FIRE

Abstract: Fire is a process—a change bringing about a result. Fire is also a resource—a source of support and help. Wildland fire begins with an ignition (natural or human caused) and becomes a product of the fuels, weather, and topography (the "fire environment"). Fire can reduce hazardous fuel accumulations and positively affect biological composition, structure, and function. Fire can also threaten social, economic and ecological values.

Past fire suppression and vegetation management practices have altered the fuel profile (mosaic of wildland fuels). These changes have led to greater flammability (sustainability of fire spread) than occurred in the natural range of variability. Ponderosa pine systems have become overstocked with younger vegetation, providing a ladder for fire spread into closed canopies. High intensity stand-replacement events over larger areas are now occurring where fires typically burned in only patterned severities earlier. Higher elevation forests are becoming more susceptible to fire on a landscape scale as they reach later stages of stand development and stands merge into larger units.

In addition, we have overlaid this fire landscape with social and economic expectations. Sustaining these expectations in a fire landscape requires management direction that recognizes fire behavior and fire effects, and that recognizes when fire is "good" and when fire is "bad." Fire protection is not always possible, and any protection comes at a cost.

In the broadest sense fire management support to the vision and goals of Arapaho and Roosevelt National Forests and Pawnee National Grasslands consists of:

- applying appropriate management actions to wildland fire events
- reducing unacceptable fuel profiles and fuel buildups
- reinforcing fire as an ecological process

Fire spread responds to changes in the fire environment, not to administrative boundaries. The implementation of fire management direction depends on support by all stakeholders to each others' efforts, logistically, strategically, and financially. The ARNF-PNG cannot by itself support wildland fire suppression efforts in critical areas of concern, for example on private property near federal lands. Such efforts require annual wildland fire agreements and strong partnerships. Fire management will continue to make public and firefighter safety the top priority on every fire, every time.

Proactive management of fire's spread and fire's effects requires management of the vegetation through a blend of mechanical treatments and prescribed fire. Generally, prescribed fire is thought to be the most cost-efficient operation. Extracting commercial products is another vegetation management tool available. Alternatives A, C, and I

present the greatest opportunity to use harvesting as a vegetation management tool. However, during a fire the cost of fire management operations will increase with these three alternatives in order to prevent loss of commercial value. Alternatives E and H embrace fire as an ecological process. Significant vegetation (fuel) management with these two alternatives would be required on the boundaries of the Forest to control fire spread to adjacent lands. In the interior portion of the Forests, however, the costs of fire management operations should be less. Fire management direction with Alternative B will require a combination of vegetation management tools (prescribed fire and lightning ignitions) as well as mechanical treatments (thinning and harvesting). Management responses to unplanned ignitions will meet geographic and management area direction.

INTRODUCTION

FIRE REGIMES AND FIRE-DEPENDENT ECOSYSTEMS

Detailed fire histories for a large extent of the Arapaho and Roosevelt National Forests and Pawnee National Grasslands are lacking, so that an accurate and detailed description of "natural" fire regimes is difficult. However, basic assumptions and inferences from various investigative studies on Front Range ecosystems can provide a foundation for sufficient and necessary analysis to design a fire management strategy.

A fire regime consists of a particular complex of fuel and a particular pattern of fire occurrence and behavior, described as its fire history (Pyne 1984). A fire regime can be described by the frequency and intensity of the fire events (Sando 1978) and by fire severity (Brown 1994). Fire frequency is determined by ignition sources and burning conditions (primarily fuel moisture and wind). Although related, intensity is more an indicator of resistance to control, and severity is a measure of ecological impact (e.g., to organisms, ecosystems, etc.). Intensity and severity are collectively called a fire's magnitude (Pickett and White 1985).

The ARNF and PNG landscape has three major fire regimes:

Type 1: Lower Montane to Upper Montane

Fires are either a result of the interaction of wind and slope (alignment fires) or are wind-driven across the landscape with little or no regard to topography (wind-driven fires). This fire regime was moderate to high frequency with mixed and variable (stand-replacement and nonlethal understory) magnitudes.

Type 2: Upper Montane to Sub-Alpine

Fires very seldom become big because of higher fuel moistures. However, when the fuels are dry and there is an "extreme" wind event, extensive downhill crown fire runs are possible east of the divide (wind-driven fires). Major fires in this regime occurred infrequently and were typically stand-replacement events. Smaller fires occured more often.

Type 3: Short Grass Prairie

Fires burn extremely fast under the influence of local and general winds. Often the event is short-lived and is relatively easy to manage because of the extensive road systems in the grasslands. These fires occurred frequently with low to moderate magnitude.

These three fire regimes are considered to be fire-dependent because fires significantly influence the functioning of the system (Kilgore and Heinselman 1990). Fire-dependent ecosystems are subdivided into types to further define fire's role. "Fire-maintained" systems characterize the Type 1 fire regime. A fire-maintained ecosystem is one where mixed and variable fires have maintained a functional mosaic by selectively thinning and pruning woody shrubs and trees. This mixture of fire severities across the landscape maintains a mosaic of patches that have permitted ecological interactions and fluxes among vegetation patches (Noss 1987). In the Type 2 fire regime, ecosystems are "fire-initiated"; infrequent catastrophic fires simultaneously kill organisms and facilitate sites for new organism establishments. The Type 3 regime is also "fire-initiated." However, the occurrence of fires is more frequent in rapidly-growing prairie vegetation.

The elimination of fire from a fire-dependent ecosystem can affect health and diversity since both are directly related to a properly functioning system. A biological landscape fragmented by a fire that is limited in size or burns too intensely can become limiting to key plant and animal species. A decrease in fire frequency and/or magnitude usually decreases the diversity of native species (Hobbs and Huenneke 1992). An increase in fire frequency and/or magnitude is detrimental to native species and enhances invasion by exotic species.

LEGAL AND ADMINISTRATIVE FRAMEWORK

The following acts provide the legal framework for planning and executing fire protection and for fire-use activities on the ARNF:

The Organic Administration Act - June 4, 1897 (16 U.S.C. 551): Authorizes the Secretary of Agriculture to make provisions for the protection of national forests against destruction by fire.

The Economy Act of 1932 - June 30, 1932 (41 U.S.C. 686): Provides for the procurement of materials, supplies, equipment, work, or services from other federal agencies.

The Bankhead-Jones Farm Tenant Act - July 22, 1937 (7 U.S.C. 1010, 1011): Authorizes and directs the Secretary of Agriculture to develop a program of land conservation and land utilization to protect the public lands.

The Reciprocal Fire Protection Act - May 27, 1955 (42 U.S.C. 1856): Authorizes reciprocal agreements with federal, state, and other wildland fire protection organizations.

The Wilderness Act - September 3, 1964 (16 U.S.C. 1131, 1132): Authorizes the Secretary of Agriculture to take such measures as may be necessary in the control of fire within designated wilderness.

The National Forest Management Act of 1976 - October 22, 1976 (16 U.S.C. 1600): Directs the Secretary of Agriculture to specify guidelines for land management plans to ensure protection of forest resources.

The Clean Air Act of 1977 - (amended) August 7, 1977 (42 U.S.C. 1857): Provides for the protection and enhancement of the nation's air resources.

