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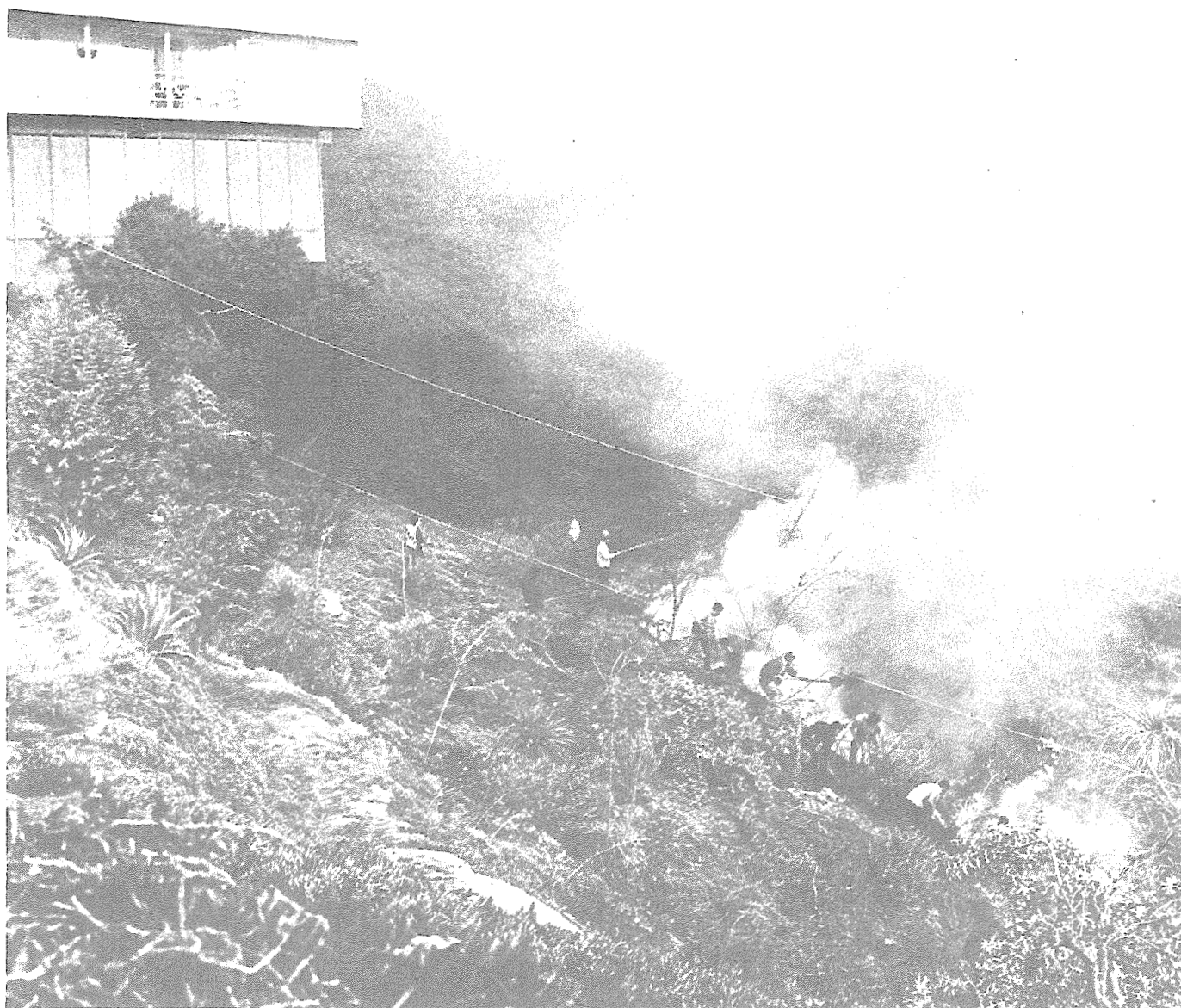
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Protecting Residences From Wildfires: a guide for homeowners, lawmakers, and planners

Howard E. Moore



Author:

HOWARD E. MOORE was Deputy State Forester of the California Department of Forestry before his retirement in 1974. He is now a fire protection consultant at Davis, Calif. He earned a B.S. degree in forestry (1948) at the University of California, Berkeley, and an M.A. degree in government (1974) at California State University, Sacramento. He joined the California Department of Forestry in 1948. This report was prepared for the Station under contract 40-9AD6-8-1083.

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This guide, based on a literature review and personal contacts, offers recommendations and standards for procedures in reducing losses of residences from wildfires. Possible solutions to the problem of fire protection are discussed in the broad areas of land-use planning and zoning, property development, structural design and construction, landscaping, accessories, occupant activities, and financial incentives. The problem of reducing fire losses in undeveloped areas is also discussed and solutions proposed. The guide is intended for homeowners, lawmakers, and members of the building, planning, and financial communities.

Retrieval Terms: fire prevention (structures), fire hazard reduction, water supply (residential), urban-wildland fire interface, insurance, construction materials (buildings)

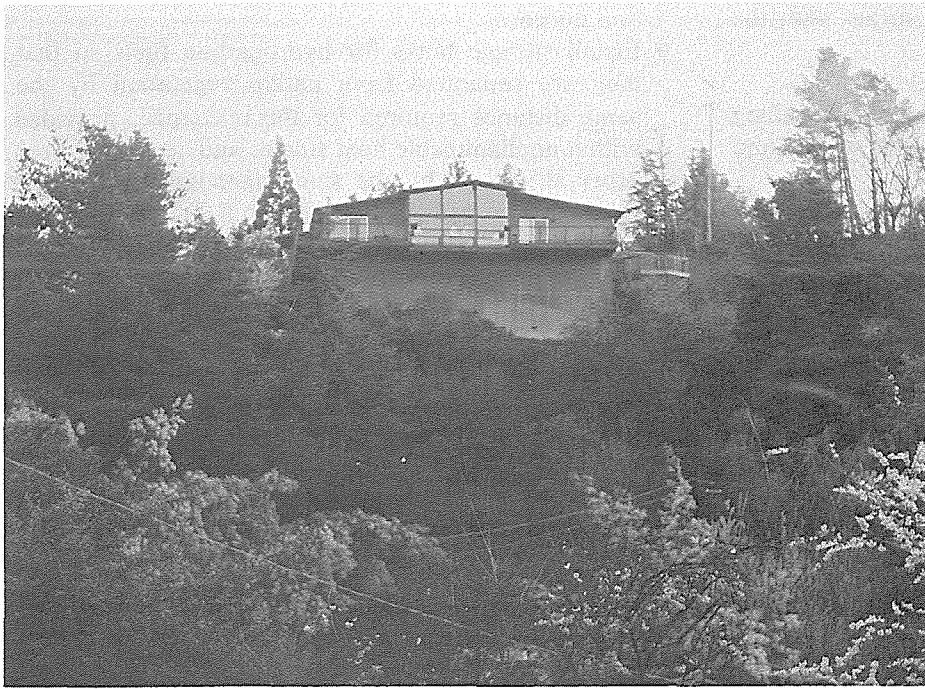
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RECOMMENDATIONS

- Zone for its relative fire hazard severity all land, whether in a city or unincorporated area, that is not already developed for residential, commercial, industrial, or cultivated agricultural use, in addition to land-use or other zoning.
- Require by law that general and specific plans contain an evaluation of fire protection problems and a delineation of the means to cope with them.
- Require all cities and counties having any areas of undeveloped wildlands within their boundaries to review their ordinances on planning, land use, building, and fire for the purpose of making them truly effective in reducing the danger of destruction of residences and other structures by wildland fire.
- Impose standards of building spacing and density for wildfire hazardous areas by local ordinances. Base such standards on a classification system related to vegetative fuels, topography, and known weather patterns.
- Prior to development of any project intended for human occupancy in wildland areas—whether the development be conventional subdivision, planned unit, cluster, lot split, commercial, or industrial—provide two or more access routes adequate to allow two-way travel over roads that are not blocked by the fire or the results of the fire (e.g., fallen trees or powerlines, vehicle wrecks).
- Authorize permit-granting agencies to require developers, before they build any structures in wildlands, to provide adequate water supplies and the means of delivering them to protect such structures.
- Incorporate perimeter protection from wildland fires into the design of every new subdivision and mobile home park developed in wildland areas.
- Install electric power distribution circuits underground in wildland areas.
- Mark every road at each intersection and identify every land parcel or home in wildfire hazardous areas, in a manner clearly visible from a public road by names or numbers.
- Dedicate structural fire station sites before approving plans for any large, expensive, or high-occupant density development in a wildland area.
- Require all buildings located in wildfire hazardous areas to have roofs with a fire-retardancy commensurate with the hazard classification.
- Cover all exterior attic and underfloor vents with screens that are adequate to prevent the entrance of flammables and firebrands.
- Design all homes and other structures to be located in or near wildfire hazardous areas with as few overhangs and projections as possible and where they are unavoidable protect them from ignition through heat and flame entrapment.
- Design, orient, manufacture, and install all glazed openings, especially large picture windows and sliding glass doors, in a way that minimizes the opportunity for interior ignition from external sources.

- In all structures that may be exposed to danger from wildland conflagrations, construct the exterior walls using fire-resistant material commensurate with the degree of hazard involved.
- Do not install permanent roof sprinklers.
- Design and equip all structures—especially dwelling units—to provide occupants warning of a fire and ready escape routes.
- Design, build, and install mobile homes with the same regard for fire safety as used in any other residence.
- Clear and bottom-prune all native vegetation (except for isolated specimen plants) in chaparral and other wildland areas for a distance from each structure appropriate to the fire hazard severity class and slope class of the site.
- Plant and maintain with fire retardant or low-fuel-volume plants all areas cleared of native vegetation for fire protection purposes, if such areas are not maintained free of flammables (e.g., paved areas).
- Irrigate landscaping plants at least until they become well established, but do not irrigate native vegetation.
- Consider the use of selective herbicides to achieve specific purposes in fire protection landscaping to be both desirable and legitimate.
- Explore the feasibility and economics of fire-retardant chemicals used on surrounding vegetation, native or planted, for home fire protection in wildfire hazardous areas.
- Maintain roofs in a fire safe manner (i.e., clean and made of fire-retardant materials).
- Maintain all yards, gardens, landscaped areas, and fire protection clearances so as to retain their fire safe qualities.
- Do not store uncovered flammable materials against the exterior wall of any building nor close enough to it to cause ignition of the structure by radiated or convective heat should the materials burn.
- Install and equip every swimming pool or other significant water source in wildfire hazardous areas such that the water may be obtained quickly and easily for firefighting purposes both by fire engines and by the occupant.
- Design, construct, and maintain fences so that they do not help wildland fires spread—especially to structures.
- Build and maintain outbuildings to the same standards of fire safety as the residence or other main structure with which they are associated.
- Design and install patios, sun decks, and balconies in ways that enhance the fire safety of the building to which they are an accessory.
- Install private water systems in a way to provide adequate, dependable source of water for fire protection purposes.
- Install storage tanks for hydrocarbon fuels so that they are separated from native vegetation by the same distance required for the residence, provided with a nonflammable heat shield, and separated from other structures by the same distance required for structures.
- Prepare and test a plan for protecting property from fire and have on hand the tools and equipment needed for such an emergency.
- Take special precautionary measures to protect property from fire during very high and extreme fire weather conditions, whether an actual fire is in progress or not.
- When a wildfire becomes a threat to a home or other structure in or near wildlands the occupants should take final protective actions and evacuate all who cannot make a positive contribution to a firefighting effort.
- Establish fire insurance rates for structures located in or near wildfire hazardous areas to reflect the actual probability of destruction by conflagration.
- Adjust the interest rates and other conditions for all real estate or development loans in hazardous wildfire areas so as to encourage fire-safe design and construction.
- Provide tax incentives to persons who meet or exceed minimum fire-safe standards, and apply tax penalties to those who fail to conform to standards.
- Treat and continuously manage vegetation fuels on all wildlands that may become fire threats so as to reduce the conflagration hazard and facilitate fire control.
- Encourage the legislative bodies of states, counties, and cities to conduct a critical review of their laws and regulations relating to wildland fire protection and, on the basis of such reviews, adopt new measures that will provide reasonable fire safety and resolve conflicts of law with other public safety and environmental protection measures.
- Establish fire defense systems in advance on all undeveloped wildlands so located as to pose a fire threat to areas developed for human use and occupancy.
- Enlist the aid of property owners and others with vested interests in homes and other structures located in or near wildland areas, both as individuals and through their organizations and associations, in seeking ways to participate in and improve the Red Flag Fire Alert System.



Each year, wildfires burn hundreds of homes and other structures in or adjacent to forests and rangelands. And even before the last flames have flickered out, some owners begin thinking about rebuilding homes on the very sites scorched by fire. This situation is not new or confined to a particular area; nor are the proposed remedies new or applicable only to a particular area.

Southern California epitomizes the problem of protecting homes from recurring wildfires. Several conditions contribute to a fire protection problem that is as severe as to be found anywhere. Vegetation, ranging from heavy stands of grass to brush to hardwoods or conifers, thrives in the Mediterranean climate there. Other conditions contributing to the high fire hazard are the large population, mountainous topography, and an increasingly affluent, mobile society encroaching into wildlands.

These same conditions are found in other regions that enjoy the Mediterranean climate—parts of Europe, Australia, Chile, and South Africa. The vegetation produced and the resulting fire protection problem are not greatly different from those found in California.

Much has been written about what can be done to remedy the problem, but few recommendations have been implemented. Many studies merely duplicate work done previously. To bring all of the pertinent information together, I reviewed the extensive literature on fire protection, and made personal contacts to obtain or confirm sources or both.

This report summarizes information on procedures for reducing losses of residences and other structures from wildfires. It outlines the problem of protecting homes from such fires, and proposes recommendations and standards. The Proposed Standards are proposals for the technically best solutions. Worded in advisory

language, these standards must be reworded into mandatory language when enacted into laws, ordinances, or other requirements.

The findings in this report apply not only to residences but to commercial, industrial, and recreational developments. Many building and fire codes now require fire-resistant construction for such developments. Few codes, however, address the problem of wind-driven fires crossing broad expanses of wildland fuels.

Responsibility for fire protection cannot be relegated to a single element of society. It calls for the combined efforts of government agencies and the private sector (*fig. 1*). More than anything else, it requires the concerted efforts of homeowners and occupants. This guide is designed to help owners, occupants, lawmakers, planners, architects, builders, bankers, insurers, and financiers meet that responsibility.

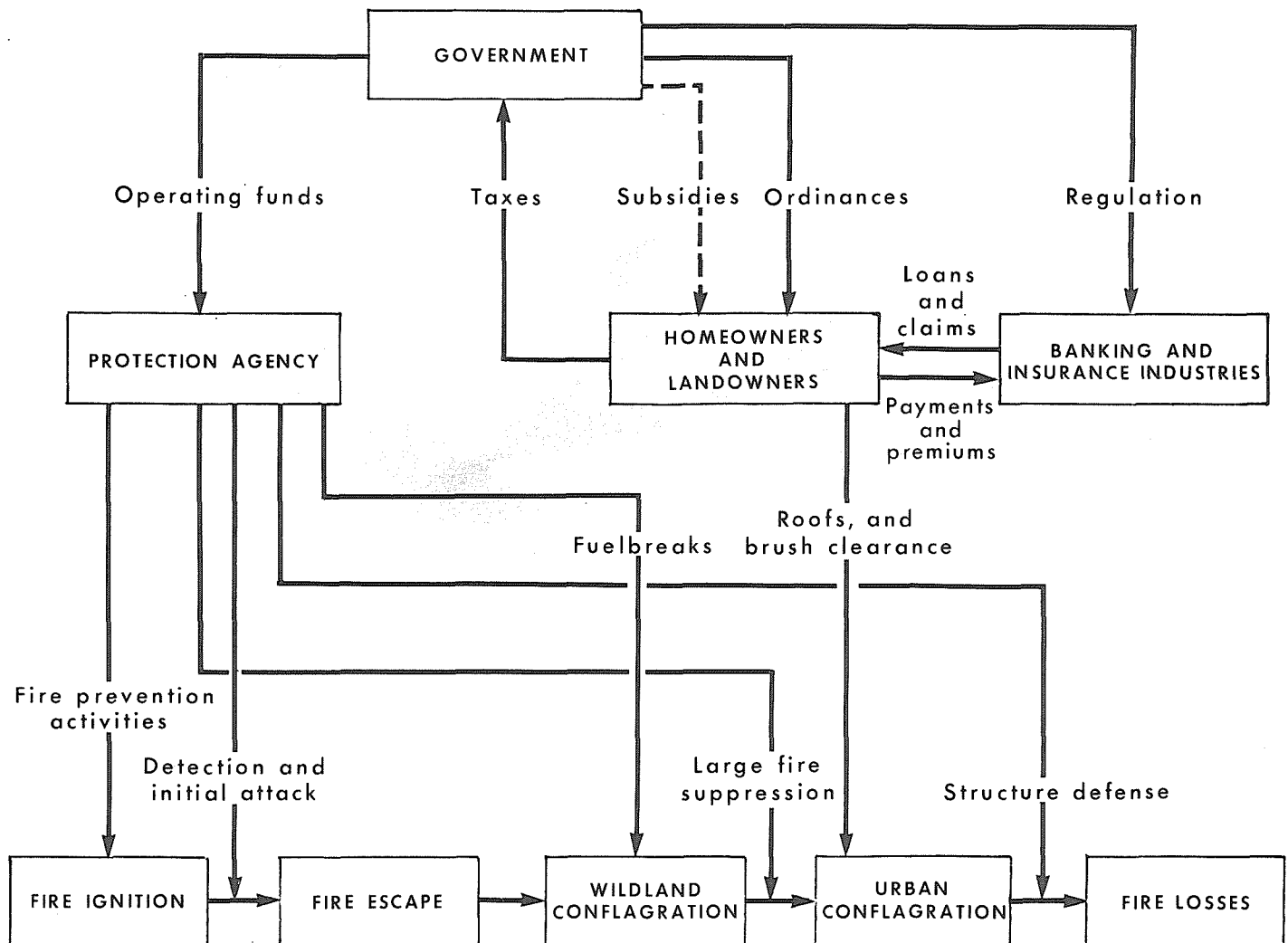


Figure 1—Parties in wildland fire protection include government agencies, homeowners, landowners, and industry. The protection proc-

ess at the urban/wildland interface includes fire prevention, fire suppression, and structure defense (Howard and others 1973).



NATURE OF THE PROBLEM

Residential Developments

Because of the congestion and pollution of major metropolitan areas, subdivisions, individual homes, and mobile home parks continue to proliferate year after year. Many are in or close to wildland fuels, subjecting them to the danger of being burned (Harvey 1974; Hulbert 1972; Orange County Bd. Sup. 1976; Oreg. St. Dep. For. 1978a). This development has usually proceeded faster than has the enactment of effective laws and ordinances to alleviate the problem. Because of financial, social and political pressures, even those efforts previously made to require firesafe construction and occupancy have been only partially enforced, and, therefore largely ineffective (Hulburt 1972).

Within commuting distance (40 to 60 miles) of metropolitan areas, development most often takes the form of relatively expensive residences on medium-to-large lots. Unless prohibited by well designed and effectively enforced ordinances, developers tend to leave as much native vegetation as possible to maintain and promote the rural effect that the buyers seek. Similarly, developers usually provide wood shingle or shake roofs, picture windows, and sun decks. Water and other utilities are usually provided only in amounts adequate for normal use unless fire codes are strictly enforced. Because of high land values, road rights-of-way tend to be narrow and, if in mountainous areas, steep. In such circumstances, residents often have only one route of ingress and egress (Orange County Bd. Sup. 1976; Los Angeles County 1973).

In addition to suburban subdivisions, hundreds of thousands of residences and their outbuildings have been built in the past few years beyond practical commuting range from cities. Such buildings can be found in any of several arrangements. One is the rural subdivision composed of second (weekend or vacation) and/or retirement homes. Except for location and the inclusion of some recreation and light commercial development, these subdivisions appear similar and present fire problems similar to those posed by suburban subdivisions.

