative assortment of residential developments situated in timbered terrain where forest crown coverage was 50% or greater. Each of the ten study sites coincides with a distinct residential development composed of a variable number of specific home sites (6 to 29 residences).

Each study site occurs within the same delineated habitat type, as defined by Pfister et al. (1977); the residences are of a permanent type of economic worth, and all of the residences in any one of the study sites are located on a forested tract. Figure 2 indicates the locations of the ten study sites.

Basic field data were collected within each of the ten study sites through the establishment of a number of "residential plots." This consisted of a selected, centralized residence, and encompassed the surrounding forest vegetation within a 10 meter radius from the residence. The number of these residential plots varied among the ten study sites, ranging from 6 to 29 (related to the size of the development). All data reported, except fuel loading, originate from these residential plots. A total of 175 such residential plots were established among the ten study sites, ranging from six (6) in Study site 9, to twenty-nine (29) in Study site 4 (see Table 6). All fire hazard data and analysis are related to this 175 residential plot sample.

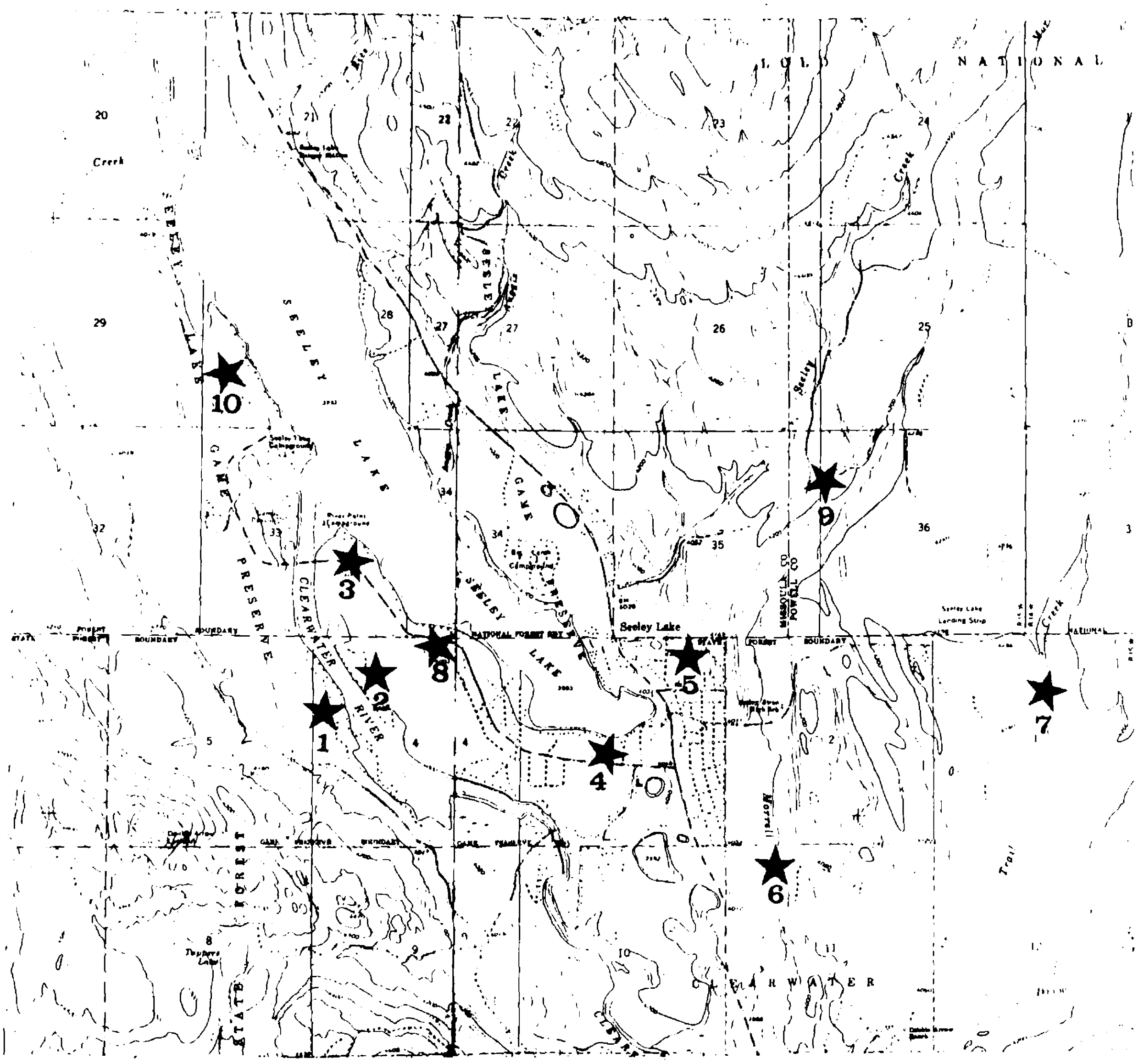
Documentation of the Residential Build-Up and Forest Fuel Interface

The first part of the study consisted of describing the interface between residence and forest, and habitat typing the vegetation in each plot. The habitat type classification of vegetation was used as outlined by Pfister et al. (1977). This is a site classification based on the potential climax vegetation of the area. Climate, geography, and disturbance factors are also taken into account here. Nomenclature of the vascular plants follows Hitchcock and Cronquist (1973) (See Appendix A for a list of species names with authorities).

The canopy coverages of each tree species in each residential plot were recorded by the following classes (Pfister et al., 1974, as modified after Daubenmire (1959): T = 0-1% coverage, 1 = 1-5%, 2 = 5-25%, 3 = 25-50%, 4 = 50-75%, 5 = 75-95%, 6 = 95-100%, if a species was in the study site, but not in the plot, a "+" was recorded. The understory species for each residential plot were also recorded using the same system. Study site ages were determined using tree age data. The major overstory tree species in each study site were aged using increment borings, taken at 1.4 meters (4.5 feet) from the ground and on the uphill side of the tree. At least five trees of each species in each study site were cored and their ages were averaged.

The physical site factors of the residential plot were recorded such as elevation, slope aspect and inclination, topographic position, and other physiographic information that seemed relevant.

Figure 2: Map of Seeley Lake area (stars represent study site locations).



To describe and evaluate the interface between residential structure and forest-fuels the following characteristics and/or conditions of the plot were recorded: 1) if a fuel break occurred, described as a change in fuel continuity, type of fuel, or degree of flammability of fuel in a strategically located parcel or strip of land to reduce or hinder the rate of fire spread (State of Utah, 1978) of not less than 6.1 meters (20 feet) around all buildings or structures. This fuel break may contain ornamental shrubbery or plants used as groundcover, provided they do not provide a means of transmitting fire from native growth to buildings or structure; 2) if the roof of buildings were constructed of fire resistant materials, such as asphalt, tile, slate, aluminum, or fire retardant-treated wood shingles or shakes; 3) if the chimney or stovepipe connected to a device burning solid or liquid fuel is equipped with a screen over the outlet; 4) if the roofs were free of needles, leaves, dead vegetative growth, moss, lichens, or any other flammable material; 5) if trees adjacent to any building or structure are kept free of dead or dying wood and moss and lichens; 6) if large amounts of slash or dead wood material were present in the plot; 7) if firewood were piled up against the structure; 8) if powerlines were aboveground or underground; 9) if there existed trees in plots with obvious fire scars, to indicate past fires in the area; 10) if the residential structure was numbered or labeled to allow rural fire fighters to find the residence in case of fire; and 11) access or escape routes were documented.

Hazard Mapping

The classification and mapping of the fire hazard of the study areas utilized Fischer's (1978) "Proposed Fire Hazard Classes for Montana Wildlands." Five classes (0,1,2,3, and 4) appeared adequate to distinguish significantly different levels of fire hazard on the basis of expected fire behavior. The likelihood of crown fire occurrence was the prime criterion for defining three of these five classes (Table 2). Class "0" vegetation (fuel) consists of either open water, bare rock, or cultivated field, all having minimum fire hazard. Class "4" vegetation, in contrast, consists of dense conifer stands greater than 55% crown coverage, with vertical fuel continuity into tree crowns, and having the highest fire hazard rating. Table 2 further describes in detail the expected levels of fire behavior and the characteristics of vegetation corresponding with each class.

After the Seeley Lake study area was classified according to fire hazard, it was then transposed onto a USGS quadrangle map (7-1/2 minute series) of the study area. The use of different colors were used to designate the five different hazard classes (Figure 8).

Rate of Spread

For each residential plot the rate of spread of a potential fire was determined using Fahnstock's (1970) Key No. 1. Key No. 1 defines thirty-six (36) distinct combinations of fuel characteristics in terms of potential rate of fire spread. Fine fuels are considered to control fire spread as long as they are not characterized as "sparse" or absent (Fahnstock, 1970). Fire spread is assumed to be entirely through the fuel bed itself, influenced by thermal radiation, convection, and conduction within the bed (Fahnstock, 1970). No basis currently exists for estimating fire spread by spotting.

Readouts of the key are relative ratings on a scale of 0-100 (chains

nverted to meters per hour (0-2000), conditioned

TABLE 2. Vegetation and Fire Behavior Characterizing Proposed Fire Hazard Classes for Montana Wildlands (Fischer, 1978)

Hazard Class	Vegetation (Fuel)	Expected Fire Behavior
0 None	None (open water, bare rock, cultivated field, etc.)	None
1 Low	Grass, weeds, shrubs, 2 feet or less in height; dead wood in contact with ground; open conifer stands with 0-35% crown coverage; also stands of aspen, cottonwood, willow; grassland and shrublands other than ceanothus. Where slash is present these stands become Class 3.	Flames less than 5 feet high, higher flareups rare; duration of highest flames brief; fire spreads slow to fast, 1-40 acres per hour; human beings can run through flames without serious injury and can occupy just-burned area; spotting generally rare, short range.
2 Medium	Dense to moderately dense flammable vegetation 2 feet or greater in height, including shrubs, conifer reproduction, abundant litter and/or herbaceous fuel; scattered conifer stands may also be present.	Flames 5 to 20 feet high, of brief duration; fire spread usually fast, at least 40 acres/hour; human beings cannot safely pass through flames but can occupy just-burned area within 15 minutes; short-range spotting common.
3 High	Medium density conifer stands with 35-55% crown coverage and surface fuels of mainly herbage and litter and some patches of conifer reproduction and dead wood. Includes old-growth conifer stands with light surface fuels regardless of crown coverage. Where slash is present or where surface fuels extend to lower part of tree crowns, these stands become Class 4.	Intermittent flareups occurring to many feet above treetops; short and medium range spotting common; behavior between flareups as in Class 1; passing through fire front sometimes possible but chancy; parts of burned area can be occupied within one-half hour.
4 Extreme	Dense conifer stands greater than 55% crown coverage with vertical fuel continuity into tree crowns. Also includes medium-density stands with dense to moderately dense understories of flammable shrubs, conifer reproduction, abundant litter and/or herbaceous fuel.	Flareups higher than trees frequent to continuous; spread up to several hundred acres per hour; passing through fire front impossible; spotting several hundred yards common, possible to a mile or more; just-burned area untendable for an hour or more.

by the following assumptions (Fahnstock, 1970): 1) No wind; 2) Other external factors equal (aspect, slope, stand density, etc.); 3) No change in relative rate of spread with change in fire danger; 4) Finest fuel present in appreciable quantity controls spread, although loading of coarser fuel may be greater.

Crowning Potential

For each residential plot the crowning potential was determined using Fahnstock's (1970) Key No. 2 and Brown (personal communication, 1979) revision to Fahnstock's key. Fahnstock's (1970) Crowning Potential Key (Key No. 2) identifies fuel characteristics that lead to crown fires in the canopy, according to the accepted definition of crowning, i.e., "fire advancing from crown to crown. . ." (USDA Forest Service, 1956). The key ranks crowning potential by increasing numbers from 0 to 10. The rankings are based on observations and deductions by Fahnstock (1970) and are purely ordinal.

The crowning key covers fire propagation both by progression of a flame front and by mass transport of firebrands (spotting). Both types of propagation operate when fine aerial fuels are abundant. Mass transport becomes increasingly important as amount and continuity of aerial fuels decline, and it is the only aerial mechanism of spread when crowns are dead, leafless, and noncontiguous. Wind or unslope is necessary for continuous spread through the crowns to occur. Factors conducive to rapid spread and high intensity of fire in lower fuels - e.g., drought, large accumulations of fuel - also aid crowning but are not the prerequisite to it. Therefore, the key is based only on essential attributes of the crowns themselves; the user must consider the other factors to estimate whether crowning is likely to occur in any given situation, according to Fahnstock (1970).

Brown (personal communication, 1979) revised Fahnstock's (1970) Crown Fire Key to include the contribution of large fuel combustion behind the fire front. The flame length calculated in the rate of spread evaluation (Key No. 1) was used. The flame length was divided by eight and rounded off to one decimal place to determine the indicator of crown fire start. If the flame length was 2.4 meters (8 feet) or longer, a value of 1.0 was used as the indicator.

Using Fahnstock's Key No. 2, the overstory characteristics, ladder fuels, and large fuel accumulations were used. Brown has included an amendment at the bottom of Key No. 2 that accounts for the presence of excessive amounts of large fuels. Large fuels often burn out behind the fire front causing intense pockets of fire that can initiate crowning (Brown, personal communication, 1979). Brown suggests that if large fuels are plentiful that Fahnstock's Crown Fire Key value should be increased by 1.

