Prescribed Burning for Vegetation Management on the Blue Ridge Parkway

by

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(ABSTRACT)

Fire is a cultural phenomenon. It is among man's oldest tools, the first product of the natural world he learned to domesticate. Since the 1970's, fire has been utilized extensively in forest management practices. This study was designed to compare prescribed burning in the fall or the spring with hand cutting to reduce the overall height of vegetation. Ten scenic overlooks on the Blue Ridge Parkway were selected for treatment. The experiment is a randomized incomplete block design.

Four permanent transects were delineated in each unit for vegetation sampling. Four one-by-five meter plots were sampled on each transect for the species and number of root crowns in three height classes: less than one meter, one to three meters and greater than three meters. Vegetation sampling was completed before and after treatment. Rate of spread was determined by non-directional grid sampling. Flame length was measured at five points within the sampling grid and fire intensity was calculated.

Prescribed burning and hand cutting stimulate sprouting of existing vegetation. Repetitive burning is necessry to effectively control hardwood sprouting on the Parkway. Fire stimulated the herbaceous community and resulted in a significant increase in the species richness. Changes is soil characteristics were slight and did not degrade the site. Personnel costs were similar but burning required fewer hours of work. Decreases in the number of personal accidents and an expected decrease in the number of personnel required to successfully complete the burns favor the use of fire to control vegetation for forest vista management.

Acknowledgements

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Above all I would like to express my appreciation to Tim Chavez and Rick Laven who share my fascination and taught me so much about fire. And to my parents who supported my decisions throughout and are thus a part of everything I do.

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Introduction and Justification

The Blue Ridge Parkway was established in 1936 as a recreationally-oriented motorway. It connects the Shenandoah National Park in Northern Virginia with the Smoky Mountains in Tennessee and North Carolina. The Parkway is 469 miles long and is well known for the mountain and valley vistas, quiet pastures and interpretations of local mountain culture.

The Blue Ridge provides the motoring recreationist the opportunity to view and enjoy a wide array of landscapes and land uses. A large portion of the recreational experience is dependent on the scenic overlooks and vistas. A vista is defined as a distant view seen through a passage in the forest or landscape, while a scenic overlook is defined as an elevated place that forms an extensive view. The Park Service refers to an area that is treated to increase the scenic view as a vista. The vistas are fill slopes from the original Parkway construction. If this area has parking, it is called a scenic overlook. These terms are often used interchangeably. Vista management is an important part of everyday management on the Parkway.

The vistas are covered with native and non-native, or exotic, plant species that can grow to a height of 3 meters in one year. It is necessary to maintain low heights of vegetation on these vistas for aesthetic and safety reasons. The current management practice is to hand clear these vistas every other year. The cutting of some woody species results in significant sprouting, and the large amounts of cut brush, saplings and mature trees lie in the cleared areas creating an unsightly viewpoint. Dried cut vegetation greatly increases the fuel loading in areas of high visitor use and results in greater wildfire potential at these locations. In some locations, the fuel buildup has become almost impossible to penetrate on foot and is, therefore, effectively eliminating handtool control of vegetation.

The first record of vista clearing was in the early 1960's. With reductions in budgeting and manpower, the Blue Ridge Parkway needs to find a safer, more economical way to clear and maintain vistas.

In the Spring of 1984, the Parkway, together with Virginia Tech, established a study on two districts of the Parkway to determine an alternative to current management practices that might protect and perpetuate the natural and historical values of the Parkway and also maintain important vistas in the most cost-effective manner (NPS Management Plan, 1984). The overall purpose of this study was to compare a prescribed burning plan with the current practice of hand clearing for vista management.

To facilitate this comparison, the specific objectives of this study were:

I. to determine the feasibility of a prescribed burning program to be conducted by the National Park Service on the Blue Ridge Parkway in Virginia by:
   A. determining the number of available prescription days.
   B. identifying any rare or endangered species present on the vistas, and the impact of burning on them.
   C. determining the vegetation response to each treatment.
   D. determining the costs per year of the program.
   E. determining if soil characteristics are adversely affected by fire.

II. to quantify fire behavior to:

A. correlate fire intensity and heat per unit area with a reduction in overall height of vegetation on the vistas.

B. correlate fire intensity and heat per unit area with stem and root crown mortality.

C. establish the relationship of depth of char on root crown as a post-burn estimate of fire intensity.

Literature Review

Fire History

Fire is a natural phenomena. With the evolution of man came the use of fire as a tool (Chandler et al., 1983). As a result, fire has touched and shaped almost every plant community in the world. Many communities have evolved to such an extent that they tolerate or even require fire to perpetuate. In many environments, fire is the most effective form of decomposition, dissemination, germination initiation and a means for nutrient recycling (Pyne, 1982; Kilgore, 1981). Wright and Bailey (1981) state that fire is a natural force in most of our plant communities and should be permitted to play a greater natural role where possible.

Primitive man used fire to aid in hunting and gathering. With the advent of Europeans to America, fire became a method of clearing land for farming or pasturing. Settlers considered trees as weeds that neither they nor their livestock could eat (Komarek, 1974). The fire history of the South is complex. Nowhere else in the country were Indian burning practices more thoroughly adopted and maintained (Pyne, 1982). After the timber industry came to the South, burning continued as a method of brush clearing and to lessen the incidence of chiggers and ticks and reduce the habitat for snakes. Following lumbering, the amount of fuel on the surface and the settlers disregard for potential future values of timber subjected many of the remaining forest stands to intense fires which rarely occurred under more natural conditions (Komarek, 1974). According to Inman Elderidge (1911), "The popular sentiment of the residents within the forests, in common with nearly all the South, is unqualifiedly in favor of the annual burning over of the Pinies."

The early 1900's saw much advancement in the field of forestry and the advent of fire management (Kilgore, 1976). The philosophy of fire management suggests that fire, in an ecological sense as well as a protection sense, should be considered when developing land management objectives, and fire related activities should be used to support the accomplishment of those objectives. (Fischer, 1978; USDA Forest Service Manual, Section 5100).

Environmental Effects of Fire

Fire Effects on Vegetation

Fire can have three basic effects on plant communities. The first is the direct effect of heat on plants. The intensity and duration of the heat production during fires has an important effect on seed and plant survival (Raison, 1979; Wells et al., 1981). Time of day and season are also very important. Traubaud (1981) used a combination of burning frequencies and burning seasons on Kermes scrub oak, *Quercus coccifera*, to determine how seasonal conditions, which effect the phenological state of species, relate to fire effects. He found that fires in summer and fall, which are more intense, decrease the sprouting ability. He also found that frequently repeated fires altered the vegetation structure. A similar study by Harrington (1985) involving Gambel oak, *Quercus gambellii,* in southwest Ponderosa pine stands showed that frequent summer burns controlled oak density, frequency and cover. Upland oak forests in the Southeast are also susceptible to fire. Garren (1943) cites Korstian (1924) who found that soil temperatures during an average fire are high enough to kill all acorns and reduce oak reproduction in the upland mixed pine and oak forests of the Southern Appalachians.

Fire Effects on Soil

The second basic environmental effect of fire is the change that occurs in the microclimate by removal of the forest floor and the standing crop. The final effect is a redistribution and changed availability of nutrient elements (Raison, 1979; Martin, 1981). Fire influences soil physical properties depending on the intensity of the fire, the amount of vegetation and forest floor consumed, the heating of the soil and the frequency of fire occurrence (Wells et al., 1981). Fire ecologists have attempted to evaluate the importance of the heat pulse in the soil by measuring the actual temperature changes. The actual transfer of heat downward will vary depending on fuels, soil type and the nature of the surface litter layer (Wells et al., 1981). If the surface organic layer is thick and moist, it serves as insulation and little soil heating occurs. Consumption of the forest floor can result in soil heating causing decreased infiltration rates and increased runoff and erosion (Wells et al., 1981).

Burning affects the chemical properties of soils by the ashing of organic materials. The ash on the soil surface affects such soil properties as pH and the concentrations of soluble elements (Raison, 1979). Nutrients in the soil may then be lost by volatilization, leaching or erosion. Lewis (1974) found that available N and P are not increased by burning but that soluble nitrate and phosphate are increased. After prescribed burning, there is often an increase in N, P, K, Ca, and Mg in the upper few centimeters of soil and a decrease further down. This is thought to be due to an increase in microbial activity (Lewis, 1974). Martin (1981) determined that 60 to 80 percent of the nitrogen in the fuels consumed is lost from the site in smoke. Whether prescribed fires enhance or degrade soil productivity will depend upon control of the degree of soil exposure and disturbance.

Prescribed Burning

Prescribed burning has been defined as the burning of forest fuels on a specific area under predetermined conditions so that the fire is confined to that area and fulfills management objectives (Bacon and Dell, 1985; Chandler et al., 1983; Anon., 1976). A more specific definition by Bacon and Dell (1985) states that prescribed fire is the skillful application of fire to fuels in a definite area under precisely defined conditions including wind speed, fuel moisture, soil moisture and other factors, in order to produce the intensity of heat and rate of spread required to produce specific results. Prescribed fire is used nation-wide to accomplish a multitude of resource management objectives in silviculture, wildlife and range management, hazard reduction, site preparation and fire suppression (Bacon and Dell, 1985; Fischer, 1978; Mobley et al., 1978; Martin and Dell, 1978). It is a widely accepted management tool (Anderson et al., 1982). The National Park Service has a natural fire program that is designed to restore fire to ecosystems that have been set aside to perpetuate natural processes (Philpot, 1983; Kilgore, 1983).

Fire Use Plan

Prescribed fire can often be used to create or maintain visually attractive landscapes (Anderson, 1982; Bacon and Dell, 1985; Mobley et al., 1978; Vaux, 1984). The success of the burn depends on the safe, controlled achievement of objectives for the site (Fischer, 1978). These objectives can best be met when a well-thought-out fire use plan is designed and implemented several months prior to the actual burning of the unit. This plan can take on many forms but usually contains at least four sections; the site description, the prescription, the burning plan, and the evaluation (Chandler et al., 1983; Fischer, 1978).

Site Description

The site description includes descriptions of the topography, fuels, local weather conditions, unit size, location, elevation, slope and other parameters. Physical features of the landscape can contribute to the fire behavior. Steeper slopes increase the effective windspeed and can result in greater rates of spread by preheating fuels. Local weather can include abnormal or unusual wind conditions which may be effected by slope position and elevation. Fire is always a complex interaction of many fuel, weather and topographic factors; these must be considered in depth for prescribed burning (Green, 1981; McRae, 1979).

Fuels and Fuel Modeling

All live vegetation and dead fuels may contribute to the available fuels complex (Maxwell and Ward, 1981). The characteristics of the live and dead vegetation determine the fuel properties. The species, quantity, and horizontal and vertical distribution of the fuel components influence the fire behavior. Certain plant species contain chemicals that become explosive at high temperatures, thus creating extreme fire behavior. Horizontal and vertical continuity of fuels can hamper control efforts by allowing the fire to reach the crowns of trees. Fire modeling requires specific fuel information that is too time consuming to measure for wildfire prediction. Fuel models were devised to represent most surface fuels by: the general vegetation type (grass, brush, timber litter or slash), the strata that will carry the fire, it's depth and compactness and the class of fuels (live or dead).

The National Forest Fire Laboratory, in an attempt to classify fuels, developed 13 stylized fire behavior fuel models. One such model, model 6, the dormant brush and hardwood slash fuel complex, is very similar to the fuel complex on the scenic overlooks of the Parkway. All models provide standard fuel loadings in each of the four size classes; one hour (dead herbaceous and roundwood less than one-fourth inch in diameter), ten hour (dead fuels one-fourth to one inch in diameter), one hundred hour (one to three inches in diameter) and one thousand hour timelag fuels (greater than three inches in diameter). A fire burning in fuel model 6, on a 60 percent slope, with a dead fuel moisture of 4 percent, would have a rate of spread of 462.7 m/hr, a fireline intensity of 10428.14 kW/m and 1.67 m flame lengths (Rothermel, 1983). Also included in the model is the fuel bed depth and the moisture of extinction (upper limit of fuel moisture content at which the fuel will no longer burn).

The fuel model then serves as input into various fire behavior prediction models (Albini, 1976; Deeming et al., 1978; Rothermel, 1983). Rothermel's fire spread model (1972) requires a measure of fuel bed properties such as continuity, compaction, and loading by live and dead fuel classes. These can be related to fire spread and intensity. Fuel loading is expressed as pounds or tons of fuel on an acre of land. The term fuel loading covers total biomass; that which is actually consumable by the fire is the available fuel (Green, 1981). The amount of available fuel is a function of fuel moisture, another important variable. Moisture content in the litter layer is important in determining the probability of ignition and how intensely and rapidly a fire will burn (Fosberg, 1977; Harrington, 1982). Also important are fuel particle properties such as: size, shape, chemical composition, and density (Brown and Davis, 1973; Rothermel, 1972). These affect fire spread, intensity, and extreme fire behaviors such as spotting, torching and crowning. The delineation of wildland fuel characteristics for fire behavior predictions are based on quantitative descriptions of fuel particle and fuel bed properties (Deeming et al., 1983). Burgan and Rothermel (1984) have created a fire behavior prediction and fuel modeling system called BEHAVE which creates site specific fuel models and allows state of the art fire prediction.

Prescription

Fire behavior modeling allows managers to predict fire behavior with reasonable accuracy and thus assists them in prescription development (Ryan and Noste, 1983); the next step in a fire use plan.

The prescription is a translation of the fire manager's objectives, such as flame length and rate of spread, into weather and fuel conditions necessary to meet those objectives (Furman, 1979). The prescription identifies, by variable, the range of conditions under which the fire may burn to meet the specified management objectives (Chandler et al., 1983). The prescription states the desired fire behavior and effects and the required environmental conditions of windspeed and direction, dead fuel moisture, air temperature, relative humidity, precipitation and time of day (Chandler et al., 1983; Green, 1981).

The lack of an adequate quantitative description of fire behavior has been cited as a problem in the literature for some time (Alexander, 1980; Cheney, 1981; Rothermel and Deeming, 1980; Wright and Bailey, 1981). The two essential and most basic elements of fire behavior are fire intensity and heat per unit area (Rothermel and Deeming, 1980). Fireline intensity, sometimes called Byram's intensity, is the most common and most useful measure of fire intensity (Chandler et al., 1983). Fireline intensity, in British thermal units per foot per second, was developed by Byram in 1959, and can be used to predict the effect of fire on items in the flame and the convective gases near the flame (Cheney, 1981; Rothermel and Deeming, 1980). The heat per unit area can be determined from the fireline intensity divided by the rate of spread. The slower the rate of spread, the more concentrated the heat per unit area. This parameter can be used to measure the heat directed at the surface and to relate fire effects in the duff and soil (Rothermel and Deeming, 1980).