Although fewer than those in subdivisions, the structures that individually cause the greatest fire protection problems are ones built by or for their occupants on individual parcels of land, each usually with its own water system. The most dangerous of these problems result from so-called lot splitting. Lot splits tend to create densities approaching those of subdivisions without any of the inherent advantages of subdivisions (e.g., access to a public thoroughfare, water system, refuse disposal, sewage system). All individually developed residences, whether on large farms or small parcels of land, are difficult to protect from fire. Their water supply is seldom adequate. Access is usually long, narrow, and slow. Electric power, if available, is subject to interruption, often by the fire itself.

A relatively new structural fire problem is the mobile home, which presents all the fire problems of the conventional home and several more. Because the structure itself is more susceptible to flash fire, occupants find it more difficult to escape. If the structure is not fitted with adequate skirting, wildfire will run quickly under

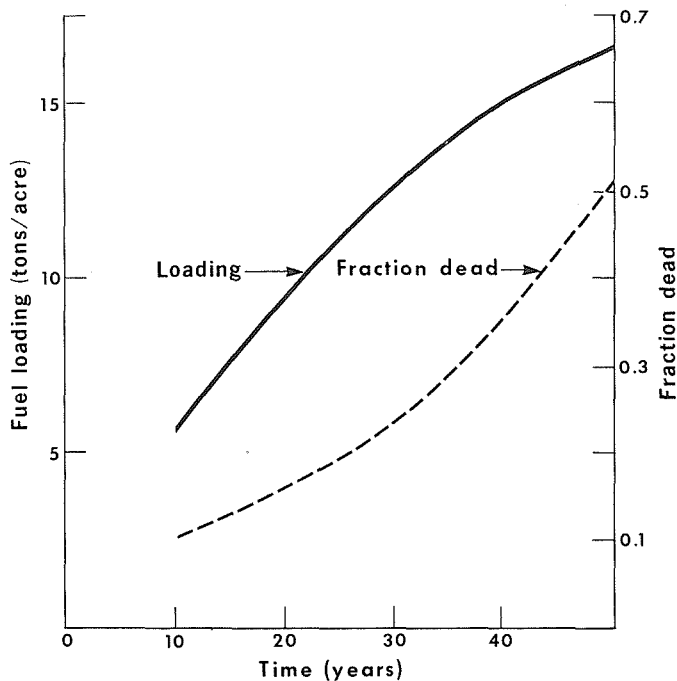


Figure 2 — Total fuel loading and fraction of dead material both increase as chamise ages (Philpot 1974).

the floor. A mobile home is easier than a conventional house to set up with little or no clearing of native vegetation. And when it is placed in a mobile home park, the spacing between structures normally is insufficient to prevent a fire from spreading by radiation or convection (Los Angeles County Fire Dep. 1970; Org. St. Dep. For. 1978a).

Fire Hazards and Risks

Fire hazards are those elements in the combustion process that actually burn or that cause the fire to burn faster or hotter than normal. Fire risks are those factors that cause fires to be ignited. To protect residences and other structures from damage by wildland fire, both fire hazards and fire risks must be understood and dealt with. Fire hazards fall into three broad categories: fuels, weather, and topography. Fuels, in turn, are composed of two types: vegetation and structures.

Composed of cellulosic materials, all vegetation is flammable to some degree. Some types (e.g., chaparral) are much more flammable than others (e.g., irrigated landscaping plants). All vegetation is more flammable at certain times than at others. Vegetation in its wild state consists of both living and dead materials. The dead materials and the fine living materials (leaves or needles and twigs) represent the bulk of the "available" wildland fuel. *Figure 2* shows how fuels increase with time. In timber stands and heavy brush fields, this available

fuel may reach 50 tons per acre. In areas of 1- to 2-year-old logging slash, fuel loading may run up to 200 tons per acre. When hundreds or thousands of acres of such volumes of fuel are burned in short periods of time—as often happens under conflagration conditions—the amount of heat and energy released approaches that of an atomic bomb. Flame lengths can exceed 100 feet. Radiated heat can ignite exposed flammable materials at distances of 100 or more feet. Convection columns carrying flaming leaves and other fire brands often extend many thousands of feet into the atmosphere and have been known to drop such firebrands several miles downwind. Thousands of homes can be exposed to these conditions (Task Force on California's Wildland Fire Probl. 1972, Helm and others 1973, Nord and Countryman 1972).

Of particular concern is the wildland fuel known as chaparral, because so much of it is in or near metropolitan areas. Chaparral also represents an unusually dangerous fire hazard because of its inherent qualities. As a "fire climax plant community," chaparral has for thousands of years not only survived repeated fires but has adapted itself to depend on fire for regeneration and survival. Thus wherever chaparral exists large-scale fire can be predicted with great certainty to occur sooner or later, and the longer between fires the larger they are (*fig. 3*). In southern California, the average time between fires in any given area (cycle time) is about 30 years (Hanes 1974, Nord and Countryman 1972, Philpot 1974, Wright 1972).

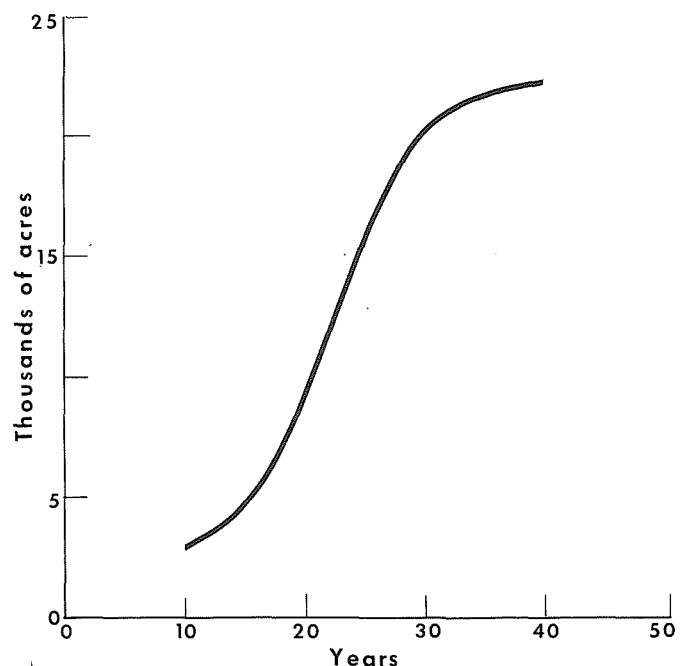


Figure 3 — A wildfire increases in size as the age of chamise increases (Philpot 1974).

Structures built in wildlands can also be hazardous fuel. They are mostly of wood frame construction, often with wood siding. Wood shingle or shake roofs are common, particularly in suburban and rural subdivisions. Attic and floor vents are often left unscreened. Picture windows and stilt or cantilever balconies facing directly into or over heavy wildland fuels are common. Many roofs and rain gutters hold large quantities of dry leaves or needles. Dooryards often are not kept clear of flammable vegetation. Any or all of these qualities contribute to make these structures one of the most hazardous fuels in the urban, suburban, rural or wildland setting (Alger 1971, Task Force on California's Wildland Fire Probl. 1972).

Weather, or more specifically "fire weather," can properly be termed a fire hazard because it aids ignition and accelerates combustion. Almost all conflagrations have occurred during periods of extreme fire weather. We can do little about the weather except to understand it and its interactions with the other hazards. Yet weather is at least as important as fuels in the urban/wildland interface fire problem.

The weather elements responsible for very high or extreme fire danger are strong winds, high temperatures, low humidities, and low fuel moisture contents. This combination can happen, and has, at almost any time of the year, including the middle of winter. In areas with Mediterranean climates, such as most of California, extreme fire weather is actually quite common during late summer and fall, and should be expected to be present one or more times at any point in the State during the period from mid-June to mid-November (Alger 1971, Task Force on California's Wildland Fire Probl. 1972, Deeming and others 1977, Phillips 1971).

By far the most critical factor in fire weather is wind. A study of fires 5000 acres or larger during the period 1961-70 revealed that at the time of start of 66 fires for which weather records were available, the average wind speed was about 30 mph; in some it went as high as 75

mph (Los Angeles County Fire Dep. 1970, Task Force on California's Wildland Fire Probl. 1972).

The most dangerous wind is the foehn (subsidence) wind, the most notorious being the Santa Ana of southern California (*table 1*). In other parts of the world this wind is known by other local names, such as mono, north wind, mistral, chinook, tramontana, and williwaw. The foehn wind produces the usual effects of winds: fanning and supplying oxygen, preheating fuels by bending flames from the vertical, and carrying burning firebrands ahead of the fire front. But it also brings dry air from continental high pressure areas, then heats and dries it further by compression as it flows to lower elevations at a velocity of up to 100 mph (Alger 1971, Orange County Bd. Sup. 1976, Task Force on California's Wildland Fire Probl. 1972, Phillips 1971).

High temperatures bring the fuels, both vegetative and structural, closer to their ignition temperatures. Low humidities dry the moisture from the fuels. Low fuel moistures, by reducing the amount of heat used in vaporizing moisture, reduce the total amount of heat needed to raise the fuel to ignition temperature. Even green fuels, particularly chaparral, can have remarkably low moisture contents after long dry summers or under adverse fire weather conditions (Deeming and others 1977, Hanes 1974, Nord and Countryman 1972, Philpot 1974, Wright 1972).

The third major hazard contributing to wildland and structural fire danger is mountainous topography. Although it increases the costs of construction and development, such topography attracts thousands of homeowners with its feeling of openness, an attractive view, and the possibility of getting above or away from the smog. Sidehill construction often makes structures more ignitable (e.g., stilts, cantilevers). Topography affects fires in some of the same ways that wind does as well as modifying, and often intensifying, the effects of the wind. Generally fires run faster uphill than down. Higher elevation fuels (e.g., houses on ridgetops) are preheated by flames and convection columns even in the absence of wind. Canyons act as chimneys trapping heat and intensifying combustion. Canyons, saddles and ridgelines deflect, and often intensify, winds. Thus the mouths of canyons on the lee side of main ridges often become raging infernos during a Santa Ana. Roadbuilding is difficult and expensive in mountainous terrain, often making ingress for firefighting manpower and equipment and egress for residents slow and difficult.¹

The fire risks involved in the structural/wildland fire problem are almost all man-caused. In the populated portions of California, 90 percent or more of the fires

Table 1—Santa Ana frequency and duration by month in southern California, 1951-60

Month	Frequency	Average duration (days)
September	11	4.4
October	19	4.5
November	26	5.0
December	18	3.7
January	7	1.7
February	10	1.9
March	17	2.5
April	8	1.8
May	7	1.4
June	4	4.5
July	2	2.5
August	0	0

Source: Countryman (1974).

¹Alger 1971, Task Force on California's Wildland Fire Probl. 1972, Deeming and others 1977, Hanes 1974, Helm and others 1973, Los Angeles County Fire Dep. 1970, Orange County Bd. Sup. 1976, Philpot 1974.

involving vegetation are caused either by people directly or by their developments (e.g., arson, various types of machines, power lines); only 4.2 percent of the conflagration fires are caused by lightning. The mere acts of developing, constructing and occupying structures in formerly wildland areas, therefore, expose both the wildlands and the structures to increased risk of destruction by fire (Alger 1971, Task Force on California's Wildland Fire Probl. 1972, Moore 1977).

The risk of structural ignition during wildland fires comes from any of three sources: direct exposure to flame, radiated heat, or firebrands carried by winds or convection columns or both. The first two of these sources can be fairly easily guarded against by proper clearance of native vegetation, landscaping, and maintenance. The last (most common) is much more complex and requires a combination of defenses, including all those described in the chapters on Land-Use Planning and Zoning; Property Development; Structural Design and Construction; Maintenance; and Undeveloped Areas. The most usual structural fuel bed for ignition by these flying firebrands, which are often carried from one-quarter mile to 2 miles ahead of the fire front, is the roof. Therefore, roofing materials and cleanliness are of prime importance as protective measures (Alger 1971, Los Angeles County Fire Dep. 1970, Orange County Bd. Sup. 1976, Task Force on California's Wildland Fire Probl. 1972, Helm and others 1973).

Fire Suppression Difficulty, Costs, and Limitations

The owners of structures in or near wildland fuels cannot depend on the fire suppression efforts of public agencies to protect their buildings from destruction. The use of tax funds to pay for enough firefighters and equipment to contain every fire that starts on the few days of very high and extreme fire weather conditions is both economically and politically infeasible. It is, in fact, also physically impossible under typical conflagration conditions of very strong, hot, dry winds. Therefore, each owner or resident must assume his or her share of the responsibility for preventive measures (Alger 1971, Los Angeles City-County Fire Bd. Inquiry 1971, Green 1977, Howard and others 1973).

Firefighting is at best one of the most hazardous activities of man. Under conflagration conditions, the risks of entrapment, asphyxiation, heat exhaustion, falling, and other injuries become so great that chief officers and other leaders will usually not allow their men to be at the head of the fire. Also under these conditions smoke and air turbulence often preclude the use of air tankers or helicopters. The only effective perimeter control, therefore, is on the flanks of the fire until it reaches some barrier or the weather changes (Los

Angeles County Fire Dep. 1970, Los Angeles City-County Fire Bd. Inquiry 1971, Howard and others 1973).

The strategy of wildland fire control requires perimeter control, containment of spread, and eventual extinguishment. Due to the scarcity of water, the tactics of wildland fire control usually consist of constructing fire lines, either by hand or with machines, burning out prepared or preexisting control lines, cooling limited areas by air drops of fire retardants, and similar measures. Such work cannot be carried out safely or effectively on steep hillsides or in close proximity to a high intensity fire in heavy fuels. It must usually be done at some natural or artificial barrier, e.g., a ridgetop or interstate freeway. If the wind is very strong, even these barriers often will not hold because of spot fires caused by flying firebrands (Alger 1971, Los Angeles County Fire Dep. 1970, Los Angeles City-County Bd. Inquiry 1971, Howard and others 1973). Consequently wildland fire control is basically incompatible with the aim of protecting structures.

Most wildland fire protection agencies consider their primary statutory mission to be resource protection, and have budgeted accordingly. In spite of this limitation, wildland firefighters normally react to human moral values when faced with a choice of either saving life or improved property, or saving several hundred acres of brush or timber. Therefore, even though their equipment and training are often poorly designed for structural firefighting and adequate water is usually lacking, firefighters tend to let the fire spread while they do the best they can to save lives and structures (Alger 1971, Los Angeles County Fire Dep. 1970, Oreg. St. Dep. For. 1978b).

Mountainous terrain complicates fire suppression in several ways. The combined effects often make it impossible to save houses from burning during major wildland conflagrations, and, as discussed earlier, steep slopes, canyons and ridges complicate and intensify the effects of wind. Even in the absence of wind, fires race much faster up a steep slope than they do on the level. It is difficult, slow and dangerous to fight fire on steep, rocky side hills. The combined effects of terrain and wind often create smoke and air turbulence conditions which preclude the use of aircraft. Mountain roads make access and response time slow and difficult for firefighters and for heavy fire trucks and other equipment. Sometimes access becomes impossible when roads are blocked by debris, other vehicles, or the fire itself or if construction of the roads themselves has made them too steep or with curves too tight to be traversed by fire engines or bulldozer transports (Alger 1971, Los Angeles County Fire Dep. 1970, Green 1977, Howard and others 1973).

The control of major wildland fires, usually involving structures, is further complicated by the communication and coordination problems inherent when the fire is being fought by multiple agencies, which is usual for

two reasons. First, wildland fires do not respect political, jurisdictional, administrative, or ownership boundaries. A fire of any appreciable size will usually spread from the protection jurisdiction of one agency to those of several other agencies. Secondly, no single agency, even the largest, has the resources to handle a major conflagration alone. Aid from other agencies, often from considerable distance, must be called in. As a result, differences in training, equipment, and radio channels regularly exist. The effects of these differences are usually minimized before a fire through joint planning and coordination between adjoining agencies. But if agencies are responding from a distance in emergency situations, coordination of the efforts can be a serious problem (Alger 1971, Los Angeles County Fire Dep. 1970, Los Angeles City-County Fire Bd. Inquiry 1971, Oreg. St. Dep. For. 1978b, Lowden and Degenkolb 1972).

The fire protection available to structures in mountainous areas in or near rural or wildland fuels is often limited in certain other ways not usual for similar structures located in cities. Federal and State wildland fire protection agencies are funded only during the wildland fire season. At other times of the year, manpower is sharply reduced, outlying stations are closed, and 24-hour service is terminated. In some areas, a local agency (county or fire district) can make up this deficiency by entering into a contract with the State for firefighting services. Other areas receive structural protection from low-budget volunteer fire departments funded by counties, fire districts, or informal donations from private citizens. Their equipment may be old, training inadequate, and response time excessive. Even when professionally manned and well equipped, county

or district fire departments generally have longer response times than do city departments and water is not as easily available. Thus the fire protection for structures in rural and wildland areas is at a somewhat lower standard (Alger 1971, Oreg. St. Dep. For. 1978b).

Floods and Erosion

Burning is not the only way in which a residence may be damaged or destroyed by wildland conflagration. A fire, particularly a large one, anywhere upslope from the structure is likely to produce flood or erosion damage or both when the next rains come. For houses near the bottoms or mouths of canyons or those perched on or directly under very steep slopes or fills, this danger may be even greater than that of direct fire damage. Of course, the opposite is true of structures located on ridges or high on slopes.²

That hillside soil bared to the elements by fire is susceptible to accelerated erosion is rather self-evident and has been noted by many researchers and fire officials. What is not so widely known is that many soil types are made hydrophobic (water-repellent) by fire. The overland flow of water during rainstorms is increased by 10 to 40 times the normal (unburned) amount because of this phenomenon. This tremendously accelerated runoff not only creates high flood waters, but provides the force needed to move soil, gravel, and boulders

²Calif. Reg., For. Serv. 1971; County Sup. Assoc. Calif. 1966; Houts 1974; Los Angeles County 1973; Los Angeles County Fire Dep. 1970; Rice 1974; Stallings 1970; Zivnaska 1974.



downslope and downstream and to transport channel deposits accumulated largely by dry erosion between fires (Houts 1974, Rice 1974, Zivnaska 1974).

Lack of Single Solution

No single solution to the fire protection problem can be proposed. Because so many hazards, risks and com-

plicating factors are involved, a combination of remedies is required to achieve any reasonable degree of fire safety for structures in or near wildland areas. Some of the potential problems should be solved long before any structures are built. Other corrective measures should be adopted during the development and construction phases. Still others must be practiced continuously or intermittently so long as the structure remains in existence.