Fuel Inventory and Appraisal

Each residential plot's down and dead forest fuels were appraised and measured in several ways. Fischer's (1979) Fuel Appraisal Photo Series was used on all residential plots for all ten study sites. The photographs are arranged according to forest cover type and subdivided according to types and amounts of fuels present. One simply flips through the photo series in the corresponding forest cover type and tries to match up the residential plot with the appropriate fuel situation in the photograph. Each photograph or specific fuel type is accom-

Key No.1: Rate of Spread (Fahstock, 1970)

	Rating (chains/hr)*
A. Fuel essentially confined to surface layer — B	
B. Fine fuel present, not sparse — C	
C. Fine fuel fluffy (1) (fig. 1a, b)	100
CC. Fine fuel jumbled (2) (fig. 1b, c)	18
CCC. Fine fuel thatched — D	
D. Small fuel jumbled (3)	10
DD. Small fuel, if present, not jumbled (4) (fig. 1d)	5
CCCC. Fine fuel compact — E	
E. Small fuel jumbled (5) (fig. 2a)	5
EE. Small fuel thatched (6)	3
EEE. Small fuel sparse or absent — F	
F. Medium fuel jumbled (7) (fig. 2b)	3
FF. Medium fuel not jumbled (8) (fig. 1e)	1
BB. Fine fuel sparse or absent — G	
G. Small fuel jumbled or thatched (9)	3
GG. Small fuel sparse or absent — H	
H. Medium fuel jumbled (10)	2
HH. Medium fuel not jumbled – I	
I. Larger fuel jumbled (11)	1
II. Larger fuel not jumbled (12)	<1
AA. Fuel available in low and/or intermediate layers — J	
J. Low dense or open; intermediate fuel sparse or absent — K	
K. Fine low fuel dense to open — L	
L. Fine low fuel dense — M	
M. Surface fuel present, not sparse — N	
N. Surface fuel fine and/or small (13) (fig. 3a, c)	100
NN. Surface fuel medium and larger (14)	80
MM. Surface fuel sparse or absent (15) (fig. 3b)	65
LL. Fine low fuel open — O	
O. Surface fuel present, not sparse — P	
P. Surface fuel fine and/or small — Q	
Q. Surface fuel fluffy (16)	100
QQ. Surface fuel jumbled or thatched (17)	75
QQQ. Surface fuel compact (18)	50
PP. Surface fuel medium and larger (19)	40
OO. Surface fuel sparse or absent (20)	30
KK. Fine low fuel sparse or absent — R	
R. Small low fuel dense — S	
S. Surface fuel present, not sparse — T	
T. Surface fuel fine and/or small — U	
U. Surface fuel fluffy (21)	100
UU. Surface fuel jumbled or thatched (22)	50
UUU. Surface fuel compact (23)	30
TT. Surface fuel medium or larger (24)	30
SS. Surface fuel sparse or absent (25)	20
RR. Small low fuel not dense — A	
JJ. Low fuel and fine and small intermediate fuel dense or open — V	
V. Low fuel fine and/or small — W	
W. Surface fuel present, not sparse — X	
X. Surface fuel fine and/or small (26) (fig. 3d, e)	100
XX. Surface fuel medium and larger (27)	90
WW. Surface fuel sparse or absent (28) (fig. 3f)	70
VV. Low fuel medium and larger — Y	
Y. Surface fuel present, not sparse — Z	
Z. Surface fuel fine and/or small — a	
a. Surface fuel fluffy or jumbled (29)	100
aa. Surface fuel thatched or compact (30)	80
ZZ. Surface fuel medium and larger (31)	65
YY. Surface fuel sparse or absent (32)	50
JJJ. Low fuel sparse or absent; fine and small intermediate fuel plentiful — b	
b. Ladder fuels present — c	
c. Fine and/or small surface fuels present, not sparse — d	
d. Surface fuel fluffy or jumbled (33)	100
dd. Surface fuel thatched or compact (34) (fig. 4a)	80
cc. Fine and/or small surface fuel sparse or absent — e	
e. Medium and larger surface fuels jumbled (35)	60
ee. Medium and larger surface fuels not jumbled (36)	40
bb. Ladder fuels absent — A	

s/hr = 2000 meters/hr

Key No. 2: Crowning Potential (Fahnstock, 1970)

	Rating
A. Foliage present, trees living or dead — B	
B. Foliage living — C	
C. Leaves deciduous or, if evergreen, usually soft, pliant, and moist; never oily, waxy, or resinous (1)	[a]0
CC. Leaves evergreen, not as above — D	
D. Foliage resinous, waxy, or oily — E	
E. Crowns dense — F	
F. Ladder fuels plentiful — G	
G. Canopy closure >75 percent (2)	9
GG. Canopy closure less (3)	7
FF. Ladder fuels sparse or absent — H	
H. Canopy closure >75 percent (4)	7
HH. Canopy closure less (5)	5
EE. Crowns open — I	
I. Ladder fuel plentiful (6)	4
II. Ladder fuels sparse or absent (7)	2
DD. Foliage not resinous, waxy, or oily — J	
J. Crowns dense — K	
K. Ladder fuels plentiful — L	
L. Canopy closure >75 percent (8)	7
LL. Canopy closure less (9)	4
KK. Ladder fuels sparse or absent — M	
M. Canopy closure >75 percent (10)	5
MM. Canopy closure less (11)	3
JJ. Crowns open — N	
N. Ladder fuels plentiful (12)	3
NN. Ladder fuels sparse or absent (13)	1
BB. Foliage dead — O	
O. Crowns dense — P	
P. Ladder fuels plentiful — Q	
Q. Canopy closure >75 percent (14)	10
QQ. Canopy closure less (15)	9
PP. Ladder fuels sparse or absent — R	
R. Canopy closure >75 percent (16)	8
RR. Canopy closure less (17)	4
OO. Crowns open — S	
S. Ladder fuels plentiful (18)	6
SS. Ladder fuels sparse or absent (19)	2
AA. Foliage absent, trees dead — T	
T. Average distance between trees 33 feet or less — U	
U. Ladder fuels plentiful — V	
V. Trees with shaggy bark and/or abundant tinder (20)	10
VV. Trees not as above (21)	8
UU. Ladder fuels sparse or absent — W	
W. Trees with shaggy bark and/or abundant tinder (22)	10
WW. Trees not as above (23)	5
TT. Average distance between trees >33 feet (24)	2

[a] *Rare instances have been reported, resulting from extreme drought.*

panied by a detailed description of the fuel loading, fire potential rating, and stand information. Figure 3 is a typical data sheet which accompanies each photograph. Therefore, comparison of data produced by Fahnstock's (1970) keys, Brown's (1974) modified by Oberheu (1977) Fuel Inventorying, and Fischer's (1979) Fuel Appraisal Photo Series was possible.

FIGURE 3: Sample Data Sheet of Fischer's (1979) Fuel Appraisal Photo Series.

FOREST COVER TYPE: SAF No. 212. Larch-Douglas-fir
MONTANA HABITAT TYPE: No. 292. Douglas-fir, twinflower-pinegrass phase (PSME/LIBO-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.2	0.04
0.25-1	1.5	0.34
1-3	4.0	0.90
Subtotal 0-3	5.7	1.28
3-6	5.2	1.17
6-10	2.5	0.56
10-20	0	0
20+	0	0
Subtotal 3+	7.7	1.73
Total	13.4	3.01

NFDRS FUEL MODEL	STYLIZED FUEL MOD. Albini (1976)
C	2

OTHER FUEL DATA

average duff depth: 2.2 in.
5.59 cm.

average diameter, 3+fuels:
4.1 in.
10.41 cm.

% rotten, 3+fuels: 25 %

volume of sound 3+fuels:
462 ft^3/ac
32.3 m^3/ha

STAND AND SITE DATA

AGE of overstory dominants:

LAOC	285 yrs.
PSME	246 yrs.

Average Slope: 23 %
Aspect: northwest
Elevation: 4480 ft 1366 m
Remarks: old seed-tree cut

ESTIMATED FUEL POTENTIAL

Based on an average bad day: 85-90^o temp. 15-20% R.H., 10-15 mi/h. wind, 4 weeks since rain.

Rate of spread	low
Intensity	low
Torching	nil
Crowning	nil
Resistance to control	low
Overall Fire Potential	LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: N. Fk. Howard Cr.

Photo taken: 8-29-77
By: W. C. Fischer

Actual inventorying of surface fuels was done using Brown's (1974) technique as applied by Oberheu (1977) of inventorying downed woody fuels, litter, duff, grass, and forbs, woody shrubs, and seedlings. Downed woody material is the dead twigs, branches, stems, and poles of trees and brush that have fallen and lie on or above the ground (Oberheu, 1977).

The downed woody material was measured by using the same technique as described in Brown's (1974) "Handbook for Inventorying Downed Woody Material." The litter, grass, and forbs were measured using the relative estimate method. Duff weights were calculated by using depth-weight correlations. Shrub loadings were determined from a tally of stems by basal diameter classes, using Brown's data for known brush species.

Only seven out of the original ten study sites were utilized in the inventorying of surface fuels. The seven study sites were chosen on the basis of: 1) representing all three habitat types (*Abies lasiocarpa/Clintonia uniflora*, *Abies lasiocarpa/Vaccinium globulare*, and *Abies lasiocarpa/Linnaea borealis*), 2) spanning the entire range of topographic features, and 3) covering what appeared to be the most hazardous residential developments. Each study site was sampled by ten fuel loading plots. These fuel plots were located at fixed intervals of 30 meters along transects that ran diagonally through the study site and parallel residential plots used for collection of residential structure-forest fuel interface data. The fuel plots were set up as follows (Oberheu, 1977):

Step 1: Sampling point was marked with a chaining pin. Care was taken not to disturb any downed material.

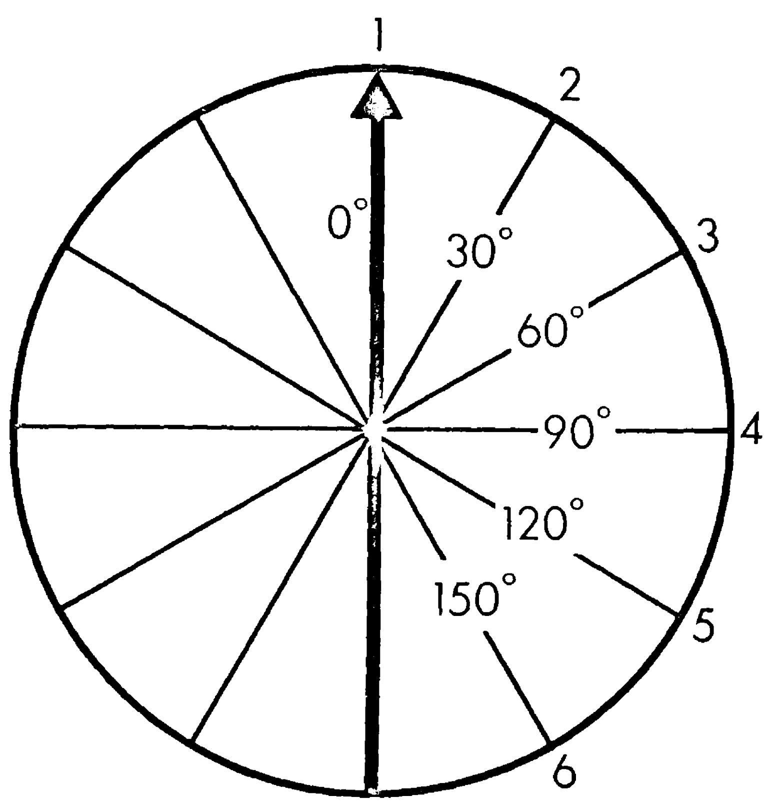
Step 2: Direction of sampling plane was determined by tossing a die to indicate one of six 30° angles between 0° and 150° (Figure 4).

The 0^{o} heading is the transect direction. To position the sampling plane one turned clockwise.

Step 3: Position of the sampling plane was denoted by placing a 2.1 meter (6.8 foot) inventory rod out from the chaining pin parallel to the ground in the direction determined in step 2 (Figure 5). A 15.2 meter (50 foot) tape was used along the same line to measure 7.5 centimeter (3 inches) materials. The tape and rod together fix the position of vertical sampling planes.

Step 4: Next, the four relative estimate subplots and the two one square meter (1/4 mile acre) brush plots on the ground in relation to the direction of the sampling plane were located. The two brush plots were marked with chaining pins (Figure 5).

Figure 4: Locating sampling plane by using die to pick one of six directions for fuel inventory (Oberheu, 1977).



The fuel loading field data were processed by the Northern Forest Fire Laboratory, Missoula, Montana, and the results were used as a comparison for the data derived from Fischer's (1979) Fuel Appraisal Photo Series.

Rates of fire spread and intensity were determined utilizing Albini's (1976) Nomographs for Stylized Fuel Models. Albini (1976) used Rothermel's (1972) spread rate model equations to produce a set of graphs to estimate fire behavior in a wide variety of situations. The fire behavior described by the nomographs pertain to the leading edge of a spreading surface fire. It does not include spread by spotting (firebrands or embers), crown fire (spread through coniferous tree crowns), or the long-term residual fire intensity.