Preburn Monitoring

The prescription also contains a subsection on preburn monitoring to determine when environmental conditions are right to reach the objectives of the burn (Fischer, 1978). For the past 50 years, it has been accepted that moisture content of fuels has a controlling influence on flammability (Johnson, 1984). The distribution of moisture in the upper and lower litter layers is proportional to the amount and depth to which it is consumed (Johnson, 1984; Norum, 1977; Sandberg, 1980). As a result, the moisture content of some type of precalibrated indicator fuel is often measured.

The indicator acts as an integrator of all the environmental factors and aids the resource manager in identifying when the prescribed conditions are present.

Analysis of climatological data can identify periods when prescription variables are reached. Programs RxWTHR and RxBURN, developed by the U.S. Forest Service, utilize archived weather data for a climatological analysis. This can aid the fire manager in scheduling fire use based on the number of probable burning days (Bradshaw and Fischer, 1981). Historic weather records reveal patterns which can be used by fire planners to designate preferred seasons for prescribed burning (Furman, 1979).

Treatment Strategy

The final input to the prescription is the treatment strategy. Firing pattern, ignition method and ignition technique are the major part of this (Fischer, 1978). Ignition pattern or techniques can be used to control fire behavior (Rothermel and Rinehart, 1983; Shea et al., 1981).

Fires can be categorized as head fires and back fires. A head fire burns with the wind, generally has a faster rate of spread and a greater intensity (Mobley et al., 1978). Backing fires move very slowly and are comparable to fire behavior on no slope with no wind conditions (Rothermel and Rinehart, 1983). The greater heat of a head fire gives it preference when burning conditions are poor because it preheats fuels and lowers their moisture content. Head fires are advantageous at times when selective killing of brush and certain tree species is an objective (Brown and Davis, 1973). Backfires are useful when a slow moving, less intense fire is necessary to acheive management objectives.

There are three basic ignition patterns; strip, center, and area ignition (Shea et al., 1981). Determining the ignition pattern is dependent on the prevailing burning conditions of temperature and relative humidity, the wind direction, topography, area, and location of roads, hazards and safety zones (Shea et al., 1981). A center fire consists of firing in such a way that a strong convective column is formed in the center and the fire is drawn in. This type of ignition is employed on level ground and slopes less than 20 percent (Brown and Davis, 1973). Spotting up to a mile away is highly probable with this technique (Mobley, 1978). Strip firing is laying down fire in progressive strips on slopes greater than 20 percent. Under optimal burning conditions, control problems can result on the leeward side of the unit as little inflow of air occurs (Shea et al., 1981). The benefits of this method are quick firing, smoke dispersal (Mobley, 1978), and even burning (Brown and Davis, 1973). The final method is area or perimeter ignition. Firing is simultaneous in many spots at once in area ignition or in a strip along the perimeter. In both cases the fire is allowed to burn into the middle (Cheney, 1981; Brown and Davis, 1973). This method is applicable on small areas with light to moderate fuels or as an auxiliary to another firing pattern. As with all burning techniques, a base control line, usually on the downwind side or strategic control point, is made secure with black lining (Mobley, 1978).

Burning Plan

Once an acceptable prescription has been written, the fire manager prepares a burning plan. This plan describes what is to be done and why, when it will be done, who will do it, how they will do it, equipment and supplies needed and cost estimates (Chandler et al., 1983b; Fischer, 1978). There are six sections to a burning plan; preburn preparation, monitoring, test fire and ignition procedures, holding, demobilizing and mopup,and postburn evaluation (Chandler et al., 1983b). Preburn planning, holding, and demobilization and mop-up deal primarily with personnel, while monitoring, test fire and ignition procedures, and postburn evaluation are all strongly tied to fire behavior.

Monitoring Fire Behavior

Fischer (1978) placed such high importance on the necessity of careful monitoring that postburn evaluation is an entire section of the fire use plan. Direct physical links of fire behavior to fire effects requires knowledge of variables that are not only difficult to measure, but even more difficult to predict such as: heat flux and duration of the glowing combustion stage after the flamming front passes. As stated earlier, Rothermel and Deeming (1980) identified two key parameters of fire behavior --heat per unit area and fireline intensity --and offer methods for quantifying them from field observations of flame length and rate of spread.

Flame length can be estimated at the fire visually or by indicators. Ryan (1981) developed a method for passive measure of flame length by suspending a flame retardant string over the ground and, after the fire passage, measuring the distance from the ground to the bottom of the string. Van Wagner (1973) used height of crown scorch to calculate fireline intensity. Height of stem bark char has also been used, but Cain (1984) found that these measurements underestimated the flame length in prescribed burns. The most common method in the literature is to ocularly estimate the flame length relative to some scale (Rothermel and Deeming, 1980; Rothermel and Rinehart, 1983). Some work has been done using photography or motion pictures to help eliminate the problems associated with viewing very intense fires (Adkins and Clements, 1976; Pickford and Sandford, 1975).

Fireline intensity can be calculated in kiloWatts per meter of fire front by the formula:

$$I = H \times W \times R$$

H = heat of combustion or heat yield in kW/kg of fuel

W = weight of the fuels consumed in kg/m^2

R = the rate of spread in m/min.

The equation developed by Rothermel and Deeming (1980) is:

$$I = 258 \times fl^{(2.17)}.$$

I = fireline intensity in kW/meter

fl = flame length in meters

Rate of spread is the next variable specified by Rothermel and Deeming that is easily measured in the field. One method; assuming low intensity, slow moving fires that are safe to work near, is to drop premeasured markers or metal tags at the head of the fire. The time each marker is dropped is recorded (Rothermel and Deeming, 1980; Rothermel and Rinehart, 1983). Another method is to observe fire spread relative to a fixed point or landmark and plot the spread on a high resolution map (Rothermel and Rinehart, 1983). A major difficulty associated with measuring the rate of spread is that the fire can spread in any direction. Timing the spread between any two points assumes that the fire spreads parallel to the line drawn between those points --an assumption that rarely holds true (Simard, 1978).

Simard et al. (1978) developed a set of equations that converts three time measurements to a direction and rate of spread across an equilateral triangle. This is considered non-directional sampling. The problems are that it assumes a uniform spread rate and direction, and if one measurement is lost, the equations cannot be used (Simard et al., 1982). To solve this, Simard (1982) developed a five point sampling grid that creates eight individual triangles for measurement (Figure 1). Therefore, relative differences between the triangles reflect the degree to which the assumption of uniformity is broken. Also, if one point is lost, at least three triangles remain. The rate and direction of spread can be calculated from the following equation:

$$D = \tan^{-1}(\ \alpha\,((t_3 - t_1) \div (t_2 - t_1)) - \beta)$$

$$r = (\sqrt{\alpha} \times S \times \cos D) \div (t_2 - t_1)$$

D = direction relative to baseline t_1 *and* t_2

r = rate of spread

S = length of either side adjacent to the 90 degree angle

α, β = constants, determined by the specific case being analyzed

(Simard et al., 1982)

From the measurements of rate of spread taken at the burning site, a calculation of heat per unit area can be made for fire effects correlations. Rothermel and Rinehart (1980) state that heat per unit area may be calculated by the following formula.

$$HA = 60 \times I/R$$

HA = heat per unit area in kJ/m

R = rate of spread in m/min

I = fireline intensity in kW/m

Some measure of the heat pulse in the soil has been researched in an attempt to quantify the glowing combustion stage of the fire. Artley et al. (1978) measured the maximum soil temperature reached during a prescribed burn using heat sensitive lacquer and found that low soil warming caused low root mortality. This method was also employed by Shearer (1975). Silen (1956) stated

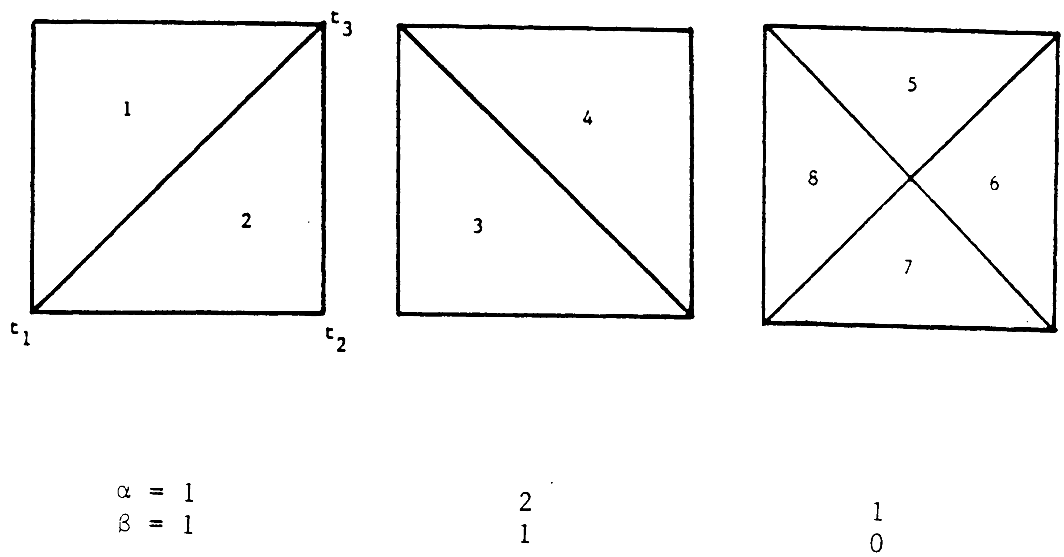


Figure 1. **Five-Point sampling grid for measure of non-directional rate of spread on the Blue Ridge Parkway:** The sampling grid may be divided into eight individual triangles with an associated α and β constant to calculate rate and direction of fire spread.

that critical temperatures are believed to occur in a very thin layer at the surface and that these high temperatures are responsible for seedling and stem mortality.

Postburn Evaluation

The final section of a fire use plan is the evaluation. This section includes precise statements of the actual accomplishments of the fire (Fischer, 1978). A written report combines the measured variables to determine if the objectives of the burn have been met. The manager needs to look at the site that has been treated to determine the immediate effects of the fire. Other effects may not be apparent until after the subsequent growing season, in which case, the report will need to be revised (Fischer, 1978). This report should include actual environmental conditions that preceed the fire and that occurred during the fire. A statement of the actual costs and an explanation of any differences should be included with any observations and recommendations (Fischer, 1978). Because of the difficulties associated with the quantification of fire behavior for direct correlation with fire effects, there is a need for estimators of fire intensity that can be measured in post-burn situations (Cain, 1984).

Vegetation Response to Burning on the Blue Ridge Parkway

Introduction

Vegetation control is a significant problem for Blue Ridge Parkway personnel. Native and exotic hardwood species have invaded the scenic overlooks and vistas of the Parkway and obstruct viewing. The Parkway personnel have hand cut this vegetation leading to unsightly and unsafe fuel buildups. In addition, hardwood species in the South are difficult to control because of prolific sprouting. Prescribed burning has effectively achieved hardwood control from Texas to the South Carolina coastal plain. (Ferguson, 1957; Grano, 1970; Lotti, 1956). and may be effective on the Blue Ridge Parkway.

A successful prescribed burning program is one that safely and efficiently achieves the land and resource management objectives. The comparison of costs to benefits is one measure of success or failure of a prescribed fire project. Other measures could include: vegetation density, size and species mix, and soil effects variables. Fire has the potential for altering the chemical, biological, physical and hydrological properties of soils.

Burning affects the chemical properties of soils by ashing the organic materials contained in the aboveground vegetation and litter layers. The ash on the soil surface further affects various soil chemical properties such as pH and soluble nutrient concentrations (Wells et al., 1979). Few fires burn hot and long enough for complete combustion of organic material (Boerner, 1982). As a result, soils are covered with organic ash mixed with charred plant parts. The amount and nature of ash depositied varies greatly among ecosystems because of differences in maximum fire temperatures (Boerner, 1982). Fire temperature will also affect the amount of volatilization.

Information obtained from monitoring vegetation is one of the key elements necessary to determine how well resource management objectives are being met. The purpose of this study was to determine the vegetation response to prescribed burning in the fall and spring and to determine if prescribed burning is a feasible management alternative to the present practice of hand cutting. Feasibility was defined in terms of available burning prescription days, threat to any rare or endangered species, effective vegetation control, cost-effectiveness, and a lack of overall site degradation (characterized by soil nutrient changes).

Study Area

The study was set up as a randomized block design with four blocks and three treatments. The units were blocked on a rating criteria for homogeneity. The three treatments were: burning in the fall, burning in the spring, and the current practice of hand cutting in the summer. The third and fourth blocks are incomplete because the fire weather prescription parameters were not reached in those areas to make a safe and efficient burn possible. The study site was located on the Vinton and Peaks of Otter districts of the Blue Ridge Parkway, approximately twenty miles east of Roanoke, Virginia (Figure 2). Three of the blocks were on south facing slopes and one was on a north to northwest slope. All the units were fill slopes from the original construction of the Parkway so they were steep and rocky, with slopes greater than 60 percent. The primary problem species are *Robinia pseudoacacia* and *Ailanthus altissima*, with *Liriodendron tulipifera* and *Acer rubrum* appearing in lesser numbers.

Virginia

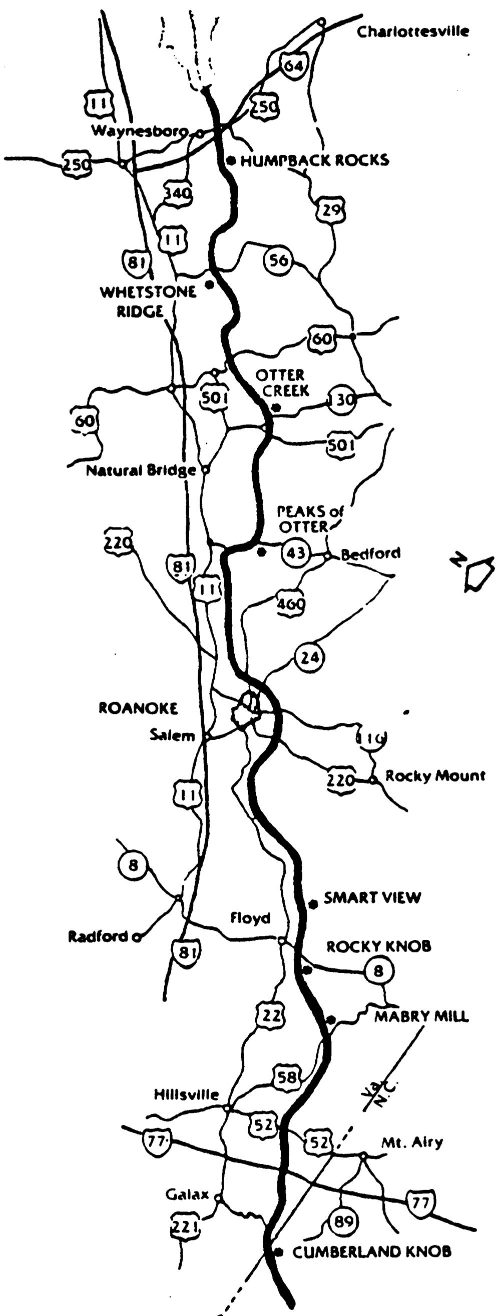


Figure 2. Map of the Vista Locations on the Blue Ridge Parkway in Virginia

Methods-Experimental

Treatments were scheduled when the prescription parameters of temperature, relative humidity, wind speed, and fuel moisture were met. Three units were burned in November, 1984 (fall) and three more were burned in April, 1986 (spring) (Table 1). An analysis of available prescription days was conducted with the help of the United States Forest Service in Atlanta, Georgia. The programs RxWTHR and RxBURN, developed by Bradshaw and Fischer in 1981, were utilized to screen various combinations of prescription variables to eliminate those which are unlikely to occur simultaneously, and to provide a detailed summary of prescription occurrence frequencies. (Examples of user information sheets are found in Appendix B.) The programs were run on archived weather infromation from U.S. Forest Service weather stations located at Arnold Valley, Virginia, for the Peaks of Otter district, and Craig, Virginia, for the Vinton district. The archived records show measurements for January through June only, the spring fire season in the South.