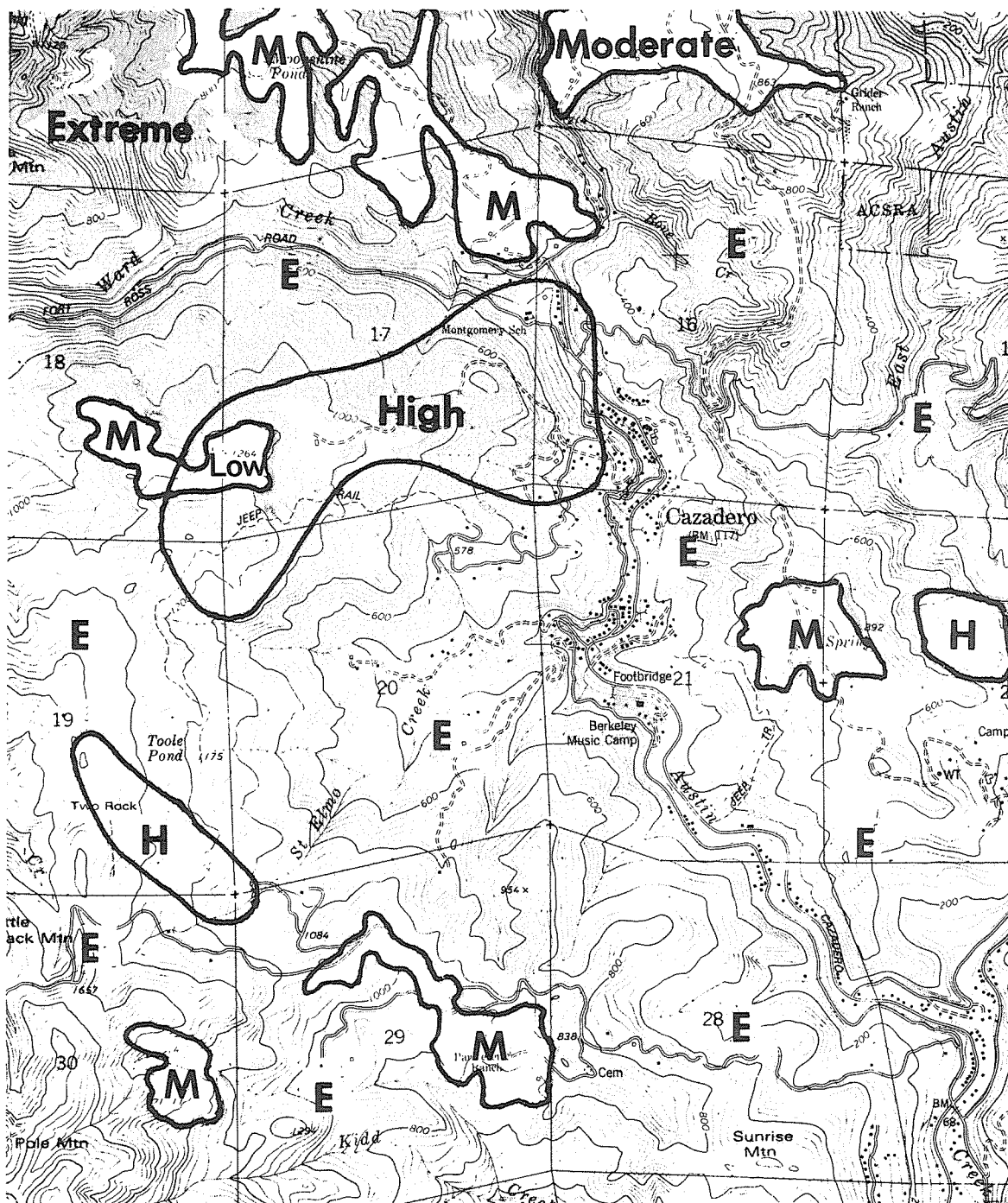


Figure 4 — The severity of fire hazard in an area can be classified and mapped.

LAND-USE PLANNING AND ZONING

Land-use planning and zoning are governmental functions critical to public safety—including fire protection. But because these functions are political as well, they are subject to intense differences of opinion and to public controversy. Therefore, they tend to lag behind development until the problem becomes aggravated, much in the fashion of the traffic light that is installed only after eight or ten deaths have occurred at the intersection. Being political they are also subject, even after enactment into law, to pressures for variances and modifications. Therefore, they are seldom as effective as fire protection personnel would like to see them. With few exceptions, they cannot be made retroactive and, consequently, older developments are not much affected by them. Where land-use planning and zoning have been enforced, however, they have achieved significant degrees of fire safety (Oreg. St. Dep. For. 1978b, San Bernardino County Bd. Sup. 1974).

Fire Hazard Severity Classification

Fire hazards are relative and range from the base level hazard found in any urban area to the extreme hazard found amid heavy chaparral on a steep side hill in an area where extreme fire weather commonly occurs (fig. 4), such as southern California. Some counties where the problem was recognized early (as long as 40 years ago) have taken the simplistic in-or-out approach to wildland fire hazard zoning. Those which have entered the field recently (in the past 5 years) have tended to employ two or three hazard levels in their zoning (Orange County Bd. Sup. 1976, Los Angeles County 1937, San Bernardino County Bd. Sup. 1974, Helm and others 1973).

Probably the best approach to fire hazard classification or zoning from the standpoints of both technically correct theory and practical application by local planning department staffs is that developed in 1973 by the California Department of Forestry. It rates fire hazard based on three weighted values each of fuels, weather, and topography (table 2). In light of more recent information (Deeming and others 1977) the limits and factor weights may be revised, and whether a "low" or "base level" fire hazard classification should be recognized at the lowest levels of all factors in the table should be explored. Still the factors used and the approach to

combining and analyzing them are sound. Technically it might be more correct to use up to 20 fuel types and five slope classes as recognized by the National Fire Danger Rating System (Deeming and others 1977) but this would unnecessarily complicate analysis and mapping.

In any event, this system or a modification of it can identify those areas which present varying degrees of fire hazard, including those so hazardous that no construction or development should be allowed. It can also indicate which areas can be made reasonably safe through the application of various levels of design, construction, and maintenance standards (Orange County Bd. Sup. 1976, Task Force on California's Wildland Fire Probl. 1972, San Bernardino County Bd. Sup. 1974, Helm and others 1973).

Any such system should provide for raising to the next higher level of hazard those limited areas that are in saddles above canyons on the windward side of ridges or at the mouths of canyons on the lee side of main ridges (Los Angeles County Fire Dep. 1970).

Proposed Standards: Establish fire hazard severity zones on the basis of a graded classification system using fuel loading, fire weather, and slope as primary factors. Recognize and map at least two, but preferably three, levels of hazard. Provide for classification in the next higher category of especially hazardous situations, such as saddles on ridges above windward canyons and mouths of lee canyons.

Table 2—Fire hazard rated on three weighted values of weather, fuels, and topography in California wildlands¹

Critical fire weather frequency	I			II			III		
	Slope (pct.)			Slope (pct.)			Slope (pct.)		
Fuel loading:	0-40	41-60	61+	0-40	41-60	61+	0-40	41-60	61+
Light (grass)	M	M	M	M	M	M	M	M	H
Medium (scrub)	M	M	H	H	H	H	E	E	E
Heavy (woods-brushwood)	H	H	H	H	E	E	E	E	E

Source: Helm and others (1973).

¹M = moderate hazard, H = high hazard, E = extreme hazard.

General and Specific Plans

In dealing with wildfire, county or city plans vary greatly between one local government and another. Some plans merely recognize the fact that a fire problem may exist; other plans provide a detailed exposition of the nature and extent of the problem and a timetable for coping with it. General plans are prepared by the planning staff and approved by the planning commission and the governing body of a political subdivision of the State, i.e., county or city. They generally include Land Use, Transportation, Public Safety (which includes fire), and other elements designed to promote orderly growth and development. In California, some elements are mandatory and others optional by State law. One mandatory element is Public Safety, but in the past, there have been no standards to which this element had to be prepared³ (Orange County Bd. Sup. 1976, Oreg. St. Dep. For. 1978b, County Sup. Assoc. Calif. 1966, Task Force on California's Wildland Fire Probl. 1972, San Bernadino County Bd. Sup. 1974).

Proposed Standards: Require that fire protection elements of general and specific plans cover both basic structural protection and protection from wildland fire, that protective measures enumerated in these plans correspond to the level of fire hazard severity found to exist in the area covered by each plan, and that the fire department participate in reviewing plans.

Zoning Ordinances

General plans and the various uniform codes (building, fire, etc.) have no force or effect until adopted by ordinances of local governing bodies (e.g., county boards of supervisors, city councils, fire district boards of directors) and provided with penalty sections (Task Force on California's Wildland Fire Probl. 1972).

In California, general plans including safety elements are mandated to counties and cities by State law (California Government Code Sect. 65300 et seq.). The standards set by the State to which these plans and elements must be prepared, especially those having to do with wildland fire, have been very weak. Consequently, an almost total lack of uniformity exists from one local jurisdiction to another. The governmental units that are larger, most heavily damaged in the past, and more progressive have adopted enabling ordinances containing rather comprehensive requirements relating to fire safety. In contrast, some of the smaller units and those that have not perceived or understood the severity of the problem have treated it in one sentence or one paragraph (Task Force on California's Wildland Fire Probl. 1972).

One important element of the General Plan is the Land-Use Element. It establishes the areas that can be devoted to different uses (e.g., residential, commercial,

manufacturing, agriculture, open space). This element has great potential for enhancing structural fire safety in wildland areas if wildland fire hazard severity classes are accounted for during its development. So far this potential has rarely been considered, and no case has been found where the Land-Use Element of the General Plan was actually implemented in this manner.³

The Uniform Building Code (UBC) published by the International Conference of Building Officials has been adopted by many counties and cities. Others have no such code or ordinance. A major component of the UBC is the establishment of Fire Zones I, II, III. These zones set standards by requiring decreasing degrees of fire safety to be built into structures of various types of occupancy and prohibit certain occupancies in Zones I and II. Zone III generally encompasses residential areas having the lowest (base level) fire danger and requires minimal fire safety construction. In all zones, the standards are designed to provide protection from fires starting within the building or in another one nearby (3 to 20 feet). The problem of fires approaching through large expanses of vegetation is not addressed anywhere in the UBC (Task Force on California's Wildland Fire Probl. 1972, Int. Conf. Build. Off. 1976).

A few jurisdictions that have adopted the UBC by reference in an ordinance have amended it in various ways to attempt to cover the wildland fire problem. Some have added fire zones and incorporated certain restrictions and requirements for structures located in them. Others have declared fire hazardous wildland areas to be in Fire Zone II. In most cases the only effective remedial measure is the requirement of fire-resistive roofing (Build. News, Inc. 1977, County Sup. Assoc. Calif. 1966, San Bernardino County Bd. Sup. 1974).

Proposed Standards: Recognize varying degrees of wildland fire hazard in local ordinances. Establish construction and spacing standards commensurate with each degree, and make such standards applicable to residences and their appurtenant structures as well as to other types of occupancy.

Spacing and Building Density

To provide a reasonable degree of fire safety, building spacing and density must be different in mountainous areas, wildlands, and rural areas than they are in urban areas. This differentiation is needed because the usual source of ignition of the structure in the wildland or rural setting is external while in the more developed city situation it is internal. Exceptions to this general rule do

³Hastings, John H. 1977. Fire safety guides for wildland planners. (Unpublished report on file, Region V, California Department of Forestry, Monterey, Calif.)

occur, but they are relatively rare (Alger 1971, Los Angeles City-County Fire Bd. Inquiry 1971).

The Uniform Building Code (UBC), Uniform Fire Code (UFC), and most subdivision codes are based on two assumptions: an internal ignition and a fire department response time of less than 15 minutes. These are relatively safe assumptions in most cities and some fire districts, but are valid only in very limited areas where fire protection is provided by a county, State, or Federal agency. They are almost totally irrelevant in most mountain and wildland areas where only seasonal resource fire protection is usually available (Alger 1971).

In addition to being subject to external ignition and up to 2-hour response times, structures built on sloping ground are affected by the same fire behavior phenomenon discussed earlier in relation to the wildland fuel. The slope creates an effect similar to that of wind and causes fire to spread faster uphill than downhill or on the level. Buildings situated on slopes should be required, therefore, to be spaced farther apart than similar buildings built on essentially level ground. On excessively steep slopes (more than 55 percent), all wood frame construction probably should be prohibited³ (Los Angeles County Fire Dep. 1970, Oreg. St. Dep. For. 1978b, County Sup. Assoc. Calif. 1966, San Bernadino County Bd. Sup. 1974, Helm and others 1973).

In recent years a new concept in residential development has been adopted in some areas. This is the cluster development in which the population density limitations of general land-use plans are met by placing individual homes or multifamily residences (e.g., duplexes, apartments, condominiums) in small groups on smaller lots than would otherwise be required. The land area thus saved is reserved for community open space. This practice is esthetically pleasing to most people, and can also improve the fire safety in rural or wildland areas as long as certain minimum spacing standards are followed. The space between buildings, for instance, should not be less than half that required between residences in

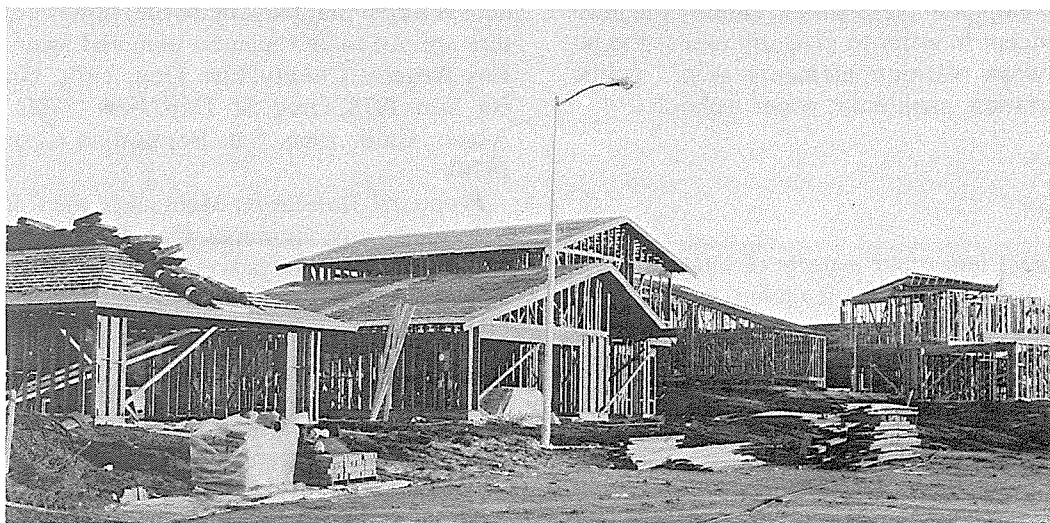
conventional subdivisions in similar areas. And the native vegetation should be modified at least to fuelbreak standards of width and hazard reduction in the spaces between clusters (Task Force on California's Wildland Fire Probl. 1972, Colo. St. For. Serv. 1977).

Because of the close spacing commonly employed in mobile home parks, those situated in wildland fire hazardous areas are particularly susceptible to destruction or serious damage from conflagrations. Required spacing between mobile homes in such parks should be no less than that allowed between buildings in a cluster development in a similar fire hazard classification zone (Los Angeles County Fire Dep. 1970).

Most of the references on structure density and spacing base their recommendations primarily on slope. Only rarely are the other primary factors contributing to wildland conflagrations (i.e., fuels and weather) mentioned, mostly in work done in the late 1970's. The most logical and defensible standard on which to base structure density and spacing requirements is fire hazard severity classification and mapping (Colo. St. For. Serv. 1977, Helm and others 1973).

Proposed Standards: Establish minimum standards of building spacing and density, as shown below. Provide for the imposition of higher standards or the prohibition of building where local conditions (e.g., excessively steep slopes, ridge saddles, canyon mouths) create critical fire hazards:

Hazard class:	Individual buildings		Prop. line setback Feet	Clusters	
	Density	Spacing		Between bldgs.	Between clusters
Moderate	3 per acre	60	30	30	100
High	1 per acre	80	40	40	150
Extreme	1 per 4-5 acres	100	50	50	200





PROPERTY DEVELOPMENT

Only the developer of a property can provide some of the vital means of fire protection, such as access and water supply. It is the developer's responsibility to know about them, and to design them into the project before any structures are erected. But others have related responsibilities. Planning departments should develop and legislative bodies should adopt minimum standards. Planning departments, with advice and assistance from operating departments (e.g., fire, public works, sanitation), should enforce the standards even if they must deny approval of nonconforming proposals. People with financial interests (e.g., bankers, insurers) should satisfy themselves that firesafe features are incorporated in the project before committing their resources. All development plans should employ the master planning concept in order to properly assess the interactions between various elements (e.g., public safety, transportation, sanitation, water, schools).^{3,4}

Access

One of the most important aspects of land development from the fire protection viewpoint is access. It involves a great deal of engineering and expense and is almost impossible to improve or alter after development is complete. If inadequate, access becomes critical dur-

ing a conflagration both from a firefighting standpoint and with regard to life safety³ (Alger 1971, Los Angeles County Fire Dep. 1970, Los Angeles City-County Fire Bd. Inquiry 1971, Oreg. St. Dep. For. 1978a, County Sup. Assoc. Calif. 1966, Colo. St. For. Serv. 1977).

Adequate ingress and egress are necessary to allow safe and rapid passage of both fire equipment and private vehicles in opposite directions simultaneously. But they can be costly not only in the expense of road construction but also in the resulting reduction of saleable lots because they require space. This is particularly true in lot-splitting situations where the original parcel can be divided only into four or less new parcels, thereby reducing the opportunity to spread costs. Adequate access is a cost that must be borne, however, if past disasters are not to be repeated time and again (Alger 1971, Los Angeles County Fire Dep. 1970, Orange County Bd. Sup. 1976, Oreg. St. Dep. For. 1978b, County Sup. Assoc. Calif. 1966, San Bernardino County Bd. Sup. 1974).

Proposed Standards: Meet all of the following standards; deny any variances that do not show positively that they will not adversely affect firefighting and evacuation capabilities:

1. Provide two or more routes of access to a public road, preferably on opposite sides of the development (loop roads with single entry do not meet this standard).
2. Dedicate streets and roads to public use and maintenance. If they are allowed to remain private, provide for their maintenance in perpetuity.

⁴Colo. St. For. Serv. 1977; County Sup. Assoc. Calif. 1966; Los Angeles County Fire Dep. 1970; Orange County Bd. Sup. 1976; Oreg. St. Dep. For. 1978a, 1978b; San Bernardino Bd. Sup. 1974.

3. Set minimum dedicated right-of-way at 60 feet to provide two 12-foot hard surface traffic lanes, two 8-foot parking lanes, and two 10-foot roadside strips wherein fire hazards shall be abated.
4. Base minimum centerline radius of curvature of streets and roads on fire hazard severity classification: moderate—50 feet, high—75 feet, extreme—100 feet. Allow no variance to less than 50-foot radius.
5. Establish road grade based on fire hazard severity classification: moderate—12 percent, high—10 percent, extreme—8 percent. Allow no variance to exceed 200 feet in length or 2 percent above standard, and only on straight line portions of the road.
6. Do not permit any dead-end streets. Allow cul-de-sacs provided they do not exceed these lengths based on fire hazard severity classification: moderate—800 feet, high—700 feet, extreme—600 feet. Require cul-de-sacs to have a turning area at the end of not less than 90-foot diameter.
7. Require bridges to have a minimum load limit of 36,000 lbs. (18 tons), and to not be narrower than the driving portion of the road serving each end.
8. Stipulate that each lot or parcel must have direct access to a road meeting the above standards, such access to be traversable by a modern structural fire engine.
9. Design road and street intersections to be as close to 90 degrees as terrain will permit, for at least 80 feet from intersection centerlines, and in no case allow the angle of such road intersections be less than 45 degrees.
10. Clear the area within 200 feet on each side of the centerline of all roads and maintain it to fuelbreak standards—except for structures.

Water Supply

Water is still the most effective tool for fighting wildland fire when and where it can be obtained in sufficient quantity. It is really the only effective tool for fighting home and most other structural fires. Therefore, a large, dependable source of water above that required for normal daily domestic purposes must be provided for at the time a subdivision (including mobile home park), shopping center, recreation area, or individual homesite is planned and developed³ (Alger 1971, County Sup. Assoc. Calif. 1966, Natl. Fire Prot. Assoc. 1974).

The amount of water reserved for firefighting purposes and the size and type of delivery system provided depend on (a) the degree of wildfire hazard involved (fire hazard severity classification); and (b) the type and location of the occupancy (home or mobile home in a subdivision; farm or other individually developed homesite; multiple such as commercial, recreational, industrial, apartments, etc.). The water requirements

for multiple occupancies are usually stipulated by the insurance carrier or local fire department or both. Although normally based on requirements for fighting an interior fire, they are usually adequate for protecting the building from an encroaching wildland fire as well, because usually these requirements are set quite high to reflect both the financial property risk and the multiple life risk.