The following outlines the procedure of using the nomographs. First, the best of Albini's 13 fuel models was determined for use in each site. The fuel models are grouped into fuel community groups: grass and grass-dominated fuel complexes, chaparral and shrubfields, timber litter, and logging slash. The fuel community groups are further subdivided into categories according to the amount of fuel present. Next, the "variable" factors (wind speed, terrain slope, and fuel moistures) were determined. Terrain slope was measured in the field, wind speed was determined from "10 Day and Monthly Wind Speed Summaries for June, July, August, and September from 1961 - 1970," obtained from the records of the Northern Forest Fire Laboratory for the Seeley Lake Ranger District. Fuel moistures were also obtained from records of the Northern Forest Fire Laboratory.

Fire behavior was then calculated using the nomograph with the

Figure 5: Diagram of total fuel inventory plot setup (Oberheu, 1977).

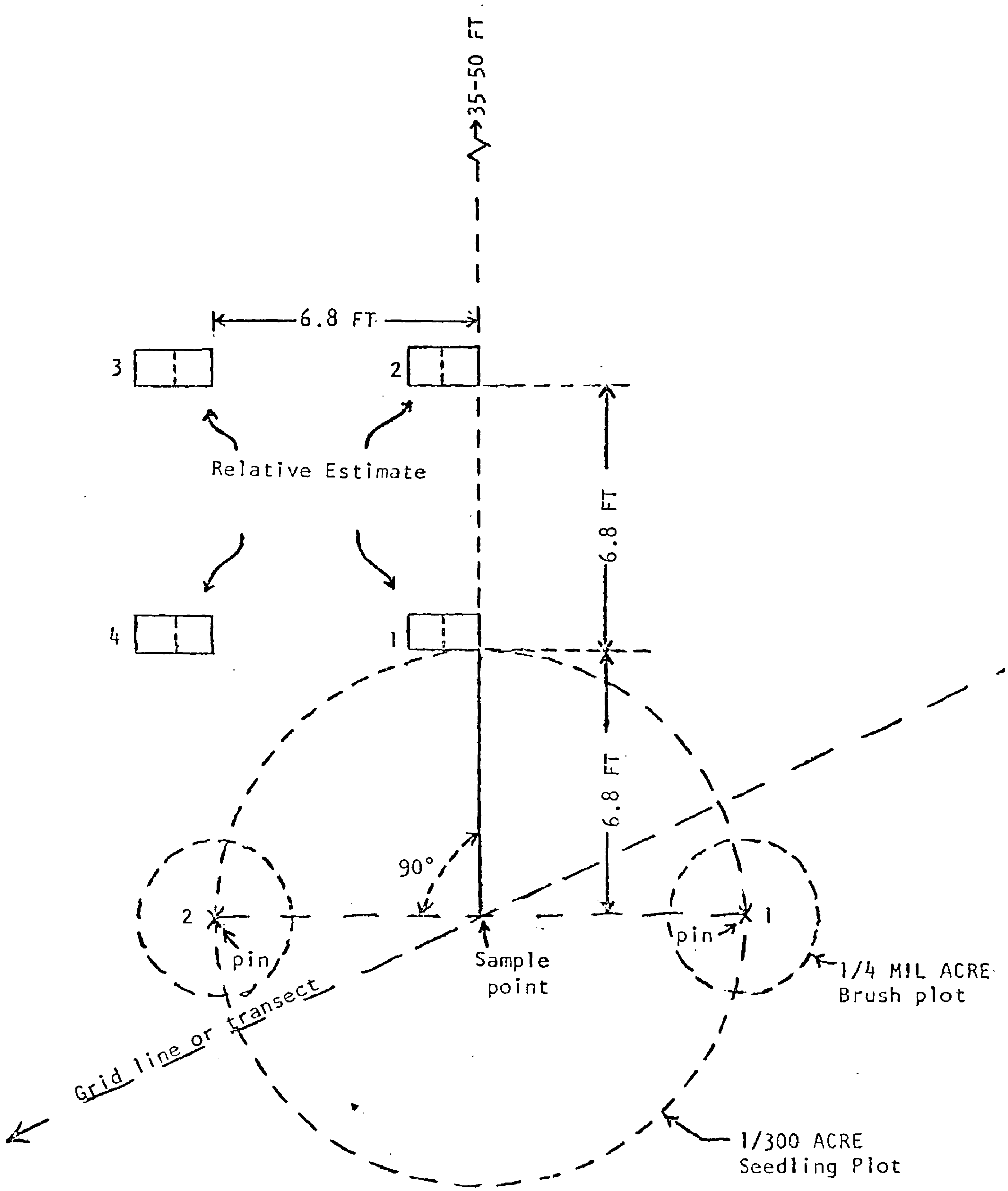


Figure 6: Albini's (1976) nomograph for fuel model 10 - timber (litter and understory) - low windspeeds.

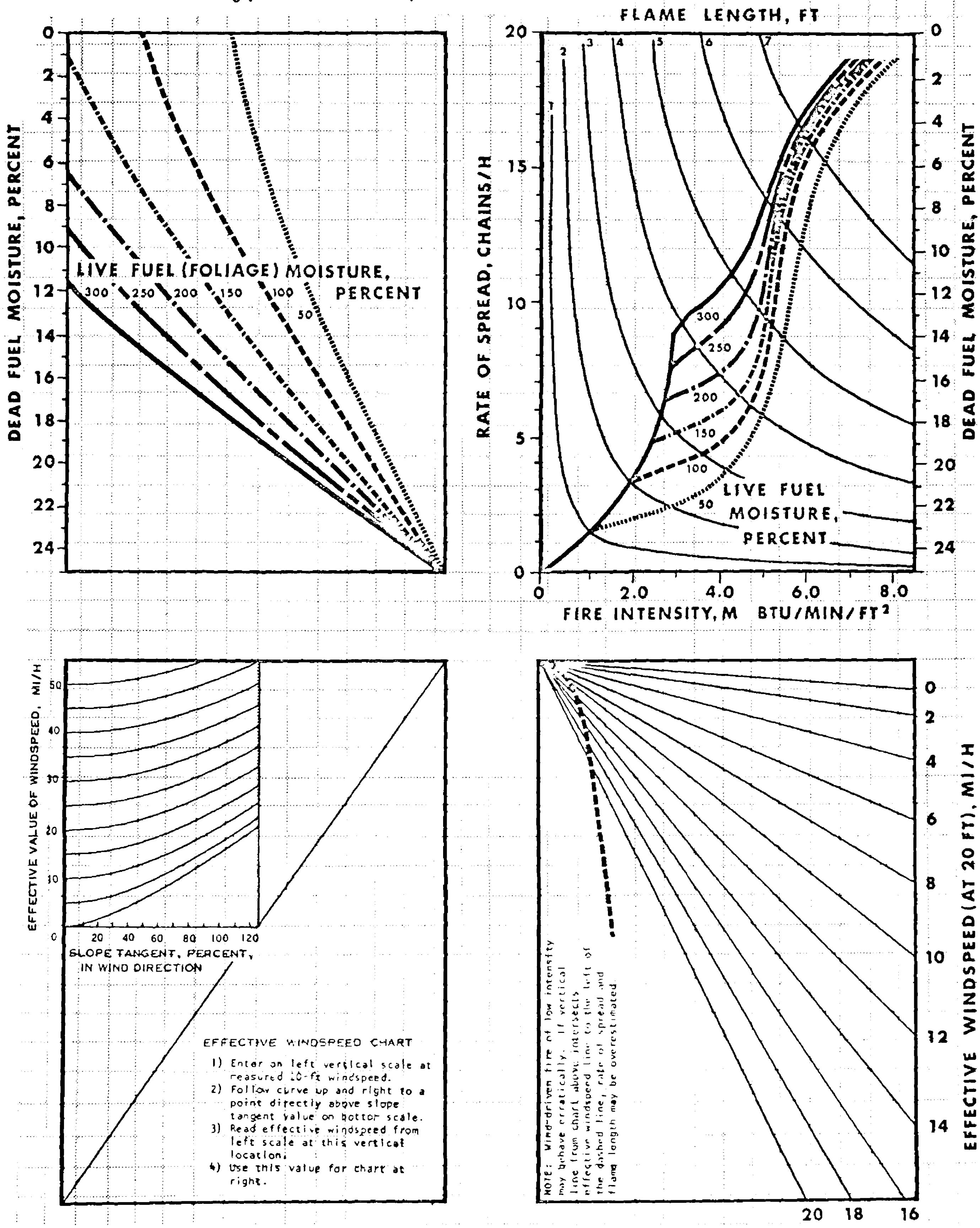
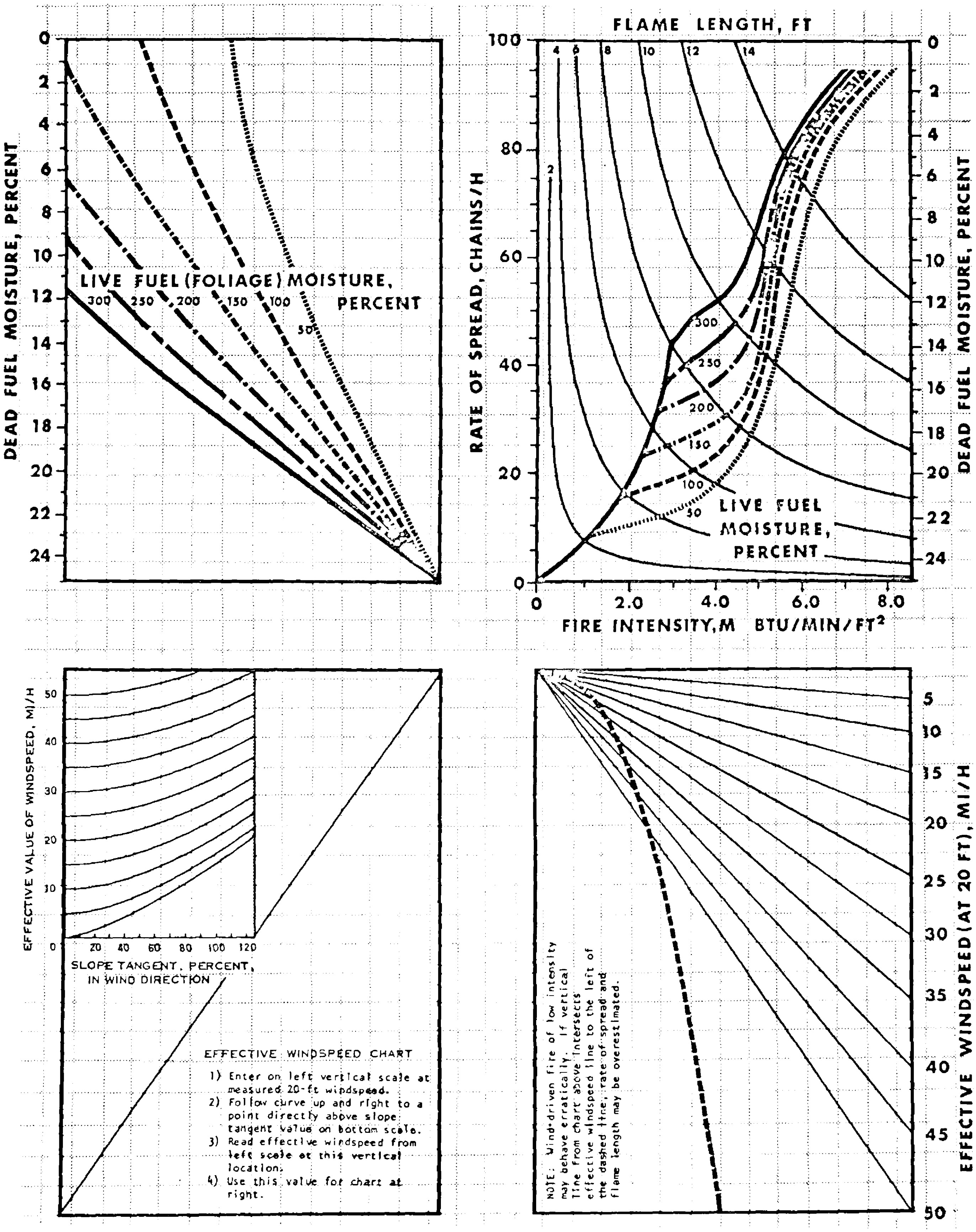


Figure 7: Albini"s (1976) nomograph for fuel model 10 - timber (litter and understory) - high windspeeds.



appropriate effective wind speed range. For each fuel model, there were two nomographs--one for low and one for high wind speeds (Figures 6 and 7). These results were then compared with the data produced from the use of Fahnstock's (1970) keys for the rate of spread and crowning potential.

Fire History

Due to the limited amount of field time available, the fire frequencies of the study area were formulated from records obtained from the Seeley Lake Ranger Station and from Davis, Clayton, and Fischer's (1980) study on the fire ecology of Lolo National Forest. Further elaboration of Davis, Clayton, and Fischer's study will be presented in later chapters. Arno and Sneck's (1977) techniques of analyzing fire scars in the annual growth rings of surviving trees, for determining fire frequency was deemed unsuitable due to the limited amount of field time.