A series of four permanent transect lines were set out in each unit to sample the vegetation. The transect lines run down the slope on the same azimuth as the slope aspect. Each transect was marked at the top and bottom by a 1.5 m section of metal rebar. The first transect line was located, at random, by distance and compass direction to a permanent site fixture to aid in relocation of the plots. Four 1 by 5 m plots were sampled on each transect. The distance between plots varied to reflect the differences in unit size and shape. The vegetation inventory included species by height class, number of root crowns in the plot, and the groundline diameter of the tallest stem. The three height classes were: greater than 3 m, 1 to 3 m, and less than 1 m. Those species less than 1 m in height were inventoried by ground cover class based on coverage of 1 m^2 (Table 2).

The total sampling area was 80 m^2 for each unit. Vegetation inventories were conducted in the summer of 1984, and remeasured in the summer of 1985. Vegetation changes were summarized based on a percent change in the number of stems, or percent control value in each height class. Percent change was calculated by:

Table 1. Blue Ridge Parkway Vista Management Plot Locations, Characteristics and Treatments Applied

Block	Milepost	Name	District	Size	Aspect[1]	Treatment
				(ha)		
1	72.8	Terrapin Mtn.	Peaks	0.36	SE	fall burn
	73.8			0.31	SE	spring burn
	81.9	Headforemost		0.31	SE	hand cut
2	86.4	Upper Goose	Peaks	0.47	SSW	fall burn
	89.4	Creek Valley		0.66	SSW	hand cut
	89.3			0.31	SSW	spring burn
3	93.0	Bobblet's Gap	Peaks	0.40	SE	fall burn[2]
	93.0	South		0.40	SE	hand cut
4	127.8		Vinton	0.36	N	spring burn[3]
	128.4			0.32	NW	hand cut

[1] SE = southeast, SSW = south southwest, N = north, NW = northwest.
[2] A spring burn was not completed in this block.
[3] A fall burn was not completed in this block.

Table 2. Ground Cover Classes for Vegetation Inventories on the Blue Ridge Parkway

Ground Cover Class	Percent Cover	Midpoint
6	93 - 100	96.5
5	75 - 92	83.5
4	50 - 74	62.0
3	25 - 49	37.0
2	8 - 24	16.0
1	0 - 7	3.5

Percent change = (number of stems post-treatment - number of stems pre-treatment) ÷ number of stems pre-treatment

Soil factors measured to determine possible changes in site quality as a result of burning included; total soil nitrogen, nitrate nitrogen, extractable phosphorus, calcium, magnesium, and potassium and percent organic matter. A composite sample made up of 5 subsamples taken at locations within each unit were collected. Total N was determined by Kjeldahl procedures (Bremner and Mulvaney, 1982). Nitrate N was extracted with 0.2 N copper sulfate and measured with an ion specific electrode (Danhke, 1971; Oien and Selmer-Olsen, 1969). Phosphorus and all the cations were extracted with a double acid solution of 0.5 M HCl and 0.5 M H_2SO_4. Phosphorus was measured by a phosphomolybdate complex (Watanbe and Olsen, 1965), and the cations were measured by atomic absorption spectrophotometry. Organic matter was determined using Walkley-Black procedures (Nelson and Sommers, 1982).

Methods-statistical

Unbalanced data and significant pretreatment differences between hand cut units and the fall burn units, primarily in block 3, precluded a post-burn analysis of variance. A general linear model (GLM) was used to analyze the data. GLM, by estimating missing values, can provide tests of hypotheses for the effects of a linear model regardless of the number of missing cells or the extent of confounding effects (SAS Manual, 1985). Unplanned means comparison tests were run to determine treatment effects. Scheffe's multiple-comparison procedure for all main effects was the most appropriate due to the small number of means and degrees of freedom (Sokal and Rohlf, 1981). Scheffe's test never declares a contrast significant if the overall F test is not significant.

Results and Discussion

The RxWTHR output summarized the historical weather data as requested from 1975 to 1985 (Table 3). (Co-Occurence tables for temperature, relative humidity and wind speed are presented in the Appendix.) Craig station is located at 399 m elevation. This location approximates the location of the burning units on the Vinton District at 350 m. This station had the lower average temperature, relative humidity and wind speed of the two, with an average wind direction from northeast in the winter. The average wind direction switched to the southwest in April and May. Arnold Valley, which is located at 237 m elevation, had an average wind direction out of the southeast. Arnold Valley approximates the location of the Peaks of Otter district at 781 m.

The RxBURN output summarized the prescription occurrence information for each station based on input variables determined by fire behavior modeling and the National Park Service. The preferred and acceptable conditions are presented in Table 4. Table 5 contains the prescription occurrence summary. There is little difference between the two stations. Arnold Valley has two days with the preferred weather conditions during the spring fire season. Craig station has only one day. Arnold Valley, or the Peaks of Otter has 15 days of acceptable burning weather conditions, while Craig, or the Vinton district, has 14 days. The ideal burning period is defined as that 10 day period of highest frequency of preferred or acceptable burning conditions. For each district, there are two 10 day periods, beginning March 21st and April 11, when conditions are acceptable for prescribed burning (Figure 3).

Although a period of acceptable burning conditions was found, the analysis does show that the predominance of weather is not acceptable. The great difficulty found during the research project in finding suitable burning days is supported by these analysis. Furthermore, it would indicate that, if a regular operational program of vista burning were to be implemented, careful monitoring of weather conditions would have to be an integral part of it, and the ability to respond quickly to the onset of favorable conditions would have to be incorporated into the organization. The Park Service must prepare their personnel in anticipation of acceptable burning days. Line construction or maintenence must be conducted early in the season. The spring burning season is also a time of high recreational use on the Parkway. The National Park Service has presented interpretive programs on prescribed fire to Park visitors. These programs serve to entertain and to educate the public on natural resources and are very well received.

Table 3. Average Daily Weather Values Over a Ten Year Period from the RxWTHR Program

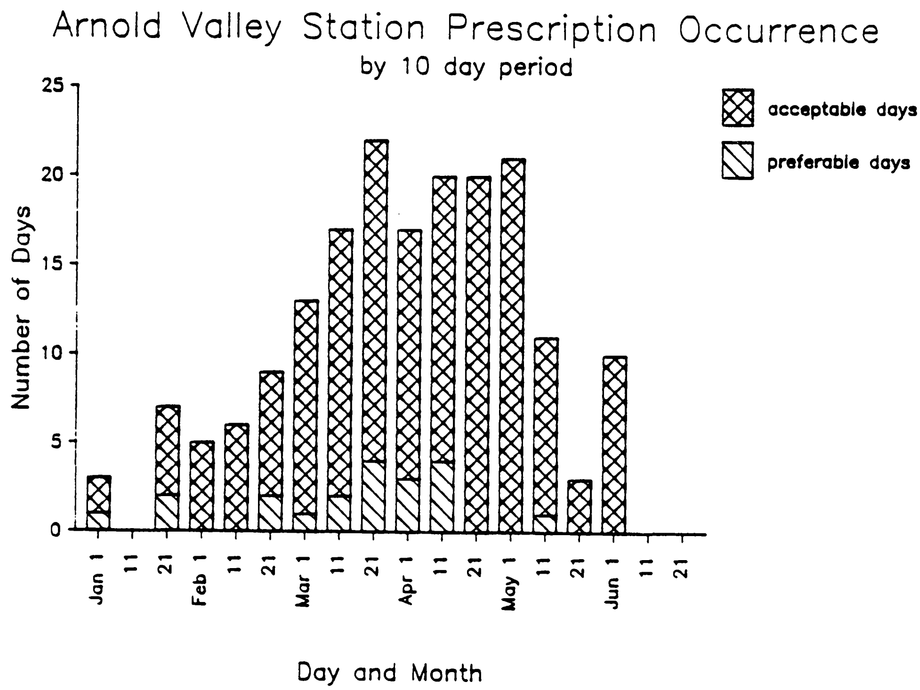
Station	Month	Temperature	Relative Humidity	Wind Speed
		(^{0}C)	(%)	(km/hr)
Arnold Valley	January	3.8	66.3	7.4
	February	7.5	58.2	7.7
	March	12.3	51.5	9.7
	April	19.0	47.4	10.9
	May	23.9	53.1	6.8
Craig	January	1.9	58.7	6.4
	February	6.2	52.9	8.5
	March	11.2	46.1	8.9
	April	17.9	42.4	9.3
	May	22.7	49.9	6.6

Table 4. Summary of Preferred and Acceptable Prescription Factors for each Station from the RxWTHR Program

Burn Conditions	Temperature	Relative Humidity	Wind Speed
	(^{0}C)	(%)	(km/hr)
Preferable			
Minimum	10.0	35	8
Maximum	20.5	39	11
Acceptable			
Minimum	10.0	30	0
Maximum	23.9	44	16

Table 5. Ten Year Prescription Occurrence Summary for Planning Prescribed Burning on the Blue Ridge Parkway

Station	Prescription Occurrence Information	Preferable	Acceptable	Unacceptable
Arnold Valley	Days/season within prescription (percent)	2 1%	15 10%	129 88%
	Month of highest prescription frequency (percent probability)	Mar Apr 2%	Apr 17%	Jan Jun 96%
	10 day period of highest Rx frequency begins (percent probability)	Mar 21 Apr 11 4%	May 1 23%	Jun 21 100%
Craig	Days/season within prescription (percent)	1 1%	14 9%	138 90%
	Month of highest prescription frequency (percent probability)	Mar Apr 2%	Apr 16%	Jan 98%
	10 day period of highest Rx frequency begins (percent probability)	Mar 21 Apr 11 3%	May 1 20%	Feb 1 100%



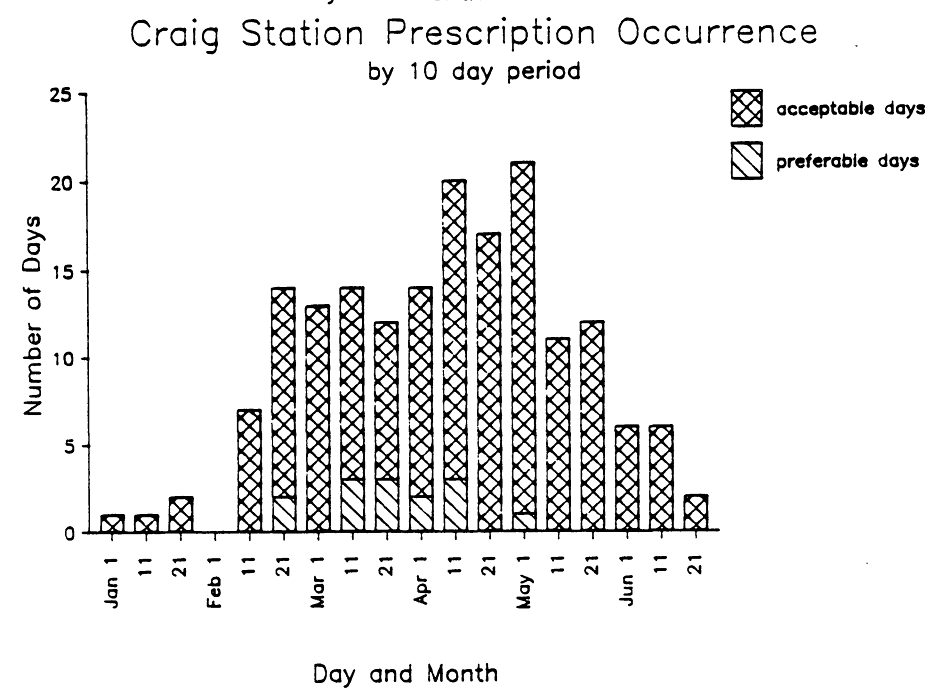


Figure 3. Summary of Acceptable and Preferable Spring Burning Conditions in a Ten Year Period on the Blue Ridge Parkway

Vegetation inventories indicated that no species considered rare or endangered in the state of Virginia existed on the sampled units. Consequently, burning those units should not be considered a threat to rare or endangerd species.

Interpretation of the influence of burning on average stem height, as shown in Table 6, can be a bit confusing. It must be remembered that a change in average height is shown by a change in the number of stems in each of the three height classes. A positive (+) change indicates that there were more stems in this height class in one growing season after treatment than before treatment. Also, it must be remembered that significance comparisons are between treatments within height classes, not between height classes.

The tabulated results show that all treatments resulted in an increase in the number of stems in the two shorter height classes. In both of these classes, burning was followed by a greater number of stems than hand cutting, although only fall burning resulted in a statistically significant increase. Apparently, spring burning resulted in a lower number of stems (re-sprouting) in the 1 to 3 m class than fall burning. These results are in accord with the findings of Grano (1970) and Harrington (1983), who found that the number of stems increased sharply as a result of burning. With regard to stems higher than three meters, those that would interfere most with tourist vision, all treatments resulted in fewer stems. Because of the high variability and small sample numbers, the differences among treatments were not statistically significant.

The literature emphasizes a need for repetitive burning for control of sprouting in hardwoods. Lotti (1956) found that a short series of summer burns would effectively eliminate sweetgum from a loblolly pine stand. Grano (1970) found that repeated summer burns at 1 to 2 yr intervals could reduce sprouting in hardwoods to any desired amount. Reductions due to frequent burning are also reported by Harrington (1983) and Trabaud and Lepart (1981).