Adequate water for firefighting purposes, either by a fire department or by the occupant, has been unavailable and unreliable on many occasions where homes were involved. In some cases, adequate water was available but not developed, as the potential fire problem was not recognized. In other situations the problem was recognized but considered a remote possibility. Sometimes the cost was considered too high. Sometimes a sufficient water supply was not available at any price—and in such a situation, the structure should not have been built. A common cause of water deficiency is the practice of extending or adding on to a subdivision where the water system was adequate for the original development and is adequate for domestic service to the addition but is insufficient to provide fire flows both to the original and to the additional developments.³ (Alger 1971, Los Angeles County Fire Dep. 1970, Orange County Bd. Sup. 1976, County Sup. Assoc. Calif. 1966).

In contrast to normal daily use, consumption of water for firefighting purposes is of relatively short duration but of high volume. Water is also used during emergency conditions when electric power service may well be interrupted. Different engineering, therefore, is required than would be needed for a purely domestic water system. Water supplies for firefighting involve large storage facilities, high-volume mains, and dependable delivery (either gravity or pumps with alternate standby power sources). These facilities should be provided during the development phase as their price skyrockets if they must be added after development and occupancy³ (Orange County Bd. Sup. 1976, Oreg. St. Dep. For. 1978b, County Sup. Assoc. Calif. 1966, Natl. Fire Prot. Assoc. 1974).

Proposed Standards: Adhere to the following standards as they apply to individual projects, and do not permit variances because they would expose both life and property to unacceptable risks:

1. All structural developments regardless of type or location to have a dependable supply of water adequate for both normal daily consumption and emergency fire needs.
2. Where homes or other small buildings are supplied by their own independent water systems, they are to have a minimum storage capacity of 2500 gallons, supply mains of at least 1½-inch diameter, one 1½-inch standpipe conveniently located for fire engine filling, and at least two hose outlets 50 or more feet

from the building in addition to outlets on the exterior of the building.

3. The water systems of commercial, industrial, recreational, and multiple-dwelling (apartment or condominium) developments are to be engineered to meet Standard 1 above and approved by the fire agency having jurisdiction.
4. Subdivisions and mobile home parks are to be provided with 6-inch or larger circulating (loop) mains and storage capacity sufficient to provide the minimum fire flow indicated below for at least 2 hours with a residual pressure of 30 lb/in², and have fire hydrants of at least 6-inch diameter with these maximum spacings:

Hazard class:	Hydrant spacing (ft)	Minimum flow (gal/min)
Moderate	700	500
High	500	750
Extreme	300	1000

5. Any area large enough for helicopter landing and take-off (e.g., school yard, parking lot) is to have at least one hydrant.

Perimeter Protection and Fire Access

The point or line at which the urban/wildland interface is most critical is the edge of the undisturbed native vegetation nearest to the structure. For a farm or other wildland home, this is the edge of the clearing made for that building. How thorough and extensive the clearing

must be is the subject of various State and county laws. The same laws apply to clearing around buildings in subdivisions and mobile home parks, but are seldom adequate to meet the life and property threats involved in these more densely developed areas. What is needed in these developments is some sort of perimeter clearance or treatment of the native vegetation to a greater distance from the structures than that required by existing statutes and ordinances (Orange County Bd. Sup. 1976, Ore. St. Dept. For. 1978b, County Sup. Assoc. Calif. 1966, Task Force on California's Wildland Fire Probl. 1972).

The greatest distance to which vegetative treatment is required by any existing law is 100 feet from the structure. Perimeter treatment around subdivisions and other high value areas (e.g., mobile home parks, recreation areas, shopping centers) should be at least to fuel-break standards (200 feet minimum). And it should embody certain additional features for two reasons: (a) Vegetative and structural fuels must be physically separated by enough distance to reduce to an acceptable level the danger of ignition of structures by direct flame impingement or radiation—an even greater clearance (usually impractical if not impossible) would be necessary to protect against windborne firebrands; (b) firefighters must have a place in which to fight the fire before it reaches the structures, and so it is necessary to incorporate features which allow access by the firefighters and their equipment to the treated area (Los Angeles County Fire Dep. 1970, Orange County Bd. Sup. 1976, County Sup. Assoc. Calif. 1966, Green 1977).

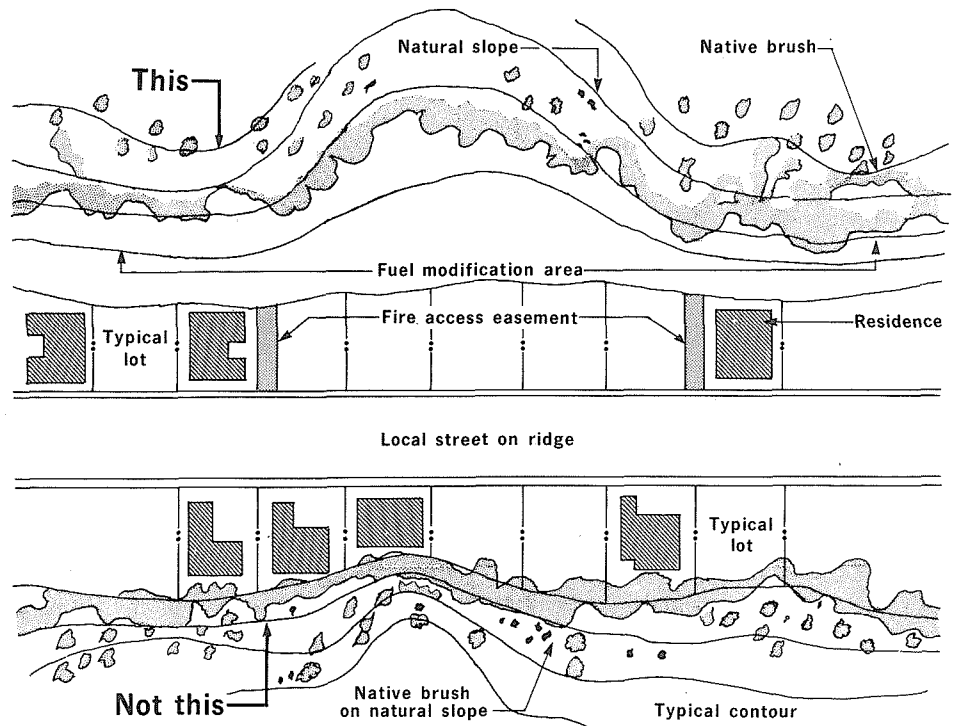


Figure 5—Fire access easements are needed for firefighters to get to areas treated for fuel modification (Orange County Bd. Sup. 1976).

This dual need can be met in several ways and many combinations thereof. Probably the best means from the firefighter's standpoint is a perimeter street with structures on the inside and a fuelbreak or greenbelt on the outside. Usually this design is economically feasible only if the adjacent area is to be subsequently subdivided. In certain topographic situations, such a design is impossible (Orange County Bd. Sup. 1976).

Another way to achieve perimeter protection is to construct a fuelbreak or greenbelt behind the outside structures (*fig. 5*). Fuelbreaks are strips of land in which the volume of vegetative fuel is reduced to an acceptable level and maintained in that condition. Greenbelts are similar strips of land wherein not only is the volume of native vegetation greatly reduced but much or all of it is replaced with irrigated introduced species. Strip parks and golf courses, are examples of greenbelts. They perform multiple functions (i.e., fire protection, recreation, esthetic benefits) and can often be made to pay for themselves (Los Angeles County 1973,, Green 1977).

Although practical in economic and sometimes physical terms, fuelbreaks or greenbelts present some problems. Access to the treated area by firefighters is denied unless fire access easements are provided and dedicated to such use. These easements should be wide enough and of low enough gradient to allow access by motorized fire equipment as well as by personnel (Orange County Bd. Sup. 1976, County Sup. Assoc. Calif. 1966).

Other developments which can serve the purpose of perimeter fire protection, at least for limited pieces of the perimeter, are recreation areas (particularly water-based ones), parking lots, school yards, and baseball or other athletic fields. With such developments placed on the perimeter the amount of otherwise unproductive fuelbreak and easements needed would be reduced⁸ (Alger 1971).

Proposed Standards: Include reduction of native vegetative fuels to at least fuelbreak standards as part of perimeter fire protection for subdivisions and mobile home parks. Provide access lanes to the treated area at least 12 feet wide for firefighting manpower and ground equipment at intervals not to exceed one-quarter mile. Base the minimum width of the treated strip on fire hazard severity classification: moderate—200 feet, high—300 feet, extreme—400 feet. Dedicate such treated areas and access lanes to public use and provide for their maintenance in perpetuity.

Electric Power Distribution

Overhead transmission and distribution of electric power is a major source of ignition for the conflagrations that have destroyed many hundreds of homes in California and elsewhere in recent years. Contrary to

popular belief the large high-voltage transmission lines are not the worst offenders. In one study they accounted for less than 8 percent of the fires over 5000 acres in size. They are commonly built of sturdy materials, maintained with adequate vegetative clearances, and inspected frequently and thoroughly (Task Force on California's Wildland Fire Probl. 1972, Moore 1977).

Distribution circuits accounted for nearly 17 percent of the conflagrations studied (Task Force on California's Wildland Fire Probl. 1972). This proportion was exceeded only by arson and was equalled by machine use. All other fire causes were smaller in number. Distribution circuits are of two types: primary and secondary. Primary circuits bring the power from the substation to the user's transformer. Primary electric power distribution circuits are a serious cause of wildland conflagrations. The thousands of miles of these lines present a tremendous exposure and an almost insurmountable problem of inspection and maintenance. Secondary circuits, which convey power from the transformer to the point of use (e.g., home, pump), usually cause fires because of inadequate vegetative clearance which is not now regulated by any State or local law. Secondary circuits cause nearly one fire for every two caused by primary distribution lines (Calif. Div. For. 1972, Moore 1977).

In about the lower half of their voltage range (i.e., 2.4 to 17 kilovolts), primary distribution circuits can successfully be installed underground rather than overhead. In the foreseeable future, even higher voltage lines can be installed underground. The subdivision codes of many cities now require such installation in all new subdivisions, although usually for visual esthetic reasons. The same requirement could be imposed in rural and wildland areas for fire protection reasons. Such a requirement would eliminate both primary and secondary circuits as sources of vegetation fires since the transformers would be at ground level or below. From this location the secondary circuit (service drop) is almost always placed underground also (Governor's Study Comm. Conflagrations 1966, Task Force on California's Wildland Fire Probl. 1972, Moore 1977).

If for some reason (e.g., excessive rock, preexisting overhead service) the cost of underground installation cannot be justified in relation to fire safety benefits, the developer should arrange for and the permitting agencies require very high standards of construction, vegetative clearance, inspection and maintenance of overhead power lines (Governor's Study Comm. 1966, Oreg. St. Dep. For. 1978a, County Sup. Assoc. Calif. 1966, Task Force on California's Wildland Fire Probl. 1972, Moore 1977).

Proposed Standards:

1. Install all new distribution circuits and extensions of existing circuits underground in fire hazardous wildland areas, if technologically feasible.

2. Place underground, all distribution circuits (new or existing) carrying less than 20,000 volts in areas of "extreme" fire hazard severity class.
3. Maintain the following clearances between vegetation and conductors (wires) for all overhead power lines:

Fire hazard severity class:	Secondary distribution	Primary distribution	
	0-750 volts	2.4-17KV	18-35KV
		<i>Feet</i>	
Moderate	2	4	6
High	4	6	8
Extreme	6	8	10

Street Names and Numbers

Subdivisions are usually provided with visible street names or numbers and lot or building numbers as a convenience to the buyers and visitors. Often, however, the signs are hard to read, sometimes even difficult to find. Many rural and mountain areas have become essentially urbanized through lot splitting and other sale of individual parcels and subsequent construction, and in these situations there is no developer to assign names and numbers. Roads often get their names from their destinations, names of old-time property owners, etc. Parcels or homes commonly are assigned box numbers by the Postal Service.

Positive identification of location is not merely convenient to a firefighter or other public safety officer responding to a reported emergency or radioing for help; it is an absolute necessity. Developers or others assigning and posting names and numbers can greatly assist in

providing adequate fire protection if they will make the signs as permanent as possible and large enough and with enough color contrast and reflective character to be read easily from a moving vehicle at night as well as in the daytime³ (Oreg. St. Dep. For. 1978a, Oreg. St. Dep. For. 1978b, Task Force on California's Wildland Fire Probl. 1972, Colo. St. For. Serv. 1977).

Proposed Standards: Construct signs of nonflammable materials, with letters at least 3 inches high, half-inch line width, and a reflective color that contrasts sharply with the background of both the sign itself and the surrounding vegetation.

Fire Station Sites

Existing fire stations in wildland areas usually are not located correctly nor are they manned and equipped adequately to provide structural fire protection to subdivisions and other developments. Developers of large subdivisions or mobile home parks or of shopping centers or apartment or condominium complexes should recognize this deficiency and dedicate one or more sites for structural fire stations at the outset. After development is complete, suitable sites will no longer be available (Oreg. St. Dep. For. 1978b, County Sup. Assoc. Calif. 1966, San Bernardino County Bd. Sup. 1974, Colo. St. For. Serv. 1977).

Proposed Standards: Dedicate fire station sites when:

1. No fire station capable of providing structural fire protection exists within 4 miles of the development.
2. The development is to encompass more than 640 acres or is to have an occupant density of more than eight dwelling units per acre.





STRUCTURAL DESIGN AND CONSTRUCTION

Because of the behavior of wildland fires, how a building is designed and constructed is the most important factor in providing fire safety for a home or other structure. Properly built homes can survive conflagrations even if many of the other protective measures discussed in this report are absent. Even homes apparently well separated from wildland vegetation will be destroyed if poorly designed and if constructed without regard to fire safety. The architect and building contractor, therefore, are key figures in providing safety. Many others (e.g., legislative and governing bodies, building inspectors, financiers, insurers, buyers) need to be knowledgeable and be able to exert pressure that will guarantee adherence to fire safe practices in design and construction.^{3,5}

Roofing

The roof is the most vulnerable part of a building during a fire—especially one in chaparral or oak areas. Because of its horizontal component, a roof can catch and hold the flying firebrands almost invariably associated with the strong winds and convection columns characterizing these fires. Unlike ground fire, these firebrands soar beyond any type of firebreak, natural or

artificial, and thus endanger structures as far as a mile away from the wildfire (Alger 1971, Los Angeles County Fire Dep. 1970, Howard and others 1973, Lowden and Degenkolb 1972, Smaus 1978b, Wilson 1962).

Recognizing this vulnerability to fire from external sources, the Uniform Building Code requires “fire-retardant roof coverings” in Fire Zones I and II, the high value and high life hazard areas in or near the business sections of cities. Many local jurisdictions have adopted the UBC by reference or by basing their own code on it. A few local jurisdictions have amended the UBC or their own codes to require “Class C” or better roofing as defined in UBC Standard 32-7 in wildfire hazardous areas. Most wildland areas still have no requirements regarding roofing materials (Build. News, Inc. 1977, San Bernardino County Bd. Sup. 1977, Los Angeles County 1937, Intl. Conf. Build. Off. 1976, Holmes 1971).

Most structures at or near the urban/wildland interface are either not covered by a building code, are in Fire Zone III, or are permitted to have any type of roofing material, or at most, Class C roofing. In the past 30 or 40 years, wood shingles or shakes have become popular with architects and buyers alike. Various fire-retardant treatments have been available for about 20 years, but only in the past 10 years or so have any of them been made relatively permanent (i.e., will retain a significant degree of fire-retardancy for 5 years or more). Although shakes and shingles with Class C rating are available, none meet the Class B requirement for “fire-retardant” roofs as defined in UBC Standard 32-7.

³Alger 1971; Task Force on California's Wildland Fire Probl. 1972; County Sup. Assoc. Calif. 1966; Howard and others 1973; Lowden and Degenkolb 1972; Oreg. St. Dep. For. 1978a; Smaus 1978a, 1978b; Wilson 1962.

Treated shakes or shingles cost more than untreated, and in the absence of a local code requiring them are seldom installed. Thousands of homes and other buildings exposed to the threat of wildland fires, therefore, are roofed either with untreated shakes or shingles, with ones which were merely dipped in fire-retardant chemical, or with ones from which the treatment has been leached by the weather. These roofs are not only serious hazards to the buildings on which they are installed but also to any other buildings downwind from them which are similarly roofed. Once a shake or shingle roof catches on fire, shakes or shingles peel off and are carried as new firebrands on the convection column and the wind.⁶

Many types of firesafe roofing materials are available. Some are less expensive than wood shakes or shingles, others more costly. They include Class A and B built-up assemblies, Class A and B prepared roofing, properly installed Class C mineral surfaced asphalt shingles, asbestos cement shingles or sheets, concrete slabs, metal, slate shingles, fiber glass shingles, and clay or concrete tile. Although most of these materials are not currently popular for residences, many can be made quite attractive—especially if the rest of the building is designed to accommodate them (Oreg. St. Dep. For. 1978a, Intl. Conf. Build. Off. 1976, Smaus 1978a).

The probability that a house of a given roof type and with brush clearance will be burned can be estimated from records compiled by the Los Angeles City Fire Department for the 1961 Bel Air Fire, in southern California. These records cover a sampling of 1,850 homes. For the probabilities shown it is assumed that houses are exposed to the rate of wildfire destruction observed in the Bel Air Fire. Values have been interpolated to match the brush clearance categories of the insurance industry (Howard and others 1973):

Brush clearance (ft):	Roof type	
	Approved by insurance industry	Unapproved by insurance industry
0 to 30	0.243	0.495
30 to 60	.054	.286
60 to 100	.016	.144
100+	.007	.148

The most cost-effective means of protecting homes from destruction by fire in or near the wildlands is a combination of approved fire-resistive roofing and clearance of 100 feet or more from the native brush for each home (fig. 6).

Proposed Standards: Base roofing materials required on the following fire hazard severity classification: moderate—Class C, high—Class B, extreme—Class A.

⁶Alger 1971, Holmes 1971, Howard and others 1973, Los Angeles City-County Fire Bd. Inquiry 1971, Los Angeles County Fire Dep. 1970, Lowden and Degenkolb 1972, Wilson 1962.

Vents

Another Achilles' heel to the attack of homes by windborne firebrands is an unprotected attic or under-floor vent. Although unprotected vents are not as well-documented as a cause of structure fires as flammable roofs, flying embers can easily enter a structure through such vents. If they land on any ignitable material, the inaccessability of the interior to suppression efforts almost certainly will lead to destruction of the house. The presence of flammable materials (e.g., dry leaves or grass, waste paper) is almost assured by the same mechanism—strong wind—that brings the firebrand. To remove this hazard, vents can be screened to prevent the entrance of flammable materials and firebrands but still allow the passage of air.^{3, 7}

Proposed Standards: Use vent screens of corrosion-resistant wire mesh with a mesh size of one-quarter inch.

Overhangs and Stilt Construction

Two other common architectural practices present serious fire hazards to a home built in or near the wild-

⁷Building News, Inc. 1977; Task Force on California's Wildland Fire Probl. 1972; Governor's Study Comm. Conflagration 1966; Howard and others 1973; Los Angeles Fire Dep. 1970; Natl. Fire Prot. Assoc. 1974; San Bernardino County Bd. Sup. 1977; Wilson 1962.