The National Forest Directives System (manuals and handbooks) outlines the administrative framework for fire management activities: the protection of resources and other values from wildfire, and the use of prescribed fire to meet land and resource management goals and objectives. The framework in these manuals and handbooks provides for cost-efficient wildfire protection and embraces the positive roles that fire plays on National Forest lands. The following portions of the directives apply directly to fire management as addressed in the *Forest Plan*: *FSM 2324.2—Management of Fire* (in wilderness), *FSM 5100—Fire Management.* In particular, the Washington Office Amendment 5100-94-4 (12/9/94) of *FSM 5130 - Fire Suppression* recognizes strategies minimizing suppression costs and resource damage.

For the ARNF and PNG, annual county operating plans and the Colorado State Forest Annual Service Operating Plan comprise the framework for fire to be managed cooperatively with other agencies on the local level. These plans are updates made to the Interagency Cooperative Fire Protection Agreement and are reviewed annually. The cooperating counties are Boulder, Clear Creek, Gilpin, Jefferson, Grand, and Larimer. The ARNF and PNG Fire Management Plan and each District's Fire Management Plan are all updated annually as well.

AFFECTED ENVIRONMENT

FIRE AS AN ECOLOGICAL PROCESS

Current plant and animal communities and Forest and Grassland landscapes are a result of several widespread disturbance factors, of which fire is one. The effects of fire disturbance are very complex and highly variable, and are influenced by the past and current landscape, the amount and distribution of fuels, weather, and other elements. Typical landscape patterns and fire behavior for the Type 1 and Type 2 fire regimes are described in the following sections to provide a framework for understanding the current conditions and potential environmental consequences.

Landscape Patterns and Fire Behavior

Type 1 Fire Regime - Lower Montane to Upper Montane

Historically, frequent fire occurred through lightning and pre-settlement human ignitions, and had an important role in maintaining the diversity of stand structures and landscape patterns in this fire regime. Mixed and variable severity fires maintained ponderosa pine as a seral dominant in many open stands and periodically cleansed the forest floor of fuel accumulations. In the Boulder area, Veblen and Kitzberger (1995) determined a composite mean fire interval (time between fires) of 8 to 28.4 years in this fire regime. Gordon (1994) cites two studies indicating a mean fire interval (MFI) of 8 to 9 years in the lower montane ecotones scattered with mountain shrubs, and an MFI of 35 to 40 years on the higher, moister (north-facing) sites.

However, Gordon notes that the current montane fire regimes have been altered by harvesting and burning (late 1800s), favorable climatic growth conditions (early 1900s), fire suppression actions (since approximately 1920), and recent insect outbreaks (late 1900s). These alterations, and consequent decreases in fire frequency, have led to an increase in surface and crown fuels and to changes in the forest structure. There are denser forests with fewer openings, a multilayered vertical structure that increases ladder fuels, and a higher proportion of shade-tolerant species.

In a regime that was characterized by a mosaic of burn patterns, current conditions (the fuel profile) have increased the probability of stand-replacement events over a larger area. Such conditions create greater risk to life and property, potentially increase destruction and depletion of the soil structure and nutrients, and worsen pollution from wildfire smoke. If these conditions are not changed, the healthy functioning of the system is increasingly at risk.

Type 2 Fire Regime - Upper Montane to Sub-Alpine

The lodgepole pine and Engelmann spruce/subalpine fir systems dominate the Type 2 fire regime. Fire generally burns in one of two ways in this regime. First, once initiated by lightning, the fire smolders for possibly up to several days, then burns out. Live and dead fuel moisture conditions and the lack of ladder fuels (low branches and understory) and limited winds, severely limit fire spread. Climax lodgepole pine forests have very little herbaceous vegetation on the forest floor; fine surface fuel is not a critical factor. However, in moderately dry conditions, the mature lodgepole pine stand can burn in a "log-to-log" pattern (Agee 1993). In this pattern a smoldering fire burns from log to log, only singeing the adjacent live herbaceous vegetation. Although these fires are of low intensity, they can make the standing trees susceptible to insects, disease, and rot.

Alternately, the fire burns actively in the overstory of older stands caused by more ladder fuels in the understory, drier conditions, and stronger winds (wind-driven fire). The younger the stand, the less likely it is to burn (Renkin and Despain 1992). Consequently, a patchy mosaic of stand ages results in a patchy mosaic of burn patterns of varying severities. However, high winds can move a crown fire through all successional stages. This fire spread continues until there is a significant change in the fire environment -- a change in the fuels, weather, and/or topography. Most often this change is a decrease in the winds and an increase in atmospheric moisture. Large fires in spruce/fir systems appear usually to have started at lower elevations. Most likely these starts are in lodgepole pine stands and depend on strong winds to drive them as crown fires into the higher elevations. In the past, although infrequent, these fires typically involved the major portion of a sixth-level watershed (approximately 10,000 acres).

Studies reveal fire frequencies in the sampled montane and subalpine lodgepole pine forests to be 50 to 150 years and 200 to 400 years, respectively (Covich et al. 1994). Stands in the subalpine forests have longer intervals of 200 to 700+ years. This fire regime is characterized by high-intensity crown fires. The effect on the understory and soil structure of these crown fires can vary considerably, even though the canopy may be removed. The effect will depend on the amount of dead and down fuel on the forest floor, as well as on fuel and soil moisture.

Currently, nearly all fires in this regime are suppressed within one or two days (burning periods), after the crown fire runs. A change in stand age, moisture conditions, and/or winds will remove the fire activity from the aerial fuels and offer an opportunity for successful suppression. During this initial period of fire spread, it is possible for the crown fire to burn up to 2,000 acres. Unsuppressed, it is highly possible that this fire, with dry conditions and another strong wind event, would burn several thousand acres more through the course of the fire season.

Without stand-replacement disturbances, stands in this fire regime will become older, continue to develop greater amounts of dead and down fuels, and seral old-growth lodgepole communities will be replaced. When an ignition occurs during a period of dry conditions, the disturbance can easily cross a landscape; strong wind events will ensure it.

There are two other important ecological characteristics of the Type 2 fire regime:

> Standing snags contribute to the protection of biological diversity. Unlike ponderosa pine and Douglas-fir systems, crown fires dominate Type 2 fire regimes and usually leave standing snags in the burned area. These snags provide a gradated "edge effect" to the remaining interior forests and serve to protect regenerating vegetation from wind, drought, frost heaving, and other hardships.
>
> Old-growth lodgepole pine is naturally perpetuated in a shifting mosaic across the landscape and does not survive in a single stand. Seral lodgepole pine can exhibit old-growth characteristics; Mehl (1992) lists standard attributes used as regional characterizations of old-growth. Unlike the ponderosa pine and Douglas-fir fire regime, this condition may not last long in one stand with the frequencies and intensities shown in the natural range of fuel profile variation, i.e., stand-replacement fires every few centuries. However patches of old-growth conditions may appear in a shifting mosaic on the landscape over time (Mehl 1992).

Type 3 Fire Regime - Short Grass Prairie

Frequent fires occurred on the Grasslands and were undoubtedly important in sustaining the unique biotic communities found there. The intensities were low to moderate and fire spread rapidly across the prairie until the fire environment changed, probably with higher humidities which quickly affect fuel moistures. Currently, fires are suppressed by local volunteer firefighters or burn out without direct ARNF-PNG employee involvement.

The grassland community does not develop highly flammable fuel profiles. The structure of the vegetation, however, does influence the habitat effectiveness of the mountain plover. Ongoing programs are being used to maintain the proper habitat through the use of prescribed fire.