Prescribed burning on the Blue Ridge Parkway caused an increase in species diversity (Table 7); however, there was little statistical difference between burning in the fall and the spring except in

Table 6. Percent Change in the Average Number of Root Crowns by Treatment on the Blue Ridge Parkway[1]

Height class	Treatment		
	Hand cutting	Fall burn	Spring burn
< 1 meter	+ 26.6 a	+ 44.8 a	+ 28.5 a[2]
1 to 3 meters	+ 90.4 a	+ 279.0 b	+ 132.0 a
> 3 meters	- 16.8 a	- 7.2 a	- 8.0 a

[1] Percent change = ((# of root crowns after - # of root crowns before) ÷ # of root crowns before) × 100
[2] Values within height class not followed by the same letter differ significantly at $\alpha = 0.05$.

Table 7. Changes in Species Richness[1] by Height Class and Treatment on the Blue Ridge Parkway.

Height class	Treatment		
	Hand cutting	Fall burn	Spring burn
	(%)	(%)	(%)
< 1 meter	-16 a [2 3]	+ 67 a	+ 17 a
1 to 3 meters	-16 a	+ 63 b	+ 46 b
> 3 meters	-25 a	+ 40 b	+ 37 a

[1] Richness = number of species (Spp) ÷ number of individuals^2 (ind^2)
[2] Change in richness = (richness after - richness before) × 100
[3] Values within height class not followed by the same letter differ significantly at $\alpha = 0.1$.

the greater than 3 m class, where fall burning increased diversity significantly. Burning increased diversity in the 1 to 3 m and greater than 3 m classes. Some of this may be explained by the high statistical variability or the occurrence of isolated individuals that are mainly annual, seed-reproducers that populate the site when the soil is bare. While all three treatments opened the canopy, only burning reduced the fuel loading and exposed the mineral soil for seed germination. An example of this is *Setaria*, an annual grass that increased from 0 in 1985 to 91 individuals greater than 1 m following spring burning in block 4. Also, vines were classified by height if they were climbers like *Vitis*, a prolific sprouter, and *Clematis virginiana*, a herbaceous vine. A large proportion of the individuals gaining dominance in response to prescribed burning are perennial herbs and shrubs. In contrast, Trabaud and Lepart (1981) determined that in spite of frequent burning in Mediterranean ecosystems, the floristic composition remained the same. The number of taxa persisting or becoming established in the plots was dependent on the frequency and season of burn. The increases in floristic richness were more pronounced for Autumn burning.

Analysis of soil properties before and after fire indicated only minor changes (Table 8). Changes in the total soil N and organic matter were slight, as were those for acid-extractable NO_{3}, Mg^{+2}, *and* K^{+}. Statistically, there was a significant rise in pH and extractable Ca and P. Increasing pH could explain increases in the availability of Ca and P (Pritchett, 1979). Increased pH has been linked with an increase in nitrification following fires in grasslands (Boerner, 1982). This increase in nitrification and some nutrients, combined with an increase in light and temperature could increase seed germination of new species and might be the cause of increasing species diversity.

There are two reasons to explain why prescribed fire produced little detectable change in the soil chemical properties during prescribed burning. First, prescribed burning consumed only a small portion of the litter layers, which resulted in very little ash deposit. Secondly, sampling was conducted immediately after burning, before leaching of nutrients into the mineral soil could occur . Small sample sizes may have contributed to our inability to detect changes in soil chemical properties. The preservation of the lower duff layer following burning helped to prevent erosion. Ero-

Table 8. Changes in Soil Characteristics Following Prescribed Burning on the Blue Ridge Parkway

Soil characteristic	Pre-burn			Post-burn		
	Mean		s^2	Mean		s^2
pH	5.59	a	0.67	6.17	b	0.83 [1]
Total N (%)	0.23	a	0.15	0.15	a	0.11
Mg (ppm)	111	a	22	111	a	19
Ca (ppm)	1080	a	235	1109	b	211 [2]
K (ppm)	121	a	29	119	a	25
P (ppm)	16.8	a	14.1	21.7	b	14.0
OM (%)	2.3	a	1.3	3.4	a	1.6
NO_3 (ppm)	22.7	a	11.7	45.3	a	30.6

[1]means within a row followed by the letter a differ significantly at $\alpha = 0.05$.
[2]means within a row followed by the letter b differ significantly at $\alpha = 0.1$.

sion was also prevented by the complete restoration of the percent cover in the first growing season after the prescribed burns.

Personnel costs were similar for all treatments. The costs for treatments are presented in Table 9and reflect a 3.5 % wage increase for all Park Service employees between the fall burns in 11/84 and the hand cutting and spring burning in 8/85 and 4/86 respectively. Prescribed burning during either season required fewer hours of work than hand cutting with an average of 42.5 hours for fall burning, 40 hours for spring burning, and 51 hours for hand cutting. Burning in the fall or spring could represent a savings in time and wages for the Park Service. State burning laws in Virginia restrict burning in the spring to after 4 p.m. which required the Park Service to pay overtime to some employees. However, it is possible that personnel requirements will decrease as the Park Service becomes more familiar with burning and the safety procedures involved in a district-wide or park-wide prescribed burning program. The Park Service did find a decrease in the number of personal accidents while prescribed burning compared to hand cutting.

Conclusions

Because of the dependence of a successful prescribed burn on the local weather conditions, a study was made of the historical weather information at sites near the Blue Ridge Parkway. Using the Park Service criteria, it was determined that there are at least 14 days of acceptable weather in the spring fire season at the weather station locations. The Parkway itself is located at a higher elevation and the burning units are generally located midslope. Windspeeds can be expected to increase with the increase in elevation and the number of prescription days may vary.

Feasibility of prescribed burning was examined for effective vegetation control, or vegetation response. Although burning did not reduce the number of root crowns on the average, it did appear as effective as the current practice of hand cutting in the greater than 3 m height class. These results must also be considered in terms of other benefits, such as an increase in species richness and a lower accident rate. There was no evidence to suggest that burning degrades site quality. Soil pH

Table 9. Personnel Costs and Hours for Treatment on the Vista Management Project for the Blue Ridge Parkway

Block	Treatment					
	Hand cutting		Fall burn		Spring burn	
	($)	(Hrs)	($)	(Hrs)	($)	(Hrs)
1	522	71	948	53	801	59
2	256	34	298	32	218	26
4	560	48			471	36
Average	446	51	623	42	497	40

increased slightly as did extractable Ca and P but there were no other detectable changes in the soil nutrients and organic matter content.

We feel that as the Park Service becomes more familiar with this type of management program, we recommend that they install a program of repetitive prescribed burns to control the overall height of vegetation on the scenic overlooks and vistas of the Blue Ridge Parkway. There are indications that, as burning is repeated on an area, the plant community will become more diverse and the periodicity of burns can be lengthened. Only further experimentation can determine if this is true.

Fire Behavior on the Blue Ridge Parkway

Introduction

The direct effect of fire on the plant is controlled by fire intensity and heat duration (Rothermel and Deeming, 1980). Understanding a direct physical link of fire behavior to fire effects requires knowledge of variables that are difficult to measure and even more difficult to predict. Field observations of flame length and rate of spread can serve to estimate fireline intensity and heat per unit area. Most studies on fire-induced change have been conceived and designed "after the fact", which means study areas are selected on burned areas and compared to adjacent unburned stands judged to be similar (DeBano and Conrad, 1978). In this situation, it is difficult to establish that direct physical link of fire behavior and fire effects.

Ferguson (1957) found that headfires killed significantly more stems than backfires and that growing-season fires killed more hardwood understory. Fire is usually considered to have the greatest effect on those systems where it is infrequent and intense (Christensen, 1978). However, the response to fire will vary depending on the role of fire in that ecosystem. In areas of infrequent fire, even a low intensity burn may represent an intense disturbance. Once fire is introduced, its effects may alter the ecosystem indirectly through changing the fuel characteristics or nutrient availability. The purpose of this paper was to determine if fire behavior could be correlated with measured variables such as, duff moisture, depth of char, and control of vegetation height and thereby account for some of the variation found in root crown mortality or sprouting of selected problem species.

Study Area

The area studied was on the Blue Ridge Parkway in Southwest Virginia. The study design was a randomized block of four blocks and three treatments: vegetation control by prescribed burning in the fall, in the spring and by hand cutting. Study of the fire behavior took place on the three units burned in April, 1986. These units were fill slopes from the construction of the parkway. Slopes varied between 50 and 60 percent with two on southwest aspects and one on a north aspect.

The vegetation composition prior to treatment varied with each block. Those species taller than 3 m represented only a small portion of the biomass at the site, yet these are the species the National Park Service seeks to control. Once the vegetation obtains a height greater than 3 m it begins to obstruct viewing from the parkway and lessens the motoring recreationists experience. Block one was a mixture of *Acer rubrum*, *Liriodendron tulipifera*, *Quercus prinus*, and *Sassafras albidum*. Block two was 100 % *Ailanthus altissima*, while block four had only six root crowns of *Liriodendron tulipifera* in the greater than 3 m class.

Methods-experimental

A 12 m^2 grid was set out in each unit to sample rate of spread by non-directional sampling techniques developed by Simard et al. (1982). Since fire is not a uniform treatment, measuring fire behavior for correlation with fire effects requires a measure of the variability and not just the averages. Simard's technique allows for eight individual measures of rate of spread. A five-point grid was set out prior to the actual burning of the site. This grid has four corner posts forming a square and a post in the center. One side of the square was set on the second transect line as labeled on the map of each unit. Each side of the square is 12 m and begins 3 m from the upper stake of the transect line on the same bearing as the transect. The size of the side allows a 5% error of measurement assuming the rate of spread does not exceed 12 m/minute (38.7 chains/hour). The remaining posts were set using compass directions to create 90 degree angles with the baseline. The center post was at 8.48 m from each corner and created 45 degree angles from each line.

The posts set in the unit were approximately 3.65 m long and painted in .6 m increments to serve as reference for ocular measure of flame length. Four spotters stood at the top of the unit, two on each side, to record fire behavior measurements. One held a stop watch and began timing the fire when ignition began. The time to reach each point was recorded and plotted on a unit map (t_1, t_2, -- Figure id 'beta' unknown --). The other spotter observed the flame length and depth at each of the posts and recorded it. The flame length and rate of spread were utilized in the following equations:

Residence time $RT = D \div R$

RT = residence time in minutes

D = flame depth in meters

R = rate of spread in m/min

Fireline Intensity $I = 258 \times Fl^{(2.17)}$

I = fireline intensity in kW/m

Fl = flame length in meters

Heat per unit area $HA = 60 \times I/R$

HA = heat per unit area in kJ/m^2

I = fireline intensity in kW/m

R = rate of spread in m/min

(Rothermel, 1980)

In addition, an attempt was made to monitor the maximum temperature at the surface of the soil and down the profile to a depth of 15 cm. Pressed asbestos board with a heat sensitive lacquer was buried in the fire behavior grid. The lacquer indicates temperatures of 93 to 621 ^{0} C (200 to 1150 ^{0}F). The temperature boards were set on edge approximately one m from each corner with two per side of the square. On one of the two center lines, two boards were placed 1 m on either side of the post. The soil profile was disturbed as little as possible. Samples of upper and lower duff were taken twice at each post in the fire behavior grid before and after burning. Upper duff corresponds to the litter layer or the L forest floor horizon consisting of unaltered dead remains of plants and animals. Lower duff corresponds to the F layer, the fragmented layer immediately below the litter layer and consisting of partly decomposed organic materials that are still recognizable (Pritchett, 1979).

Within the fire behavior grid, selected specimens of black locust, yellow poplar, and red maple were tagged with aluminum tags at the base and numbered with the block, species and bearing from the nearest post. These specimens were measured at the root collar for depth of char. The charring on the stem on the down hill side was sliced away until unburned wood was found. A caliper was used to measure the depth of the surface to the unburned wood. This is considered the depth of char. The following season, the tagged species were checked for mortality.

Methods-statistical

Because of the small sample sizes, the data was tested for normality. The dependent variable selected was the relative change in height pre- and post-treatment (percent control). When standard transformation procedures failed to normalize the data, it was necessary to construct a regression model in which the dependent variable is not continuous. The distribution of the data indicates two trends, mortality or 100 % control, and less than 100 % control. As such, a binary code (1 = dead, 0 = live) was assigned to represent the data and a logistic regression model was created (Pindyck and Rubenfeld, 1981).

Results and Discussion

Fire behavior on the spring burns was moderate in intensity with slow rates of spread (Table 10). The greatest intensity was found in the southwest corner of block 1 at 715.6 kW/m This area also had a slow rate of spread at 1.2 m/min so the heat/area is high at 35,780 kJ/m^2. Correlation analysis indicates strong correlation between the height of vegetation before burning and the heat per unit area. The larger the vegetation, the greater the rate of spread. The Pearson correlation coefficients are presented in Table 11. There is a correlation between rate of spread and heat per unit area which suggests that the greater the fire spread, the lower the heat in one area. This relationship can be expected because of the dependency of heat per unit area on intensity and rate of spread. Residence time is correlated with rate of spread for the same reason.

Correlation analysis also suggests relationships between depth of char on the stem and the upper duff moisture, fireline intensity and rate of spread. However, since these are negative or inverse relationships and the magnitude of change in the depth of char is so slight, there is a tendency to question the validity of these correlations as reflections of actual cause and effect relationships. A more probable cause and effect relationship can be found in the correlations between upper duff moisture and fire behavior parameters. Sandberg (1980) found this to be the case in the Douglas-fir type in western Montana. He states that the critical moisture value is approximately 30 percent, below which duff burns independently of woody fuels. Duff is dried out by a surface fire to a depth that is dependent on the duration of the fire or the residence time.

These results suggest that fireline intensity alone may not be the appropriate variable to guage some fire effects. After passage of the flaming front, considerable burning may take place. This is called

Table 10. Fire Behavior for the Spring of 1985 on the Blue Ridge Parkway Vista Management Project

Block	Post	Flame length	Flame depth	Rate of spread	Fireline intensity	Heat/ area	Residence time
		(m)	(m)	(m/min)	(kW/m)	(kJ/m ^{2})	(min)
	1	1.60	1.75	1.20	715.61	35780.6	1.5
	2						
1	3	0.53	0.69	1.26	65.97	3141.3	0.5
	4	0.30	0.22	1.26	19.58	932.6	0.2
	5	0.53	0.61	0.64	65.97	6184.4	0.9
	1	0.91	1.06	15.67	212.46	813.5	0.06
	2	0.76	0.61	35.83	143.04	239.5	0.01
2	3	0.76	0.61	11.84	143.04	724.9	0.05
	4	0.30	0.46	16.07	19.59	73.1	0.03
	5	1.37	1.68	45.91	512.16	669.4	0.04
	1	0.69	0.53	0.78	113.81	8754.4	0.7
	2	0.61	0.53	0.78	88.14	6779.9	0.7
4	3	0.61	0.53	1.26	88.14	4197.1	0.4
	4	0.61	0.45	1.76	88.14	3004.7	0.3
	5	0.53	0.46	0.88	65.97	4477.4	0.5

burn-out and is difficult to ascertain without thermocouples or a measure of combustion, consumption and heat (Alexander, 1982). Fireline intensity is best related to the direct impact of fire on tree damage and mortality (Alexander, 1982). Because of the strong correlations between upper duff moisture and fire behavior, the next logical step would be to build a predictor model for fire behavior. Due to the small sample sizes, abnormalities in the distribution of the data could not be reconciled, so modeling was not an option at this point.