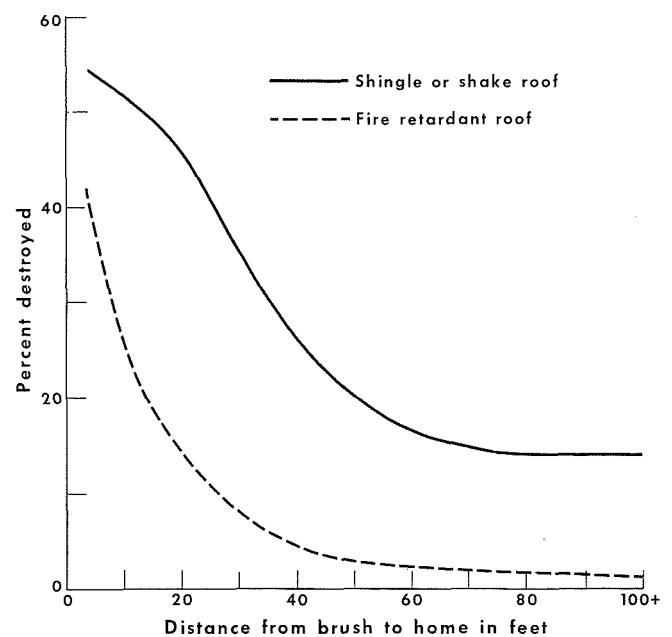


Figure 6—The greater the distance between a dwelling and brush, the better the chance it has of escaping destruction in a fire (Wilson 1962).

lands: (a) overhanging or projecting members (e.g., eaves, balconies, raised sun decks), which are likely to be found anywhere and are always dangerous; and (b) stilt construction. The latter, although dangerous anywhere, is particularly so on sidehill sites because the uphill side forms a trap for heat and flames. The danger, directly caused by vegetative fuels being under the building, is then aggravated by the wind accompanying conflagrations (County Sup. Assoc. Calif. 1966, Colo. St. For. Serv. 1977, Wilson, 1962).

Structures with overhangs or stilt construction, or both, are usually ignited by flames sweeping against the underside of the projection or the building itself. A wildfire running uphill ahead of a strong wind through heavy brush or timber to within a few feet of a house built on stilts and with a cantilever balcony and 4- or 5-foot eaves is a positive prescription for disaster. This sequence is not as uncommon as it might sound. Hill-side homes often offer spectacular views, and balconies are often provided to take full advantage of the view. Wide eaves are commonly built to shade windows. On a hillside, one side of a house may be at ground level or below while the other side is 15 or 20 feet, or possibly more, above ground level (Deeming and others 1977, Helm and others 1973, Smaus 1978b, Wilson 1962).

These architectural fire hazards can be overcome by a number of measures. One is to construct any overhanging member or building of nonflammable materials (e.g., metal or concrete) of at least 1-hour or 2-hour fire resistive materials as defined in the UBC. Another is to encase stilts so that there is no opening below the floor of the building, balcony or sun deck. Roofs can be built without eaves. Sidehill houses can be designed with two or three floor levels, thus utilizing what otherwise would be not only a fire trap but wasted space.^{3,4}

Proposed Standards:

1. Construct eaves, cantilever balconies, and other similar overhangs with undersides of materials that meet the following UBC specifications, depending on fire hazard severity class: moderate—fire-retardant pressure treated wood or equivalent; high—1 hour; extreme—2 hour.
2. For structures supported wholly or in part on stilts, encase all underfloor areas to the groundline with materials meeting the standards for exterior vertical walls in the same area or zone.

Glass

Windows can easily be a weak point in the fire protection of a home for two reasons. They allow entrance of

radiated heat of such intensity that interior materials (e.g., furniture, drapery, clothing, papers) are ignited. And they admit convective heat, firebrands, or flames when they are open or broken. Large picture windows and sliding glass doors are particularly vulnerable to these hazards. The orientation of the glass surface will determine the degree of hazard it represents. If it is on the windward side of the building or is facing toward a concentration of vegetative fuel, the danger is heightened. If it is downwind or shielded by some non-flammable obstruction, the danger will be reduced (Alger 1971; Los Angeles County Fire Dep. 1970; Lowden and Degenkolb 1972; Smaus 1978a, 1978b; Wilson 1962).

Windows cannot be abandoned or prohibited. The opportunity to enjoy a spectacular view or the feeling of spaciousness afforded by a sliding glass door opening onto a patio, sun deck, or swimming pool is hard to give up. But the danger of fire can be reduced by installing nonflammable shutters or fire-retardant drapes; by orientating away from concentrations of vegetative fuels; by shielding with nonflammable balconies or decks; and by using tempered or double-paned windows or both, or wire glass (Orange County Bd. Sup. 1976; Oreg. St. Dep. For. 1978a; Task Force on California's Fire Probl. 1972; Lowden and Degenkolb 1972; Smaus 1978a, 1978b).

Proposed Standards:

1. Hold to a minimum the size and number of glazed openings on the side of the house facing the normal fire carrying wind or the downhill side or both.
2. Use extra-strength glass (thick, safety, tempered, or double-paned, or both).
3. Protect windows and sliding glass doors with non-flammable shutters, balconies or decks, and fire-resistant drapes.
4. Orient any glazed openings so that they do not face concentrations of vegetative fuels within 100 feet, unless such openings are provided with fireproof shutters.

Siding

Most home fires in urban areas have internal sources of ignition. Therefore, the materials of which their exterior walls are constructed are of relatively minor importance from a fire protection standpoint. The architect, therefore, has considerable latitude in design. By contrast, home fire ignitions during a wildfire are almost entirely external (assuming all openings are protected as discussed earlier). Thus fire-resistancy of exterior walls becomes of great importance, and the choice of materials must be restricted. Contrary to this safety requirement is the strong tendency on the part of both architects and buyers toward an increasingly rustic appearance as the site gets deeper into the chaparral or

³Building News, Inc. 1977; Task Force on California's Wildland Fire Probl. 1972; Colo. St. Forest Serv. 1977; County Sup. Assoc. Calif. 1966; Int. Conf. Build. Off. 1976; Lowden and Degenkolb 1972; Smaus 1978a, 1978b.

woods. As a result many structural fires in rural areas have started by direct ignition of external wood siding, garage doors, and porches. This hazard is heightened if concentrations of fuels (e.g., vegetation, firewood, wood fences) are too close to the wood-encased house (Alger 1971, Los Angeles County Fire Dep. 1970).

Many materials are available for exterior wall use that have varying degrees of fire-retardance up to 2-hour ratings or even higher. Some of these can be made to appear quite rustic. Others have unique visual qualities of their own. They vary in ascending order of fire safety from wood siding or panels pressure-treated with fire-retardant chemicals (same leaching problems as for shingles and shakes) through stucco, metal siding, brick, asbestos-cement shingles or corrugated panels to concrete block or poured concrete and rock walls. To achieve full fire-resistant effect, all but the solid concrete or rock walls must be properly applied over suitable base materials, as defined in the UBC, continuously from the ground or foundation to the roof or eaves³ (Orange County Bd. Sup. 1976, Oreg. St. Dep. For. 1978a, County Sup. Assoc. Calif. 1966, Intl. Conf. Build. Off. 1976, Smaus 1978a).

Proposed Standards:

1. Build exterior walls of such materials as to provide the following degrees of fire resistance based on fire hazard severity class; moderate—fire-retardant pressure-treated wood or equivalent; high—1-hour, extreme—2-hour.
2. Extend the applicable degree of fire-resistance of all exterior walls from ground level to roof line.

External Sprinklers

Sprinklers permanently mounted on the roof have been suggested as a defensive measure, particularly in order to offset the hazard of wood shingles or shakes, either treated or untreated. Such sprinklers could be either automatic, similar to internal fire sprinklers, or activated manually by the occupant. However, most authorities argue against the value and advisability of sprinklers as a viable alternative to safe roofing materials. Sprinklers could, theoretically, prevent roof ignition from flying firebrands, but rather large volumes of water would be required at a time when loss of water pressure can normally be expected. Also, if activated too soon, a sprinkler system will contribute to the loss of water pressure and very likely cease to function before the actual danger arrives. In this case its benefits would be almost totally lost by evaporation, and it does not appear to be an adequate substitute for approved fire-resistant roofing material³ (Alger 1971, Los Angeles City-County Fire Bd. Inquiry 1971, Smaus 1978b, Wilson 1962).

Proposed Standards: Allow permanently installed roof sprinklers only where the structure has its own independent water source that will not deplete the supply of water for nearby properties nor for use by organized firefighting manpower and equipment. Such systems, when installed, should have a dependable water source (gravity or alternate power).

Safety of Human Life

Of even greater importance than protecting homes from destruction by wildland fire is avoiding the loss of human life. No structure should be designed and built in any way that could trap people inside while it is burning. Occupants should have ample warning and positive means of exit (Governor's Study Comm. 1966).

Proposed Standards:

1. Install in each dwelling unit one or more smoke detectors—at least one of which shall be in or near sleeping areas.
2. Install in each dwelling unit at least two door exits by means of which ground level may be reached.
3. Install in each room, especially each bedroom, two means of exit—one of which must be to the outside of the building.
4. If a window provides one of the exits it must be no more than four feet above floor level and capable of providing an opening no less than 22 inches in least dimension and 5 square feet in area.

Mobile Homes

Mobile homes have grown remarkably in numbers in rural areas in the past 10 years, both in mobile home parks and as substitutes or replacements for detached single family residences. They are subject to all the fire problems and vulnerabilities discussed earlier for conventionally constructed houses and a few of their own. Insofar as possible mobile homes should conform to the same recommendations and standards as conventional homes in the interests of fire safety for both the building and its occupants (Los Angeles County Fire Dep. 1970, Oreg. St. Dep. of For. 1978a).

Mobile homes usually stand a reasonable chance of avoiding roof fires from windborne firebrands because most of them have insulated metal roofs. On the other hand, since the metal involved is usually fairly thin aluminum, heavy long-burning firebrands can melt through the roof and fall inside where they may ignite furnishings.

Of greater concern and probability is the danger of fire coming under the structure and igniting the floor. The best way to avoid this is to provide complete skirt-

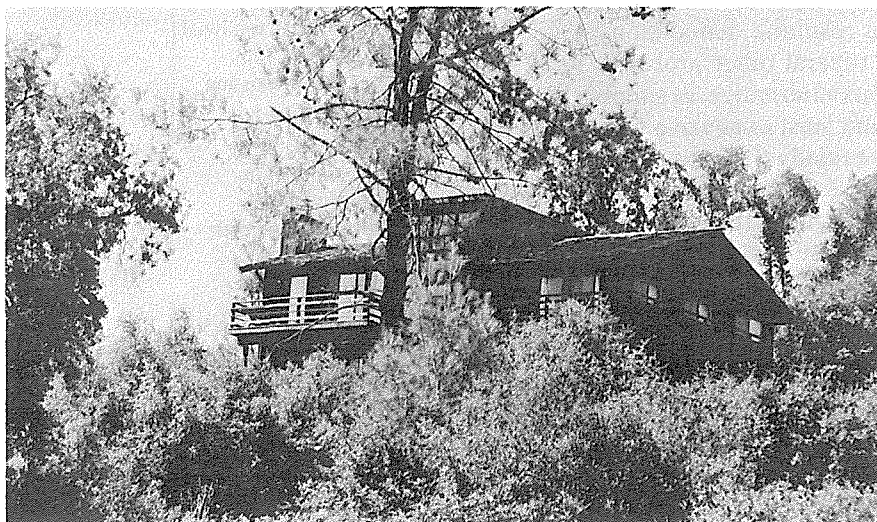
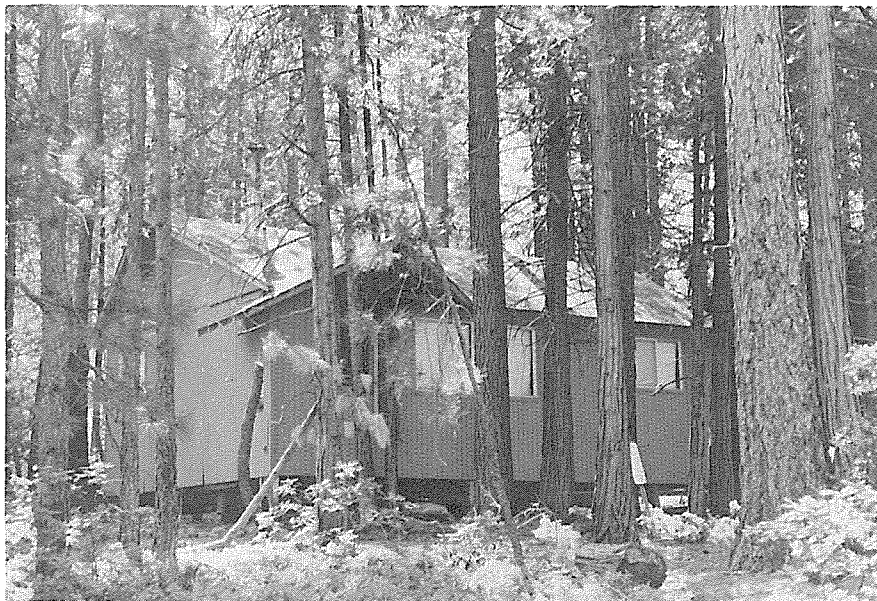
ing, preferably metal, from floor-line to ground-line all the way around the home. Such skirting requires proper venting which should meet the same mesh or opening standards as for conventional homes (Oreg. St. Dep. For. 1978a).

Other fire problems common to mobile homes are unprotected sliding glass doors and picture windows, wide carports and porch canopies attached to the main structure, and carpeted or exposed wood porches or sun decks. Large panes of glass need some kind of protection from breakage which would allow an external fire to enter the structure. Any overhang will trap and intensify heat and flames. Flammable horizontal surfaces will collect windborne firebrands.

Probably the greatest fire safety problem of mobile homes (and this also applies to all types of recreational vehicles) is the life hazard. The fatality rate for this type of structure per 100,000 fires is several times that for conventional homes. There are three causes for such a

high fatality rate: (a) the flash nature of interior fire spread often encountered in these units; (b) highly toxic and very thick smoke and gasses are given off by the many plastics commonly used in the interior; (c) the generally inadequate exit or escape capability of mobile homes. Mobile homes rarely have more than two exterior doors. Most of their windows or the individual panes, except for a picture window in the living room, are too small and too high off the floor to allow a person to climb out.

Proposed Standards: Require mobile homes to meet the same standards of fire safety as conventionally built houses, and, in addition, be provided with (a) full skirting; (b) a means of quickly enclosing, or detaching, carports and porch canopies during fire emergency situations; and (c) nonflammable, or at least fire-retardant, porches and sun decks, if any such areas are provided at all (carpeting of such areas should be prohibited).





LANDSCAPING

The proximity of a structure to native vegetation is a direct measure of the probability of its destruction by conflagration sooner or later. Flammable roofs and inadequate brush clearance are by far the most significant contributors to hazard and their elimination would provide the most cost-effective prescription available (*table 3* and *fig. 7*). Nonflammable roofs and brush clearance are not the only protective measures needed; however, they are the most critical and, if resources are limited, should receive top priority (Alger 1971, Los Angeles County Fire Dep. 1970, Los Angeles City-County Fire Bd. Inquiry 1971, County Sup. Assoc. Calif. 1966, Howard and others 1973, Wilson 1962).

Total removal of all vegetation for a specified distance from a house is impractical for several reasons. Not only would the resulting denudation be unsightly but it would create several other problems (e.g., dust, erosion). The obvious alternative is suitable landscaping. In its simplest and least expensive form, such landscaping would be essentially the type of treatment given areas chosen for fuelbreaks in the wildlands. In its most advanced form it might take the shape of an irrigated and shaded lawn or an intricately designed planting of carefully selected fire-resistant or low fuel-volume plants. In any event, the purpose is the same: to reduce heavy loadings of vegetative fuels sufficiently far from the structure to avoid ignition of the building by radiated heat or direct impingement of flames and to allow firefighters a place in which to work when it becomes necessary to save the house³ (Alger 1971, Los Angeles County Fire Dep. 1970, Los Angeles County 1973,

Pacific Southwest For. and Range Exp. Stn. 1963, Wilson 1962).

Table 3—Differences in protection policies involving brush clearance and roof conversion, costs, and homes destroyed, Santa Monica Mountains, southern California

Protection policy	Homes destroyed annually	Annual cost of protection program	Average annual cost plus loss to society, including program cost
	Avg. no.	MM dollars ¹	MM dollars ¹
Present situation: existing roof types and brush clearance	60	0	11.0
Native brush removed 100 feet from all homes with existing roof types	45	0.6	9.6
Conversion of all wood roofs from unapproved to approved type with existing brush clearance	21	3.1	8.9
Both brush clearance to 100 feet and conversion to approved roofs	7	3.7	7.6

Source: Howard and others (1973).

¹1973 dollars.

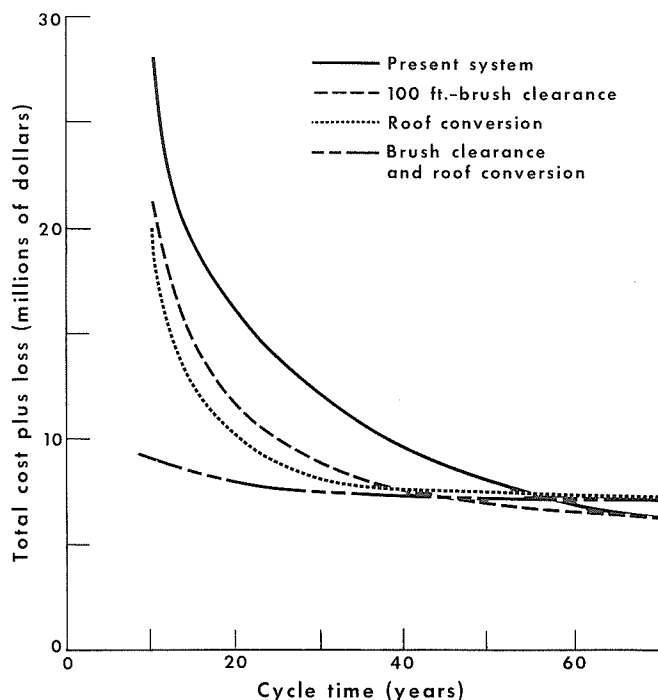


Figure 7—The cycle or average time between chaparral fires is estimated to be 30 years. Costs can be reduced by brush clearance or roof conversion or both (Howard and others 1973).

Native Vegetation

The first step in landscaping for fire protection is to remove flammable native vegetation, which includes naturalized introduced species (e.g., eucalyptus), for some distance in all directions from the structure. California State Law (Section 4291, Public Resources Code) and ordinances of several local jurisdictions require clearance for 30 feet. A few local ordinances require it for 100 feet, but these laws and ordinances generally do not mean complete denudation of the land. The key word is “flammable,” usually interpreted to mean all dead vegetative matter and enough live crowns to avoid the direct spread of fire from one tree or bush to another. To complete the job properly, remaining crowns should be pruned enough to avoid their ignition by a ground fire (*fig. 8*) (Alger 1971, County Sup. Assoc. Calif. 1966, Los Angeles County 1973, Pacific Southwest For. and Range Exp. Stn. 1963, Green 1977).

Seldom is a 30-foot brush clearance adequate to protect a home from wildfire. California State law recognizes this fact by providing for an extension to 100 feet upon a finding of necessity by the Director of Forestry. Likewise several local ordinances in southern California require a minimum clearing of 100 feet. Even these distances may not be enough. Several fuelbreak planning and design studies on intensity of radiated heat and

on flame lengths under high wind conditions indicate that 200 feet may be more appropriate under conflagration conditions. Actual brush clearance needs on the ground cannot be legislated. They are determined by native fuel loading, slope, expected wind velocity, and types of building materials to be protected. In certain situations, a 400-foot clearance may be barely adequate³ (County Sup. Assoc. Calif. 1966, Los Angeles County 1973, Pacific Southwest For. and Range Exp. Stn. 1963, Natl. Fire Prot. Assoc. 1974, Task Force on California's Wildland Fire Probl. 1972).

Adequate brush clearance is purely a matter of fire physics, and has nothing to do with property ownership or boundaries. Within limits it can be made easier by positioning the building with adequate set-back from all property lines. In most subdivisions, even the so-called ranch subdivisions, however, lot sizes are too small to allow for up to 400-foot clearance without some of it being on a neighbor's property. Some local ordinances take care of this problem up to 100 feet from the building by declaring any and all flammable native vegetation within that distance to be a public nuisance and requiring its abatement regardless of ownership. This approach could be extended both in distance and to other jurisdictions³ (Los Angeles City-County Fire Bd. Inquiry 1971, Task Force on California's Wildland Fire Probl. 1972, Howard and others 1973).