CURRENT CONDITIONS ON THE ARNF

Fuel profiles in both the Type 1 and Type 2 fire regimes have become more flammable across the landscape. A decrease in fire frequency has led to an increase in surface and crown fuels in many areas and a modification of forest structure. This change in fuel profile is most apparent in the Type 1 regime. However, on the landscape scale, forest stands in the Type 2 regime are reaching higher levels of flammability as they reach later stages of stand development.

Historic suppression policies limited and even caused erroneous understanding of fire ecology, and although well intentioned, had have adverse results. Fire suppression has interfered with fire as a systemic process, and in doing so has made suppression costs, and the costs of failure, that much greater. In addition, complex socioeconomic values are being asked of a fire-landscape, requiring appropriate fire management direction to sustain these values.

Fuel Profiles and Range of Natural Variation

Flammability is related to flame length, which is a direct measure of fire intensity. Flammability constrains suppression capabilities. The flammability of ARNF Type 1 fire regime fuel profiles is rated low, moderate, or high, based on cover type, canopy closure and tree diameter. Dead, downed fuels are assumed to be correlated to these fuel profile components. In this current analysis, multistoried stands are not explicitly incorporated into flammability ratings.

The ARNF range of natural variation (RNV) of Type 1 fuel profiles typically supported fires with mixed and variable intensities. However, to protect threatened values, modification of these fuels may be justified to facilitate suppression actions.

The ARNF Type 2 fire regime fuel profiles' flammabilities are identified by stand age. Turner et al. (1994) demonstrates that landscape susceptibility to crown fire spread depends on the spread patterns among the more flammable later stages of lodgepole pine and Engelmann spruce/subalpine fir stands (late LP2, LP3, late SF2, and SF3; see the Fuel Profile Flammability Map (Figure 3.13), which indicates these connected stands.

Effective wildfire suppression has occurred in the American West for less than 100 years. With fire-return intervals greater than 100 years it is difficult to say whether the ARNF Type 2 fuel profiles are significantly beyond their ranges of natural variation. Ignitions have been successfully extinguished that would otherwise have spread over thousands of acres. Therefore, in order to

minimize the probability of future conflagrations, the management of ignitions in a way that accepts burn areas, where values at risk are lowest, is appropriate.

Characterizing Future Fire Events

Two methodologies are used to characterize future fire events. First, one can perform a frequency analysis on past fire activity. This is the approach used in budgeting fire suppression programs and the one used in the National Fire Management Analysis System (NFMAS). A frequency analysis of the ARNF's past wildfire activity over the 22-year period from 1970 to 1991 predicts 55 ignitions (roughly half natural and half human-caused) for a total of 1,160 acres burned per year.

A second method, Wildland Fire Management Assessment, looks at the future susceptibility of a landscape to wildfire from potential increases in human-caused ignitions and increases in fuel profile flammabilities. The fire-return intervals on the ARNF are, for the most part, greater than the 22 years used in the first method. Therefore, susceptibility analysis perhaps highlights the potential impact in costs and efforts better than frequency analysis. See Figures 3.13 (Fuel Profile Flammability Map) and 3.14 (Ignition Frequency Map). Both growth in human use in and adjacent to the Forest, and an increase in fuel profile flammability, have increased susceptibility to fire on the ARNF. Given the current course of action, more catastrophic fires of greater magnitude should be expected.

The Wildland Fire Management Assessment also characterizes the values (desired conditions) at risk, which include resource values (e.g., old growth and wildlife habitat) as well as economic values (e.g., homes, campgrounds, suitable timber). Figure 3.15 depicts these at-risk values. The Wildland Fire Management Assessment Map overlays the locations of fuel profile flammability, potential frequency of ignitions, and values with representations of the proximity to other private and public lands, to derive the general fire management direction for the ARNF and PNG.

FIRE MANAGEMENT

Fire management direction influences fire in two significant ways: by managing unplanned ignitions and by modifying fuels prior to fire ignition.

MANAGING UNPLANNED IGNITIONS

All wildland fires resulting from an unplanned ignition will receive prompt and aggressive initial action. However, it is not economically feasible or logistically possible to develop an organization to control all unplanned wildland fires all the time and under all weather conditions. Instead, a wildfire detection, prevention, and initial attack organization is mobilized so that, given an ignition on a "90 percent" day (a day surpassed by only 10 percent of the fire-season days for extreme fire weather), the resulting fire can be kept to less than 300 acres (the predetermined escape fire size).

Multiple ignitions are not included in the design. The National Fire Management Analysis System (NFMAS) is used on the ARNF to guide funding for this level of suppression and presuppression organization.

Regardless of the effectiveness and efficiency of the initial attack organization there will be failures to immediately control fire spread because of extreme "outlier" weather events.

Therefore, wildland fire management strategies have been specified in advance for the management of a fire's spread once it has escaped the initial suppression action. Safety, suppression costs, and values at risk determine the exact strategy and operational tactics. Direct benefits to resources cannot be used as criteria in selecting a response. However, as is often the case, the use of an appropriate suppression response to manage a given ignition can indirectly benefit resources.

The three management responses to wildland fire, also called wildland fire management strategies, are direct control, perimeter control, and prescription control. All share two common goals: to protect human safety and to manage appropriately the risks and impacts of present and future wildland fires. Figure 3.16, the Wildland Fire Management Strategy—Fuel Management Priorities Map, shows areas covered by each kind of control strategy.

