Wildland Firefighting

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By

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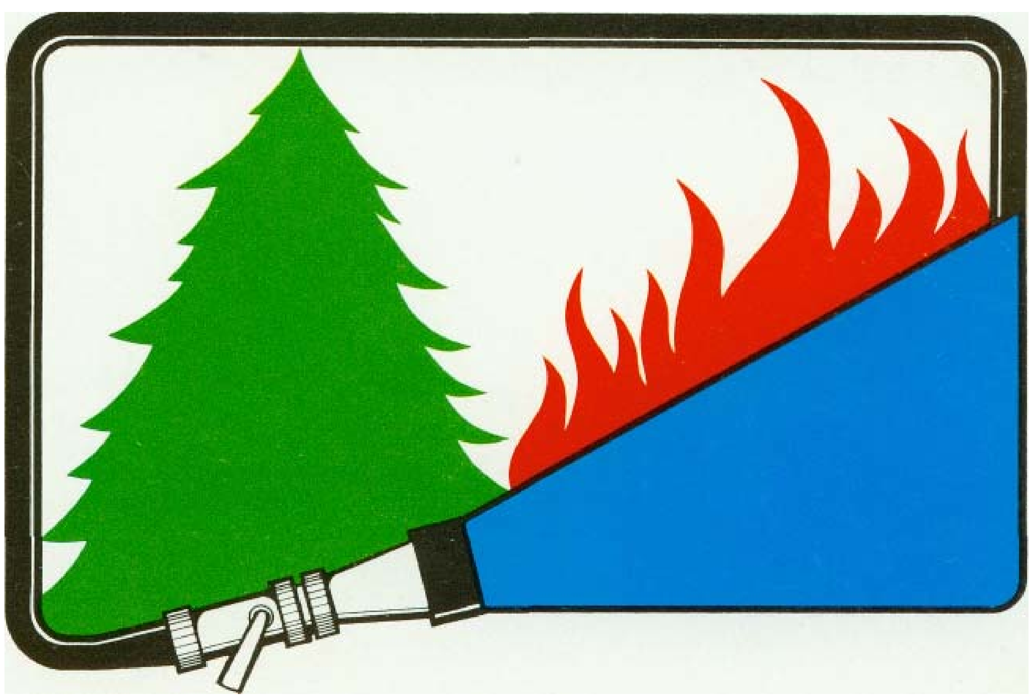

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Acknowledgement

A special acknowledgement is made to C. Raymond Clar and Leonard R. Chatten. These men, while CDF employees, co-authored **"Principles of Forest Fire Management".** This text book, revised in 1966, has been used by fire agencies and educational institutions throughout the U.S. and various parts of the world for some thirty years.

The impetus to write **"Wildland Fire Fighting"** came from **"Principles of Forest Fire Management"** and ideas and material were drawn from it to produce this text. We graciously acknowledge the work of these accomplished fire officials and learned gentlemen.

The Authors

Bill Clayton Dave Day Jim McFadden

Dedication

The authors of this book are not seeking fame or fortune; together we have nearly 80 years of wildland firefighting experience, which only means we have worked a long time. Our intention is to provide you with the best wildland firefighting information available, thereby making your job safer. We dedicate this book to you.

We wish to thank the following people whose hard work and dedication to principle have made this book possible:

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CHAPTER 1

INTRODUCTION

This text has been written for any organization whose firefighters may be required to fight a wildland fire. Wildland fire is defined as any type fire that burns vegetative cover, whether grass, brush, timber, grain, or slash. Also included in wildland firefighting is the direct protection and extinguishment of structures that actually serve as an adjunct to the wildland fuel base and make the work of wildland firefighting considerably more complex.

This book is designed for engine company personnel, hand crew members, bulldozer operators, air attack crew members, and initial attack fire command officers. It covers the basic physical factors involving wildland firefighting such as fuel, topography, weather, and resulting fire behavior. Several chapters are devoted to the fire attack components such as air and ground forces and the tactics, strategy, and organization necessary for their employment. Also included are special chapters on fuel management and fire line safety.

The text would not be complete without some discussion of one factor that is necessary to produce positive fire ground results and forms the cohesive base for all firefighting operations **- leadership.**

Firefighting always has been and undoubtedly will continue to be an important cooperative and synergistic activity. Scientific knowledge and technical ability in firefighting are useless unless firefighters of all ranks can effectively coordinate the human resources under their command.