CHAPTER V

RESULTS AND DISCUSSION

Fire History and Ecology

Fire, in many forms is the predominant factor responsible for the vast array of seral communities in the Seeley Lake area. The earliest individuals to describe the vegetation of the area were deeply impressed with the importance of fire (Ayers, 1900; Whitford, 1905). They commented on the large extent of fires at these early dates and the vast amount of land supporting small trees or brush as a result of past burns.

Large fires were common in the Seeley Lake area up into the 1930's. Since that time modern fire-fighting techniques have prevented the development of any fires larger than a few hectares within the study area. Although many stands date from the large fires which occurred in the first third of this century, the lack of large fires since this time results in a corresponding, lack of young forests.

This lack of climax stands constitutes another significant gap in the successional sequence. The oldest forests encountered are 110 years in age and contain seral species of *Larix occidentalis*, *Pseudostuga menziesii*, and *Pinus contorta*. This absence of climax forests and the presence of fire scars on the older *Larix occidentalis* attests to the all encompassing effect of fire.

Fire is a pervasive force in the Seeley Lake due to the fact that the summers tend to be warm and dry with frequent lightning storms. During many years conditions are probably too moist for the development of large fires, but every few years extremely dry summers occur during which intense fires are possible. Table 3 indicates that the majority of fires which have occurred since 1940 were started by lightning. Therefore, the assumption that lightning-caused fires have been prevalent before recorded fire history can be made.

Fire occurrence in the Seeley Lake area was first recorded in 1889, when six large fires covered almost the entire Ranger District. In 1910, the year much of the northwest Rockies burnt, the Seeley Lake area was also covered by six large fires. From 1910 until 1940, when fire fighting techniques prevented the development of any fires larger than a few hectares in the study area, the average number of large fires (over 100 hectares) was about four. Beginning in 1940 precise fire frequencies were recorded (see Table 3).

Data shown in Table 3 indicates the number of fires and the sources of ignition for fire occurrence in the Seeley Lake Ranger District from 1940-1978. Eighty-one percent of all the fires were started by lightning, with 19% of the fires due to man's activity in the forest. Smoking (started 6% of all fires), forest utilization (3%), and recreation (3%) were the three major man-caused sources of fires within this period. The study area is a heavily used recreational area, residential area, and contains a large sawmill, and is traversed by many powerlines and state highways. Indications are that the risk of fire will increase with increased residential development.

Davis, Clayton, and Fischer (1980) identify ten "Fire Groups" of habitat types based on fire roles in forest succession. The Seeley Lake study area fits into two of those Fire Groups. Study sites 4, 5, 6, 7, and 9 being of either ABLA/VACA or ABLA/LIBO (more specifically ABLA/LIBO-VASC) habitat types (see Table 5) belong to Davis, Clayton, and Fischer's Fire Group Seven. Fire Group Seven is characterized by cool habitat types usually dominated by Pinus contorta regardless of the climax species. Study sites 1, 2, 3, 8, and 10 being of the ABLA/CLUN habitat type fit into Fire Group Nine, which is characterized by moist lower subalpine habitat types.

Two effects of fire on Pinus contorta forests of Fire Group Seven are evident. First, light to moderate intensity ground fires thin the understory and prepare a mineral bed for the seeds released from serotinous cones. In some cases, the frequency of fire prevents the successful establishment of more shade-tolerant species such as Pseudostuga menziessi, Picea engelmannii, and Abies lasiocarpa.

Second, Pinus contorta forests of this group seem to invite stand-destroying wildfires. Mountain pine beetle (Dendroctonus ponderosae) epidemics can create large amounts of downfall and standing snags. Down and dead wood provide abundant fuel for an intense fire. Wind-driven crown fires cause stand replacement over large areas. Abundant seed supplies after such fires, provided by Pinus contorta's serotinous cones, usually result in very dense, even-aged stands of Pinus contorta. Therefore, fire insures perpetuation of the Pinus contorta forest thereby maintaining a "fire climax" community.

The role of fire in seral Pinus contorta forests is almost exclusively as an agent which perpetuates Pinus contorta. Without periodic disturbance the more tolerant species can replace Pinus contorta because it doesn't regenerate successfully under shaded conditions. Periodic fires interrupt the natural course of succession and increase the proportion of Pinus contorta with each burn. Moderate intensity burns disrupt the succession without destroying the forest. The ability of Pinus contorta to set seed while still in the sapling stage gives it an added advantage over competing species. Within 50 to 100 years after fire in a Pinus contorta dominated forest a reestablished pine cover will exist even though shrubs and herbaceous cover may temporarily become dominant immediately after the burn. The regeneration of spruce, fir, and other conifers largely depends on the availability of a seral source.

Brown (1975) discussed the fuel accumulation concept for Pinus contorta forests and illustrated the fire potential trends over time. Pinus contorta forests are particularly susceptible to such fires when the forest is overstocked and when suppression mortality and downfall contribute to the fuel situation. Other factors such as dwarf mistletoe infestations, mountain pine beetle outbreaks, and effects of preceeding fires often create large fuel accumulations which contribute to violent widespread burns.

Old growth Picea engelmannii/Abies lasiocarpa forests represent an advanced stage of the fire initiated Pinus contorta forest. They are not a self-perpetuating climax community. Picea engelmannii doesn't regenerate well under a dense closed canopy, and in the absence of fire, Picea engelmannii/Abies lasiocarpa will progress towards an Abies lasiocarpa/Picea engelmannii community.

Natural fire frequency in Pinus contorta forests varies from a few years to two hundred years. This is generally insufficient time for Pinus contorta to be replaced by climax species. In some areas the

TABLE 3: Fire occurrence summaries from 1940-1978, for the Seeley Lake Ranger District, according to the various sources of ignition.

	NUMBER OF FIRES STARTED BY THE FOLLOWING SOURCES OF IGNITION							
Year	Lightning	Smoking	Forest Utilization	Equipment	Recreation	Land Occupancy	Incendiary	Misc.	Total Fires
1940-44	69	4			1			1	75
1945-49	70	7			3			3	83
1950-54	27	4	2		2			5	40
1955-59	35	5	3		2			6	51
1960-64	77	3	1	2	3	4		4	94
1965-69	84	11	3	2		3	3		106
1970-74	101	2	9		5		1		118
1975-78	41		3	1	4	1		3	53
	81%	6%	3%	1%	3%	1%	1%	4%	175

successional status of Pinus contorta is in doubt because of the scarcity of other conifers within vast tracts of Pinus contorta forests. In these areas pine is apparently a fire maintained "disclimax" (Davis, Clayton, and Fischer, 1980). Fire would have to be excluded for centuries before the issue can be settled with certainty.

Studies of fire history have shown that fire is a regular feature of Pinus contorta disclimax forest. In Group Seven habitat types occurring in the Bitterroot National Forest, Arno (1976) found that the mean fire/free interval was 21 years with a range of 3 to 67 years. These figures represent fire occurring somewhere in a sizeable stand (100 to 200 acres; 40 to 81 hectares) and not the frequency of fire reoccurring on a specific site. Gabriel (1976) reported an average of 40 years and Tande (1977) 27 years. Studies from other areas in the Rocky Mountains vary but are essentially in agreement with these figures. Severe and multiple burns have usually favored Pinus contorta above all other associated conifers.

Perhaps the primary fire management consideration in Group Seven habitat types is protection from unwanted fire during extended periods of drought and during severe fire weather conditions. Fires at such times often crown and become holocausts that result in complete stand mortality if the Pinus contorta stand is ready physiognomically to burn (Despain and Sellers, 1977). Opportunities for fire use are limited in natural stands because of the low fire resistance of Pinus contorta, Picea engelmannii, and Abies lasiocarpa.

The primary use of prescribed fire in Group Seven habitat types has been for hazard reduction and site preparation in conjunction with tree harvesting (Davis, Clayton, Fischer, 1980). Broadcast burning and windrowing and burning have been the most often used methods of accomplishing these tasks. A very important caution regards the need to retain a certain amount of woody material for maintenance of forest site quality. Current understanding of the relationships between organic matter and ectomycorrizae in northern Rocky Mountains forest soils is based on recent work in Western Montana (Harvey, Jurgens, and Lareson, 1976, 1978, 1979). Slash of all sizes is necessary to avoid soil movement, disturbance and to supply nutrients and moisture from decaying wood and humus for germinating seeds.

A major concern in the management of Pinus contorta in the general forest zone is the regulation of sweeping crown fire. A key element in this regulation is the establishment and maintenance of an age-class mosaic (Davis, Clayton, Fischer, 1980). This can be accomplished through harvest practices and fire use.

Fire Group Nine, characterized by moist lower subalpine habitat types (ABLA/CLUN in the Seeley Lake study area), have a low fire frequency. Fires that do occur are often severe, and the effects may be long lasting. These habitat types rarely progress to mature climax forests because of the fire regime.

The role of Pinus contorta is that of an intolerant species whose very existence is dependent on periodic fires. Being an intolerant species, it is unable to regenerate successfully in conditions associated with later forest succession. Here is is not the dominating seral species. It usually occurs in mixed forests with Pseudotsuga menziesii, and Larix occidentalis.

Larix occidentalis is the most fire resistant conifer in the northern

Rocky Mountains. It possesses a thick, fire-resistant bark and has a tendency to self-prune its lower branches. Light to moderate ground fires, therefore, have little effect on mature Larix occidentalis. Even young seedlings will often survive high temperatures for short durations.

However, it is vulnerable to damage in these habitats because it grows in dense forests in association with low-canopy conifers and tall shrubs which can carry fire into the crowns. It is a sub-climax species maintained by fire. It cannot successfully regenerate in shaded conditions of the later successional stages and will lose dominance to more tolerant species if overtopped. It is a major seral component in these forests in northwestern Montana (Pfister et al., 1977). Locally, it may occur in nearly pure stands.

Pseudotsuga menziesii is a fire-resistent tree, however, saplings are vulnerable to surface fires because of their thin bark, resin blisters, closely spaced inflammable needles, and thin bud scales (Davis, Clayton, Fischer, 1980). The moderately but dense branching habit of saplings enables surface fires to be carried into the crown layer. Older trees develop a relatively unburnable, thick layer of insulative bark which provides protection against low to medium intensity fires. In these habitat types, it is a major, fire-promoted component of seral forests in the lower subalpine habitat types (Davis, Clayton, Fischer, 1980). Pseudostuga menziesii is susceptible to fire damage in this group because it grows in dense forests. Conifer regeneration and tall shrubs provide a fuel ladder for fire to enter the canopy. While the thick bark offers older trees limited protection from surface fires, fires which reach the crowns destroy trees of all ages.

Pseudotsuga menziesii is more shade tolerant than Larix occidentalis and Pinus contorta. Its ability to endure shade enables it to regenerate after the fire-initiated forest has been established. When shade conditions become too limiting for Pseudostuga menziesii, it is replaced by Abies lasiocarpa and Picea engelmannii.

In these habitats, Picea engelmannii functions primarily as a persistent seral component of the stand. Fire recycles Picea engelmannii stands usually reverting them into Pinus contorta, Pseudotsuga menziesii, and Larix occidentalis mixtures.

Abies lasiocarpa has the same relationship to fire in this group as it does in Group Seven. Its low fire resistance makes it readily vulnerable to death or severe injury from burning. Thus, fire acts as a recycling agent which reduces the Abies lasiocarpa component and often replaces it with early seral species.

Abies lasiocarpa is the major climax dominant in this group. Where fires are infrequent, as in the cold, wet habitat types, Abies lasiocarpa has time to attain dominancy. In the drier and lower elevation habitat types, as in the Seeley Lake area; however, Abies lasiocarpa is usually subordinate to more aggressive early serals, such as Pseudotuga menziesii, Pinus contorta, Larix occidentalis, and sometimes Pinus ponderosa. Here, fire is more frequent and seral species are more competitive.

Abies lasiocarpa may begin producing cones when only 20 years old, but maximum seed production is by dominant trees 150 to 200 years old. The tree's performance as a seral is enhanced by its ability to germinate and survive on a fairly wide range of seedbeds. Abies lasiocarpa has the advantage of a large seed which can quickly produce a vigorous root system.

In a closed canopy situation, establishment and early survival of

Abies lasiocarpa are favored by relatively deep shade. It can exist under low light conditions better than most associated species, but cannot compete successfully with Picea engelmannii where light intensity exceeds more than 50% of full sunlight.

Fire is less frequent in these subalpine habitat types than in other groups. Fire intensity can vary between light surface fires and stand-replacing burns. By opening the canopy and preparing a mineral seedbed, fire encourages shade-intolerant species.

Pseudotsuga menziesii and Pinus contorta are the major components of seral forests in the Seeley Lake area, with Larix occidentalis also being predominant in these forests. Picea engelmannii and Abies lasiocarpa may be present in the fire-initiated stand, but they usually do not become prominent until later successional stages.

The mesic climate, dense stand habit, and long interval between fires in the subalpine forests lead to replacement burns (Davis, Clayton, Fischer, 1980). Fire maintains these forests in a seral status. If these forests have not been continuously disturbed by past fires, the climax Picea engelmannii and Abies lasiocarpa would dominate most areas.