Attempts to monitor the maximum temperature at the surface of the soil were inconclusive. Carbon deposits from smoke during the spring burns on the Parkway were heavy and blackened the asbestos boards thus obscured any visible changes in the lacquer. Heat sensitive lacquer techniques used to sample for surface and soil temperatures have been utilized successfully by Artley et al. (1978) and Shearer (1975).

Because of the distribution of the data, an alternative to standard regression modeling was used. The logistic model is based on the cummulative logistic function given as: $P_i = F(Z_i) = F(\alpha + \beta X_i)$ or $P_i = 1 \div (1 + e^{-z}) = 1 \div (1 + e^{(-\alpha+\beta x_i)})$ P_i is the probability that an individual will make a certain choice, given knowledge of X_i. The dependent variable in this regression equation is simply the logarithm of the odds that a particular choice will be made. This is sometimes called the log likelihood and it implies that changes in independent variables will have their greatest impact on the probability of choosing a given option at the midpoint of the distribution (Pindyck and Rubinfeld, 1981).

When this analysis was used to predict mortality from fire behavior in the spring of 1986, only one significant model was created. This model has a r value of 0.211 and a p value of .0538. The model is: P_i = -8.89 + .024 I + 1.729 R. While the probabilities are not high, this model does allow the user to improve a random guess by a small margin. When the fireline intensity is 88.14 kW/m and the rate of spread is 1.26 m/min, the probability of predicting mortality correctly is 58.7 % (Appendix D).

Table 11. Pearson True Product-moment Correlation Coefficients for Fire Behavior and Vegetation Parameters

	% Control	Htpre	Char	Upper	Lower	I	R	RT	HA[1]
% Control	1.0000	-0.04270	-0.02754	0.12759	0.18973	-0.21111	0.00315	0.00569	-0.13104
power	0.0000	0.7883	0.8625	0.5016	0.4508	0.1852	0.9844	0.9718	0.4141
N	42	42	42	30	18	41	41	41	41
Htpre	-0.04270	1.00000	-0.02056	0.41471	0.39517	0.33628	-0.68177	0.33670	0.59488
power	0.7883	0.0000	0.8946	0.0183	0.0856	0.0275	0.0001	0.0273	0.0001
N	42	44	44	32	20	43	43	43	43
Char	-0.02754	-0.02056	1.00000	-0.35832	-0.13513	-0.30465	-0.32442	0.15874	-0.01252
power	0.8625	0.8946	0.0000	0.0046	0.4651	0.0093	0.0054	0.1829	0.9169
N	42	44	74	61	47	72	72	72	72
Upper	0.12759	0.41471	-0.35832	1.00000	0.16851	0.34476	0.61802	-0.63623	-0.36843
power	0.5016	0.0183	0.0046	0.0000	0.2629	0.0057	0.0001	0.0001	0.0030
N	30	32	61	63	46	63	63	63	63
Lower	0.18973	0.39517	-0.13513	0.16851	1.00000	0.16513	0.02945	-0.26822	-0.14771
power	0.4508	0.0846	0.3651	0.2529	0.0000	0.2620	0.8425	0.0653	0.3164
N	18	20	47	46	48	48	48	48	48
I	-0.21111	0.33628	-0.30465	0.34476	0.16513	1.00000	0.61009	-0.01923	0.37652
power	0.1852	0.0275	0.0093	0.0057	0.2620	0.0000	0.0001	0.8708	0.0009
N	41	43	72	63	48	74	74	74	74
R	0.00315	-0.68177	-0.32442	0.61802	0.02945	0.61009	1.00000	-0.63434	-0.34800
power	0.9844	0.0001	0.0054	0.0001	0.8425	0.0001	0.0000	0.0001	0.0024
N	41	43	72	63	48	74	74	74	74
RT	0.00569	0.33670	0.15874	-0.63623	-0.26822	-0.01923	-0.63434	1.00000	0.79514
power	0.9718	0.0273	0.1829	0.0001	0.00653	0.8708	0.0001	0.0000	0.0001
N	41	43	72	63	48	74	74	74	74
HA	-0.13104	0.59488	-0.01252	-0.36843	-0.14771	0.37652	-0.34800	0.79514	1.00000
power	0.4141	0.0001	0.9169	0.0030	0.3164	0.0009	0.0024	0.0001	0.0000
N	41	43	72	63	48	74	74	74	74

[1] % Control of vegetation by height class
Htpre = height (size) of vegetation before burning
Char = depth of char on the stem at the root collar
Upper = duff moisture in the L layer
Lower = duff moisture in the F layer
I = fireline intensity
R = rate of spread
RT = residence time
HA = heat per unit area

Conclusion

The purpose of this paper was to determine the direct effect of fire on vegetation. Fire behavior can be directly correlated with fire effects. Although problems with the data precluded developing predictor equations for fire behavior based on pre-burn measurements, fireline intensity and rate of spread can predict mortality to a certain extent. Predictability can be improved by increasing the sampling intensity. The variation in the fire behavior as an independent variable does not effect the ability to model, but it will have a significant effect on the fit of the model.

Fire behavior is dependent upon, and well correlated with, upper duff moisture and the height of vegetation before treatment. This finding might lead to the tentative conclusion that repetitive burning might be more effective if carried out with an interval between burns of two or more years, to allow a build-up of more duff and greater height of vegetation. Perhaps the greatest benefit of this research is an increased understanding of, and an ability to predict, fire effects. Prediction of biological and ecological effects of fire must ultimately be linked with quantitative characteristics of fire behavior.

Summary

This study was undertaken at the request of the National Park Service to determine if prescribed burning in the spring or fall was an effective, yet safe, alternative to their current practice of hand cutting vegetation to control the overall height on the scenic vistas of the Blue Ridge Parkway. It was expanded to look at the direct effects of fire behavior on vegetation, possible site enhancement or degradation, and to develop possible predictor equations for the land manager. We examined several aspects of "feasibility" in order to answer the Park Service in an operational manner.

1. Are there enough days in a particular season with the weather conditions necessary to safely acheive the management objectives?

    - We feel that the answer to this is yes. According to a ten year analysis of weather conditions in January through May for the Parkway area, there are at least 14 days per year when acceptable conditions are reached. By expanding the window on acceptable weather conditions, the number of acceptable burning days can be expected to increase. Burning on days with lower or higher temperatures with the same range of relative humidity and windspeed, would give you the highest frequency of co-occurrence in the months of March through May (Appendix A). For example, increasing the temperature from 23.9

^{0}C to 26.7 ^{0}C would increase the percent frequency of co-occurrence by 2.2 % without a significant effect on the fire behavior.

- The 10 day periods with the greatest frequency of acceptable burning days begin on March 21 and April 11. Prescription burning days are most likely to occur within these periods. Because of state restrictions on open burning during the period of March 1 to May 15, the Park Service must schedule spring burns to begin after 4 pm. This will require the authorization to pay overtime or compensation time.

2. Does burning threaten any rare or endangered species present on the vistas?

- No, it is highly unlikely that burning would effect any rare or endangered plants on the parkway because of habitat differences. There are 10 endangered species (plants) in Western Virginia. Possible habitat along the Blue Ridge Parkway consists of wet woodlands, shale barrens and hardwood understory. If endangered species did inhabit the vistas, they would be disturbance or pioneer species that would benefit because burning opens the area to the possible germination of new plants.

3. Is this program cost-effective?

- We feel the answer to this is yes. Trends indicate that burning in the fall or spring is less expensive than hand cutting in terms of hours of work. When the Park Service becomes more familiar with burning, we hope that the numbers of non-essential personnel will drop and further reduce costs.

- Burning results in fewer personal accidents and serves as a means of fuel reduction as an added benefit.

4. Is the fire as effective in controlling the height of vegetation as the current practice of hand cutting?

- We feel the answer to this is yes, particularly if the Park Service is willing to burn these sites on a repetitive basis. Studies have shown this to be an effective means of controlling hardwood sprouts.

- Also, burning results in an increase in the plant diversity in the first year. This is an important Park Service natural resource management goal.

5. Does burning cause site degradation characterized by soil nutrient changes?

   - No, slight rises in pH and extractable Ca and P are not a cause of site degradation and can be linked to increases in species diversity.

6. Is the public receptive to the practice of prescribed burning on the Blue Ridge Parkway?

   - Yes, Park Service interpretive programs on the possible benefits of fire have been presented to the public at the Peaks of Otter Visitor Center with no negative feedback. This type of interpretive work combined with public contact on the Parkway while the burns are in progress should ensure continued support for burning for vista management.

Correlation analysis indicates that fire behavior is dependent upon, and correlated with upper duff moisture. Fire behavior parameters can be directly linked to stem and root crown mortality, particularly fireline intensity and rate of spread. The ability to develop predictor equations was strongly inhibited by the distribution of the data points and the small sample sizes.

In conclusion, we feel that the National Park Service can implement a safe and effective program of prescribed burning based on the results of this study. The necessity of repetitive burns for hardwood sprout control has been presented in the literature. Initial results indicate that an increase in fireline intensity and/or an increase in burning frequency is necessary for complete control of vegetation on scenic overlooks of the Blue Ridge Parkway. Prediction of the biological and ecological effects must be linked with quantitative characteristics of fire behavior. Continued monitoring of the sites burned in this study is recommended.

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Appendix A. Co-occurrence Tables for Windspeed, Relative Humidity, and Temperature for the Blue Ridge Parkway.

TEMPERATURE - RELATIVE HUMIDITY - WIND SPEED

PERCENT FREQUENCY OF CO-OCCURRENCE, GIVEN TO TENTHS PERCENT

ARNOLD VALLEY 14429011
** JAN. ** 1975-1995

WIND SPEED LT 6 MPH — RELATIVE HUMIDITY %

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55		.4	.8	6.7	3.2	7.5	9.9	4.4	3.2	18.3
55 - 59		.8			1.2	.8	.4			.4
60 - 64						.4				
65 - 69										
70 - 74										
75 - 79										
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	1.2	.8	6.7	4.4	8.7	10.3	4.4	3.2	18.7

WIND SPEED 6 - 11 MPH — RELATIVE HUMIDITY %

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55	.4	.4	1.2	4.4	4.8	6.0	3.6	2.8	1.2	8.3
55 - 59			.4				.4	.4		
60 - 64				.4	.4		.4		.4	
65 - 69						.4				
70 - 74										
75 - 79										
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.4	.4	1.6	4.8	5.2	6.3	4.4	3.2	1.6	8.3

WIND SPEED 12 - 17 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55			.8		.9	.4	1.2			.8
55 - 59				.4	.4					
60 - 64										.4
65 - 69										
70 - 74										
75 - 79										
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.0	.8	.4	1.2	.4	1.2	.0	.0	1.2

WIND SPEED 18 - 23 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55						.4				
55 - 59										
60 - 64										
65 - 69										
70 - 74										
75 - 79										
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.0	.0	.0	.0	.4	.0	.0	.0	.0

Appendix A. Co-occurrence Tables for Windspeed, Relative Humidity, and Temperature for the Blue Ridge Parkway.

TEMPERATURE - RELATIVE HUMIDITY - WIND SPEED

PERCENT FREQUENCY OF CO-OCCURRENCE, GIVEN TO TENTHS PERCENT

ARNOLD VALLEY (442901)
** FEB ** 1975-1985

WIND SPEED LT 6 MPH

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
					RELATIVE HUMIDITY %					
LT 55		.8	.4	7.6	7.6	3.4	7.6	2.5	2.1	14.8
55 - 59	.4		.8	.8	.8	.8	.8	.4	.4	.8
60 - 64					1.7	2.1				.4
65 - 69			1.3		.8	.4	.4			
70 - 74			.4	.4						
75 - 79										
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.4	.8	3.0	8.9	11.0	6.8	8.9	3.0	2.5	16.1

WIND SPEED 6 - 11 MPH

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
					RELATIVE HUMIDITY %					
LT 55		.4	1.7	3.8	3.4	4.7	2.5	1.3	.4	1.3
55 - 59				.8	2.1					
60 - 64			.4		.8	.4		.4		
65 - 69				.8		.8				
70 - 74			.4		.4			.4		
75 - 79				.4						
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.4	2.5	5.9	6.8	5.9	2.5	2.1	.4	1.3

WIND SPEED 12 - 17 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55			.4	.8	.4		1.3	.4	.4	.8
55 - 59					.4		.4			.4
60 - 64			.4	.4	.8			.4		
65 - 69					.8	.4				
70 - 74						.4				
75 - 79			.4	.4						
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.0	1.3	1.7	2.5	.8	1.7	.8	.4	1.3

WIND SPEED 18 - 23 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55										
55 - 59										
60 - 64										
65 - 69										
70 - 74										
75 - 79										
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Appendix A. Co-occurrence Tables for Windspeed, Relative Humidity, and Temperature for the Blue Ridge Parkway.