Figure 3.13

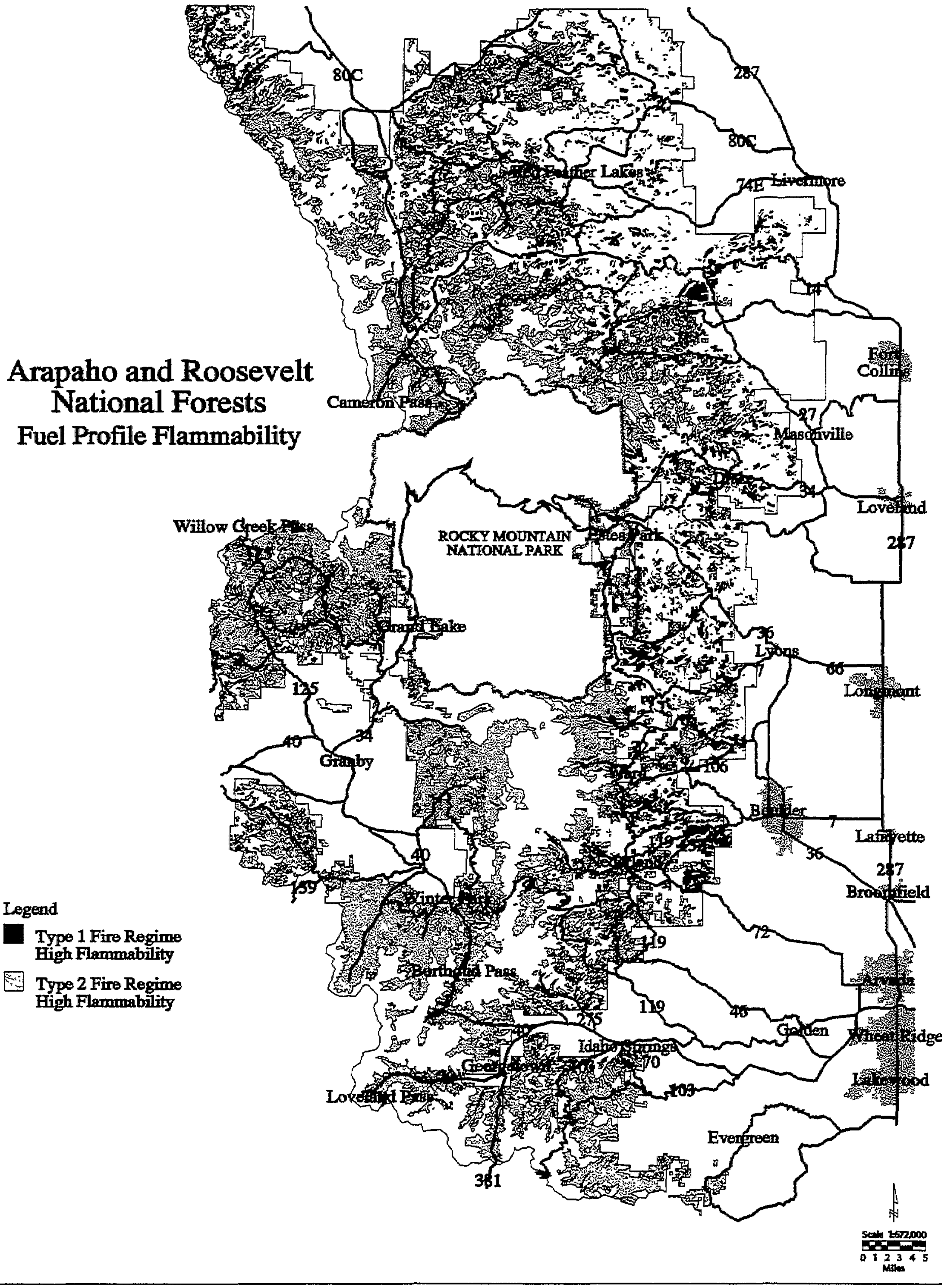

Arapaho and Roosevelt
National Forests
Fuel Profile Flammability
Legend
Type 1 Fire Regime
High Flammability
Type 2 Fire Regime
High Flammability
ROCKY MOUNTAIN
NATIONAL PARK
Cameron Pass
Willow Creek Pass
Grand Lake
Granby
Winter Park
Berthoud Pass
Georgetown
Idaho Springs
Loveland Pass
Evergreen
Golden
Wheat Ridge
Lakewood
Arvada
Broomfield
Lafayette
Boulder
Nederland
Ward
Longmont
Lyons
Estes Park
Loveland
Masonville
Fort Collins
Livermore
Red Feather Lakes
80C
287
74E
14
27
34
36
66
7
72
119
106
125
40
139
70
103
285
381
Scale 1:672,000
0 1 2 3 4 5
Miles

Figure 3.14

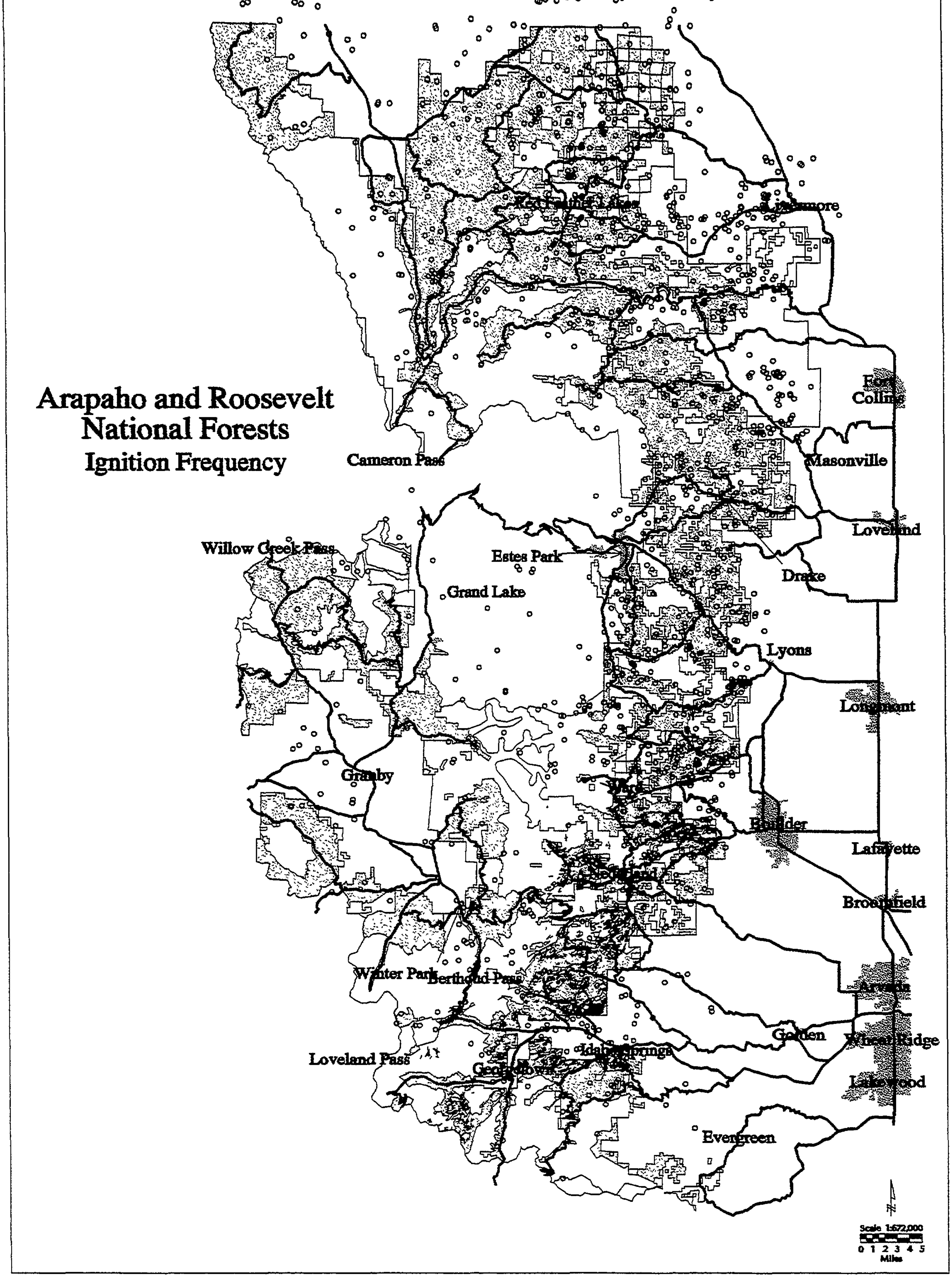

Arapaho and Roosevelt National Forests
Ignition Frequency
Cameron Pass
Masonville
Estes Park
Grand Lake
Willow Creek Pass
Drake
Lyons
Granby
Lafayette
Winter Park
Berthoud Pass
Golden
Loveland Pass
Evergreen
Scale 1:672,000
0 1 2 3 4 5
Miles