Arno (1976) reported an average fire frequency of 24 years for habitat types belonging to this group in his study in the Bitterroot Valley. In a more mesic forest type in Coram Experimental Forest, Sneck (1977) reported an average frequency of 140 years for these habitat types. Davis, Clayton, Fischer (1980) estimate that fire frequencies in Lolo National Forest stands fall within the above extremes.

According to Davis, Clayton, Fischer (1980) the effect of past fire suppression efforts has been to limit the spread of recent fires in these habitats. Over time this will lead to abnormal fuel loadings and create a greater hazard that now exists.

Without periodic disturbance, the mature seral stand will progress into a forest of climax species. This requires decades, perhaps centuries, of uninterrupted succession since many intolerant species can live for 300 to 400 years. A climax forest can develop if the forest goes many years without burning. In theory this could happen, but it is unusual for habitat types in the lower subalpine group to escape burning for that long (Davis, Clayton, Fischer, 1980). A severe fire in the climax forest recycles the site to the early successional stages.

Fire protection is usually necessary during severe burning conditions especially for areas where timber production is a management objective (Davis, Clayton, Fischer, 1980). At other times, fires may be of low to moderate intensity and result in only moderate or no damage to overstory trees, despite the relatively low fire resistance of many of the species present. The preceeding statement refers to undisturbed natural forests. If slash is present, unacceptable tree mortality can result under quite easy burning conditions.

The historical analysis of fire reveals the frequency, relative severity, and aerial spread of past fires. Collectively, this information describes characteristic fire behavior and effects for an area, which in turn helps to determine the "role" of fire in a forest type. The role can be further used to understand the autecological effects of fire on individual species as well as fire's relationship to plant communities. Fire history studies provide the insight to fire in various ecosystems and the effects of fire exclusion.

Provided with fire history information land managers have a scientific basis on which to develop fire management prescriptions to maintain or restore resources and to evaluate the consequences of policy alternatives. Knowledge of historic fires more clearly defines the risk involved in permitting fire as well as the benefits.

Hazard Classification

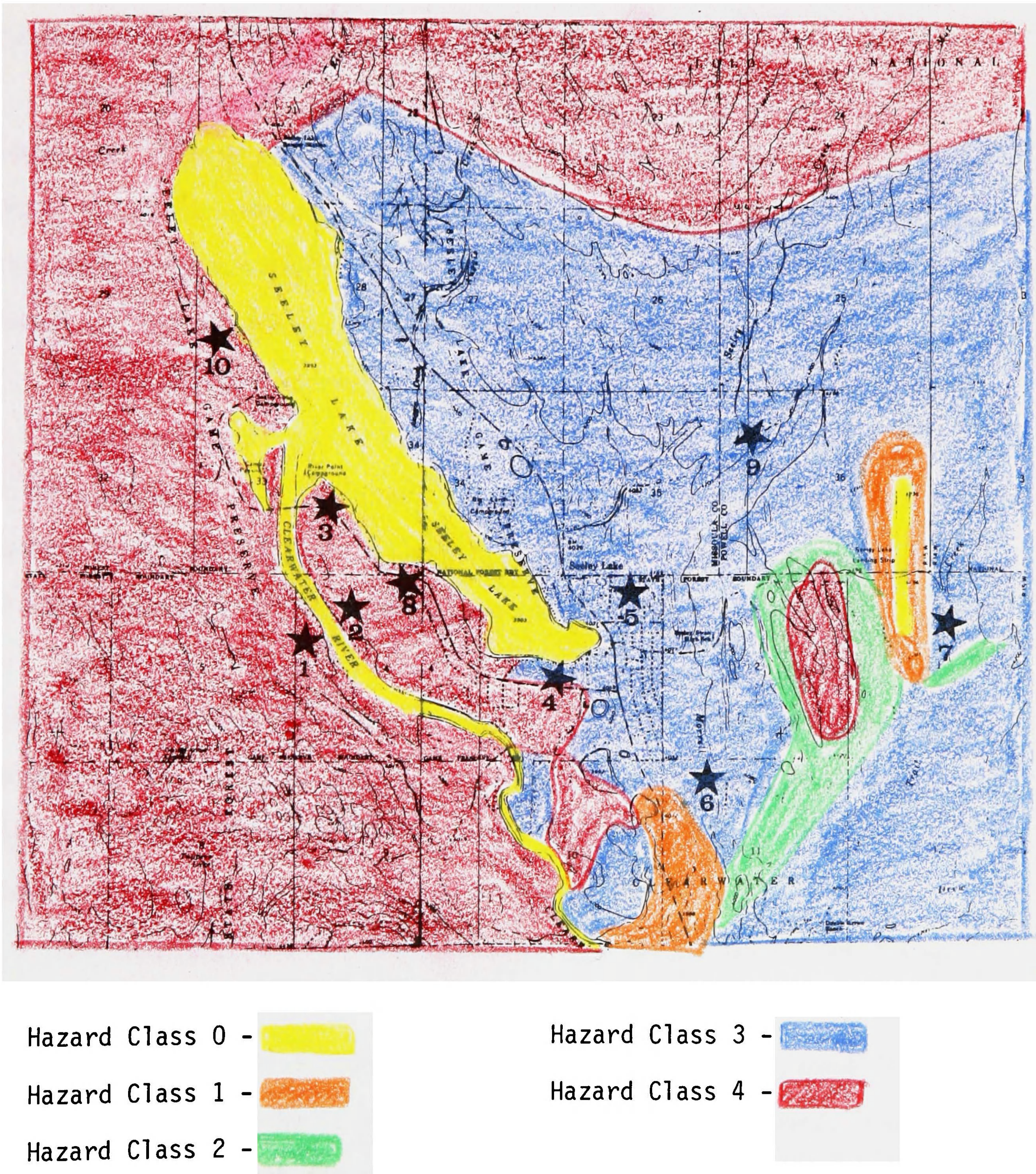
The study sites and surrounding areas including private and U.S.D.A. Forest Service land were classified as to Fischer's (1979) Fire Hazard Classes (see Table 2). Figure 8 illustrates the hazard classes for the Seeley Lake area on a U.S.G.S. 7-1/2 minute series map.

Study sites 1, 2, 3, 8, and 10 were all classified as being in Hazard Class "4" that is, having an extreme fire hazard. These study sites consist of dense conifer forests having crown coverage greater than 55% and with vertical fuel continuity into the tree crowns. Also included are medium-density forests with dense to moderately dense understories of flammable shrubs, conifer reproduction, abundant litter and/or herbaceous fuel.

The expected fire behavior for study sites being of Hazard Class "4" would consist of flareups higher than trees, with fire spread up to several hundred hectares per hour. The fire front would be impossible for a person to walk through. Spotting of up to several hundred meters would be common and possible to a kilometer or more. The just-burned area would be untendable for an hour or more (Fischer, 1979).

Study sites 4, 5, 7, and 9 were classified as being in Hazard Class "3", that is, having an overall high fire potential rating. These are medium density conifer forest with 35-55% crown coverage and surface fuels of mainly herbage and litter and some patches of conifer reproduction and dead wood. These study sites consist mainly of even age *Pinus contorta*

Figure 8: Map of Seeley Lake area showing fire hazard classes.



as the overstory, with surface fuels being litter and herbage.

The expected fire behavior for Class "3" would consist of intermittent flareups occurring to many meters above the treetops; with short and medium range spotting common; passing through the fire front is sometimes possible but chancy; and parts of burned area can be occupied within one-half hour.

Hazard Class "2" occurs in areas adjacent to the study area (see Figure 8). The vegetation of Class "2" consists of dense to moderately dense flammable vegetation 0.6 meters (2 feet) or greater in height, including shrubs, conifer reproduction, abundant litter and/or herbaceous fuel. Scattered conifer forests may also be present.

The expected fire behavior for Class "2" would consist of flames 1.5 to 6.1 meters (5 to 20 feet) high of brief duration. Fire spread would usually be fast, at least 16 hectares/hour (40 acres/hour). Human beings cannot safely pass through flames but can occupy just-burned area within about 15 minutes. Short-range spotting would be common.

Hazard Class "1" also occurs in areas adjacent to the study area (see Figure 8). Class "1's" vegetation consists of grass, weeds, and/or shrubs of 0.6 meters (2 feet) or less in height; dead wood in contact with ground; and open conifer forests with 0-35% crown coverage. Where slash is present these forests become Class "3."

The expected fire behavior for Class "1" would consist of flames less than 1.5 meters (5 feet) high, with higher flareups rare. The duration of the highest flames would be brief. The fire would spread slow to fast, 0.4-16 hectares per hour (1-40 acres per hour). Human beings can run through flames without serious injury and can occupy just-burned area. Spotting generally is rare and short-ranged.

Hazard Class "0" has essentially no vegetation nor fuel to support a fire. Therefore, there would be no fire hazard in these areas, consisting of open water (Seeley Lake itself), bare rock, or cultivated field.

The following treatments and precautions are necessary to make forest residences reasonably firesafe (Fischer, 1978).

Hazard Class "4" - Thin out trees to obtain a spacing of 3.7 meters (12 feet) between trees, or a spacing equivalent to the diameter of the trees plus 2.4 meters (8 feet), whichever is wider. Dispose of all slash resulting from the thinning. Any poles, posts, or firewood recovered from the thinning should be stacked at least 30.5 meters (100 feet) from structures.

Hazard Class "3" - Thin trees to a diameter-plus-2.4 meter spacing or wider for a distance equal to at least two tree lengths from the outline of the structure on all sides. Dispose of all slash and deadwood.

Hazard Class "2" - Dig out potentially flammable small trees and shrubs from a strip about 21.3 meters and about 10.7 meters on the other three sides. Occasional clumps may be retained as landscaping features. Each spring rake litter from under trees and shrubs in the cleared strip.

Hazard Class "1" - None required. Cleanup of any large amounts of deadwood within 30.5 meters of structure suggested.

Hazard Class "0" - None required.

Habitat Types and Canopy Coverage

The study sites were habitat typed according to Pfister *et al.* (1977). Table 5 indicates the habitat types for each study site and the average canopy coverage for each species of trees, shrubs, and forbs and grasses in each of ten study sites.

Study sites 1, 2, 3, 8, and 10 are classified as being in the Abies lasiocarpa/Clintonia uniflora (ABLA/CLUN) habitat type, with a dense crown coverage consisting of Abies lasiocarpa, Pseudotsuga menziesii, Picea engelmannii, and Larix occidentalis. The shrub layer's major components are Linnaea borealis, Vaccinium globulare, and Vaccinium scoparium. The forb layer is composed of mainly Arnica latifolia, Clintonia uniflora, and Calamagrostis rubescens.

Study sites 4 and 5 are classified as being in the Abies lasiocarpa/Vaccinium caespitosum (ABLA/VACA) habitat type, having a tree canopy composed almost exclusively of Pinus contorta with some Pseudotsuga menziesii and Larix occidentalis. The shrub layer of these stands containing Vaccinium caespitosum, Vaccinium scoparium, and Linnaea borealis, form a dense layer. Calamagrostis rubescens is the major grass present in the forb and grass layer, with a trace of Arnica latifolia in addition.

Study sites 6, 7, and 9 are classified as being in the Abies lasiocarpa/Linnaea borealis (ABLA/LIBO) habitat type, having a dense tree canopy of mostly Pinus contorta with some Larix occidentalis, Pseudotsuga menziesii, Abies lasiocarpa and Picea engelmannii. Linnaea borealis, Vaccinium globulare, and Vaccinium scoparium are the major shrubs present. The forb and grass layer contains mainly Arnica latifolia and Calamagrostis rubescens.

Residential Build-Up and Forest Fuel Interface

Table 6 summarizes the characteristics of the interface between the residential structure and forest fuels. The average percentage all

TABLE 4: Summary of physical site factors for study sites.

Study Site	Location	Elevation (meters)	Slope Aspect	Slope Inclination	Topographic Position
1	Clearwater River west	1220	95.2^{o}	5.7%	Riverbottom
2	Clearwater River east	1220	50.0	3.2	Riverbottom
3	Seeley Lake west River Pt. to L.L.	1220	50.3	3.7	Lakeside bench
4	Seeley Lake west L.L. to Mill	1220	65.0	6.0	Lakeside bench
5	Downtown Seeley Lake	1250	113.0	16.3	Lower slope
6	Double Arrow subdivision	1230	63.5	16.7	Lower slope
7	Seeley Lake Estates subdivision	1280	207.0	12.8	Mid-slope
8	Seeley Lake west main road	1220	67.4	9.2	Lakeside bench
9	Morrel Creek Road	1300	117.2	10.0	Mid-slope
10	Seeley Lake west north of River Pt.	1220	62.0	17.0	Lakeside bench

TABLE 5: Presence and average coverage (calculated from coverage class midpoints) of species present in each of 10 study sites.