TEMPERATURE - RELATIVE HUMIDITY - WIND SPEED

PERCENT FREQUENCY OF CO-OCCURRENCE, GIVEN TO TENTHS PERCENT

ARNOLD VALLEY (4429011)
** MAR ** 1975-1985

WIND SPEED LT 6 MPH

TEMP (F)	RELATIVE HUMIDITY % BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55			1.1	4.6	5.7	2.9	2.9	2.1	3.6	5.7
55 - 59				1.8	2.1				.7	.7
60 - 64			1.1	1.4	1.8	3.2		.4	.7	.7
65 - 69				1.4	2.5	1.1				
70 - 74				.7	.4	1.4				
76 - 79				.4	.4	.4				
80 - 84										
95 - 99										
90 - 94										
GE 95										
TOTAL	.0	.0	2.1	10.4	12.9	8.9	2.9	2.5	5.0	7.1

WIND SPEED 6 - 11 MPH

TEMP (F)	RELATIVE HUMIDITY % BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55		.4	1.1	7.5	2.9	2.9	1.8	1.4	.4	.7
55 - 59			.7	2.1	.4	.4		.4	.4	.4
60 - 64		.4	1.1		.7	.4				.7
65 - 69			.4	.4	.4	1.1	.4			
70 - 74			.4	.4	.4		.4			
76 - 79				1.1						
80 - 84					1.4					
95 - 99										
90 - 94										
GE 95										
TOTAL	.0	.7	3.6	11.4	6.1	4.6	2.5	1.9	.7	1.8

WIND SPEED 12 - 17 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55			.4	1.4	1.8	.7	.7	.4		
55 - 59			1.1	.4		.4	.4			
60 - 64			.4	.4		.4			.4	.4
65 - 69			.7	.4		.4	.4			
70 - 74			.4		.7	.4				
75 - 79										
80 - 84				.4	.7					
85 - 99										
90 - 94										
GE 95										
TOTAL	.0	.0	2.9	2.9	3.2	2.1	1.4	.4	.4	.4

WIND SPEED 18 - 23 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55										
55 - 59										
60 - 64				.4		.4				
65 - 69										
70 - 74						.4				
75 - 79										
80 - 84										
85 - 99										
90 - 94										
GE 95										
TOTAL	.0	.0	.0	.4	.0	.7	.0	.0	.0	.0

TEMPERATURE - RELATIVE HUMIDITY - WIND SPEED

PERCENT FREQUENCY OF CO-OCCURRENCE, GIVEN TO TENTHS PERCENT

ARNOLD VALLEY (442901)
** APP ** 1975-1995

WIND SPEED LT 6 MPH — RELATIVE HUMIDITY %

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55			.3	.3	1.0	2.1	.3	.3	1.0	1.0
55 - 59				1.0	.7	1.4	.3	.3	.3	1.7
60 - 64			1.0	1.0	1.4	2.1		.3	1.7	1.4
65 - 69		1.0	1.4	2.1	.7	1.0	1.0	.3		1.0
70 - 74				2.8	.3	1.4	.3	.7		
75 - 79		.3	.7	1.0	.7	1.4	.3			
80 - 84			.3	1.7	.3		.7			
85 - 89			.7	1.0						
90 - 94			1.0	.3						
GE 95										
TOTAL	.0	1.4	5.6	11.5	5.2	9.4	3.1	2.1	3.1	5.2

WIND SPEED 6 - 11 MPH — RELATIVE HUMIDITY %

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55	.3	.7	.3	.7	1.0	.7	.7		.7	.7
55 - 59				1.4	1.4	.7	.3			
60 - 64	.3		1.7	1.4	2.8	.3		.3		.3
65 - 69			.7	2.1	1.4	1.7	.3	.3		
70 - 74			.3	2.1	1.4	1.4	1.0			
75 - 79				1.0	.3	1.4	.7			
80 - 84			1.4	2.1	.7		.3			
85 - 89				.3						
90 - 94			.3	.3						
GE 95										
TOTAL	.7	.7	4.9	11.5	9.0	6.2	3.5	.7	.7	1.0

WIND SPEED 12 - 17 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55			.3	.7	.7					
55 - 59				.3	.3	.7				.3
60 - 64			.3	.3	.3	.3		.3		
65 - 69				.7	.3	.3				
70 - 74				.7		1.4	.7			
75 - 79			.7	.3	.3	.3				
80 - 84				1.0			.3			
85 - 89			.7							
90 - 94										
GE 95										
TOTAL	.0	.0	2.1	4.2	2.1	3.1	1.0	.3	.0	.3

WIND SPEED 18 - 23 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55			.3	.3	.3					
55 - 59										
60 - 64										
65 - 69										
70 - 74										
75 - 79										
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.0	.3	.3	.3	.0	.0	.0	.0	.0

Appendix A. Co-occurrence Tables for Windspeed, Relative Humidity, and Temperature for the Blue Ridge Parkway.

Appendix A. Co-occurrence Tables for Windspeed, Relative Humidity, and Temperature for the Blue Ridge Parkway.

TEMPERATURE - RELATIVE HUMIDITY - WIND SPEED

PERCENT FREQUENCY OF CO-OCCURRENCE, GIVEN TO TENTHS PERCENT

ARNOLD VALLEY (442901)
** MAY ** 1975-1985

WIND SPEED LT 6 MPH — RELATIVE HUMIDITY %

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55										
55 - 59						.4			.7	.7
60 - 64			.4	.7	.4	.4			.4	2.9
65 - 69				1.1	1.8	1.4	.4	.4	.4	1.8
70 - 74		.7	1.1	1.4	4.3	2.9	1.8	1.8	1.1	.7
75 - 79			1.1	2.2	2.9	3.6	3.6	1.8	.7	1.4
80 - 94			.7	1.4	5.1	6.9	1.4	.4		.4
85 - 89		.4		1.4	2.5	1.1				
90 - 94				1.8	.4					
GE 95										
TOTAL	.0	1.1	3.2	10.1	17.3	16.6	7.2	4.3	3.2	7.9

WIND SPEED 6 - 11 MPH — RELATIVE HUMIDITY %

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55						.4				
55 - 59				.4						
60 - 64						.4				
65 - 69		.4	.4	1.1	.4	1.4	.7		.4	
70 - 74			.4	1.1	1.1	.7	.4			.4
75 - 79		.4	.4	1.8	.4	1.1	1.1	.4		
80 - 94				2.2	1.9	.4	.4			
85 - 89			.4	.4	1.4	.4	.4			
90 - 94										
GE 95										
TOTAL	.0	.7	1.4	6.9	5.1	4.7	2.9	.4	.4	.4

WIND SPEED 12 - 17 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55										
55 - 59										.4
60 - 64			.4	.4	.4	.7		.4		
65 - 69			.4							
70 - 74				.7		.4				
75 - 79					.4	.4				
80 - 84					1.1	.4				
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.0	.7	1.1	1.9	1.8	.0	.4	.0	.4

WIND SPEED 18 - 23 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55										
55 - 59										
60 - 64										
65 - 69										
70 - 74										
75 - 79										
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

TEMPERATURE - RELATIVE HUMIDITY - WIND SPEED

PERCENT FREQUENCY OF CO-OCCURRENCE, GIVEN TO TENTHS PERCENT

CRAIG (4440011)
** JAN ** 1975-1985

TEMP (F)	WIND SPEED LT 6 MPH — RELATIVE HUMIDITY % BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE	WIND SPEED 6 - 11 MPH — RELATIVE HUMIDITY % BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55		.4	5.8	9.6	10.4	10.0	7.5	6.7	5.0	15.0	.8	1.7	3.7	4.6	1.2	2.5	1.7	1.7	2.5	3.3
55 - 59			.4		.8					.4						.4				
60 - 64							.4													
65 - 69																			.4	
70 - 74																				
75 - 79																				
80 - 84																				
85 - 89																				
90 - 94																				
GE 95																				
TOTAL	.0	.4	6.2	9.6	11.2	10.0	7.9	6.7	5.0	15.4	.8	1.7	3.7	4.6	1.2	2.9	1.7	1.7	2.9	3.3

TEMP	WIND SPEED 12 - 17 MPH										WIND SPEED 18 - 23 MPH									
LT 55				1.2	.4	.4	.4							.4						
55 - 59																				
60 - 64																				
65 - 69																				
70 - 74																				
75 - 79																				
80 - 84																				
85 - 89																				
90 - 94																				
GE 95																				
TOTAL	.0	.0	.0	1.2	.4	.4	.4	.0	.0	.0	.0	.0	.0	.4	.0	.0	.0	.0	.0	.0

Appendix A. Co-occurrence Tables for Windspeed, Relative Humidity, and Temperature for the Blue Ridge Parkway.

Appendix A. Co-occurrence Tables for Windspeed, Relative Humidity, and Temperature for the Blue Ridge Parkway.

TEMPERATURE - RELATIVE HUMIDITY - WIND SPEED

PERCENT FREQUENCY OF CO-OCCURRENCE, GIVEN TO TENTHS PERCENT

CRAIG (444031)
** FEB ** 1975-1985

TEMP (F)	WIND SPEED LT 6 MPH — RELATIVE HUMIDITY % BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE	WIND SPEED 6 - 11 MPH — RELATIVE HUMIDITY % BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55		1.3	4.4	11.0	3.1	5.7	7.9	3.5	3.1	11.0		.9	2.6	6.2	.9	5.7	.9	.4	.4	2.6
55 - 59	.4		.9	.9	.4		.4	.4	1.3					.9	.9		.4		.4	
60 - 64			.9	.9	.4	.4	.4					.4		.4						
65 - 69			.4		.9			.4				.4		.9		.4	.4			
70 - 74				.4									.4	.9	.4			.4		
75 - 79																				
80 - 84																				
85 - 89																				
90 - 94																				
GE 95																				
TOTAL	.4	1.3	6.6	13.2	4.8	6.2	8.8	4.4	4.4	11.0	.0	1.8	3.1	9.3	2.2	6.2	1.8	.9	.9	2.6

TEMP	WIND SPEED 12 - 17 MPH BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE	WIND SPEED 18 - 23 MPH BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55			1.3	1.3	1.3	.4	.9							.4	.4					
55 - 59			.4	.4																
60 - 64				.4										.4						
65 - 69																				
70 - 74		.4	.4			.4														
75 - 79																				
80 - 84																				
85 - 89																				
90 - 94																				
GE 95																				
TOTAL	.0	.4	2.2	2.2	1.3	.9	.9	.0	.0	.0	.0	.0	.0	.9	.4	.0	.0	.0	.0	.0

TEMPERATURE - RELATIVE HUMIDITY - WIND SPEED

PERCENT FREQUENCY OF CO-OCCURRENCE, GIVEN TO TENTHS PERCENT

CRAIG (4440011)
** MAR ** 1975-1985

WIND SPEED LT 6 MPH — RELATIVE HUMIDITY %

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55	.3	1.4	3.8	7.0	6.3	3.5	2.4	4.2	4.2	2.4
55 - 59			1.7	1.0	1.4	.3	.3	.7	1.4	
60 - 64		.3	2.1	1.0	1.4	.7	.3	.3	.3	.3
65 - 69			.7	1.7		1.4	.3			
70 - 74			.7	.3	.7	.7				
75 - 79		.3	.3	1.0						
80 - 84					.3					
85 - 89										
90 - 94										
GE 95										
TOTAL	.3	2.1	9.4	12.2	10.1	6.6	3.5	5.2	5.9	2.8

WIND SPEED 6 - 11 MPH — RELATIVE HUMIDITY %

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55		1.0	2.8	5.6	3.1	2.8	1.0	1.0	.3	.3
55 - 59		.7	.3	.7	1.0		.3			
60 - 64		.3	1.4	.7	.7	.3	.7		.3	
65 - 69					1.4	.3		.3		
70 - 74			.3	1.0		.3				
75 - 79			.3	.3	.7					
80 - 84				.3	.3					
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	2.1	5.2	8.7	7.3	3.8	2.1	1.4	.7	.3

WIND SPEED 12 - 17 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55		.3	1.4		.7	.3	.3			
55 - 59			.3	.3	.3	.3		.3		
60 - 64			.3							
65 - 69			.3	.3	.3		.3			
70 - 74	.3									
75 - 79										
80 - 84			.3							
85 - 89										
90 - 94										
GE 95										
TOTAL	.3	.3	2.8	.7	1.4	.7	.7	.3	.0	.0

WIND SPEED 18 - 23 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55					.3	.3	.3			
55 - 59					.3		.3			
60 - 64										
65 - 69										
70 - 74					.3					
75 - 79										
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.0	.0	.0	1.0	.3	.7	.0	.0	.0

TEMPERATURE - RELATIVE HUMIDITY - WIND SPEED

PERCENT FREQUENCY OF CO-OCCURRENCE, GIVEN TO TENTHS PERCENT

CRAIG (4440011)
** APR ** 1975-1985

WIND SPEED LT 6 MPH

TEMP (F)	RELATIVE HUMIDITY % BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55			.3	2.0	2.7	2.0	2.0	.3	2.0	1.0
55 - 59			1.0	.7	1.4	1.0	.7	1.4	.7	.3
60 - 64	.7	.3	2.4	.7	1.0	1.7	.7	.7	.7	.7
65 - 69		.7	1.0	2.0	1.0	1.4	.3			.3
70 - 74	.7		1.7	2.0	1.4	2.0	2.4	.3		
75 - 79		.7		1.0	.3	.7				
80 - 84		.3	.3	.3						
85 - 89		.3	1.4	.3						
90 - 94			.3							
GE 95										
TOTAL	1.4	2.4	8.5	9.2	7.9	8.9	6.1	2.7	3.4	2.4

WIND SPEED 6 - 11 MPH

TEMP (F)	RELATIVE HUMIDITY % BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55	.3	.3	3.1	1.4	1.0	1.0	.7	.3		
55 - 59		.7	.7	1.0					.3	
60 - 64			2.4	.3	1.4	.7		.3		
65 - 69		.7	1.4	1.4	1.0	.7		.3	.3	
70 - 74		.3	1.4	1.0	1.0	1.0	1.0			
75 - 79			.7	1.0	1.4	1.0	.3			
80 - 84		.7	2.7	2.0						
85 - 89	.3		.3	.3						
90 - 94										
GE 95										
TOTAL	.7	2.7	12.6	8.5	5.8	4.4	2.0	1.0	.7	.0

WIND SPEED 12 - 17 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55			.3	.3	1.0		.3			
55 - 59		.3			.3					
60 - 64			1.0	.3						
65 - 69			.3							
70 - 74				.3		.7				
75 - 79						.3				
80 - 84	.3		.3							
85 - 89			.3							
90 - 94										
GE 95										
TOTAL	.3	.3	2.4	1.0	1.4	1.0	.3	.0	.0	.0

WIND SPEED 18 - 23 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55					.3				.3	
55 - 59										
60 - 64				.3						
65 - 69										
70 - 74					.3					
75 - 79										
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.0	.0	.3	.7	.0	.0	.0	.3	.0

Appendix A. Co-occurrence Tables for Windspeed, Relative Humidity, and Temperature for the Blue Ridge Parkway.