Figure 3.15

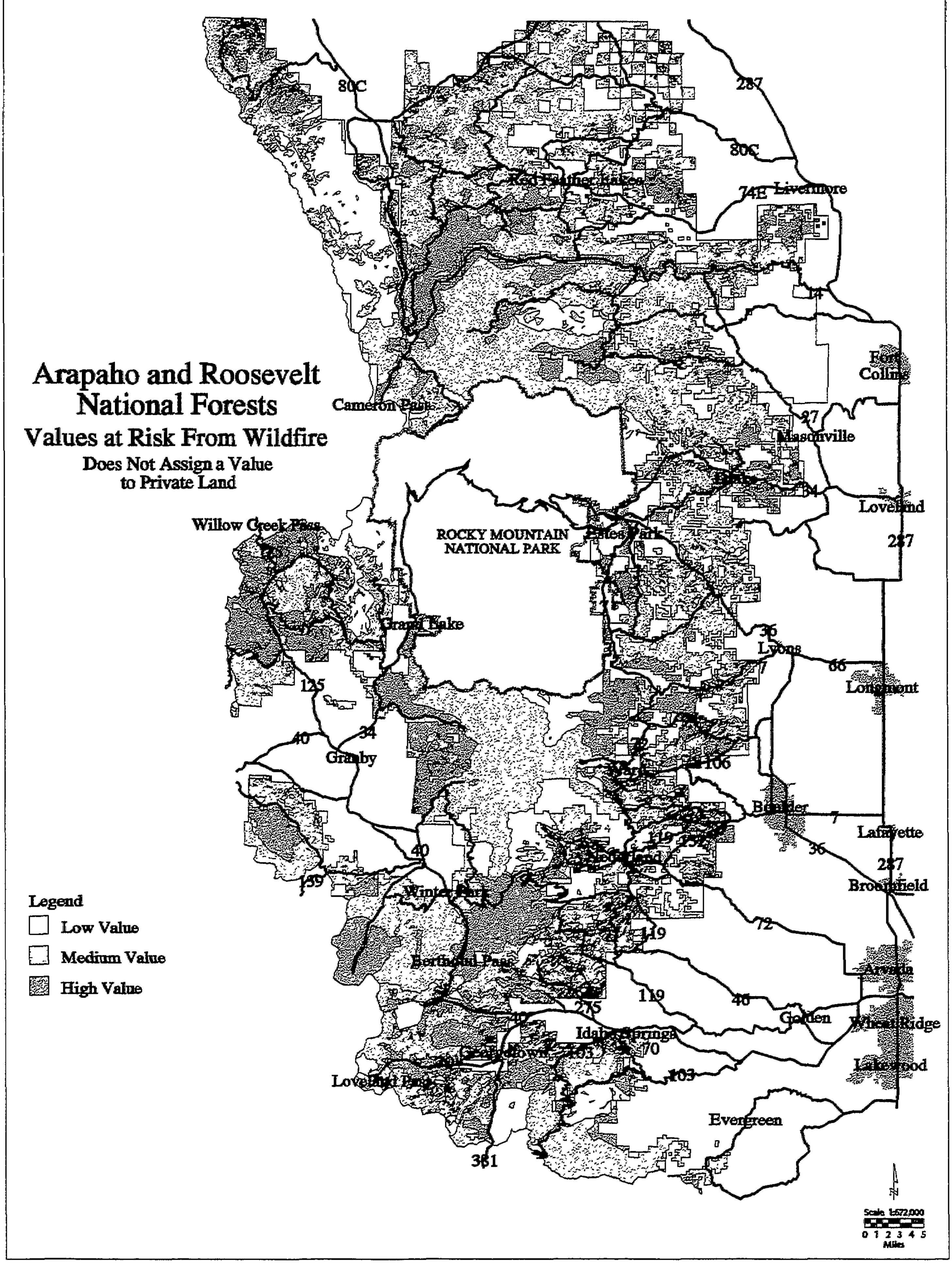
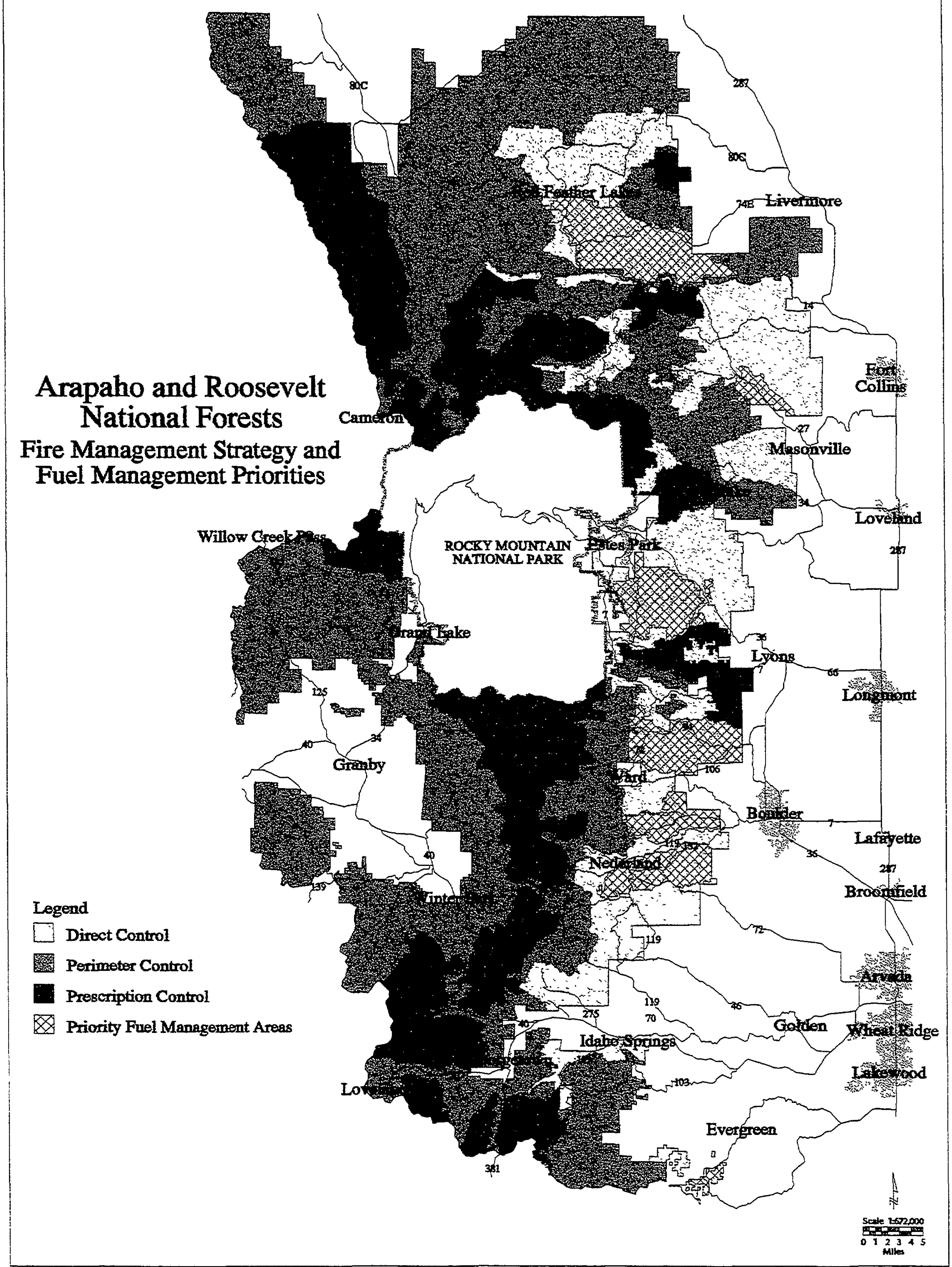