	STUDY SITE NUMBER AND HABITAT TYPE									
	1 ABLA/ CLUN	2 ABLA/ CLUN	3 ABLA/ CLUN	4 ABLA/ VACA	5 ABLA/ VACA	6 ABLA/ LIBO	7 ABLA/ LIBO	8 ABLA/ CLUN	9 ABLA/ LIBO	10 ABLA/ CLUN
TREES										
Abie lasi*	32	29	27	0	0	6	7	33	8	31
Pseu menz	24	20	26	3	4	8	10	25	12	23
Pice enge	26	23	24	0	0	9	8	27	7	19
Pinu cont	18	22	24	51	49	39	44	16	46	26
Lari occi	20	24	26	3	2	12	14	18	12	25
SHRUBS										
Amel alni	2	3	1	1	2	1	1	2	1	4
Linn bore	17	18	16	19	17	12	16	15	13	16
Loni utah	1	1	1	0	0	2	1	1	3	1
Rubu parv	5	4	7	0	0	0	0	6	0	5
Vacc caes	0	0	0	23	21	0	0	0	0	0
Vacc glob	12	13	15	3	2	12	13	14	14	12
Vacc scop	10	9	11	19	21	18	21	13	19	12
FORBS & GRASSES										
Arni lati	21	21	23	2	3	23	22	21	24	22
Clin unif	5	4	6	0	0	0	0	7	0	5
Gali trif	1	1	1	0	0	1	0	1	1	2
Chim umbe	1	1	1	0	0	0	0	1	0	1
Corn cana	4	3	5	0	0	0	0	6	0	5
Tiar trif	4	2	6	0	0	0	0	5	0	7
Pyro secu	1	1	1	0	0	2	3	1	3	1
Good oblo	1	1	1	0	0	0	0	1	0	1
Cala rube	8	7	9	39	36	13	12	10	16	7

*Species names were abbreviated using the first four letters of each name. See Appendix C for a detail list of species and abbreviations.

residential plots (n=175) in all ten study sites having a fuel break (a change in fuel continuity in a strategically located strip of land to reduce or hinder the rate of fire spread) of not less than 6.1 meters around the residential structure was 41.3%. Study sites 5 and 6 (located in downtown Seeley Lake and the Double Arrow Subdivision, respectively see Table 4 for physical site factors for study sites) had the highest percentage of plots with fuel breaks.

The total percentage of residential plots with fire-resistant roofs were high (96.1%) in all study sites, indicating that roof ignition would be low except where accumulation of debris on roofs is high, as in 55.1% of all residential plots. Study sites 5, 6, and 7 had a low percentage of residential plots with debris (needles, branches, leaves, dead vegetative growth, moss, lichens, or any other flammable material) on their roofs. Study sites 2, 3, and 10 had an extreme percentage of residential plots with debris on their roofs.

Eighty-five and four-tenths percent of all residential plots had large amounts of slash or deadwood material present in the plot. This slash could be a major source of ground fuel for a fire. The percentage of all residential plots having fire ladder material on trees (live or dead branches on trees up to 30.5 meters high and lichen growth on branches) adjacent to residential structures was also high (74%). This indicates that ladder fuels are present for a ground fire to travel quickly to the crown of the trees and then to the residential structure. Another source of fuel for a fire would be stacks of firewood adjacent to a residential structure. This would be a fuel source giving a potential fire a means of spreading from the ground to the residential structure.

TABLE 6: Summary of characteristics of residential build-up and forest fuel interface.

	STUDY SITES										
	1	2	3	4	5	6	7	8	9	10	Average
% of plots with a fuel break	32	38	26	45	58	58	42	31	33	50	41.3
% of plots with fire-resistant roof	100	100	100	100	100	87	74	100	100	100	96.1
% of plots with debris on roofs	63	100	95	45	0	12	32	54	50	100	55.1
% of plots having slash	100	88	95	90	83	80	68	92	83	75	85.4
% of plots having trees containing fire ladder material, adj. to structure	87	77	89	69	33	63	63	92	67	100	74.0
% of plots having fire-wood near structure	8	15	79	14	17	9	11	77	17	8	25.5
% of plots with power-lines above ground	100	100	100	100	92	46	100	100	33	100	87.1

TABLE 6: continued

	STUDY SITES										
	1	2	3	4	5	6	7	8	9	10	Average
Type of structure*	2^o	2^o	2^o	1^o	1^o	1^o	1^o	1^o	2^o	1^o	
Land leased (L) or private (P)	L State	L State	L USFS	P	P	P	P	P	L State	L USFS	
Number of residential plots	16	25	19	29	12	24	19	13	6	12	175

*1^o structure refers to primary and permanent residences, whereas 2^o structure refers to secondary residences, such as summer or recreational homes, which is occupied only part-time.

The average percentage of all residential plots with firewood adjacent to structure was 25.5%, having only study sites 3 and 8 with a high percentage of plots containing firewood as a potential fire hazard.

The percentage of plots with powerlines aboveground was determined to be 87.1%. Study sites 6 and 9 both had over 50% of their residential plots with underground powerlines. The fire hazard of aboveground powerlines is great. The Pattee Canyon fire of 1977, near Missoula, Montana was initiated by two powerlines coming together in the wind and sparking. This fire destroyed six residential structures and charred about 480 hectares of forest and grassland. Therefore, the potential of fires being started by aerial powerlines exists in the Seeley Lake area.

The residential structures in the study area are of two types--primary or permanent residences and secondary residence, such as summer or recreational homes, which are occupied only part-time. The land upon which these residential structures occupy is of three types--privately owned, U.S. Forest Service leased, and State of Montana leased. Therefore, the management of fuels on these three different types of sites may vary according to the agency involved.

Study site 6 (Double Arrow Subdivision) was the study site with the least hazardous conditions. The greatest amount of hazard reduction via fuel management was initiated in this site. The Double Arrow Subdivision planners removed a large percentage of slash in each plot and burned the slash in centralized area, thereby reducing the hazard.

To summarize, the residential structures are essentially immersed within the forest fuels, with little if any boundary separating the fuels from the structure. This situation is potentially hazardous in terms of forest fires. Suggested fire hazard ameliorative treatments will be discussed in the next chapter under Management Implications.

Residents' Views

A survey was taken on the attitude of the homeowners to fire. For every 10 meter radius residential plot corresponding to one individual residential structure, an interview was attempted with the homeowner. Several visits were needed to find the homeowners at home. Sixty percent (n=104) of the residents (n=175) responded to the interviews. The remaining 40% (n=71) of the residents were not at home after several attempts or did not wish to respond to the questions.

The following questions were the ones discussed with the homeowners:

1) Did they believe fire was a natural phenomen?

2) Did they believe there is a serious fire hazard where they lived?

3) Could they anticipate any problems which could arise while evacuating their premises during a forest fire?

4) Have they done anything to modify the fire hazard, that is eliminate the forest fuel (green lawn around structure, pruned trees, etc.)?

5) Have they seen the pamphlet put out by the USDA Forest Service on wildland homes and fire?

The results of these interviews closely paralleled the results obtained by Hulbert (1972) in his study in Colorado of the fire problems in rural suburbs. Hulbert interviewed residents of mountain homes and subdivisions in Jefferson and Boulder Counties of Colorado.

The results of both interviews indicated a general feeling of overconfidence by most residents toward the potential danger of forest fire.

Eighty percent of Seeley Lake residents interviewed indicated that they thought the forest fire danger was low or only moderate in the forested area they resided in. Seventy-five percent of Hulbert's interviewees indicated that they thought the forest fire danger was low or moderate in the mountains of Colorado. Only one person in twenty-five in Seeley Lake believed that fire was a natural phenomenon. Twenty percent of all the Seeley Lake residents interviewed anticipated problems which could arise while evacuating their premises during a forest fire. The overall feeling of Seeley Lake residents to fire was that, "there hasn't been a fire here in 40 years, so there probably is not much danger of fire here now."

Rate of Spread

The rate of advance of the head of a fire is called the forward rate of spread or rate of spread for purposes of this study. The rate of spread of a potential fire was calculated for each study site in several ways.

One method of determining rate of spread used Fahnstock's (1970) Key No. 1. Table 7 summarizes the fire potential ratings of study sites, including rate of spread (measured in meters per hour). Readouts of Fahnstock's Key are relative ratings on a scale of 0-100 chains per hour (Table 7 and this thesis use the metric units of meters per hour, therefore a scale of 0-2000 meters per hour was utilized), conditioned by the following assumptions: 1) No wind; 2) Other external factor equal (aspect, slope, etc.); 3) No change in relative rate of spread with change in fire danger; 4) Finest fuel present in appreciable quantity controls spread, although loading of coarse fuel may be greater.

Study sites 1, 2, 3, 8, and 10, all belonging to ABLA/CLUN habitat type, were calculated to have a rate of spread of 1609.6 meters/hour (see Table 7). These stands were composed of dense canopies in each of the layers (trees, shrubs, and forbs). The fuels of these study sites were available in low (<1.8 meters) and intermediate (1.8-6.1 meters) layers, with surface fuels being fine and dense and ladder fuels available. The absolute ratings for fuels for the northern Rocky Mountains in meters-per-hour are low-350, medium-600, high-1300, and extreme-2000. Thus, the value of 1609.6 meters/hour for the ABLA/CLUN habitat types in the Seeley Lake area is somewhere between high and extreme for the rate of fire spread. High values for rate of spread imply large areas burned.

Study sites 4, 5, 6, 7, and 9 belonging to the drier _Pinus contorta_-dominated ABLA/VACA or ABLA/LIBO habitat types were determined to have a rate of spread of 1509.0 meters/hour. This value is in the upper region of the high rating.

Therefore, all ten study sites within the study area were determined to have a high potential forward rate of fire spread, using Fahnstock's (1970) Key No. 1.

Rate of spread was also determined using Albini's (1976) Nomographs for Stylized Fuel Models. Albini utilized Rothermel's (1972) spread rate equations to produce a set of graphs to estimate fire behavior in a wide variety of situations (see Figures 6 and 7). The Seeley Lake study sites were all grouped into one of Albini's fuel community group No. 10--timber with litter and understory. Therefore, only nomograph No. 10 was used to determine potential fire behavior. Potential fire behavior was determined at both low (5 mph) and high (30 mph) wind speeds and for three different times of the year--early summer (June), mid-summer (July-August) and late

TABLE 7: Summary of fire potential ratings for study sites. (Rate of spread and crowning potential as determined using Fahnstock's (1970) keys).

Study Site	Habitat Type	Stand Age	Hazard Class	Rate of Spread (m/hr)	Crowning Potential	Overall Fire Potential Rating
1	ABLA/CLUN	110	4	1609.6	81*	high
2	ABLA/CLUN	85	4	1609.6	81	high
3	ABLA/CLUN	65	4	1609.6	81	high
4	ABLA/VACA	75	3	1509.0	46	medium
5	ABLA/VACA	65	3	1509.0	46	medium
6	ABLA/LIBO	75	3	1509.0	46	medium
7	ABLA/LIBO	70	3	1509.0	46	medium
8	ABLA/CLUN	110	4	1509.0	76	high
9	ABLA/LIBO	80	3	1509.0	46	medium
10	ABLA/CLUN	110	4	1509.0	76	high

*Crowning potential ranges from 0 to 100.

summer (September). At different times of the year, the dead fuel and live moisture varies (Table 8). In early summer, when foliage is maturing and still developing with full turgor the live fuel moisture would be 200% and dead fuel (fine fuels) moisture would be 10%. In mid-summer, when foliage is mature, new growth complete and comparable to older perennial foliage, the live fuel moisture would be 100% and dead fuel moisture 5%. Late summer, live fuel moisture would be 50%, when foliage is entering dormancy.

Table 8 indicates that at low windspeeds the potential rate of spread for all three seasons is relatively low. Studies of the relation of wind speed to rate of spread of small fires show a rapid acceleration in rate of spread with increasing windspeed (Brown and Davis, 1973). The potential rate of spread at high windspeeds in the Seeley Lake area is relatively high for early summer and very high for mid-summer and late summer. These rates of spread parallel closely the ratings determined using Fahnstock's Key No. 1. Consequently, the key does identify fuels in terms of conditions that are recognizable in the field and essentially independent of specialized technical knowledge. Owners of residential structures within forested regions therefore should be able to use the key to determine potential fire behavior.

The potential for a rapidly spreading fire in the Seeley Lake area is high. Table 3 indicates a large number of lightning-caused fires are frequent in the study area. Lightning combined with forest fuels with a high potential of rapid rate of spread indicates a very hazardous area for forest fires.

TABLE 8: Summary of fire behavior characteristics (rate of spread, fire intensity, and flame length) for Seeley Lake, determined by Albini's (1976) nomographs for stylized fuel models, at low (5 mph) and high (30 mph) wind speeds.

	Early Summer		Mid-summer		Late Summer	
	low	high	low	high	low	high
Dead fuel moisture (%)	10	10	5	5	5	5
Live fuel moisture (%)	200	200	100	100	50	50
Rate of spread (m/hr)	241	1207	321	1589	322	1598
Intensity (Watt/m^2)	262.89	289.17	315.46	331.37	352.25	362.77
Flame length	1.68	4.27	2.13	4.42	2.44	4.88

Crowning Potential

The crown fire potential is estimated by combining two of the factors necessary for crown fire, the intensity of surface fires which initiate crowning and the capability of the overstory to sustain a crown fire (Brown, personal communication, 1979). Crowning potential for the study sites was determined using Fahnstock's (1970) Key No. 2, as amended by Brown (1979). The key, as amended by Brown (1979) ranks crowning potential by increasing numbers from 0 to 100.

Table 7 indicates that study sites 1, 2, and 3 have a crowning potential of 81, a relatively high rating. The likelihood that a ground fire would spread to the crown is extremely high in these study sites. The crowns in these study sites are dense, with the canopy closure greater than 75% and ladder fuels plentiful. Thus, a crown fire would be a reasonable probability. Study sites 8 and 10 have a crowning potential of 76, which also indicates a high probability of a crown fire.