Any of several methods of vegetation removal may be used, depending on cost, timing, final result desired, topography, and rock outcroppings and would include hand chopping, bulldozing, discing, and burning. Killing with herbicides does not, in itself, accomplish the purpose. In fact, if the dead plants are not removed, the fire hazard is increased rather than reduced. Removal by one of the other methods while the plants are still live is usually easier (Pacific Southwest For. and Range Exp. Stn. 1963, Green 1977).

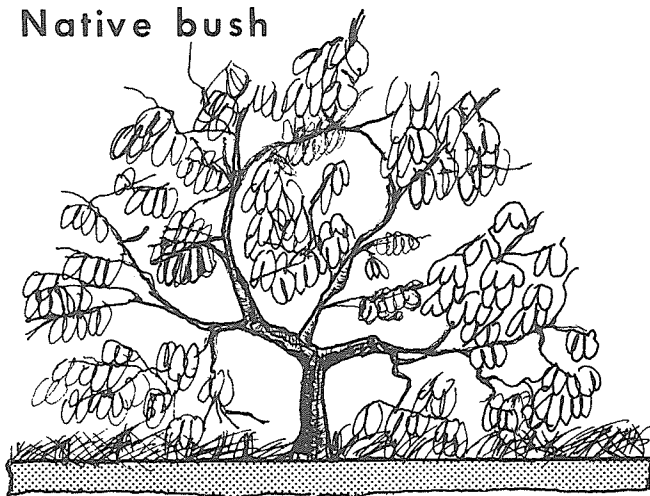
Proposed Standards: Require native vegetation clearance and thinning, regardless of property ownership, for the following distances from structures:

Direction from structure:	Fire hazard severity class		
	Moderate	High feet	Extreme
Upslope—25 pct +	30	60	100
Across slope or 0–25 pct	60	100	200
Downslope—25 pct +	100	200	400

Plantings

In replacing the removed vegetation, keep and augment the benefits of the removal. Planted, as well as retained, native trees and bushes should be spaced far enough apart that their crowns will still be separated when full-grown. They should not overhang the house. The space between these trees and bushes should be

Native bush



Pruned bush

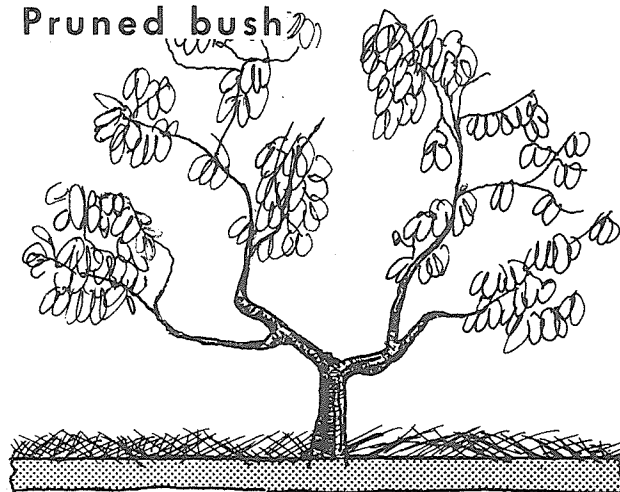


Figure 8 — Native plant species should be pruned to reduce fire hazard.

covered with relatively low-growing and fire-retardant plants, a greater variety of which exist than is commonly known. On the other hand some common landscape plants are highly flammable and should not be used. One of the best and easiest to maintain is lawn. Others include both introduced and native ground covers and small flowering plants.⁹

Much research has been done recently on so-called fire-resistant plants for home, fuelbreak, and roadside plantings. The research has included both native plants and introduced ones, the latter coming primarily from areas of the world with Mediterranean climates (e.g., Australia, Chile, South Africa, Caucasus Mountains). Although some plants burn more slowly than others because of high salt, ash, or moisture content, the difference is generally not worth the time and expense of propagating them. In recent years the focus has, therefore, been on finding plants with low volume and height, and therefore, with low heat output, as well as some degree of fire retardance (Los Angeles County 1973, Green 1977, Nord and Countryman 1972, Wilson 1974).

Several plants have desirable attributes of fire retardance, low maintenance requirements, availability and range of successful plantings. These include white trailing iceplant (*Delosperma alba*), dwarf aloe (*Aloe aristata*), shortleaf aloe (*Aloe brevifolia*), croceum iceplant (*Malephora crocea*), crocea (*Malephora crocea* var. *purpureo*), creeping Australian saltbush (*Atriplex semibaccata*), lippia (*Lippia canescens* var. *repens*), and quaking aspen (*Populus tremuloides*). At least as many others are equally effective but only in limited

climatic zones. Two others show a good deal of promise in test plantings but are not yet available on the commercial market: creeping sage (*Salvia sonomensis*), and Castlevale saltbush (*Atriplex cuneata*). A decorative plant to be avoided is any species of juniper, even the prostrate variety, as all species contain a high volatile oil content and are unusually flammable (Alger 1971, Los Angeles County 1973, Green 1977, Nord and Countryman 1972).

The initial choice and planting of the landscaping plants does not complete the job. All require a certain amount of maintenance, both to retain their fire protection effectiveness and to keep them healthy and attractive. Various plants have differing water requirements. All need weeding, at least until they get well established. Most, including the iceplants, need to have dead branches and leaves removed periodically. Lawns need to be mowed (Alger 1971, Los Angeles Times 1978, Los Angeles County 1973, Pacific Southwest For. and Range Exp. Stn. 1963, Green 1977).

Proposed Standards: Use only those plants that have been tested and proved to have significant fire protection qualities.

Irrigation and Sprinkling

Almost any landscape planting for fire protection purposes will require some irrigation—at least while it is getting established. The installation of pipes, hose bibs, and sprinklers should be part of the job. Different types of plants have different water needs, however, and thus general area-wide sprinkling should be avoided. Many of the best plants are similar to chaparral in their low water requirements and can be damaged or even killed by too much water. Other plants have

⁹Alger 1971, Green 1977, Los Angeles County 1973, Los Angeles Times 1978, Nord and Countryman 1972, Orange County Bd. Sup. 1976, Pacific Southwest Forest and Range Exp. Stn. 1963, Wilson 1974.

fairly high water requirements. The different types should be separated and each provided with its own water source (Alger 1971, Orange County Bd. Sup. 1976, Los Angeles County 1973).

It has been suggested that rather than removing the native vegetation, it be made fireproof by sprinkling or other form of irrigation. The limited research so far conducted indicates that this approach will not solve the home fire protection problem. Large quantities of water are required to raise significantly the moisture content of the soil and the live fuels in the summer and fall. And watering would stimulate growth rates, thereby increasing the quantity of vegetative fuels that then increase the heat energy released in a fire (Orange County Bd. Sup. 1976, Los Angeles County 1973, Younger 1974).

Proposed Standards: Design and install irrigation systems so that plants with differing water requirements can be irrigated separately on different schedules.

Herbicides

Many chapparral species and some other native plants are sprouters. Unless the root crowns are removed in the initial clearing process, which may not be desirable for soil erosion reasons, they will resprout quickly and profusely. If not controlled they will recapture the site within 2 to 5 years, negating both the clearing and the landscaping. The control of weeds and wild grasses among plantings must also be considered. Properly prescribed and applied herbicides are often the most effective and economical means of achieving both of these objectives (Los Angeles County 1973, Pacific Southwest For. and Range Exp. Stn. 1963, Green 1977, Harvey 1974).

Although herbicides are not useful for the initial clearance of native vegetation, they can help prevent regrowth and maintain desirable landscaping. They must, however, be used with considerable caution in

order not to produce undesirable results, i.e., killing plants which have been planted at much expense in time, labor, and money. The advice, if not the services, of farm advisors, agricultural commissioners, and licensed herbicide applicators should be obtained. In some cases, alternate means of control may be better, and might include grazing and browsing by livestock (horses, sheep, goats), hand chopping or grubbing, and prescribed burning (Orange County Bd. Sup. 1976, Pacific Southwest For. and Range Exp. Stn. 1963, Task Force on California's Wildland Fire Probl. 1972, Green 1977).

Proposed Standards: Use herbicides only as prescribed by persons knowledgeable and qualified in their use and application.

Fire-Retardant Chemicals

The feasibility of applying fire-retardant chemicals for conflagration protection purposes to vegetation surrounding a home has not yet been explored thoroughly. These chemicals, used extensively in wildfire control, are known to have a fire suppressent effect. They do, however, have some qualities which make their use for home fire protection questionable. They are quite expensive. Although they retain their fire retardant qualities after drying, they wash off readily with light amounts of rain or sprinkling. The old ones are soil sterilants. The new ones are fertilizers which would probably promote undesirable as well as desirable growth. Arguments in their favor are that they would reduce considerably the heat energy emitted by the burning of either native or planted vegetation. Used without the dye included for aerial firefighting, they are almost colorless when dry and their application would not alter the appearance of any vegetation significantly.





MAINTENANCE

Although many of the most important actions in providing fire safety for a structure located in a wildfire hazardous area take place during the planning, designing, constructing, and landscaping phases they do not end there. Maintenance must begin the day the occupant moves in and continue so long as the building stands, or all the original built-in protection may be in vain. Many cases have been documented wherein a structure, once reasonably fire-safe, burned down after it or the area around it had been allowed to deteriorate (e.g., birds' nests under the eaves, accumulations of leaves and dry grass in yard and gardens or on roofs, regrown brush). Roofs also deteriorate in varying lengths of time and require repair or replacement (Alger 1971, Los Angeles County Fire Dep. 1970, Los Angeles County 1973, Wilson 1962).

Roofs and Rain Gutters

The roof is the most critical point in maintenance as well as in construction for the protection of a structure from a conflagration in chaparral or other wildland. The most common problem arises from the accumulation of dead leaves or needles which can build up to considerable depth in the troughs of peaked roofs, in rain gutters and behind the wall extension above the roof line that is commonly used with flat roofs. Any place where windblown leaves will accumulate is an ideal place for windborne firebrands to drop. Under these conditions

even so-called "fire-retardant" roofs will ignite. Another attractive place for firebrands to ignite is in birds' nests under eaves and the ends of unplugged tiles. The obvious preventive solution is to remove all such accumulations before each fire season and at least once during the season (Alger 1971, Los Angeles County Fire Dep. 1970, County Sup. Assoc. of Calif. 1966).

An older home is no more immune to destruction by wildfire than is a new one. Its roof is certain to require repair or replacement eventually. When this time comes it is only good business as well as insurance for future fire safety to upgrade the fire protection rating of the materials used. The UBC and many local ordinances state that whenever 25 percent or more of a roof is replaced it must meet the standards for the fire zone in which it is located, and this is a good rule of thumb for use in wildfire hazardous areas (Building News, Inc. 1977; Intl. Conf. of Build. Off. 1976).

Proposed Standards:

1. Remove all loose flammables (e.g., dry leaves or needles, paper, birds' nests) from roofs, eaves, and rain gutters at the beginning of each fire season and any time they accumulate to a depth of 1 inch or more.
2. Not more than 25 percent of the area of a roof should be replaced within any 3-year period with materials that are not approved for new roofs in the same wildfire hazard severity classification area.

Yards

Yards, gardens, landscaped areas, and fire protection clearings require a great deal of maintenance. No vegetation is immortal, and flammable dead vegetative material is going to accumulate. Often such accumulation is not readily apparent to the unpracticed eye. Individual dead twigs and branches may be hidden by live exterior foliage. Dead leaves may be under or behind live plants. Annual grasses and weeds can grow almost anywhere. All such dead vegetative material should be removed and disposed of before it becomes tinder for carrying a wildfire to the house (Los Angeles County Fire Dep. 1970, Orange County Bd. Sup. 1976, Los Angeles County 1973, Smaus 1978b).

Even if vegetation is kept pruned and weeded, yards will collect a certain amount of flammable litter. Leaves and needles fall. Scrap paper blows in on the wind. All such material should be regularly collected and disposed of. In many areas they must be hauled away to an approved landfill either by a refuse disposal service or by the occupant because local air pollution regulations prohibit burning. In those areas where burning is permitted it should be done only in an approved incinerator under permit from the local fire protection agency. Open debris burning has caused a good many conflagrations in the past, although it has been somewhat rare in the past 10 or 12 years due to recent restrictions and controls (Alger 1971).

Because of natural plant succession, clearances around structures for fire protection will almost invariably revert to native vegetation unless positive steps are taken to maintain the clearance. Maintenance can be

accomplished in several ways: by skillful use of herbicides, by browsing and grazing livestock, by disking, by hand chopping or grubbing, or by prescribed burning (table 4). Many people living in wildfire hazardous areas keep horses and some keep cattle or sheep. Research by the United States Forest Service and California Department of Forestry has shown that goats enjoy a diet of chaparral and are very effective at maintaining fuel-breaks. Horses, cattle, and sheep are primarily grazers and will only browse on very young succulent chaparral but are good at reducing the fuel loading of dry grass. The method or combination of methods used is not important as long as thought and effort are put into maintaining the fire protective qualities of the clearing (Orange County Bd. Sup. 1976, Los Angeles County 1973, Green 1977).

Proposed Standards: Remove and dispose of all dead vegetative and other flammable material, in amounts which will carry ground fire or convey fire from one bush or tree to another, by means permitted by State law and local ordinance.

Storage

It is common in suburban, and in rural areas especially, to store certain flammable materials outdoors, often stacking them against the side of the house, garage, or barn. The most common such materials are firewood, lumber, and hay, but there are many others. This practice is very dangerous as far as the fire safety of the structures is concerned. Stored flammable mate-

Table 4—Relative cost of alternative methods of brush regrowth control

Control method	Cost per acre, by year										Present value	
	0	1	2	3	4	5	6	7	8	9 and beyond	6 pct.	10 pct.
1976 dollars												
Herbicides	30	30	30				30			30 in 10th yr & every 4th yr thereafter	185	135
Goat grazing	5	5	5	5	5	5	5	5	5	5 per yr every yr	85	50
Mechanical clearing (disk)	30		30		30			30		30 in 9th yr & every 3d yr thereafter	210	145
Hand cleaning	100		100		100		100		100	100 in 10th yr & every 2d yr thereafter	875	565
Prescribed burning	20			20			20			20 in 9th yr & every 3d yr thereafter	125	80

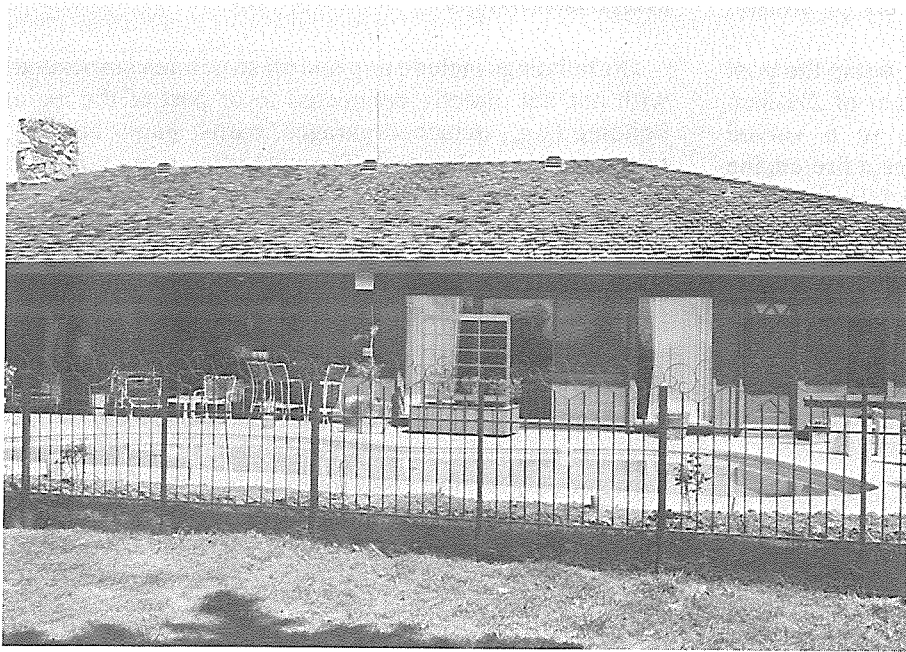
Source: Orange County Bd. Sup. (1976).

rials should be under cover to prevent windborne firebrands from landing on them. If covering them is not feasible or it is not possible to store them inside the building then they should be separated from the building by enough distance to save the building from ignition should the materials catch fire. It is still the best practice to cover them with sheet metal or some other fire-retardant material (Alger 1971, Los Angeles County Fire Dep. 1970, Wilson 1962).

Proposed Standards: Store flammable materials either:

1. Inside of properly designed and constructed fire-safe buildings, or
2. Separated from any buildings by the same minimum distance required for building spacing in the wildfire hazard severity class in which the structures are situated.





ACCESSORIES

Although the most important factors in determining the probability of a structure surviving a large wildland fire are the materials of which a residence is constructed and its location with respect to vegetative fuels, others must also be considered. One of the more important is the number, type, and location of various accessories and their manner of installation. Some of these accessories (e.g., wood fences and outbuildings, fuel tanks) can increase the hazard. Others (e.g., brick fences, portable pumps for swimming pools) can reduce it. The effects of some (e.g., water pumps, patios) depend entirely on their manner of installation.

Swimming Pools

Wherever the water supply is adequate to support them, swimming pools have become prominent accessories to rural and suburban homes in recent years, particularly in southern California where the length of the season of their use makes the investment most worthwhile. These pools can be important for providing fire protection to the home, or they can be of no help whatsoever, depending on how they are installed and equipped. To a lesser degree the same can be said for other bodies of water on the premises (e.g., stock ponds, fish ponds, creeks) (Alger 1971, Governor's Study Comm. 1966, Los Angeles City-County Fire Bd. Inquiry 1971, Oreg. St. Dep. of For. 1978a).

The first and simplest way in which pools can be made a part of the fire protection system is their place-

ment and screening. If located on the windward and/or downhill side of the house and screened from public view by masonry or other nonflammable wall or fence they provide a good deal of the needed separation between the structure and the native vegetation. The wall will protect sliding glass doors from radiated heat and may also provide some deflection of wind, thus assisting in protection from windborne firebrands.

The most important benefit of swimming pools or other bodies of water, however, is as a source of firefighting water, but this aid is quickly negated if there is no way to get the water. Every pool, therefore, needs to be so installed and equipped that the water in it can be obtained and used either by a fire engine or by the occupant, or preferably, by both. For the fire engine to get the water it must be able to get close enough to the pool to draft water with its pump and suction hose. If this is not a possibility the pool will need a bottom drain leading to a standpipe near the street to which the engine can hook up. For the occupant to be able to make emergency use of the water, a pumping system is needed. A gasoline-powered portable pump is best for this purpose because of the danger of electric power outages during conflagrations (Oreg. St. Dep. For. 1978a, Task Force on California's Wildland Fire Probl. 1972, Lowden and Degenkolb 1972, Smaus 1978b).

Proposed Standards:

1. Provide unobstructed direct access by a fire engine to within 16 feet of the water surface (a gate that can

be opened quickly by firemen would not be considered an obstruction).

2. If Standard 1 is physically impossible, equip the pool with a bottom drain and piping system of 2½-inch minimum diameter that terminates in a valved standpipe. Locate the standpipe where a fire engine may quickly hook up and draft water from it.
3. In addition to following either Standard 1 or 2, store a portable gasoline-powered pump, complete with 8 feet of suction hose, 100 feet of fire hose, and a fire nozzle, at a place convenient to the pool or other water source.