Arapaho and Roosevelt National Forests
Values at Risk From Wildfire
Does Not Assign a Value to Private Land
Legend
Low Value
Medium Value
High Value
ROCKY MOUNTAIN NATIONAL PARK
Willow Creek Pass
Cameron Pass
Grand Lake
Granby
Winter Park
Berthoud Pass
Loveland Pass
Idaho Springs
Georgetown
Evergreen
Golden
Wheat Ridge
Lakewood
Arvada
Broomfield
Lafayette
Boulder
Longmont
Lyons
Estes Park
Masonville
Loveland
Fort Collins
Livermore
Red Feather Lakes
Nederland
80C
287
74E
14
27
34
36
66
7
125
40
139
119
72
275
103
70
381
106
Scale 1:672,000
0 1 2 3 4 5
Miles

Figure 3.16



Arapaho and Roosevelt National Forests
Fire Management Strategy and Fuel Management Priorities
Legend
Direct Control
Perimeter Control
Prescription Control
Priority Fuel Management Areas
ROCKY MOUNTAIN NATIONAL PARK
Livermore
Fort Collins
Masonville
Loveland
Estes Park
Lyons
Longmont
Boulder
Lafayette
Broomfield
Arvada
Wheat Ridge
Lakewood
Golden
Evergreen
Idaho Springs
Nederland
Ward
Granby
Grand Lake
Willow Creek Pass
Cameron
Scale 1:672,000
0 1 2 3 4 5
Miles

Direct Control is the immediate and complete extinction of a wildland fire and is usually restricted to new fire starts, to steady-state fires that have not reached large sizes, to selected portions of large fires, and to protection of critical assets such as houses. The costs, risks, and implementation of direct control strategy of structure fires are shared with the local stakeholders who request the strategy. Suppression of structure fires is not a charge of the ARNF and PNG, and does not require this fire management strategy.

Perimeter Control uses fire lines to confine the active zone of spreading fire. Actual fireline locations (i.e., direct vs. indirect) are selected to minimize the combined costs of suppression and the values that could be lost in a fire. The benefits of fire's effects may also be used to determine fireline locations.

Prescription Control allows a fire to burn and considers it to be controlled as long as it burns within specified geographic boundaries and predetermined conditions (weather, preparedness levels, etc.). These parameters are specified in a written prescription. The prescription allows those fires to continue to burn that are seen as advancing management goals. The fire may be caused by lightning or by people.

Each geographic area in the *Forest Plan* specifies a wildland fire management strategy to be used, or refers the reader to the *Wildland Fire Management Strategy Map* enclosed with the *Forest Plan.*

The implementation of any strategy does not come without risks. The following table identifies the risks associated with the three strategies, describes each risk's impact and explains prevention and mitigation measures that will be taken.

Table 3.80 Risks Associated with Wildland Fire Management Strategies

Risk	Potential Impacts	Prevention/Mitigation
Fire exceeds fire management strategy and requires more costly suppression actions.	• The public or firefighters experience safety hazards. • Firefighting resources are unavailable or overwhelmed, and values in areas outside the intended perimeter are threatened or damaged. • Suppression efforts consume public funds.	• Fire behavior analyst and line officer apply best professional judgment in defining the fire's maximum manageable area. • Daily validations, documented in the *wildland fire situation analysis*, also incorporate best professional judgement. *These two preventative measures will affect all of the following risk categories.*

Risk	Potential Impacts	Prevention/Mitigation
Smoke degrades air quality.	• People in the affected area experience health problems, poor visibility at scenic vistas and elsewhere, and other impacts. • Legal limits on fine particulate matter as set in the National Ambient Air Quality Standards are violated.	At the current time wildfire is exempt from the Clean Air Act. However, for prescribed fire, smoke modeling and checking weather forecasts are two of the tools available during daily planning to project smoke impacts and ensure they remain tolerable. Smoke monitoring is an integral part of daily validation. Judicious control of smoldering portions of a fire may sometimes be appropriate.
Fire damages private property. Examples include structures and livestock.	• Owners lose both financial and nonmonetary benefits of their property. Financial compensation may be delayed, and may require property owner's time and attention. • Public funds and staff time are redirected from other activities in order to reimburse damages.	Awareness of values at risk is the first step in protecting them and is a key consideration in the selection of both overall strategies and specific tactics.
Fire damages public assets such as roads, trails, cadastral boundary trees, and merchantable timber.	Replacing improvements diverts public funds. Meanwhile, users do not receive benefits from the improvements. Some assets cannot be rebuilt, and are lost temporarily or permanently.	• For prescription control strategies, areas are defined to exclude improvements that would be inappropriate to place at risk. • For perimeter control strategies, potential damages will be identified to help determine the particular strategy to be used.

Risk	Potential Impacts	Prevention/Mitigation
Fire disrupts recreation.	• Public safety is jeopardized. • Public access is restricted, displacing recreationists. • Public access is safe and not restricted, but recreationists feel their experience has been diminished. • Permittees and others earn less income from recreationists, including losses from being required to move their venues.	Each *wildland fire situation analysis* will address public safety, including the quantity and use levels of trails and other recreation facilities that the fire may affect. Concerns and hazards may include fire, snags, smoke, trail conditions, and campsite availability. Signs or public contact may be appropriate.
Fire disrupts permitted activities such as grazing and firewood cutting.	• Permittees lose benefits of Forest access.	A *wildland fire situation analysis* will address the fire's potential effects on grazing permittees, and what would be involved in relocating them for the fire's duration. Commercial users in a fire's vicinity will be informed of the start and progress of strategies and operations. Then users are responsible for removing their belongings and evacuating the location.

Risk	Potential Impacts	Prevention/Migration
Fire kills members of threatened, endangered or sensitive species; or degrades their habitat.	Extinction becomes more likely.	Most threatened, endangered or sensitive species are native and have evolved with fire. Prescription and perimeter control strategies may help critical species directly, by reducing the potential for more severe fire, or by decreasing competition from fire-intolerant species. Alternately, these strategies may be a threat, as when escape cover nearby is no longer available, or where fire suppression has already facilitated atypically severe fire. Before each fire season, fire managers should review critical species listings.
Fire promotes erosion and stream siltation by removing stabilizing vegetation cover.	• Topsoil is lost, degrading land quality. • Erosion physically destabilizes watercourses, jeopardizing structures and other values downstream. • Stream siltation or changes in water quality damage aquatic habitat.	The potential for erosion and degraded water quality after a fire depends on topography, fire history, the depth and type of soil, the fire's location relative to streams, fire severity and duration, and duff consumption. Soil distributions and streams have developed through evolutionary time with fire. However, to ensure sustaining the desired condition throughout the landscape, both soil and water will be considered when a *wildland fire situation analysis* is prepared.

Risk	Potential Impacts	Prevention/Migration
Fire damages cultural artifacts.	• Heritage resources are lost without being fully evaluated or mitigated.	The potential to prevent damage to known sites is considered in a *wildland fire situation analysis.* If artifacts are discovered during tactical operations an archeologist will be used to develop methods to mitigate damages. While some artifacts are susceptible to fire, others are not, or are not susceptible to all fire intensities.
Fire harms rather than supports ecosystem health.	• Land ranges farther from its desired condition, perhaps irreversibly. • Exotic species are enhanced. • Vegetation is converted to a type outside a range of historic variability.	Too little is known about ecosystems where fire has been suppressed, so there is a large element of uncertainty in assessing these impacts. Particularly in assessing risk to ecosystem health, fire managers must balance the risk of causing immediate harm against the possibility of greater future harm if the fire is suppressed. Neither mechanical treatment nor prescribed fire are feasible in all forested ecosystems in the Arapaho & Roosevelt National Forests within the next ten years. However imperfect, an appropriate management of an unplanned-ignition is one of the only ways to rein in ecosystem damage caused by suppression.