Study sites 4, 5, 6, 7, and 9 were determined to have crowning potentials of 46, which is an intermediate value. These have canopies composed almost exclusively of Pinus contorta, with canopy closure less than 75%, but with ladder fuels plentiful. The likelihood that a fire would progress to the crowns in these stands is approximately 50%.

The crowning potential key is another method homeowners can utilize to determine the potential fire hazard of their land. The key approach to fuel description is straightforward and simple in concept, but it emphasizes that full description of even a rather simple fuel involves cognizance and interrelation of much detailed information about the fuel.

Overall Fire Potential Rating

Utilizing Albini's nomographs potential fire (reaction) intensity (Watt/m^2) and flame length (meters) were calculated for the Seeley Lake area (see Table 8). Fire (reaction) intensity is the rate of heat release per unit time. The predicted (reaction) fire intensity for early summer at low wind speeds is 262.89 Watt/m^2, which is a hot fire. Brown and Davis (1973) use 92 Watt/m^2 as the upper limit for a fire of low intensity. Therefore, the predicted fire intensities for mid-summer and late summer at either low or high wind speeds would be extreme.

Albini (1976) uses a flame length of 3.3 meters as an indicator of a fire which is likely to have serious spotting and crowning. The average flame lengths determined at high wind speeds for early, mid, and late summer in Seeley Lake are all over 3.3 meters (these range from 4.27 to 4.88 meters) (see Table 8). The flame lengths determined at low wind speeds ranged from 1.68 to 2.44 meters. These values are indicative of fires where spotting is likely but not serious and crowning possible. However, these flame length values don't take into account the tendency of flames to pulsate or burn in surges. Flame lengths vary greatly during fires of all intensities.

Table 7 summarizes potential fire behavior for the ten study sites. Overall fire potential ratings were determined using the various characteristics of the forest fuel and residential structure interface (Table 6), fuel loads (see Tables 10-16), and the fire behavior ratings (rate of spread, crowning potential, and fire intensity). Study sites 1, 2, 3, 8, and 10 (ABLA/CLUN habitat type) determined to have a high overall fire potential rating. These study sites have large fuel accumulations, dense canopies, and ladder fuels plentiful. If a fire would start (due to lightning or man), it would spread forward quickly, spread to the crowns, and be very hot. The fuels of these study sites can be managed to lessen the hazard of fire. The next chapter discusses these measures.

Study sites 4, 5, 6, 7, and 9 (composed of ABLA/VACA and ABLA/LIBO habitat types) dominated by _Pinus contorta_, are determined to have a medium overall fire potential rating. These stands are drier and have less fuels than the ABLA/CLUN study sites. The _Pinus contorta_ study sites, however, are maintained by fire; therefore, fires are more frequent but less intense than the ABLA/CLUN study sites.

Access Routes

Residential structures and/or subdivisions located within forested regions should have two or more access or escape routes. Loop drives with one entrance point do not satisfy this need.

Table 9 summarizes the number, type, and condition of escape routes into and out of the sample stands. Study sites 1, 2, 3, 4, and 10 had at least one terrestrial access route and either Seeley Lake or the Clearwater River nearby to escape into in case the access route was cut-off by fire. Study site 6 had several plots where there was only one access route. The remaining stands had at least two access routes. Wind storms associated with lightning storms could possibly cause windfalls across escape routes, making at least two escape routes necessary.

Roadside slash is a fire-related problem associated with providing access in forested land. In many cases, when roads are built, trees are merely pushed to the side and left to deteriorate. As the needles and branches dry out, they provide ideal fuel for fire. Study sites 1, 2, 3, 4, 5, 8, 9, and 10 all had slash piles alongside the access routes. Only study sites 6 and 7 (both new subdivisions) had a high percentage of plots without roadside slash.

Condition of the access roads was documented. Study sites 1, 2, and 10 access routes were narrow, broken-up (not recently graded), winding roads and were, therefore, rated poor. Roads rated good were wide enough to handle two-way traffic, paved or recently graded and having less than a six percent grade. The roads rated fair were either narrow or broken-up with many problems.

Fuel Loading

A detailed summary of averaged fuel loading data for study sites 1-7 is presented in Tables 10-16. Fuel loads in the ABLA/CLUN forests (study sites 1, 2, and 3) ranged from 163 metric tons/hectare to 288 metric tons/hectare. The amount of material less than 7.6 cm (3 inches) in diameter doesn't change very much from study site to study site. It is the amount of large material that determines the load. This large material is usually disturbed fairly evenly throughout the study site.

TABLE 9: Summary of the characteristics of access routes and escape routes for the study sites in the Seeley Lake area.

Study site	Average number of escape routes	Type of escape route	% of plots with slash alongside route	Condition of access roads
1	2	2^0 dirt rd*, river	56	poor
2	2	2^0 dirt rd., river	100	poor
3	3	1^0 access rd#., lake	74	good
4	3	1^0 access rd., lake	100	good
5	2	2^0 dirt rd.	100	fair
6	2(1)	2^0 dirt rd.	17	good
7	2	2^0 dirt rd.	11	fair
8	2	1^0 access rd.	92	good
9	2	2^0 dirt rd.	67	good
10	2	2^0 dirt rd., lake	75	poor

* 2^0 dirt roads are unpaved roads ranging from primitive dirt roads to improved dirt roads.

\# 1^0 access roads are paved all-weather roads.

Frequently, the fuel load may be a result of a few very large diameter deadfalls. These study sites have an average fuel load greater than the average load of the other. These study sites have a greater percentage of their fuel load made up of large diameter downfalls.

Study sites 4, 5, 6, and 7 have average fuel loads ranging from 92 metric tons/hectare to 160 metric tons/hectare. In these relatively young forests (65-75 years) composed primarily of Pinus contorta, the fuel load is considerably less than the ABLA/CLUN sites. The fuels are often the result of natural thinning. The larger diameter fuels seen in the ABLA/CLUN study sites are missing here.

The average fuel load in the Seeley Lake area is high for the habitat types involved; as compared to the fuel loads for the same habitat types in Davis, Clayton, and Fischer's (1980) study in the Lolo National Forest. The fuel loads for the ABLA/CLUN forests in the Lolo National Forest ranged from 10 to 200 metric tons per hectare; as compared to 163 to 288 metric tons per hectare in the Seeley Lake area. The fuel loads for the ABLA/VACA and ABLA/LIBO forests in the Lolo National Forest ranged from 10 to 88 metric tons per hectare; as compared to 92 to 160 metric tons per hectare in Seeley Lake. Therefore, a large amount of fuels exist in the Seeley Lake area. These fuels are continuous (see Tables 10-16). Fuel continuity is a primary factor in the behavior of fire. Fuels of different sizes are well represented in the study sites. Small diameter fuels are abundant, a necessary factor for the ignition and rapid spread of a potential fire. To summarize, the overall fire potential for the Seeley Lake area from the analysis of the fuel loading is high, that is a destructive crown fire for the Seeley Lake area is quite probable.

Table 10: Summary of fuel loading in Study site 1 for 10 fuel plots sampled. Fuel weights are expressed in metric tons/hectare.

Fuel loading summary	Average	Standard Deviation
Dead fuel load	153.64	62.25
Live grass and forb	0.33	0.26
Live brush	0.26	0.37
Total fuel load	162.57	56.92
Percent error	11.1	
Fuel depth (cm.)		
Green depth	25.0	
Dead depth	7.75	
Brush depth	27.13	14.37
Duff depth	6.63	2.30
Shrub loading		
Low shrubs	0.26	
Medium shrubs	0.01	
High shrubs	0.01	
Live shrubs	0.26	
Dead shrubs	0.02	
Total shrubs	0.28	
Percent cover		
Total brush	13.9	
Dead brush	2.5	
Total grass and forb	37.1	
Dead grass and forb	26.9	
3+ volume and diameter		
Sound volume(cu-m)	3.61	
Sound diameter(cm)	19.23	
Rotten volume(cu-m)	1.41	
Rotten diameter(cm)	36.25	
Seedling count		
Average height(cm)	5.0	
Total (trees/hectares)	2616.0	
Stand Age	110.0	
Average Crown Base(m)	23.58	

Table 11: Summary of fuel loading in Study site 2 for 10 fuel plots sampled. Fuel weights are expressed in metric tons/hectare.

Fuel loading summary	Average	Standard Deviation
Dead fuel load	286.69	136.65
Live grass and forb	0.28	0.12
Live brush	0.34	0.53
Total fuel load	287.81	134.89
Percent error	15.00	
Fuel depth (cm)		
Green depth	24.00	
Dead depth	9.18	
Brush depth	24.50	9.30
Duff depth	6.83	1.80
Shrub loading		
Low shrubs	0.31	
Medium shrubs	0.00	
High shrubs	0.04	
Live shrubs	0.34	
Dead shrubs	0.01	
Total shrubs	0.35	
Percent cover		
Total brush	15.4	
Dead brush	2.5	
Total grass and forb	43.8	
Dead grass and forb	18.8	
3+ volume and diameter		
Sound volume(cu-m)	13.40	
Sound diameter(cm)	25.93	
Rotten volume(cu-m)	1.16	
Rotten diameter(cm)	20.00	
Seedling count		
Average height(cm)	9.06	
Total (trees/hectare)	192.00	
Stand Age	85.00	
Average Crown Base (m)	30.17	

Table 12: Summary of fuel loading in Study site 3 for 10 fuel plots sampled. Fuel weights are expressed in metric tons/hectare.

Fuel loading summary	Average	Standard Deviation
Dead fuel load	255.34	169.29
Live grass and forb	0.33	0.19
Live brush	0.54	0.67
Total fuel load	260.58	168.76
Percent error	20.50	
Fuel depth (cm)		
Green depth	24.00	
Dead depth	7.75	
Brush depth	22.63	7.85
Duff depth	5.63	1.87
Shrub loading		
Low shrubs	0.54	
Medium shrubs	----	
High shrubs	----	
Live shrubs	0.54	
Dead shrubs	0.01	
Total shrubs	0.55	
Percent cover		
Total brush	26.40	
Dead brush	2.50	
Total grass and forb	32.10	
Dead grass and forb	30.00	
3+ volume and diameter		
Sound volume(cu-m)	110.19	
Sound diameter(cm)	41.50	
Rotten volume(cu-m)	46.65	
Rotten diameter(cm)	38.33	
Seedling count		
Average height(cm)	13.00	
Total (trees/hectare)	1368.00	
Stand Age	65.00	
Average Crown Base(m)	25.90	

Table 13: Summary of fuel loading in Study site 4 for 10 fuel plots sampled. Fuel weights are expressed in metric tons/hectare.

Fuel loading summary	Average	Standard Deviation
Dead fuel load	158.30	135.85
Live grass and forb	0.29	0.19
Live brush	0.41	0.63
Total fuel load	159.68	135.26
Percent error	26.80	
Fuel depth (cm)		
Green depth	9.08	
Dead depth	3.33	
Brush depth	14.25	13.72
Duff depth	5.23	3.37
Shrub loading		
Low shrubs	0.24	
Medium shrubs	----	
High shrubs	0.08	
Live shrubs	0.41	
Dead shrubs	0.01	
Total shrubs	0.42	
Percent cover		
Total brush	9.80	
Dead brush	2.50	
Total grass and forb	25.50	
Dead grass and forb	21.90	
3+ volume and diameter		
Sound volume(cu-m)	42.57	
Sound diameter(cm)	36.68	
Rotten volume(cu-m)	34.86	
Rotten diameter(cm)	56.25	
Seedling count		
Average height(cm)	21.25	
Total (trees/hectare)	300.00	
Stand Age	75.00	
Average Crown Base (m)	25.90	

Table 14: Summary of fuel loading in Study site 5 for 10 fuel plots sampled. Fuel weights are expressed in metric tons/hectare.

Fuel loading summary	Average	Standard Deviation
Dead fuel load	111.91	41.45
Live grass and forb	0.17	0.16
Live brush	0.22	0.28
Total fuel load	117.55	41.57
Percent error	11.20	
Fuel depth (cm)		
Green depth	11.00	
Dead depth	6.93	
Brush depth	11.50	6.30
Duff depth	5.00	2.50
Shrub loading		
Low shrubs	0.13	
Medium shrubs	----	
High shrubs	0.02	
Live shrubs	0.21	
Dead shrubs	0.01	
Total shrubs	0.22	
Percent cover		
Total brush	6.50	
Dead brush	2.50	
Total grass and forb	18.30	
Dead grass and forb	34.90	
3+ volume and diameter		
Sound volume(cu-m)	17.70	
Sound diameter(cm)	15.75	
Rotten volume(cu-m)	0.51	
Rotten diameter(cm)	10.00	
Seedling count		
Average height(cm)	18.75	
Total(trees/hectare)	1632.00	
Stand Age	65.00	
Average Crown Base(m)	22.85	

Table 15: Summary of fuel loading in Study site 6 for 10 fuel plots sampled. Fuel weights are expressed in metric tons/hectare.