The group leader can get things done only by coordinating the efforts of the group members. Cooperation among all personnel is dependent upon effective communications. Misunderstanding of an officer's directions, failure to indicate to firefighters the significance of their jobs in the total scheme of things, absence of means of bringing forward a firefighter's ideas and attitudes, failure to enlist the interest and enthusiasm of subordinates, and poor teamwork are all weaknesses in human contacts that lower the levels of fire ground efficiency. This interest may even develop into deliberate opposition and conflict between different units or among personnel and officers.

Materials, equipment, and even money are controllable within defined rules and practices. Personnel are not. Individuals differ emotionally, physically, and mentally in their interests, attitudes, sentiments, and beliefs. Even when faced with a similar set of circumstances, individual reactions may greatly differ.

In dealing with others there is no latitude for sentimentality. Condescension will be rejected for what it is. Even though the approach may be regarded merely as "some new fangled management idea," ^ treating people with dignity and respect will always ' bring better results than a patronizing manner. Treating people with respect will result in higher morale and greater cooperation.

Leadership depends not only on knowledge and experience of the factors involved, but also on personal trust that inspires group members to blend their individual skills, differences, and energies into a cooperative effort. The leader is not a passive person;
he is not someone whose main function is to be on the fireline. The leader acquires status through active participation and demonstration of his capacity to carry cooperative tasks through to completion. A *t* supervisor also has a duty to the fire service to encourage a subordinate's aspirations to leadership and to assist staff to develop the attributes of leadership. This can be done in several ways: by rating potential leaders against the requirements of certain jobs, and by rotating them through jobs (without showing favoritism to individuals), by including the subject of leadership for discussion at company and battalion meetings, and by initiating training in those areas where it is lacking.

It cannot be over stressed that the initiative that makes an individual a leader must come from within one's self. Nothing can make an individual a leader overnight nor can dependence on senior officers develop leadership. Firefighters must individually decide what they want, study the job so they can develop the capacity for it, use every means they can to fit it, grasp the opportunities as they come up, and then go to it. THE BASIC FUNCTION OF A LEADER IS TO INSPIRE PEOPLE TO THEIR BEST EFFORTS. Leaders not only know what should be done, but also how to get it done. Flexibility of mind is most important to leadership. What was wise to do yesterday may well be a very foolish decision today. In the fire service, changes come quickly in some cases and slowly in others, and the ' effective leader must speedily adjust himself and the organization.

Qualities required of leaders in the fire service are courage, will power, judgment, knowledge, and flexibility of mind. There is still one last quality - the greatest of them all, integrity. Integrity and unselfishness always permeate good leadership. Throughout the fire service there is a vast army of personnel and there is no lack of potential leaders. The overall result of successful fire ground operations depends upon the leaders of our battalions and individual companies of crews. [1]

[1]-*Operations - Tactics and Administration in the Field Country Fire Service, Victoria, Australia*

WILDLAND FIRE FIGHTING

CHAPTER 2

WEATHER

Anyone acquainted with the behavior of a wildland fire recognizes the vital influence of the weather. Likewise, anyone who has studied how weather is made and modified in nature and how it is forecast should be impressed with the complexity of that science.

The relationship of weather to fire behavior is much too important to be passed over lightly. However, it is important to realize that forecasting is complex, and requires facilities so widespread, that this aspect of weather is best left in the hands of experts. The presence of such experts at the fire scene has been, and will continue to be, extremely valuable.

The effect of general weather conditions upon the fuel and fire situation is powerful. The high pressure in Utah followed by strong Santa Ana winds in California, or the storm being born off Alaska are of tremendous importance. Warning of anticipated weather could very well rank as unsurpassed in value among all of the tools available to the fire manager.

There are great fundamental laws that are constantly at work making and remaking the weather at every level. With this basic knowledge, field observations on weather behavior should be much more accurate.

When experienced firefighters are given a general prediction of the weather, they automatically convert the prediction into anticipated fuel condition and fire behavior. The long habit of associating brisk, dry winds with severe burning conditions is inclined to make anyone forget that the first is cause and the other effect.

Three master forces govern the making of weather upon earth. These master forces are: heat from the sun - called solar energy, the force of gravity, and the desire of all elements to seek a state of balance or equilibrium.