TEMPERATURE - RELATIVE HUMIDITY - WIND SPEED

PERCENT FREQUENCY OF CO-OCCURRENCE, GIVEN TO TENTHS PERCENT

CRAIG (444031)
** MAY ** 1975-1995

WIND SPEED LT 6 MPH — RELATIVE HUMIDITY %

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55					.3	.3			.9	
55 - 59			.3	.3		1.3	.3	.6	.3	.6
60 - 64		.3		.9	.6	.3	.9	.6	1.6	
65 - 69			1.6	1.6	.6	2.2	.3	1.9	2.5	1.6
70 - 74	.3		.9	3.5	2.2	3.5	2.5	2.5	.9	.3
75 - 79		.6	1.3	1.9	2.8	3.5	3.8	1.3		
80 - 84		.3	1.6	1.6	4.1	3.5	1.6			.3
85 - 89			1.3	1.6	1.3	.3	.3			
90 - 94										
GE 95										
TOTAL	.3	1.3	7.0	11.4	12.0	14.9	9.8	7.0	6.3	2.8

WIND SPEED 6 - 11 MPH — RELATIVE HUMIDITY %

TEMP (F)	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55			.3			.3	.3			
55 - 59				.3	.6					
60 - 64			.3	.6		.6	.3			
65 - 69			.9	.3	.3	1.3	.3			
70 - 74			.9	.3	1.9	.6	.3		.3	
75 - 79	.3		.6	1.3	2.5	1.9	.6	.3		
80 - 84	.3		1.3	1.6	.3	.3	.9			
85 - 89	.3				.3	.3				
90 - 94										
GE 95										
TOTAL	.9	.0	4.4	4.4	6.0	5.4	2.8	.3	.3	.0

WIND SPEED 12 - 17 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55										
55 - 59				.3						
60 - 64				.3						
65 - 69					.3	.3				
70 - 74			.3							
75 - 79										
80 - 84			.3	.3						
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.0	.6	.9	.3	.3	.0	.0	.0	.0

WIND SPEED 18 - 23 MPH

TEMP	BELOW 10	10 TO 19	20 TO 29	30 TO 39	40 TO 49	50 TO 59	60 TO 69	70 TO 79	80 TO 89	90 AND ABOVE
LT 55										
55 - 59										
60 - 64			.3							
65 - 69										
70 - 74										
75 - 79										
80 - 84										
85 - 89										
90 - 94										
GE 95										
TOTAL	.0	.0	.3	.0	.0	.0	.0	.0	.0	.0

Appendix B. User Information Sheets for RxWTHR and RxBURN

Alexandra M. Wilson

238 Cheatham Hall

Blacksburg, Va. 24060

RXBURN -- USER INFORMATION SHEET

Total Number Different Stations in This Run 02

User's Name ____________, Subunit ____________, Unit ________

Project[1/] ____

Fire Weather Station Information: Station name Craig, No. 444001

Elevation 1310 ft., Latitude 37°50', Climate class[2/] 3, Slope class[3/] ________

Fuel model[4/] ______, Last frost[5/] ____________, Grass type[5/]: annual ______, perennial ______

Year begin 1975, Year end 1985, Date begin 0101, Date end 0701

Fire Weather Station Information: Station name Arnold Valley, No. 442901

Elevation 780 ft., Latitude 37°60', Climate class[2/] 3, Slope class[3/] ________

Fuel model[4/] ______, Last frost[5/] ____________, Grass type[5/]: annual ______, perennial ______

Year begin 1975, Year end 1985, Date begin 0101, Date end 0701

Site Adjustment Factors (if any):

Aspect ______ (1=north, 2=east, 3=south, 4=west), Site elevation ____________ ft.

Canopy cover ______ (1=open, 2=closed)

Duff/Soil Horizon Information (if Duff Moisture selected. See User's Guide, Appendix D):

Layer	Duff/Soil Type	Thickness
1		cm
2		cm
3		cm
4		cm
5		cm

1/ Use up to 80 characters
2/ See User's Guide, appendix C
3/ See User's Guide, appendix B
4/ For NFDRS indicies only. See User's Guide, appendix A
5/ For NFDRS indices only

Prescription Factor Selections (Check and set limits for up to 15 factors.):

	Factor	Preferable Rx Minimum	Preferable Rx Maximum	Acceptable Rx Minimum	Acceptable Rx Maximum
	State of the weather				
x	Temperature (deg. F)	50	69	50	75
x	Relative humidity (%)	35	39	30	44
	Wind direction (8 point)				
x	Wind speed (mi/h)	5	7	0	10
	Max temperature (24 h, deg. F)				
	Min temperature (24 h, deg. F)				
	Max relative humidity (24 h, %)				
	Min relative humidity (24 h, %)				

Alexandra M. Wilson

238 Cheatham Hall

Blacksburg, Va. 24060

RXWTHR -- USER INFORMATION SHEET

Total Number Different Stations in This Run 02

User's Name ________, Subunit ________, Unit ________

Project 1/ ________

Fire Weather Station Information: Station name Arnold Valley, No. 442901

Elevation 780 ft., Latitude 37°60', Climate class 2/ 3, Slope class 3/ ________

Fuel model 4/ ________, Last frost 5/ ________, Grass type 5/ : annual ________, perennial ________

Year begin 1975, Year end 1985, Date begin 0101, Date end 0701

Site Adjustment Factors (if any): ________

Aspect ________ (1=north, 2=east, 3=south, 4=west), Site elevation ________ . ________ ft.

Canopy cover ________ (1=open, 2=closed)

Duff/Soil Horizon Information (if Duff Moisture selected. See User's Guide, appendix D):

Layer	Duff/Soil Type	Thickness
1	________	____ cm
2	________	____ cm
3	________	____ cm
4	________	____ cm
5	________	____ cm

1/ Use up to 80 characters
2/ See User's Guide, appendix C
3/ See User's Guide, appendix B
4/ For NFDRS indices only. See User's Guide, appendix A
5/ For NFDRS indices only

Summary Table(s) Requested (Select up to 15):

- ___ State of the weather
- x Temperature (degrees F)
- x Relative humidity (%)
- x Wind direction (8 point)
- x Wind speed (mi/h)
- ___ Max temperature (24 h, deg. F)
- ___ Min temperature (24 h, deg. F)
- ___ Max relative humidity (24 h, %)
- ___ Min relative humidity (24 h, %)
- ___ Precip duration (last 24 h)
- ___ Precip amount (24 h, 0.01 in)
- ___ 1 hour fuel moisture (%)
- ___ 10 hour fuel moisture (%)
- ___ NFDRS ERC
- ___ NFDRS BI
- x Duff Moisture (24 h average, %)

Co-occurrence Table(s) Requested (If 2-way table desired leave last space blank. If selected, Wind Direction must always be listed first.):

1 temperature with relative humidity with wind speed

2 ~~wind direction~~ with ~~wind speed~~ with ________

3 ________ with ________ with ________

4 ________ with ________ with ________

5 ________ with ________ with ________

Alexandra M. Wilson

238 Cheatham Hall

Blacksburg, Va. 24060

RXWTHR -- USER INFORMATION SHEET

Total Number Different Stations in This Run 02

User's Name ________, Subunit ________, Unit ________

Project[1/] ________

Fire Weather Station Information: Station name Craig, No. 444001

Elevation 1310 ft., Latitude 37°50', Climate class[2/] 3, Slope class[3/] ________

Fuel model[4/] ________, Last frost [5/] ________, Grass type [5/]: annual ________, perennial ________

Year begin 1975, Year end 1985, Date begin 0101, Date end 0701

Site Adjustment Factors (if any):

Aspect ____ (1=north, 2=east, 3=south, 4=west), Site elevation ________ ft.

Canopy cover ____ (1=open, 2=closed)

Duff/Soil Horizon Information (if Duff Moisture selected. See User's Guide, appendix D):

Layer	Duff/Soil Type	Thickness
1	________	____ cm
2	________	____ cm
3	________	____ cm
4	________	____ cm
5	________	____ cm

1/ Use up to 80 characters
2/ See User's Guide, appendix C
3/ See User's Guide, appendix B
4/ For NFDRS indices only. See User's Guide, appendix A
5/ For NFDRS indices only

Summary Table(s) Requested (Select up to 15):

- ____ State of the weather
- x Temperature (degrees F)
- x Relative humidity (%)
- x Wind direction (8 point)
- x Wind speed (mi/h)
- ____ Max temperature (24 h, deg. F)
- ____ Min temperature (24 h, deg. F)
- ____ Max relative humidity (24 h, %)
- ____ Min relative humidity (24 h, %)
- ____ Precip duration (last 24 h)
- ____ Precip amount (24 h, 0.01 in)
- ____ 1 hour fuel moisture (%)
- ____ 10 hour fuel moisture (%)
- ____ NFDRS ERC
- ____ NFDRS BI
- x Duff Moisture (24 h average, %)

Co-occurrence Table(s) Requested (If 2-way table desired leave last space blank. If selected, Wind Direction must always be listed first.):

1 temperature with relative humidity with wind speed

2 wind direction with wind speed with ________

3 ________ with ________ with ________

4 ________ with ________ with ________

5 ________ with ________ with ________

Appendix C. Blue Ridge Parkway Vista Management Project Species Table

Code	Latin name	Common name
ACA	Actinomeris alternifolia	Wingstem
ACN	Acer negundo	Box elder
ACP	Acer platenoides	Norway maple
ACR	Acer rubrum	Red maple
AIA	Ailanthus altissma	Tree of heaven
ALJ	Albizia julibrissin	Mimosa
AMS	Ambrosia species	Ragweed
AML	Amelanchier laevis	Serviceberry
APC	Apocynum cannabinum	Hemp dogbane
ARC	Arctium species	Burdock
ARG	Agrostis species	Bent grass
ASS	Asclepias species	Milkweed
ASP	Aspediaceae	Fern
AST	Aster species	Aster
BEL	Betula lenta	Black birch
BOV	Botrychium virginianum	Rattlesnake fern
BRS	Bromus species	Brome grass
CA	Carya species	Hickory
CAD	Castenea dentata	American chestnut
CAG	Carya glabra	Pignut hickory
CAS	Cardus species	Thistle
CAT	Carya tomentose	Mockernut hickory
CEO	Celtis occidentalis	Hackberry
CLS	Clematis virginiana	Virgin's bower
COA	Cornus alternifolia	Alternate leaf dogwood
COC	Corylus cornuta	Beaked hazel-nut
COF	Cornus florida	Flowering dogwood
COM	Cornus amomum	Silky dogwood
COS	Cornus stolinifera	Red-osier dogwood
CRS	Crataegus species	Hawthorn
CUC	Cuscuta compacta	Love vine
DAC	Daucus carrota	Wild carrot
DIO	Discorea villosa	Wild yam
DIV	Diodia virginiana	Diodia
DVI	Diospyros virginiana	Persimmon
ERH	Erectitus hieracifolia	Fireweed
EUF	Eupatorium fistulosum	Hollow joe-pye
EUR	Eupatorium rugosum	White snake root
FRA	Fraxinus americana	White ash
FRP	Fraxinus pennslyvannica	Green ash
FRS	Fragaria species	Strawberry
GAL	Galium triflorum	Bedstraw
HAV	Hamamelis virginiana	Witch-hazel
HOL	Houstonia longifolia	Long-leaved bluet
HYA	Hydrangea aborescens	Hydrangea
IMF	Impatiens pallida	Jewelweed
IMS	Impatiens carpensis	Spotted touch-me-not
IPH	Ipomea sagittata	Morning glory
KAL	Kalmia latifolia	Mountain laurel
LES	Lespediza species	Clover
LIB	Lindera benzoin	Spicebush
LIT	Liriodendron tulipifera	Tulip-poplar

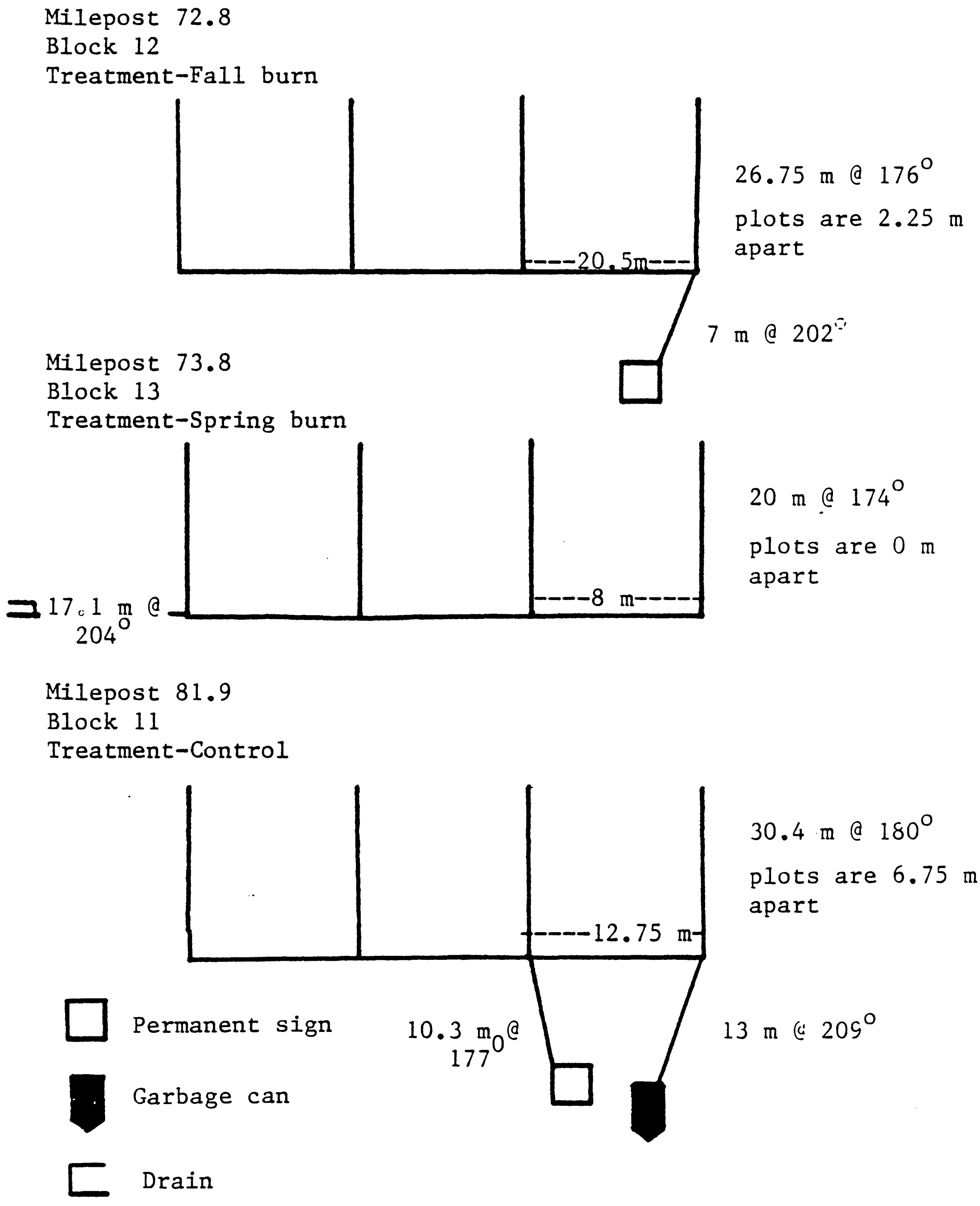
Code	Latin name	Common name
LOJ	Lonicera japonica	Honeysuckle
LYS	Lycopodium species	Ground pine
MA	Magnolia species	Magnolia
MAA	Magnolia acuminata	Cucumber tree
MNT	Mentha species	Mint
NYS	Nyssa sylvatica	Black gum
OEB	Oenothera biennis	Evening primrose
OXA	Oxydendrum arboreum	Sourwood
OXS	Oxalis stricta	Wood sorrel
PAN	Panicum species	Panicum grass
PAT	Paulownia tomentosa	Paulownia
PAQ	Parthenocissus quinquefolia	Virginia creeper
PIS	Pinus strobus	White pine
POL	Polygonatum biflorum	Solomen's seal
POS	Polygonum scandens	Climbing buckwheat
POY	Polystichum acrostichoides	Cristmas fern
PHA	Phytolacca americana	Pokeweed
PRP	Prunus persica	Peach
PRS	Prunus serotina	Black cherry
PTA	Pteridium aquilinum	Bracken fern
QUA	Quercus alba	White oak
QUC	Quercus coccinea	Scarlet oak
QUP	Quercus prinus	Chestnut oak
QUR	Quercus rubra	Northern red oak
QUV	Quercus velutina	Black oak
RHG	Rhus glabra	Smooth sumac
RHR	Rhus radicans	Poison ivy
RHT	Rhus typhina	Staghorn sumac
ROP	Robinia pseudoacacia	Black locust
ROM	Rosa multiflora	Rose
RUB	Rubus species	Blackberry
SAA	Sassafras albidum	Sassafras
SAC	Sambuccus canadensis	Elderberry
SAV	Satureja vulgaris	Basil
SET	Setaria species	Foxtail
SMI	Smilacina racemosa	False solomen's seal
SMR	Smilax rotundifolia	Greenbriar
SOS	Solidago species	Goldenrod
SPI	Spirea species	Spirea
TAO	Taraxacum officinale	Dandelion
TIL	Tilia americana	American basswood
TRI	Trilium species	Trillium
THS	Thalictrum species	Meadow rue
TRS	Trifolium species	Clover
ULT	Ulmus thomasi	Rock elm
VET	Verbascum thapsus	Common mullein
VEU	Verbena urticifolia	White vervain
VIB	Viburnum acerfolium	Maple-leaved viburnum
VIC	Vicia species	Vetch
VIA	Vitis species	Grape