Fuel loading summary	Average	Standard Deviation
Dead fuel load	129.78	81.56
Live grass and forb	0.33	0.23
Live brush	0.13	0.35
Total fuel load	132.00	81.17
Percent error	19.40	
Fuel depth(cm)		
Green depth	15.58	
Dead depth	8.50	
Brush depth	6.08	7.67
Duff depth	4.83	1.65
Shrub loading		
Low shrubs	0.04	
Medium shrubs	----	
High shrubs	----	
Live shrubs	0.12	
Dead shrubs	0.01	
Total shrubs	0.13	
Percent cover		
Total brush	4.00	
Dead brush	2.50	
Total grass and forb	43.00	
Dead grass and forb	39.60	
3+ volume and diameter		
Sound volume(cu-m)	10.80	
Sound diameter(cm)	11.50	
Rotten volume(cu-m)	37.98	
Rotten diameter(cm)	37.50	
Seedling count		
Average height(cm)	40.12	
Total(trees/hectare)	576.00	
Stand Age	75.00	
Average Crown Base(m)	22.85	

Table 16: Summary of fuel loading for Study site 7 for 10 fuel plots sampled. Fuel weights are expressed in metric tons/hectare.

Fuel loading summary	Average	Standard Deviation
Dead fuel load	90.84	39.41
Live grass and forb	0.40	0.52
Live brush	0.59	0.89
Total fuel load	92.28	39.11
Percent error	13.4	
Fuel depth (cm)		
Green depth	12.58	
Dead depth	7.75	
Brush depth	11.50	7.27
Duff depth	3.55	1.25
Shrub loading		
Low shrubs	0.33	
Medium shrubs	----	
High shrubs	----	
Live shrubs	0.58	
Dead shrubs	0.02	
Total shrubs	0.60	
Percent cover		
Total brush	17.80	
Dead brush	2.50	
Total grass and forb	36.30	
Dead grass and forb	37.10	
3+ volume and diameter		
Sound volume(cu-m)	17.73	
Sound diameter(cm)	15.23	
Rotten volume(cu-m)	3.72	
Rotten diameter(cm)	15.00	
Seedling count		
Average height(cm)	55.00	
Total (trees/hectare)	192.00	
Stand Age	70.00	
Average Crown Base(m)	22.85	

CHAPTER VI

MANAGEMENT IMPLICATIONS

(Wildfire Safety Guildlines)

The fire hazard associated with residential development within forested areas of northwestern Montana can be reduced in several ways. One option is to not build in these heavily forested areas. This is not an easily accepted alternative since many homes are already built and areas to expand in western Montana are either productive farmland or forested areas. A second alternative would be to maintain the *status quo*, that is, allow the fuels to accumulate and deal with the circumstance of a large destructive fire when it occurs. This alternative leaves lives and structures of high economic value in danger of being lost.

Loss of life and property can be minimized through establishment and enforcement of zoning restrictions that (a) bar residential use of particularly hazardous areas and, (b) require hazard reduction in the course of development where this can be accomplished to a satisfactory standard.

Each individual wildland subdivision has its own degree of wildfire hazard severity. Each proposed and existing development should be rated using Fischer's (1978) Fire Hazard Classification System and/or Fischer's (1979) Photo Series and the following factors should also be considered.

Slope - Fire spread rates increase with slope. On steep slopes, fire burns sixteen times faster uphill than downhill, because fuels are more readily available to fire flames uphill than they are downhill, and uphill heat from wildfires dries out fuel in front of fire and they ignite easier. Also, fire suppression activities become difficult on steep slopes. Slope is measured by dividing the vertical distance by the horizontal distance for a given area. The quotient is displayed as a percentage.

Aspect - Solar radiation dries out fuels on south and west facing slopes to a greater extent than on north and east facing slopes. Aspect is the average cardinal direction that the land surface faces.

Weather - This is the most important factor in determining fire behavior. With a few exceptions, wildfires burn mostly during summer months, when temperatures are high and humidity is low. Wind temperature, and humidity are the major factors of weather that influence fire behavior.

Wind - Wind is the movement of air. Air contains oxygen, which supports combustion. Wind pressure can increase burning in one direction or another. Wind carries the heat of the fire into unburned fuels, causing them to become more flammable. Wind can blow firebrands ahead of the main fire into unburned fuels creating spot fires.

Temperature - The sun can heat fuels and cause them to become more flammable. High temperatures also reduce the water content in fuels. Extended high temperature periods increase fire danger.

Humidity - The amount of water vapor in the air is relative humidity. The percent of water vapor in the air has a direct influence on how easily fuels will ignite and how intense they will burn. Fuel moisture decreases proportionately as the relative humidity of the air decreases; therefore, readily flammable. Extended periods of low relative humidity increase fire danger. Long extended periods of hot, dry weather create extreme fire danger conditions.

The following outlines suggested basic standards that residential structures and/or subdivisions located within forested areas should adhere to in relation to fire safety.

Vegetative Manipulations

1) Hazardous fuels in the form of native vegetation near structures and around the perimeter of the subdivision should be altered or removed to a specified width (distance). Irrigated vegetation should be planted in the cleared areas to prevent undue soil erosion. In steep terrain, cleared or leveled slopes should be stabilized immediately following construction. Developers and lot owners should be required to construct retaining walls, water bars, check dams, terraces, or some similar form of physical soil conservation. Fuel breaks around homes should be maintained by the landowners. Fuel breaks may contain individual tree specimens, ornamental plants, or other similar vegetation to be used as ground cover, provided it will not provide a means of transmitting wildfire from native vegetation to structures.
2) All fuels should be cleared to a specified distance around all chimneys, stovepipes, and outdoor fireplaces.
3) All structures should be kept free of dead, vegetative materials. All trees left in fuel breaks for aesthetic purposes should be kept free of dead or dying wood and lower branches pruned off to prevent the transmission of fires from the ground to the trees.

Structural Materials

1) Roofs and exteriors of structures should be constructed of fire resistant materials.

2) Structural projections such as balconies, decks, and roof gables should be constructed of fire resistant materials.

Disposal of Flammable Solid Wastes

1) All vegetation such as trees, branches, limbs, stumps, exposed roots, and brush disturbed during construction should be disposed of by chipping, burial, or removal.

2) Flammable trash or rubbish should burn in incinerators with screened outlets on "safe" days only. Screens should be constructed of non-flammable materials with size openings that will not permit ready escape of embers. All highly flammable vegetation around incinerators should be removed to a safe distance.

Road Specifications

1) A minimum of two dedicated access roads for separate ingress-egress should be provided. Loop roads with one access point do not qualify.

2) Road right-of-ways should be wide enough to accommodate fire suppression equipment and provide safe and ready escape routes in the event of a wildfire.

3) Cul-de-sacs (a road which is designed to remain permanently closed at one end, terminated by a vehicular turnaround) should be wide enough to provide adequate access for fire suppression equipment. Cul-de-sacs should have turnaround areas large enough to accommodate fire suppression equipment. Cul-de-sacs should be designed to provide safe and ready escape routes in the event of a fire. Dead end roads should not be permitted.

4) Roads should be named or numbered and visably signed as such. All lots should be numbered and visably signed as such.

5) Road grades should be such as to provide safe and ready access for fire suppression equipment, and escape routes in the event of a fire.

6) Bridges and culverts should be constructed to support heavy fire suppression equipment.

7) Public road right-of-ways should be routinely cleared of natural vegetation, and stabilized by planting fire resistant vegetation and by physical means in steep terrain.

Structural Designs

1) Roof, attic, and under floor openings should be screened or closed off.

2) Chimneys and stovepipes connected to devices burning solid or liquid fuels should be equipped with screens over the outlets.

3) Telephone and power supply systems should be underground wherever possible.

4) A fire alarm system should be considered in remote developments.

Water Supplies

1) A public water distribution system should be provided by the developer that is capable of supplying adequate fire flow volumes and pressures for extended periods of time. Minimum fire flows should be in addition to maximum daily flow requirements for other consumer uses. Fire hydrants should be installed on this system.

2) Single family dwellings should be provided with water mains. At least one exterior tap should be provided on single family water systems, and this tap will be located far enough away from the building to permit hose stream protection for all sides of the

building and roof. Multi-family dwellings should be equipped with automatic sprinkler systems.

CHAPTER VII

SUMMARY

Increased residential development in the last decade of forested valleys in western Montana has greatly compounded the problem of fire hazard. Wildfire is a natural phenomenon and western coniferous forests have evolved in the presence of repeated fires.

Seeley Lake, Montana (elevation 1250 meters) is a rapidly developing summer resort and bedroom community for those working in Missoula. A large portion of the residential development in Seeley Lake is within densely forested areas.

Fires are responsible for the vast array of seral communities in the Seeley Lake area. Large fires were common in the area up into the 1930's. Since that time modern fire fighting techniques have prevented large fires but fire frequencies are still high for the area. Lightning is the major source of fires in the Seeley Lake area with man-caused fires making up 20% of all fires.

The study area is divided into two Fire Groups. One group is characterized by cool habitat types (ABLA/VACA and ABLA/LIBO) dominated by *Pinus contorta* which is maintained by frequent fires. The average fire-free interval for these stands is between 20-65 years. The second Fire Group is characterized by moist lower subalpine habitat types (ABLA/CLUN), having a lower fire frequency. Fires that do occur are often severe due to the large accumulations of fuels. These habitat types rarely progress to mature forests because of the fire regime.

The study area was classified as being either in extreme or medium Fischer's (1978) fire hazard classes. The potential fire behavior of the area was determined by utilizing rate of spread, crowning potential, flame length, and fire intensity. The potential rate of spread, fire intensity and flame length for all study sites are high. Crowning potential of the Pinus contorta dominated sites is medium (50% likelihood fire would spread to the crown), while the ABLA/CLUN stands have a high crowning potential. The overall fire hazard potential for the study area is extreme, with the probability of a large destructive fire occurring high.

Fuel loads for the study area were calculated and used to determine the potential fire behavior. The overall fire potential rating for the Seeley Lake area is high--a fast spreading, very hot, crown fire is possible. In the young Pinus contorta (65 years) stands, fuels were the result of natural thinning or downfall, creating a matchbox effect of pole size trees. In the ABLA/CLUN stands the fuel loads were heavier, being composed of accumulated downfall of trees and denser canopy of shrubs and forbs.

The interface between the forest fuels and residential structures was documented showing that the forest fuels and residential structures were almost continuous with one another. There was little, if any, fuel break between the forest and residence. A large amount of slash adjacent to structures was common, creating hazardous conditions. The access or escape routes were documented and found to be mostly adequate but in poor condition.

Wildfire safety guidelines and suggested fire hazard ameliorative treatments were discussed.

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APPENDIX A

SPECIES LIST

TREES
Abies lasiocarpa (Hook.) Nutt., subalpine fir
Larix occidentalis Nutt., western larch
Picea engelmannii Parry, Engelmann spruce
Pinus contorta Dougl., lodgepole pine
Pinus ponderosa Dougl., ponderosa pine
Pseudotsuga menziesii (Mirbel) Franco., Douglas fir

SHRUBS
Amelanchier alnifolia Nutt., serviceberry
Linnaea borealis L., twinflower
Lonicera utahensis Wats., honeysuckle
Rubus parviflorus Nutt., thimbleberry
Vaccinium caespitosum Michx., dwarf huckleberry
Vaccinium globulare Rydb., blue huckleberry
Vaccinium scoparium Leiberg, grouse whortleberry

FORBS AND GRASSES
Arnica latifolia Bong., heartleaf arnica
Calamagrostis rubescens Buckl., pinegrass
Chimaphilia umbellata (L.) Bart., prince's-pine
Clintonia uniflora (Schult.) Kunth., beadlily
Cornus canadensis L., bunchberry dogwood
Galium triflorum Michx., bedstraw
Goodyera oblongifolia Raf., rattlesnake plantain
Pyrola secunda L., pyrola
Tiarella trifoloata L., coolwort, false mitrewort

APPENDIX B

TABLE OF CONVERSION FACTORS

MULTIPLY (Metric)	BY	TO OBTAIN: (English)
centimeters	0.39	inches
meters	3.28	feet
cubic-meters	35.31	cubic-feet
kilometers	0.62	miles
hectares	2.47	acres
metric tons/hectare	0.40	tons/acre
meters/hour	0.05	chains/hour
Watt/meter^2	19.02	BTU/min/ft^2
degrees Centigrade	$F^o=(C^o x9/5)+32$	degrees Fahrenheit

APPENDIX C

SPECIES ABBREVIATIONS USED IN TABLE 5

TREES
Abies lasiocarpa, Abie lasi
Larix occidentalis, Lari occi
Picea engelmannii, Pice enge
Pinus contorta, Pinu cont
Pseudotsuga menziesii, Pseu menz

SHRUBS
Amelanchier alnifolia, Amel alni
Linnaea borealis, Linn bore
Lonicera utahensis, Loni utah
Rubus parviflorus, Rubu parv
Vaccinium caespitosum, Vacc caes
Vaccinium globulare, Vacc glob
Vaccinium scoparium, Vacc scop

FORBS AND GRASSES
Arnica latifolia, Arni lati
Calamagrostis rubescens, Cala rube
Chimaphilia umbellata, Chim umbe
Clintonia uniflora, Clin unif
Cornus canadensis, Corn cana
Galium triflorum, Gali trif
Goodyera oblongifolia, Good oblo
Pyrola secunda, Pyro secu
Tiarella trifoliata, Tiar trif