Fences

Fences are accessory to almost every home. They vary from barbed wire fences which are no more than barriers to certain domestic livestock through various types of decorative and visual barriers, usually made of wood, to high masonry or concrete barriers. They are equally as varied in their effects on wildland fire. Even two fences of exactly the same type may have different effects, depending on how they are maintained.

Barbed wire fences have little or no effect on a fire unless wooden posts are used or they are allowed to accumulate dry grass or other flammables. Other types of wire fences (e.g., hog wire, chain link) collect windblown paper, leaves, and other flammable trash. Unless they are cleaned regularly, they contribute to the natural fuel loading. Rail fences, whether of the post or zigzag variety, add fuels, especially after they become old and weatherbeaten. Essentially solid wood fences (e.g., board, grape stake) present the same problem as rail fences and in addition act as collectors of windborne flammables. Many documented cases point to these fences as the means of carrying the fire to the structure. Masonry or other nonflammable fences may collect flammables, but rarely to such an extent that their effectiveness as a barrier to a ground fire is seriously reduced. Although this type of fence cannot guarantee protection from windborne firebrands, it has been known to deflect them so that they land in relatively safe areas rather than on the structure or on some other accessory (e.g., wooden sun deck, patio furniture). All types of fences, including barbed wire, tend to become windrows of dry grass and weeds unless well cleaned and maintained annually (Alger 1971, Los Angeles County Fire Dep. 1970, Smaus 1978b).

Proposed Standards:

1. Construct fences to the maximum extent possible of open, single-strand wire or of solid masonry construction.
2. Keep clean of loose flammable materials any fences constructed of meshed wire or of flammable materials.

Outbuildings

Outbuildings include any and all structures associated with but not directly connected to or part of the main building (e.g., detached garages, barns, pump houses, tool houses, tree houses). They are often more vulnerable to a wildfire than is the residence. Most residences are designed and built by professionals and therefore have some degree of fire protection (although seldom adequate) built in, but outbuildings seldom are. They are usually built by the occupant sometime subsequent to, often years after, the construction of the residence. In addition, because of their lower value and the fact that humans rarely live in them, they are usually not as well cleaned and maintained as the house. They tend to start off as poor fire risks and become steadily worse. Fires have been observed spreading from burning outbuildings to residences by radiation, convection, and flying burning shingles (Los Angeles County Fire Dep. 1970).

Proposed Standards:

1. Require outbuildings to meet the same standards for building spacing, roofing materials, brush clearance, etc., as the structure with which they are associated.
2. Prohibit the use of outbuildings as depositories of discarded flammable materials.

Patios, Sun Decks, and Balconies

If made of nonflammable materials and properly designed, patios, sun decks, and balconies are not only enjoyable but also can be of considerable fire protection value. By becoming part of the brush clearance and landscaping, they help reduce radiant and convective heat on the house. Judicious orientation with respect to slope, wind, picture windows, etc., can deflect wind and heat away from weak points in the fire defenses of a home. On the other hand, if made of wood or other flammable materials, covered with carpet, congested with wood or fabric furniture, or covered by a canopy or trellis, they may easily become the direct means of transmitting fire to the house (Smaus 1978a, 1978b).

Proposed Standards:

1. Construct patios, sun decks, and balconies of concrete or other nonflammable material wherever possible; but in no case, use any materials having less than 2-hour fire-resistive rating as specified in the UBC.
2. Do not carpet any unenclosed portions of these accessories.
3. If canopies or trellises are employed, provide means for quick enclosure so that windblown flames and heat cannot be trapped beneath them.

4. If the deck or floor level of a patio or sun deck is above ground level, seal off the underside of the deck or floor by skirting or by a wall to keep fire from burning beneath it.

Water Pumps

Most rural and suburban residences in subdivisions subscribe to community water systems of some type. Many that are not in subdivisions get their water from an irrigation district or private water company. Some of the latter homes must provide pressure and storage for themselves. All other residences must provide their own complete independent water systems including well or spring, pump, and storage facilities. Wherever an occupant has to provide the pump, it must be properly designed and installed and be capable of delivering enough volume for effective firefighting, probably considerably more volume than that needed for domestic use. Most such pumps are electrically powered. Care must be taken that power to the pump is not lost at a critical time, and electric service to the pump should be separate from that to the house. Since power company distribution lines can also burn down, a standby gasoline engine-powered pump should be available. Preconnected hoses should also be available both at the pump and elsewhere about the property for immediate use in case of fire (Oreg. St. Dep. For. 1978a).

Proposed Standards:

1. Install electric water pumps with independent service drops that do not pass through or onto any building.
2. Install pumps capable of delivering a minimum of 100 gal/min at 50 lb in² pressure (a desirable standard would be 250 gal/min at 100 lb in²).
3. Back up electric pumps with a gasoline-powered pump.
4. Preconnect to the pump or distribution main one or more hoses reserved for firefighting purposes and

long enough to reach to all sides and the roof of each building.

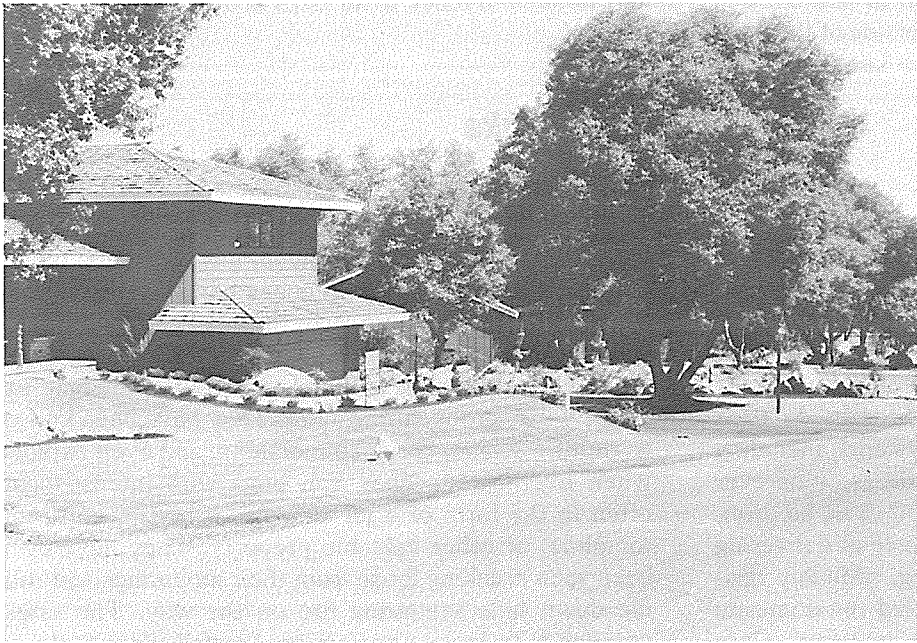
Fuel Tanks

Except for suburban subdivisions and some mobile home parks, most rural and wildland residences are heated either by liquid petroleum gas or by fuel oil. In addition many farms and ranches have their own bulk gasoline tanks. If improperly installed, protected, and separated from other structures and vegetative fuels, the containers for these hydrocarbon fuels become extremely dangerous during a fire. They have been known to rupture seams, break connections, and even explode when overheated. They can burn with intense heat, often in the form of a jet aimed at a house, barn, automobile, or other valuable property. They have even been seen breaking loose from their mountings and rolling down hills scattering fire on the way. The safest practice is to have a professional install these tanks so that they are not only safe from fire themselves but will not endanger life or other valuable property in case they do become overheated (Alger 1971).

Proposed Standards:

1. Hydrocarbon fuel tanks should be installed only by persons licensed to do so and under permit. They should not be placed in operation until approved by a fire marshal.
2. Store gasoline only in properly vented underground tanks.
3. Do not mount fuel oil tanks on the side of the residence or within 15 feet of any structure.
4. Mount LPG tanks on concrete or steel cradles that will not allow the tank to roll; if they are not spherical, orient them so that neither end points toward any structure and, regardless of shape, so that the relief valve does not point at any structure.
5. Require all hydrocarbon fuel tanks to have, properly maintained, the same amount of vegetative clearing as residences and other structures in the same wild-fire hazard severity class area.





OCCUPANT ACTIVITIES

Even if all the recommendations and standards set forth herein are scrupulously adhered to, it is still prudent for the homeowner or other occupant to take steps to protect self and home from fire (Alger 1971, Wilson 1962).

To be effective these steps should be taken in a logical three-part sequence: those things to be done, maintained, or practiced in advance of any emergency; those to be done when an emergency has been forecast or is likely to happen; those to be done when fire threatens the home. The steps in the last group depend largely for their effectiveness on the manner in which those in the first two groups are carried out. Similarly those in the second group depend largely on the steps in the first group having been taken.

Advance Fire Protection

The keys to an occupant's contribution to the fire defenses of the home or other structure are (a) planning of actions, and (b) providing equipment. Planning should include all those actions to be carried out, and by whom, when dangerous fire weather exists or is forecast as well as those tasks to be done when the structure is actually threatened by a wildland fire. Equipment not only needs to be acquired but must be strategically placed and its proper use for firefighting learned. All members of the family or other regular occupants of the structure must participate in the planning and training and must thoroughly understand the proper use of

equipment. Planning should include alternatives so that panic or ineffective actions will not occur in case the primary plan cannot be accomplished or certain equipment fails or breaks (Alger 1971, Building News, Inc. 1977, Oreg. St. Dep. For. 1978a, Hulbert 1972, Smaus 1978b).

Proposed Standards:

1. Include in fire emergency plans the following items as a minimum:
 - a. Normal and alternate escape routes in case evacuation becomes necessary.
 - b. Locations of and routes to fire-safe sanctuaries (large areas with little or no fuels) where family members can ride out the fire if egress is cut off.
 - c. Normal and alternate methods of communication with other family members.
 - d. When to evacuate. Evacuation depends on so many variables that it can only be planned on an individual property basis and with contingent alternatives.
 - e. Who is to do what when an emergency is likely and when one exists.
2. Provide the following minimum equipment for each property, preferably to be used only for firefighting or training:
 - a. Hoses preconnected to all faucets; hoses should be five-eighths inch or larger inside diameter and 100 feet long.
 - b. One or more long-handle, round-point shovels.

- c. One ladder long enough to reach the roof of the building easily.
 - d. One rake (leaf, garden, asphalt or special firefighting).
 - e. One or more 5-pound multipurpose fire extinguishers.
3. Additional desirable equipment includes.
- a. An axe.
 - b. A hoe (heavy duty or special firefighting).
 - c. One or more fire buckets.
 - d. A backpack water pump.
 - e. A portable gasoline-powered water pump.
 - f. Protective clothing for anyone who may not evacuate before the arrival of a fire (i.e., boots, long trousers, long-sleeved shirt or jacket, helmet or other head covering, gloves, goggles).

Preparations for Possible Emergency

The wildland fire protection agencies in California in cooperation with the National Weather Service, U.S. Department of Commerce, have developed a Red Flag Fire Alert System. This graduated system uses watch, warning and alert stages. It usually provides fire agencies, public utilities, and other cooperators 48 hours or more advance notice of impending critical fire weather. The public, however, is usually not notified until the critical weather has actually arrived (alert stage).

Whenever a Red Flag Fire Alert is announced by the local fire protection agency or a Santa Ana or similar wind is blowing or other conditions exist that indicate that a wildland fire, if once started, would be likely to turn into a conflagration, homeowners should start carrying out their fire protection plans. At such times checklists, if not previously prepared in the advanced planning phase, should be made and put to use. The house or other structure should be placed in a maximum state of preparedness for defense against fire (Alger 1971; Building News, Inc. 1977; San Bernardino County Bd. Sup. 1974; Smaus 1978b).

Proposed Standards: Follow any checklist previously prepared and take any of the following actions that are appropriate:

- 1. Close all openings, including windows, doors, garage doors, vents.
- 2. Close window protection equipment as available (i.e., shutters, heavy drapes, venetian or other blinds).
- 3. Remove light flammable curtains from windows.
- 4. Test water system, including any pumps on the property, each valve and each hose.

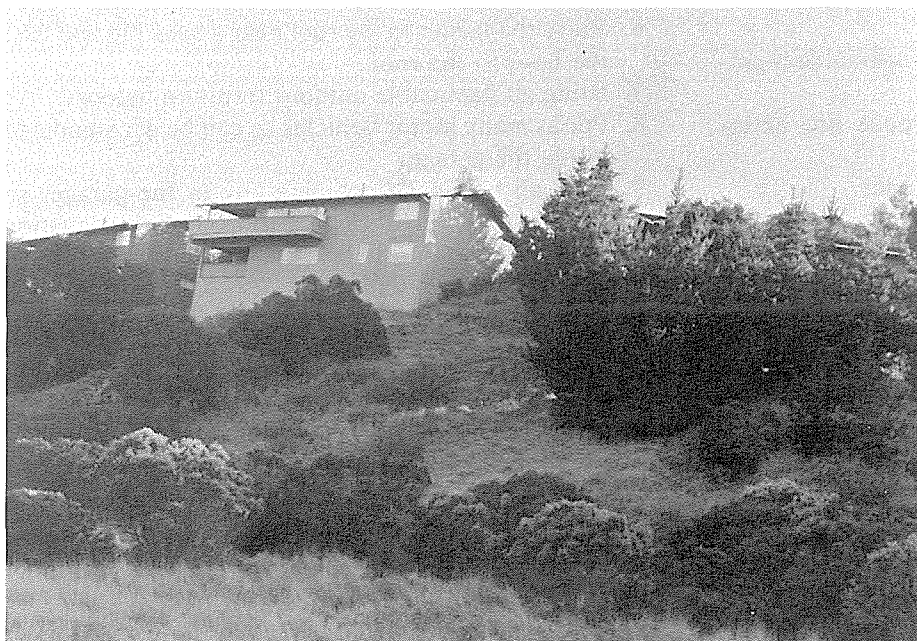
- 5. Fill buckets and other bulk containers with water.
- 6. Raise the ladder to the roof near a hose bib and take the hose to the roof.
- 7. Bring all flammable outdoor furniture indoors.
- 8. Put as many motor vehicles as can be accommodated inside the garage.
- 9. Park all vehicles, including any in the garage, so that they are heading out toward the evacuation route.
- 10. Cover windows with aluminum foil or other heat reflective material.

Wildfire Approaching

When a wildfire is in progress, certain final preparations should be made and certain decisions reached even though it may not be a threat at the moment. Wildland conflagrations can and do change direction of spread abruptly as has been documented on many occasions. Preparations at this time are concerned primarily with conserving water and fuel and reducing the flammability of the building. Whether everyone should evacuate the premises or one or more persons should remain to protect the property must be decided. Children, old people, invalids and other handicapped people should evacuate, but whether all able-bodied adults should do so will depend on the circumstances. Critical factors include: availability and dependability of water, type of roof, proximity of vegetative fuels and other structures, presence of trained and equipped firefighters, adequacy of tools and equipment, and access to fire-safe sanctuaries. Cases of doubt or indecision should be resolved in favor of life safety rather than property safety (Alger 1971, San Bernardino County Bd. Sup. 1974).

Proposed Standards: Take the following actions upon the approach of a wildland conflagration:

- 1. Shut off any natural gas, LPG, or fuel oil supplies at a point as far from the structure as the plumbing will allow.
- 2. Make certain that all water is shut off except that supplying external hose bibs which may be used for firefighting. The house should be plumbed so that closing one valve will accomplish this. If it is not, close each interior faucet and valve.
- 3. Evacuate everyone except possibly one or more able-bodied adults properly equipped to protect the structure and themselves, provided it is safe to remain.



FINANCIAL INCENTIVES

It is neither feasible nor desirable to accomplish all the above recommendations and standards by governmental action through laws and regulations, yet they all have a price, either in money or in labor, and it is not likely that more than a small portion of the homeowners will carry them out voluntarily unless the benefits can be seen to outweigh the costs. The thousands or millions of property owners cannot be expected to be informed adequately of the hazards and risks involved in home ownership over long periods of time in areas of varying fire hazard. On the other hand the few hundred people who control insurance rates, loan terms, and taxes can, and should, be so informed and take the action to set those rates in such a way as to reflect true probabilities of loss and costs of fire suppression.

Insurance Surcharges

A so-called brush surcharge has been published by the Insurance Services Office (ISO) for a good many years. Actually it is based on a combination of factors only one of which is the amount of brush clearance. The other factors used are: type of roof, fire protection class, and response time. Although a step in the right direction, the program is only partially effective for several reasons. Most important is the fact that the surcharges do not reflect the actual probabilities of destruction by fire, and in particular show unrealistic differences between approved and unapproved roofs (20-percent difference in rate compared to 95-percent difference in loss actually measured). Because of this

owners with fire-safe properties are subsidizing those with unsafe properties (*table 5*). Secondly, the surcharge schedule does not take fire hazard severity classification into account. Thirdly, not all underwriters subscribe to the services of ISO, so they are not guided

Table 5—Alternatives in roofing, surcharges, loss, and costs for protection class 4B (\$500,000 home; \$10,000 potential uninsured loss)

Alternative	Surcharge	Expected uninsured loss ¹	Program cost	Total cost
1973 dollars				
Approved roof, 0- to 30-foot clearance	200	81	390	671
Approved roof, 30- to 60-foot clearance	180	18	423	621
Approved roof, 60- to 100-foot clearance	140	5	485	630
Approved roof, more than 100-foot clearance	80	2	530	612
Unapproved roof, 0- to 30-foot clearance	250	165	0	415
Unapproved roof, 30- to 60-foot clearance	225	95	33	353
Unapproved roof, 60- to 100-foot clearance	175	48	95	318
Unapproved roof, more than 100-foot clearance	100	49	140	289

Source: Howard and others (1973).

¹Based on destruction rates from the 1961 Bel Air fire in southern California, and assuming a probability of exposure in a given year of 1/30.

by its recommendations. A revised rate schedule could easily be prepared to incorporate surcharges for substandard installations and rate reductions for those with protection in excess of the standard, and based on true probabilities which would take into account the experience gained from the thousands of buildings destroyed by conflagrations in the past 10 or 15 years (*table 6*). In order to apply to all insurance companies rather than only to those affiliated with ISO, such a rate schedule could be established by the State Department of Insurance (Los Angeles City-County Fire Bd. Inquiry 1971, Howard and others 1973).

Proposed Standards:

1. In addition to the criteria already used to determine insurance surcharges, rates should reflect various levels of fire hazard severity classification.
2. Rate schedules should be revised at 5-year intervals, or oftener, to reflect actual fire loss experience from wildland fires in the previous 10- to 15-year period.

Loan Terms

Mortgage rates and other conditions of loans could be adjusted to encourage fire-safe practices in much the same manner as suggested for insurance rates. High interest rates and other unfavorable conditions for loans on substandard projects and installations coupled with lower rates and favorable conditions for those which exceed the standards would encourage the latter. Such practice is perhaps not entirely consistent with current money market practices. But since the risk is never completely eliminated by insurance coverage, such practice would represent a judicious assessment of the risks to the lender, and would be effective with home buyers. From the standpoint of public safety it would be even more effective if applied to the large loans to developers and builders. If builders sell only fire-safe homes, subdivisions and mobile home parks, the purchasers of their products will start, at least, with low-risk situations.

Proposed Standards:

1. Bare compliance with the standards set forth above should qualify for current market interest rates.
2. Progressive degrees of noncompliance with the above standards should lead to progressively higher rates.
3. Fire-safe practices in excess of the above standards, considered minimum safe practices, should qualify for rates below current market rates.

Tax Adjustments

Fire-safe practices by property owners reduce the cost of public fire protection services. The lack of such

Table 6—*Alternatives in roofing, surcharges, loss, and costs under revised insurance surcharge rates (\$50,000 home; \$10,000 potential uninsured loss)*

Alternative	Surcharge	Expected uninsured loss ¹	Program cost	Total cost
1973 dollars				
Approved roof, 0- to 30-foot clearance	736	81	390	1,207
Approved roof, 30- to 60-foot clearance	164	18	423	605
Approved roof, 60- to 100-foot clearance	49	5	485	539
Approved roof, more than 100-foot clearance	21	2	530	553
Unapproved roof, 0- to 30-foot clearance	1,500	165	0	1,655
Unapproved roof, 30- to 60-foot clearance	865	95	33	993
Unapproved roof 60- to 100-foot clearance	436	48	95	579
Unapproved roof more than 100-foot clearance	348	49	140	537

Source: Howard and others (1973).