Keeping in mind these elementary natural forces will not qualify anyone as a meteorologist. It will, however, form a solid foundation from which to observe the making and remaking of weather, both on a grand scale and within the space occupied by a dry leaf.

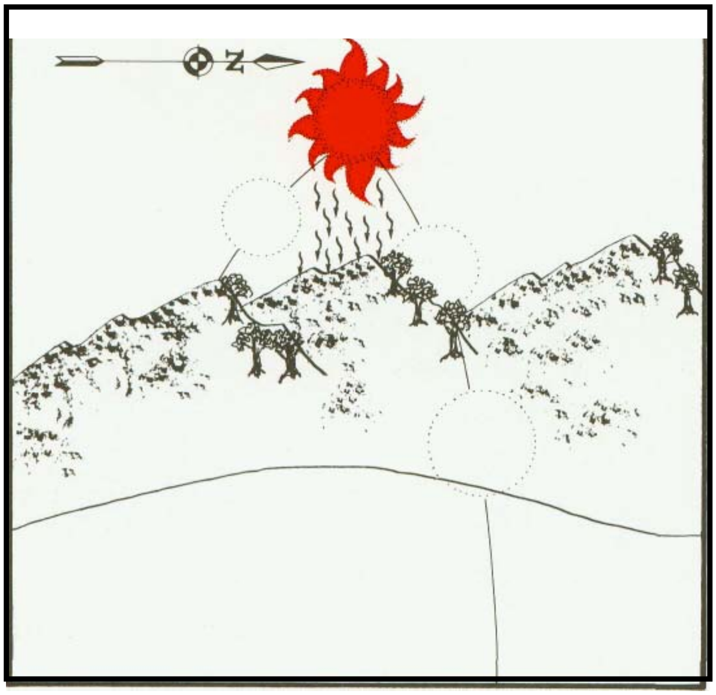
2A — National Fire Weather Service Fire Weather Forecasting Mobile Field Unit.

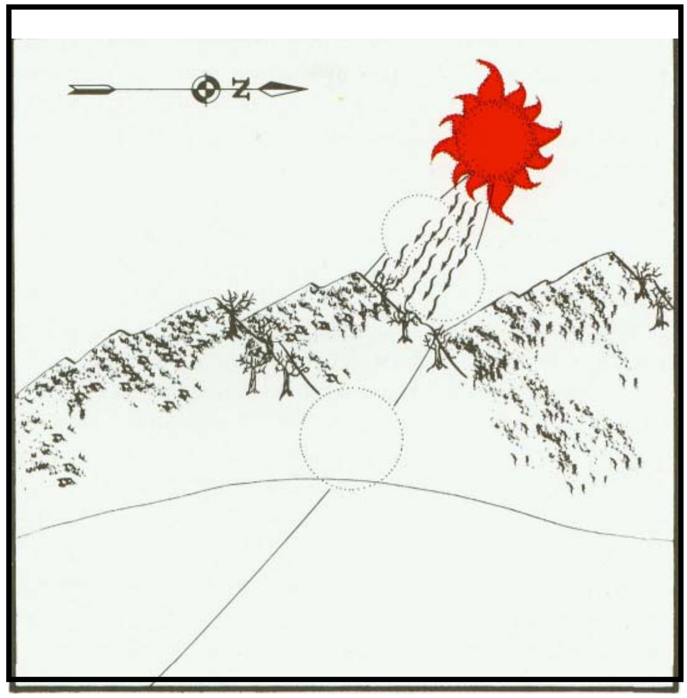
Temperature

Basic fire chemistry considers temperature as an element absolutely necessary to initiate and continue the fire process. Temperature is an element of the weather.

The range of ignition temperature of wood is between 400 and 700 degrees Fahrenheit. Normally the woody fuels of the wildland will burst into flame at approximately 540 degrees (assuming sufficient oxygen is present). Of course, the time required to produce fire at this temperature will vary with the amount of moisture in the fuel that first must be driven out by the heat.

The highest temperature that the sun could be expected to develop on a wind-sheltered surface is 150« or 160 degrees. This is far below any possibility of spontaneous combustion. However, this solar heat is significant, aside from the drying effect of such a high temperature, in that the fuel that gains a boost of a hundred degrees or more, from the sun, is well along toward combustion temperature before the igniting source is applied.