MODIFYING FUEL PROFILES

Fuel profile modification (also called fuels management) is needed to (1) implement fire management strategies for unplanned ignitions, and (2) enable fire to burn through identified ecosystems as an ecological process. The ARNF and PNG approach to fuel management is to affect the fuel profile over a large area. Small modifications in fuel profiles are insignificant because typical problem-fires move partially, if not completely, as crown fires with a wide front.

Defensible fuel profile zones (DFPZs) can maximize firefighter safety and minimize suppression costs and efforts. This is especially important in areas where suppression action warrants perimeter control because of values at risk. For a given fire regime and fire environment, the most cost-efficient fuel profile can be determined. Site-specific analysis, accomplished in concert with the fire management direction given for the geographic area, determines DFPZ location and specifications. The Fire Management Plan (FMP) documents these DFPZs.

On the landscape scale, DFPZs provide the ability to develop ecologically sensitive fuel profiles for strategic use. With DFPZs established, ignitions (both wildland and prescribed) can be managed on the ground to ensure the greatest success. The profile itself is developed to "fit" the fire regime. The concept of a fire regime, and the subsequent range of natural variation (RNV) in the regime's fuel profile, provides only a basic framework for strategic fuel management planning. Fire's effects are variable in time and space. Consequently, site-specific analysis and design must and will focus on the ecology of fire in a particular system.

The ARNF strategic view of fuels management is based on two primary assumptions. First, the estimated fire interval (EFI) for ponderosa pine, Douglas-fir, lodgepole pine, and Engelmann spruce/subalpine fir ecosystems is taken to be 20 years, 35 years, 200 years, and 500 years, respectively. This is a major assumption, estimated from Covich et al. (1994), and chosen only for this strategic analysis. Second, although fires burn in all systems at all levels of intensity and severity, ecologically significant fires have burned, on the landscape scale, at characteristic intensities. These intensities were described in the introduction to the Fire Section under the heading of fire regimes and fire-dependent ecosystems.

Fuel profiles are modified by harvesting, by wildfire, by prescribed fire, and by insects and disease. Each alternative recognizes suitable acres for harvest (see the Timber Section, under affected environment). These suitable acres are a portion of the total acres of a given ecosystem. If harvested over the course of 150 to 300 years (a rotation), the remaining acres represent the acres needing additional modification (treatment). The remaining acres, divided by the estimated fire return (EFI) represents the acres, requiring annual modification by fire, insects, and/or disease. At this time only fire, both wildland and prescribed, is factored into this analysis; insects and disease are not.

Given the assumptions above, and provided that all suitable acres are harvested and wildfires burn the expected acreages, the following tables display the acres requiring fuel management treatment, annually, in order to maintain fuel profiles within their range of natural variation.

Table 3.81 Estimate of Acres needing Fuel Management Treatment Annually for the Type 1 Fire Regime

	Alternative					
	A (acres)	**B** (acres)	**C** (acres)	**E** (acres)	**H** (acres)	**I** (acres)
Ponderosa Pine - 136,700 acres - 20 Year Estimated Fire Interval						
Suitable	56,600	9,894	59,700	0	200	23,200
Remainder	80,100	126,806	77,000	136,700	136,500	113,500
Remainder/ EFI	4,005	6,340	3,845	6,835	6,825	5,675
Annual Wildfire	450	450	450	450	700	450
Fuel Treatment Needs	3,555	5,890	3,400	6,385	6,125	5,225
Douglas-fir - 57,300 acres - 35 Year Estimated Fire Interval						
Suitable	17,400	3,378	19,900	0	0	6,500
Remainder	39,900	53,922	37,400	57,300	57,300	50,800
Remainder/ EFI	1,995	1,541	1,069	1,637	1,637	1,451
Annual Wildfire	200	200	200	200	1,300	700
Fuel Treatment Needs	1,795	1,341	869	1,437	337	1,251
Regime 1 Total Needs	5,350	7,231	4,269	7,822	6,462	6,476

Table 3.82 Estimate of Acres Needing Fuel Management Treatment Annually for the Type 2 Fire Regime

	Alternative					
	A (acres)	**B** (acres)	**C** (acres)	**E** (acres)	**H** (acres)	**I** (acres)
Lodgepole Pine - 501,400 acres - 200 Year Estimated Fire Interval						
Suitable	233,600	140,206	247,500	33,200	17,200	212,800
Remainder	267,800	361,194	253,900	468,200	484,200	288,600
Remainder/ EFI	1,339	1,806	1,270	2,341	2,421	1,443

	Alternative					
	A (acres)	B (acres)	C (acres)	E (acres)	H (acres)	I (acres)
Annual Wildfire	400	400	400	400	1,500	400
Fuel Treatment Needs	939	1,406	870	1,941	921	1,043
Spruce-Fir - 248,000 acres - 500 Year Estimated Fire Interval						
Suitable	57,700	35,429	72,200	9,900	4,000	69,000
Remainder	190,300	212,571	175,800	238,100	244,000	179,000
Remainder/ EFI	381	425	352	476	488	358
Annual Wildfire	50	50	50	50	200	50
Fuel Treatment Needs	331	375	302	426	280	308
Regime 2 Total Fuel Treatment Needs	1,270	1,781	1,172	2,367	1,209	1,351

Note the variation in acreage requiring fuel treatment under each alternative. Also, note the additional acres treated by lightning-ignited fire under Alternative H.

The ARNF assumes a cost of $90.00 per acre to treat fuels through prescribed fire. The *experienced* budget level will provide an annual treatment of 4,000 acres, while the *full implementation* budget level would allow for 7,000 acres to be treated annually. However, fuel management funding appears to be on the rise ($180,000 in 1996 for the treatment of 2,000 acres), which may increase the capability to treat additional acres.

Both budget levels nevertheless fall seriously short of the required prescribed fire needed to bring and maintain fuel profiles within their range of natural variation. It has been estimated that 10,000 acres plus need to be treated to achieve the appropriate range. Ecosystems will consequently continue to experience atypical fire characteristics. Type 1 regimes will have more intense and severe fires over a greater proportion of the area; Type 2 regimes will have stand-replacement fires of greater extent. An increase in risks to firefighter safety, higher suppression costs, and deleterious ecological effects will follow.

Fuel management projects must be prioritized using the *wildland fire management assessment* process described already. Areas that are high fuel profile flammability, high value, and moderate to high risk will receive highest priority for treatment. See Figure 3.16 (Wildland Fire Management Strategy—Fuel Management Priorities Map) for the areas on the ARNF where fuel management projects will be emphasized.

Ecosystem health and integrity projects, as well as wildlife habitat improvement projects, offer a collective opportunity to treat vegetation which also meets fuel management objectives. Prescription control strategies will also indirectly treat fuels while offering safe and cost-effective methods to manage wildland fires.

ENVIRONMENTAL CONSEQUENCES

EFFECTS COMMON TO ALL ALTERNATIVES

The structure and function of the ARNF and PNG ecosystems are not static. Fuels will continue to accumulate if fire as a natural process and mechanical manipulation are minimized. In the Type 1 fire regime, overstocking of ponderosa pine and Douglas-fir will lead to stressed trees, susceptible to insects, disease and eventual mortality. The undergrowth and fuel buildup will cause larger stand-replacement events than normal; they will be difficult and dangerous to suppress and deleterious to the ecosystem.