¹Based on destruction rates from the 1961 Bel Air fire in southern California, and assuming a probability of exposure in a given year of 1/30.

practices not only exposes the property of the owner or occupant and neighbors to increased risk of destruction by wildfire, it also makes the task of firefighting much more difficult and therefore most costly. Encouraging fire-safe practices through tax incentives would not be a new concept. Tax incentives are already used by both State and Federal Governments to promote energy conservation measures (e.g., insulation, thermal windows, weatherstripping), and they have been used in the past for other purposes. There is no reason, then, why such incentives should not be used by local and/or State governments to encourage fire-safe practices in or near wildland areas (e.g., fire engine access to swimming pool water, fire-resistant roofing, vegetative clearance, granting an easement for a fuelbreak). This approach would be accepted by property owners and occupants with much more grace than the regulatory approach (Alger 1971, Stallings 1970).

Proposed Standards: Enact through legislation tax incentives or penalties, or both, for compliance or non-compliance with minimum fire-safe practices as set forth in this report or as developed for local application based on actual experience and principles of fire behavior and meteorology and taking into account local natural vegetation.



UNDEVELOPED AREAS: AN ADDITIONAL PROBLEM

Millions of acres of forest, brush, range, and other wildland, both publicly and privately owned, are undeveloped, and probably will continue to be so. Public lands are most often set aside by law for watershed, recreation, timber production, range land, fish and wildlife, or some multiple-use combination. Only under very limited situations and under the terms of special use permits are structures allowed to be built on them. By public policy the vegetation is more valuable in these areas than residences or other structures would be. Private lands may be undeveloped for a variety of reasons: economic, physical, choice of lifestyle, legal access, etc.

In some ownerships, certain limited fire protection facilities can usually be found. Sometimes their real purpose is for land management (e.g., ranch roads for salting cattle or timber access roads). In other cases they were built specifically for fire protection (e.g., firebreaks and fuel breaks, helispots, water cisterns). Only rarely, however, and in very limited areas, have these facilities been adequate to protect nearby structures from the danger of conflagration (Los Angeles City-County Fire Bd. Inquiry 1971, Green 1977).

Two basic and several secondary reasons account for lack of fire protection in these areas. One is the sheer magnitude of the problem in reference both to area and to cost. California has between 9,000,000 and 20,000,000 acres of chaparral, and between 45,000,000 and 50,000,000 acres supporting other wildland vegetation. Many other States have similar vast areas of forest, brush, and range lands. Depending on type of

vegetation, topography, and method used, the cost of treating an acre for fire hazard reduction ranges from \$50 to \$500 for initial treatment and from \$5 to \$50 per year for maintenance.¹⁰

The second reason for lack of fire protection is the increased hazard of these areas because of Federal and State policies of total fire exclusion, starting in the early 1900's. This policy has been modified only slightly to allow a limited amount of controlled burning for land management purposes. But fuel loadings—especially dead fuels—have built up to much higher levels than under primeval conditions. Thus fires continue to reach conflagration proportions regularly in spite of greatly improved firefighting capabilities, and the amount of treatment required to reduce the hazard to an acceptable level is considerably increased (Green 1977, Hanes 1974, Houts 1974, Montague 1974, Wilson 1974).

Certain legal constraints contribute to the problem of off-site fire hazards to the wildland residence. Some of these inhibit fire hazard reduction work generally, both on-site and off-site, while others pertain to the rights of adjoining property owners. Among the constraints that inhibit the work are liability laws and environmental protection statutes. The rights of adjoining owners affect the required clearances around structures located on small lots or those otherwise too close to the bound-

¹⁰Task Force on California's Wildland Fire Probl. 1972, Green 1977, Hanes 1974, Houts 1974, Los Angeles City-County Fire Bd. Inquiry 1971, Montague 1974, Pacific Southwest Forest and Range Exp. Stn. 1963, Wilson 1974.

ary (Los Angeles City-County Fire Bd. Inquiry 1971, Task Force on California's Wildland Fire Probl. 1972).

So far, fire hazard reduction and fuels management activities have been viewed by the courts as proprietary actions that benefit only the property owner—be it the government or a private owner. As such, any harm resulting to any other person (e.g., escaped fire, air pollution, drifting or translocated herbicides) imposes a liability, either civil or criminal or both, on the person or agency performing the act. Although entirely in keeping with the Anglo-American legal tradition, this interpretation completely ignores the public protection aspects of the activity. In the United States, most fire protection, other than that of some highly specialized industrial systems, is supported at public expense and is generally treated in the legal system as immune from liability in the absence of malice or gross negligence. Reduction of wildland conflagration hazards is an outstanding exception to this general rule (Task Force on California's Wildland Fire Probl. 1972).

The concept that fuels management activities are proprietary has inhibited such activities on private land in another way: All levels of government prohibit the expenditure of public funds for a private benefit. This is entirely proper, but it again ignores the public benefit to be derived, in addition to any private benefit, from the kind of activities in question. As a result a Federal, State or county fire department or forestry agency cannot assist a private property owner in other than a purely advisory capacity in fire hazard reduction except when a clear and present danger exists (Task Force on California's Wildland Fire Probl. 1972).

Environmental protection laws (e.g., air pollution control, water quality control, pesticide control) are for the most part narrowly single purpose in concept and execution. Such laws rarely recognize relative degrees of public hazard from sources other than those to which they directly pertain. Fire hazard in rural and wildland areas easily can be a much greater threat to public safety than temporary air pollution from a prescribed fire, the killing of a few ornamental plants by an aerially applied herbicide, or temporary water contamination, for example. However the conflicts of law involved are so serious as to make fire hazard reduction work extremely difficult to accomplish (Los Angeles City-County Fire Bd. Inquiry 1971).

The California Public Resources Code (Sect. 4291) requires the clearance of flammable vegetation for 30 feet on all sides of any structure, or to the property line, whichever is nearer. This law works reasonably well, assuming adequate personnel for enforcement are available, for the true rural residences at which it was originally directed (e.g., farms, ranches, mountain cabins). It is almost totally ineffective for the rural and mountain subdivisions which have become common in the past 10 years, at least until all the lots therein are developed with houses on them. As a consequence several cities

and counties, most notably both the City and the County of Los Angeles, have enacted local ordinances extending the distance involved and imposing the requirement regardless of the property line. In most of the wildlands of the State or elsewhere throughout the country, however, the owner of a structure on a small lot or one which has been constructed less than 30 feet from the property line, cannot legally obtain fire protection clearance from the adjoining property owner (Task Force on California's Wildland Fire Probl. 1972).

Fuels Management

One solution to the threat posed by vast areas of vegetative fuels is to treat them so as to reduce the fire hazard they represent to an acceptable level. Reduction of the available fuel (dead and fine living) on broad areas or blocks is one method that can be used. Conversion of the vegetative type to a less hazardous type in long strips (fuelbreaks) strategically located in such a manner as to assist firefighters in controlling fires that do start is another. Such fuelbreaks (*fig. 9*) have proved effective in saving lives, property, and suppression costs. These two basic methods are not mutually exclusive and, with proper planning, can be combined for maximum protective effect.¹¹

Hazard reduction on large areas would be prohibitively expensive. Its use is, therefore, limited to relatively small areas (seldom larger than a few hundred acres) in locations where the values to be protected are high (e.g., downslope or upwind from a small community). Fuelbreaks are also expensive, but their cost-benefit ratio over the millions of acres of concern is much more favorable, especially if they are planned, built, and maintained for multiple use (i.e., fire protection, recreation, livestock grazing, wildlife management, water yield) (Los Angeles City-County Fire Bd. Inquiry 1971, Orange County Bd. Sup. 1976, Green 1977, Stallings 1970).

Because of the expense and its purpose—to protect the public—most fuels management work is done by public agencies. When it is done on publicly owned land it generally requires only a budget justification insofar as the legislative body is concerned. For some agencies, for example, a parks department, however, a policy change may be needed. Fuelbreaks cannot always be located entirely on public land, but they lose most of their effectiveness if left open-ended. Therefore, in order for a system to be completed, or in some cases even begun (e.g., the Santa Monica Mountains in Southern California), the fuelbreak may often have to

¹¹Task Force on California's Wildland Fire Probl. 1972, Green 1977, Houts 1974, Lancaster 1974, Montague 1974, Orange County Bd. Sup. 1976, Pacific Southwest Forest and Range Exp. Stn. 1963, Stallings 1970.

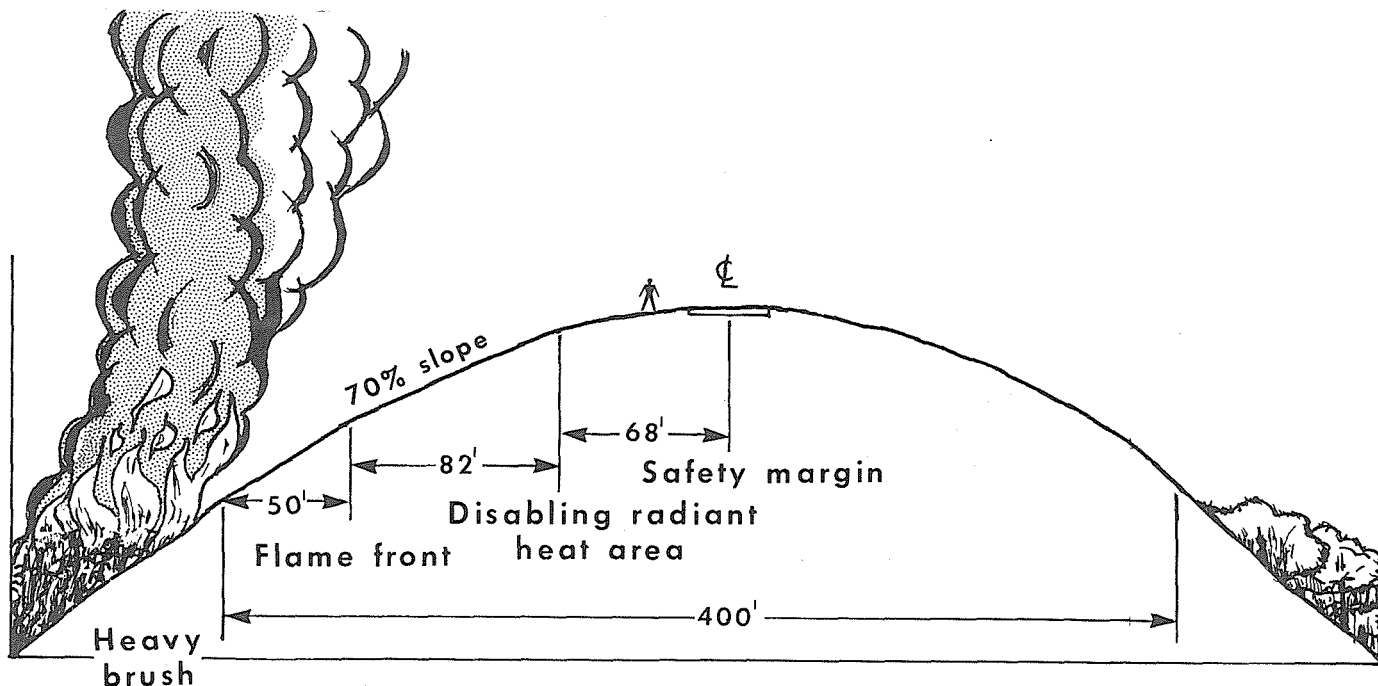


Figure 9—Distances recommended for personnel safety for the given terrain, fuel type, and conflagration burning conditions (Pacific Southwest Forest and Range Exp. Stn. 1963).

cross private land. An economic as well as a legal problem is created. This problem can be solved in any of several ways: (a) the public agency purchases the necessary strip of land (but purchase is seldom feasible unless the land is going to be used as a park or serve some other public function); (b) the agency acquires an easement or special use right-of-way at no or nominal cost, and the cost, if any, is paid either directly or by tax credit (Howard and others 1973, Stallings 1970).

The propriety of expending public funds for right-of-way access or for labor and materials to build and maintain fuelbreaks across private land is often questioned. Although the question can almost always be answered on the basis of an individual project, it would be much more logical to answer it once and for all by legislative policy. The same could be said for block hazard reduction or vegetative type conversion so long as a significant proportion of the benefits of the project could be shown to be for fire protection (Orange County Bd. Sup. 1976, Task Force on California's Wildland Fire Probl. 1972).

Proposed Standards: Build primary fuelbreaks (300 to 400 feet wide) on all main ridges, including motorways and helispots, and secondary fuelbreaks (minimum width of 200 feet) on key side ridges; evaluate the benefits to be gained from block treatment or type conversion of all critical areas upwind or downslope from communities, subdivisions, recreation sites, and other areas.

Legislation

Several matters concerning the fire safety of structures in wildlands as affected by off-site activities can be solved only by legislative actions at either the State or local levels. State Governments need to recognize the public interest in and benefit from fuelbreak, hazard reduction, and block type-conversion work whether done on public or private land. This recognition should then be related to the methods used and the legal implications of this kind of work. Where fire is used the term should be "prescribed fire" rather than "controlled burning." Fire hazard reduction should be given environmental protection status equal to air and water pollution and herbicide control. Where public benefits from work on private land are significant the State should share some of the costs; if not directly then indirectly by providing increased fire control standby services at public expense, for instance, co-insuring against any liability for escaped fire, or creating statutory limits on escape liability as long as certain standards of care were employed (Calif. Div. For. 1972, Lowden and Dengkolb 1972).

Vegetation clearance around structures is a special matter which probably requires legislative action at both State and local levels. California law requires such clearance for 30 feet and authorizes the State's Director of Forestry to require up to 100 feet if conditions are found to be extra hazardous. This statute has three weaknesses: (a) it cuts off at the property line if that is

nearer than the 30 or 100 feet; (b) the Director's authority to delegate the determination of a need for a 100-foot clearance is unclear and has, therefore, never been exercised; and (c) no method or standards for determining "extra hazardous conditions" are provided (Task Force on California's Wildland Fire Probl. 1972, Lowden and Degenkolb 1972).

A very few local governing bodies have overcome the first defect in the State law by ordinance. These brush clearance ordinances operate in much the same manner as do the more common weed abatement ordinances for vacant lots. In effect, they declare brush or weeds on both the residence property and adjoining property to be a public nuisance because of fire hazard and require the abatement of the nuisance. Many more local jurisdictions could use similar ordinances profitably. The second and third defects could be quickly remedied by legislative action authorizing delegation and recognizing fire hazard severity classification as the standard (Los Angeles City-County Fire Bd. Inquiry 1971, Task Force on California's Wildland Fire Probl. 1972, Lowden and Degenkolb 1972).

Proposed Standards: Review laws, ordinances, regulations, and other measures related to wildland fire protection on the basis of recent scientific and technological knowledge, while discounting as much as possible emotionalism, fear, and legal precedent.

Fire Defense Systems

A total fire defense system includes all the manpower, equipment, real property and organization necessary to provide fire prevention and suppression for a given area or jurisdiction. The term is used here in the more limited sense of those improvements needed to enable firefighting forces to contain a wildland fire before it becomes a conflagration endangering houses and other structures. These improvements consist of fuel-breaks, fire roads (truck trails), helispots, safety islands, water cisterns, tractor trails, and similar items³ (County Sup. Assoc. Calif. 1966, Lowden and Degenkolb 1972).

Such systems, to be effective, require detailed planning and large expenditures of manpower and money. Although not foolproof they have proved their worth on

many occasions, and those concerned with the fire safety of homes located in or near the wildlands will find it worthwhile to push for construction and maintenance of these systems (Pacific Southwest For. and Range Exp. Stn. 1963, Task Force on California's Wildland Fire Probl. 1972, Green 1977, Lowden and Degenkolb 1972).

Proposed Standards: Ensure that fire defense systems are adequate to break broad expanses of vegetative fuels into manageable parcels, provide rapid and safe access for manpower and equipment for the quick suppression of fires, and provide facilities to replenish water supplies for fire trucks and helicopters.

Fire Alert Systems

A homeowner or other occupant can do much to help protect a home from wildfire. Most of the work should be done continuously or on a routine schedule, but unfortunately it usually is not. Whether done regularly or not it becomes of critical importance when the danger of a conflagration is imminent.

Under current practices of the Red Flag Fire Alert System, the public is usually not alerted until critical fire weather has arrived. Even then, there is no assurance that more than a small segment of the public is notified because agencies rely almost exclusively on commercial radio and television to broadcast information about critical fire weather. Weather forecasts published in newspapers and broadcast by radio and television seldom provide the public with enough advance warning to be of any significant benefit. Therefore, public notices made sooner—even if they proved to be false alarms and had to be cancelled, would probably be useful. Additional means of disseminating alert notices to the public need to be explored (Orange County Bd. Sup. 1976, Task Force on California's Wildland Fire Probl. 1972, Lowden and Degenkolb 1972).

Proposed Standards: Provide property owners in affected areas with positive notification of impending critical fire weather conditions at least 24 hours in advance of the arrival of such conditions.

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GLOSSARY

Chaparral: Native brush of mixed species (scrub oak, chamise, manzanita, toyon, etc. in California).

Conflagration: A large and destructive fire, usually aggravated by strong winds which carry firebrands over natural or manmade barriers.

Controlled burning: Fire used for land management purposes (e.g., range improvement) for which advance preparations are limited to installing control lines around the perimeter and sometimes crushing the vegetation to get a hotter fire. The only weather factor usually considered is wind of such force as to make fire control difficult.

Cycle time: The average time in years between vegetation fires in a given area. Usually applied only to fires of conflagration magnitude.

Dooryard: That area adjacent to a residence which is regularly used by the occupants and on which the native vegetation has been removed or modified, including driveways, parking areas, lawns, patios, play areas, etc.

Fuelbreak: An area, usually a long strip strategically located, wherein vegetative fuels are reduced in volume and maintained so as to produce a reduction of fire intensity if a wildfire burns into it.

Greenbelt: An irrigated, landscaped, and regularly maintained fuelbreak, usually put to some additional use (e.g., golf course, park, playground).

Mediterranean climate: A relatively mild weather pattern characterized by winter precipitation and long, hot, and dry summers.

Planned unit development: A real estate development, usually of large scale, which is planned and developed as a complete community, including residen-

tial, commercial, recreational, and school facilities as a minimum.

Prescribed fire: Fire used for land management purposes which is conducted under previously prescribed conditions of temperature, humidity, fuel moisture, and wind speed and direction to achieve a specific purpose, e.g., fire hazard reduction, site preparation for planting, control of certain unwanted plants, plant disease control.

Rural: Any area wherein the residences and other developments are scattered and intermingled with forest, range, or farm land and native vegetation or cultivated crops.

Urban: In this report refers to any area wherein the residences and other works of man form an essentially solid covering of the landscape, including most areas within cities and towns, subdivisions, commercial and industrial parks, and similar developments whether inside city limits or not.

Urban wildland interface: That line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels.

Wildfire: An uncontrolled fire, usually spreading through vegetative fuels but often consuming structures as well.

Wildland: An area in which development is essentially nonexistent, except for roads, railroads, powerlines, and similar transportation facilities. Structures, if any, are widely scattered and are primarily for recreation purposes. Includes large cattle ranches and forests managed for timber production.



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FOCUS (Fire Operational Characteristics Using Simulation) is a computer simulation model for evaluating alternative fire management plans. This final report provides a broad overview of the FOCUS system, describes two major modules—fire suppression and cost, explains the role in the system of gaming large fires, and outlines the support programs and ways of implementing the system.

Retrieval Terms: fire management planning, fire suppression cost, simulation, mathematical models, FOCUS (computer program)