2B — Summer

Winter

Of course, the firefighter may take advantage of the same rule operating in reverse, especially at night or during periods of relatively cool air. Heavy fuel may be separated and turned over to cause it to give up accumulated heat into the air.

The effect of topography upon weather and subsequent fire behavior will be discussed later. This consideration pertains to the manner in which slope, exposure, latitude, and seasons affect the amount of solar heat reaching the earth.

Some generalities may be considered in respect to heat coming from the sun. During the day, a great amount of heat reaches the earth and temperatures are warmer than at night when less heat reaches us. The night temperature reduction is also regulated, in part, by the protective blanket of clouds, haze, and air. Without this protection, a significantly larger amount of our heat would be lost to the atmosphere; night temperatures would drop to very cold levels.

The angle at which sun radiation strikes the earth has direct bearing upon temperature. Visualize the winter sun as it traces a low, southerly arc across the sky. Winter **seasonal** temperatures are cooler because radiation waves are highly angular to the earth's surface. In comparison, the summer seasonal temperatures are warmer due to sun radiation striking perpendicular to the earth. Additionally, long summer days result in more heating and higher surface temperatures; more hours of darkness result in more cooling and lower surface temperatures.

Another variable is that of daily, or diurnal temperatures. Diurnal temperature variation is dependent upon the same factors discussed in seasonal temperatures. Typically, daily sunrise temperatures are the coolest with warming continuing until mid-afternoon, followed by evening cooling;

again, the angle at which sun radiation strikes the earth is important. Topographic features can modify the process, with southern slopes receiving more radiation than northern slopes.

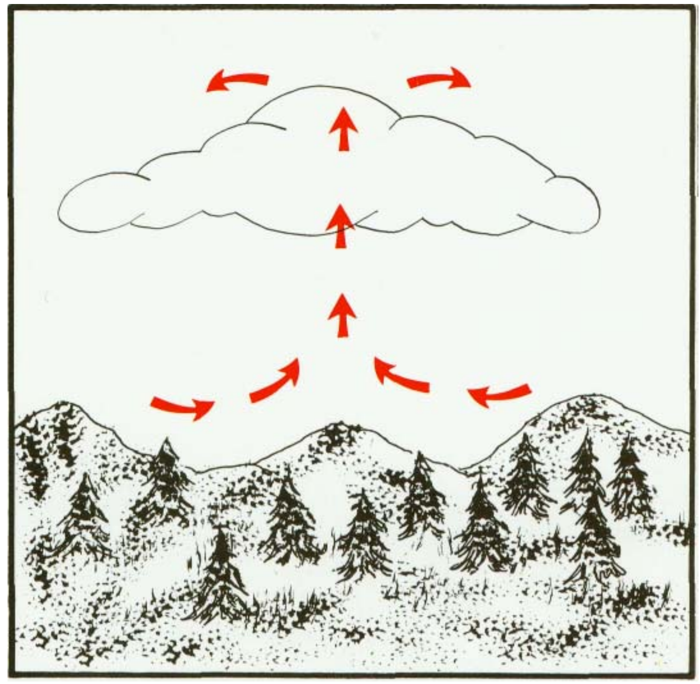
Smoldering fuels along the fireline will begin to support flame production as the sun moves higher in the morning sky. With the arrival of midafternoon, the sun will have brought fuel temperatures to their peak and fire will probably be making concerted runs into new fuels. A general cooling will take place as the sun falls closer to the horizon and flame production eventually may die out as nightfall signals a return to a smoldering fireline. An important departure from this situation is when fire likely will burn as fiercely in darkness as it did in the daytime as a result of yet another weather influence, wind.

Stable and Unstable Air Masses

Stability and instability refer to a relationship between the vertical temperature distribution within an air mass and a vertically moving parcel of air. If air mass temperature decreases sharply with altitude, conditions are favorable for air currents to rise vertically through the air mass. Thus, an unstable condition is said to exist, because vertically rising warmer air can continue movement with little or no restriction. Under this condition, calm fires may suddenly explode with violence and with erratic behavior. Unstable air above the surface is responsible.

Hot air rises and things get colder from a lower elevation to a higher one. In an unstable condition, air mass, being warmer nearer the ground, rises and keeps right on going, higher and higher, faster and faster, thus; unstable air aloft. As the hot air ascends, it pushes aside colder, heavier air. Displaced, this heavier air descends toward the ground and flattens out upon reaching the earth's surface. Firefighters get a sudden "unexpected" wind, and fire suddenly is intensified and pushed in assorted directions, perhaps across a newly constructed fireline.