In the Type 2 regime, stands will become more flammable across the entire landscape as they reach later seral stages. When dry conditions occur, the possibility of burning more acreage per fire increases. The 1988 fire activity in Yellowstone's Type 2 regime was not out of the fuel profile's range of natural variation (RNV) for those systems. Fires in the Type 2 regime characteristically burn as large stand-replacement fires.

Given current and projected future conditions, no alternative begins to mitigate the higher magnitude nor the greater extent of fire in either fire regime, unless managers address fire's systemic role in reducing ecosystem flammability.

EFFECTS ON FIRE FROM FIRE MANAGEMENT

To date, successful suppression of natural ignitions has taken current fuel profiles out of their range of natural variation. Attempting to limit values lost after ignition occurs is increasingly a losing battle because fuel profiles become even more flammable. Suppression cost plus net (resource) value change (see glossary) is currently too high for the outcome of most suppression efforts.

Alternatives A, H, E, and to some extent B more fully embrace a wide range of appropriate suppression responses as well as perimeter control for lightning-ignited fires. Alternatives C and I require more direct perimeter control to meet the desired condition outlined. As a result of the limited opportunities in the management of ignitions, Alternatives C and I will incur greater suppression costs and efforts, and will have more deleterious ecological impacts to fire regimes, both now and in the future.

Decreased opportunities to use timber harvesting to modify fuel profiles will result in more acreage requiring fuel treatment (mechanical treatment and prescribed fire) in Alternatives B, E, and H. Prescribed fire objectives for disturbance frequency, fire intensity/severity, and size are outlined by each geographic area.

EFFECTS ON FIRE FROM TIMBER MANAGEMENT

Timber harvesting can decrease fuel profile flammability. Activity fuels (slash) will be generated that require additional treatment. In Type 1 fire regimes, where the fuel profile now supports a higher than normal fire intensity, harvesting followed by prescribed fire will often be the best combination to bring the fuel profiles back to their range of natural variation. With low and moderate severity prescribed fire at the proper stage of stand development, a desired condition can be maintained. It is important to note that modification of Type 2 regime fuel profiles must be in accordance with the extent of fires that naturally occurred there, i.e., stand-replacement fires.

Alternatives A, C, and I present opportunities for treatment through harvesting. Suitable acreage provides many options for fuel profile modification. Alternatives E and H, on the other hand, virtually eliminate options for modification through harvesting.

EFFECTS ON FIRE FROM INSECTS AND DISEASE

The relationship between fire and insects/disease is not fully understood. Infestations alter the fuel profile through a series of vegetation changes. First, dead (red) needles still attached to the standing tree provide highly available aerial fuels to the fuel profile. After the needles fall, the snag does not significantly add to fire spread but is dangerous to firefighters. While re-establishing younger vegetation in the forest stand, the area is somewhat nonflammable.

As the snags age, they become part of the surface fuel layer and may increase a fire's intensity enough to carry fire into the canopy of the regeneration. At this point, the cost and effort of suppression will rise when suppression activities call for control. The resulting heat flux received by the soil also may have a deleterious effect on soil composition and structure. Regardless of the detrimental effects, insects and disease have played a positive role in ecosystem health and integrity. In locations where increased fire intensity does not threaten cultural or natural values, these fuel profile changes may be acceptable.

In the *Forest Plan*, the ecological effects of insects and disease are being recognized as viable disturbance agents. Where their disturbance has affected the forest structure and composition along a course toward the desired conditions, prescribed fire may not be necessary.

Effects On Fire From The National Forest/Residential Intermix

Greater amounts of National Forest/residential intermix create more values at risk. Consequently, the appropriate suppression response in the intermix is usually direct control. Opportunities for prescribed fire will be limited, or at least require increased cost and effort. Either way, forest stands will become more flammable if left undisturbed.

An equally important consideration is the movement of human-caused fires from the intermix into the Forest. If forested areas are disturbed at a rate higher than the range of natural variation, the elimination of some native species and invasion by exotic species may result.

Social, cultural, and ecological values in the Forest interior could also be at risk, depending on the fire's location.

The National Forest/residential intermix will require creation and maintenance of defensible fuel profile zones (DFPZs). DFPZs must be strategically placed to enable the implementation of wildland fire management strategies. Either biological or mechanical vegetation treatment must occur prior to, or instead of, prescribed fire, where values are at risk from high fire intensities due to fuel accumulations. Suppression action will always take place, but the chances of success will decrease without fuel treatment, such as in DFPZs.

All alternatives allocate similar acreages to the intermix management areas, except for Alternatives A and H. Alternative A does not allocate any acres; Alternative H allocates approximately 2.5 times more than the others. However, any increase in actual intermix acres (such as new houses built on previous, private, forested lands adjacent to National Forest lands) will increase wildland Fire management concerns, regardless of acreage designated as National Forest/residential intermix prescription 7.1.

Effects On Fire From Wilderness And Research Natural Areas

Wilderness philosophies embrace fire as an affecting "force of nature" that preserves a natural (pre-European settlement) condition. Research Natural Areas (RNAs) are managed to represent the natural conditions of ecosystems. If natural (lightning) ignitions are managed inappropriately, and fuel profiles become more flammable, there will be a loss of intrinsic and instrumental values in both of these areas when the inevitable fire does occur.

Because of the limited sizes of wildernesses and RNAs, defensible fuel profile zones need to be developed to permit options in managing natural ignitions. Fuel profiles in many areas are out of their RNVs, resulting in probable future fire intensity and severity that is not natural for those systems. These profiles must then be either biologically or mechanically treated, allowing for the natural role of fire in restoring and maintaining natural systems.

The addition of wilderness and RNAs in Alternatives B and H will have the greatest potential to restore natural fire in ecosystems. With this opportunity come additional demands on fire managers to develop site-specific plans, prepare defensible fuel profile zones, and fund implementation. Although not immediate, the outcome will be more systems that are closer to their RNV.

Effects On Fire From Grazing

Graminoids (grasses) and forbs are the primary carriers of surface fire spread in open canopy forest stands and grasslands. If grasses and forbs are overgrazed, fire spread is restricted, resulting in the dominance of species that compete more successfully in fire's absence (e.g., cheatgrass in sagebrush steppe). Forest structure and composition will then change.

While grazing removes some surface fuels like fire, it doesn't generally thin small trees. As a result, even heavily grazed Type 1 fire regime forests may become dense and more flammable over time. Grazing has very little effect in the Type 2 regime because there are fewer understory plants (or fuels) suitable to be grazed. Management coordination between prescribed fire and grazing can insure sufficient surface fuels to permit fire spread.

Alternatives A, C, and I will continue the current level of grazing with the possibility of increasing grazing levels by restocking vacant allotments. Alternatives B and E continue the same level of grazing without possibility of a grazing level increase. Alternative H will decrease 9,002 AUMs from the current and proposed 17,202 AUMs in the other alternatives.

Effects On Fire From Travel Management

An increase in roads theoretically should imply easier access to fires, where desired conditions are for commodity protection. Also, roads often provide a corridor that, in part, serves as a defensible fuel profile zone and/or perimeter for a prescribed fire. Alternatives A, C, E, and I all indicate additional and/or maintained road systems. Alternative H, with fewer roads, suggests longer response times by fire suppression engines. Without available air support, the acreage of a wildfire, as well as the cost of natural and prescribed fires, will increase.

More roads could also imply more human-caused ignitions and possibly a greater likelihood of increased values at risk, such as campgrounds and resorts.