Appendix D. 95 Percent Confidence Limits for Predicting Mortality

Mortality[1]	Intensity	Rate of Spread	Lower	Probability	Upper
	(kW/m)	(m/min)		(95%)	
0	113.81	0.780	.0147	.1487	.6717
0	88.14	0.780	.0084	.0861	.5105
0	65.97	0.884	.0135	.0904	.4202
0	88.14	0.780	.0084	.0861	.5105
0	113.81	0.780	.0147	.1487	.6717
0	88.14	0.780	.0084	.0861	.5105
0	88.14	0.780	.0084	.0861	.5105
0	88.14	1.260	.3415	.5874	.7963
1	88.14	1.260	.3415	.5874	.7963
1	88.14	1.260	.3415	.5874	.7963
0	88.14	1.260	.3415	.5874	.7963
1	88.14	1.260	.3415	.5874	.7963
0	88.14	1.260	.3415	.5874	.7963
0	65.97	1.260	.2884	.4550	.6324
0	65.97	1.260	.2884	.4550	.6324
0	65.97	1.260	.2884	.4550	.6324
0	65.97	1.260	.2884	.4550	.6324
0	65.97	1.260	.2884	.4550	.6324
1	65.97	1.260	.2884	.4550	.6324
1	65.97	1.260	.2884	.4550	.6324
0	65.97	1.260	.2884	.4550	.6324
0	65.97	1.260	.2884	.4550	.6324
0	65.97	1.260	.2884	.4550	.6324
1	65.97	1.260	.2884	.4550	.6324
1	65.97	1.260	.2884	.4550	.6324
1	65.97	1.260	.2884	.4550	.6324
0	65.97	1.260	.2884	.4550	.6324
1	43.2	1.260	.0597	.2148	.5412
0	43.2	1.260	.0597	.2148	.5412
0	43.2	1.260	.0597	.2148	.5412
0	43.2	1.260	.0597	.2148	.5412
0	43.2	1.260	.0597	.2148	.5412
0	43.2	1.260	.0597	.2148	.5412
0	43.2	1.260	.0597	.2148	.5412
1	43.2	1.260	.0597	.2148	.5412
0	43.2	1.260	.0597	.2148	.5412
1	88.14	1.260	.3415	.5874	.7963
1	88.14	1.260	.3415	.5874	.7963
1	88.14	1.260	.3415	.5874	.7963
1	88.14	1.260	.3415	.5874	.7963
1	65.97	0.884	.0135	.0904	.4202

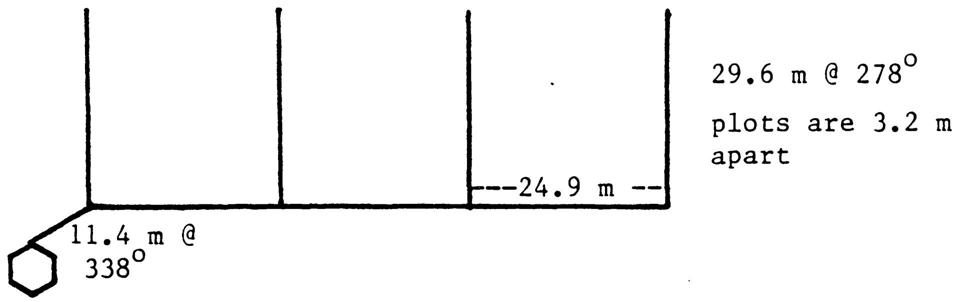
[1]Mortality codes; 1 = dead, 0 = surviving

Appendix E. Individual Unit Maps for Vista Management on the Blue Ridge Parkway

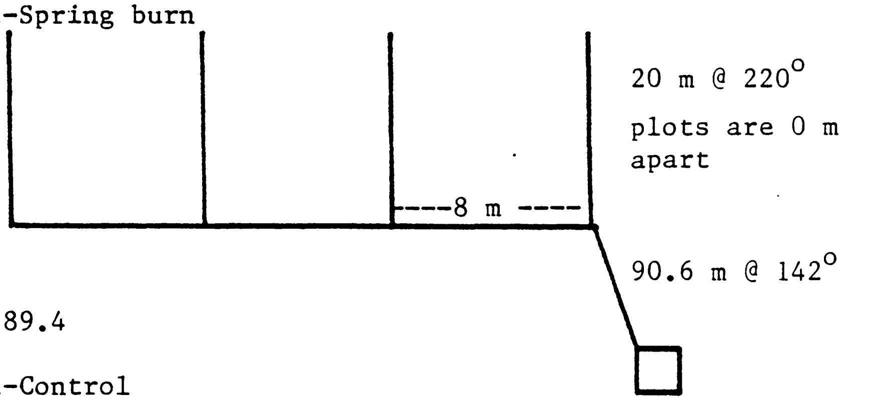


Milepost 72.8
Block 12
Treatment-Fall burn
26.75 m @ 176°
plots are 2.25 m apart
20.5m
7 m @ 202°
Milepost 73.8
Block 13
Treatment-Spring burn
20 m @ 174°
plots are 0 m apart
8 m
17.1 m @ 204°
Milepost 81.9
Block 11
Treatment-Control
30.4 m @ 180°
plots are 6.75 m apart
12.75 m
10.3 m @ 177°
13 m @ 209°
Permanent sign
Garbage can
Drain

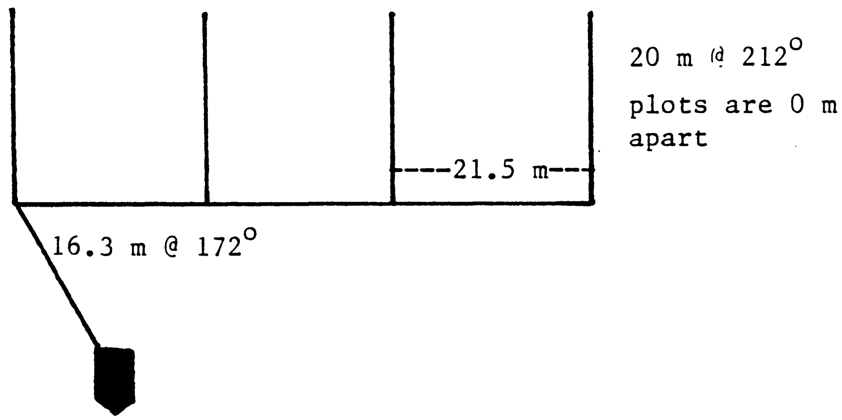
Milepost 86.4
Block 22
Treatment-Fall burn

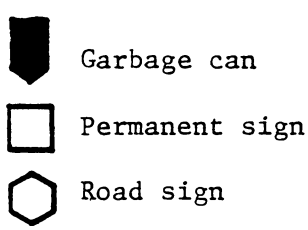


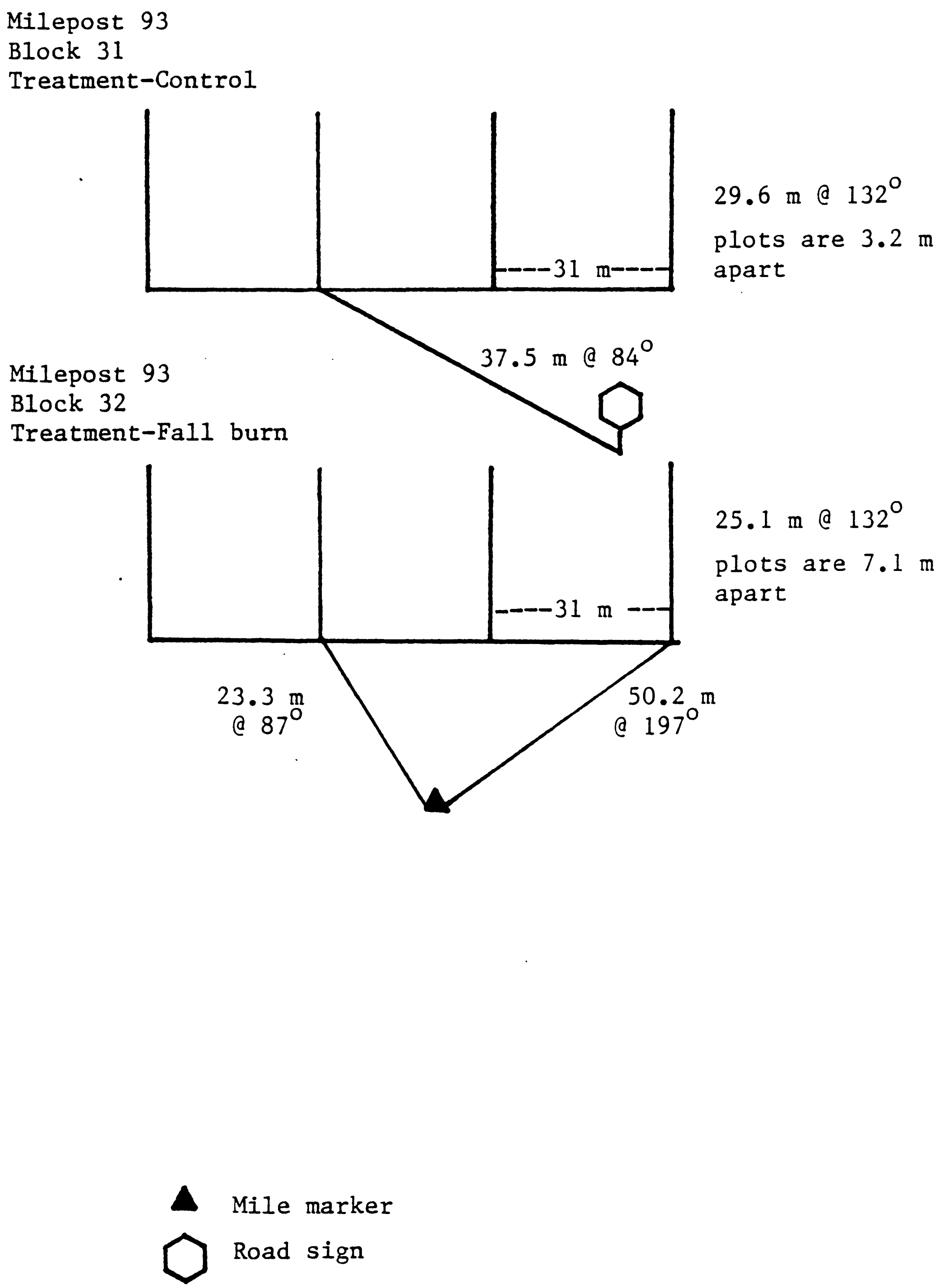
Milepost 89.3
Block 23
Treatment-Spring burn



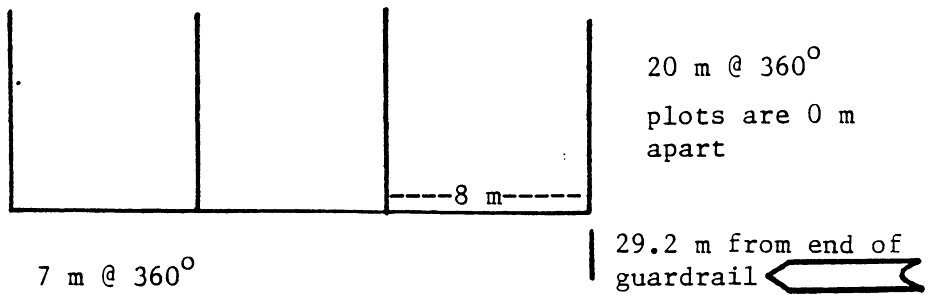
Milepost 89.4
Block 21
Treatment-Control



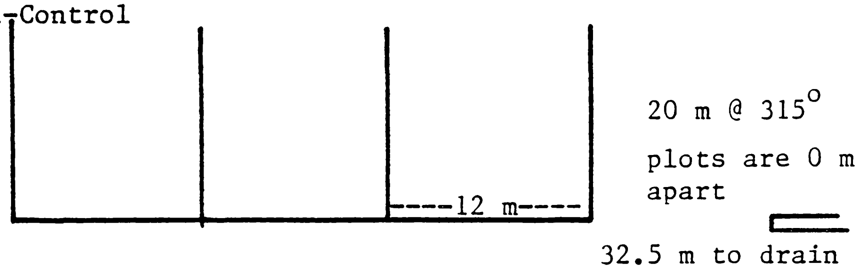


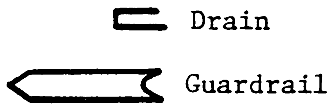

Milepost 93
Block 31
Treatment-Control
29.6 m @ 132°
plots are 3.2 m apart
----31 m----
37.5 m @ 84°
Milepost 93
Block 32
Treatment-Fall burn
25.1 m @ 132°
plots are 7.1 m apart
----31 m ---
23.3 m @ 87°
50.2 m @ 197°
Mile marker
Road sign

Milepost 127.8
Block 43
Treatment-Spring burn



Milepost 128.3
Block 41
Treatment-Control





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