In contrast, when the temperatures near the ground are more approximate to those aloft, the warm air travels slowly upward and upon reaching cooler air, is cooled itself and stops rising. This is a stable condition, for vertical air movement is stopped and temperature equalization occurs.

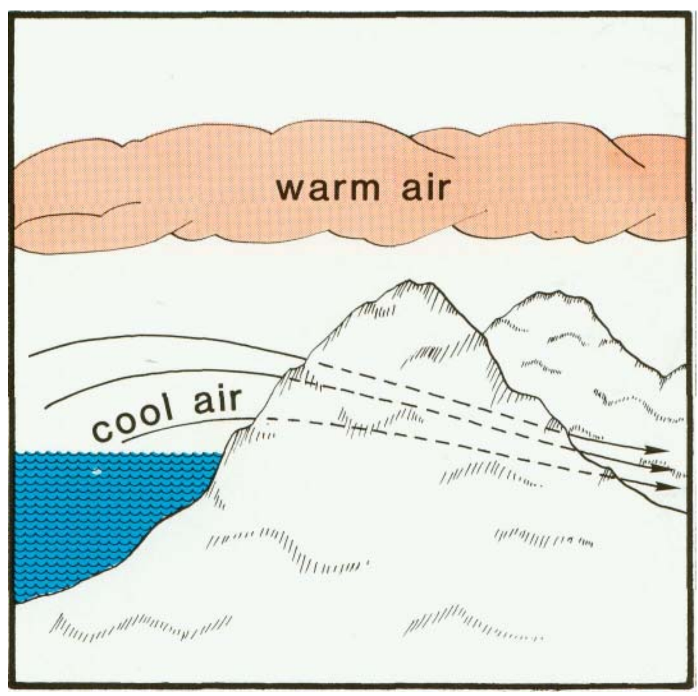


2C — Vertical Air Movement -An Unstable Condition

Temperature Inversions

As discussed earlier, under most conditions, warmer air is nearer the earth's surface, with a cooling trend at higher elevations. However, there are also normal conditions under which quite the opposite is true. Such an "opposite" is called a temperature inversion. In an inversion, cooler air is found nearer the surface, with a warming trend at a higher altitude.

Along the coasts, a marine inversion is created when cool, moist ocean air flows across the lowlands or through hill and mountain passes, to settle heavily within land depressions. This cooler air has a covering layer of warmer air; thus, a temperature inversion. When a mass of air is cooled by nighttime temperatures and becomes sufficiently heavy with moisture, it will flow downslope to collect in land depressions such as bowl shaped valleys. A covering layer of warmer air above, sometimes at a point along a canyon wall, creates the inversion of temperatures.

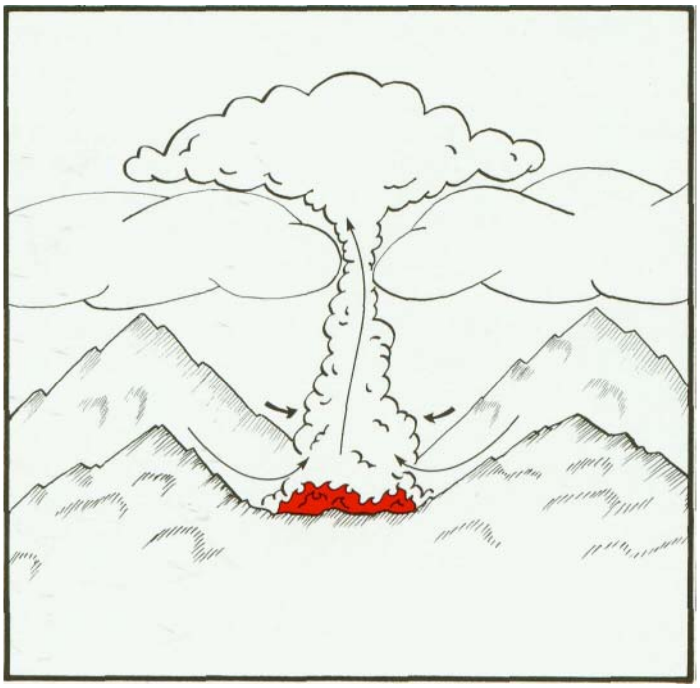


***2D** — Marine Inversion*

It is well known that wildfires often lie down during cooler nighttime hours. Many large fires are contained during this period.

Certainly, fires burning in the cooler environment of an inversion can be expected to subside, become dormant and sluggish, as higher relative humidity and higher fuel moistures become available. Firefighters working the line in the warmer layer above the inversion probably will be faced with fire activities quite different from their counterparts in the cooler area

below. While nighttime temperatures can generally be expected to drop at all elevations, they will be less advantageous in the warm upper air lid of the inversion.
The most prominent danger period involving an inversion will occur at that point when a sluggish lower elevation fire suddenly burns through the lid into the warmer air above. Intense burning, accelerated fire spread, and higher flame heights can place an unprepared crew in immediate jeopardy.



2E — The inversion is broken

Probably the world's best-known inversion layer is that which often hangs against the mountain walls above the Los Angeles basin and causes smog to be trapped below in a stable atmosphere condition.
The stability of the atmosphere situated within this inversion layer can be disturbed and finally overcome by air movement such as the Santa Ana winds in Southern California which commonly clean out the stagnation and create remarkably clear air conditions. With the stability removed, the instability of a clear day is likely to introduce a different fire behavior to be dealt with.
The process by which fire spreads up a mountain slope is partially dependent upon the stability, or instability, at hand. Spread characteristics generally are slower in stable air because of the tendency of air to remain at a given altitude. Lacking vertical movement, the stable air is not conducive to aiding fire movement continuously up long slopes. While stable conditions are said to resist vertical air movement, some movement does take place in varying degrees. Unstable air aids the development of vertical air currents and fire may be expected to extend up mountain slopes with this predominant flow. Vertical air currents do not automatically develop in unstable air; some external force or lifting action such as convection caused by surface heating or lifting over mountains (orographic lifting) must supply the initial motion. Weather elements such as thunderstorms, turbulence, hail, gusty surface winds, and showery precipitation are normally associated with unstable air.

2F— Convection column resulting/row blow up on the Boulder Fire, San Diego County, Calif.

Looking beyond the earlier example of the **Los** Angeles basin, other treacherous inversion traps are well known to experienced firefighters, especially along the northern California coast. Such situations develop and behave in the following manner. Decreasing temperature and increasing humidity of evening will cause a fire burning in a wooded canyon to "lay down" through the night. Warmth from the ground and the fire will rise until it strikes the inversion ceiling. Throughout the night some cold air may slide down the canyon sides and cover the fire area. In the morning probably a low blanket of smoky haze is the only indication that yesterday this area was ablaze. Then the sun's heat begins to be absorbed by the canyon bottom. Temperature near the ground builds up rapidly and new convection masses struggle upward against the inversion boundary. Suddenly the pressure blanket is pierced and the hot air rushes up. Fresh air is sucked toward the fire from a lower elevation or down along the canyon sides and the sleeping fire "bursts" into new life with explosive speed and energy. This example of sudden and erratic fire behavior may form a "blow up" condition.

Temperature, an important element of weather, is a necessary part of combustion, and closely related to two other weather elements, humidity and air movement.

Relative Humidity

Water vapor, which is simply water in a gaseous state, is a most important ingredient in weather. When air passing over a water surface it picks up water vapor, the process is called evaporation. The oceans are **the** primary source of water vapor to the atmosphere. Lakes, rivers, moist soil, snow, and vegetation furnish lesser amounts.

The **dew point** is that temperature, at any given altitude, at which the air becomes completely saturated. The term **relative humidity** indicates the ratio of the amount of water vapor actually present to the maximum amount that the air potentially could hold. If relative humidity is 100%, the air is said to be completely saturated; it can hold no more water vapor.

In contrast, if the relative humidity is measured at 50%, then the air is only *Vi* saturated and potentially can hold 50% more water vapor. When the relative humidity descends below about 30 percent, the situation is becoming favorable for wildland fire. The dryer air is more able to pick up water vapor from the fuel, with the result that less time is required for heat to bring about combustion. Fuels absorb and give up moisture at different rates; larger fuels are affected very slowly by humidity changes. Grass is affected quite readily and may not burn at all when humidity of 40 plus percent is present for an hour or so.

Firefighters can take advantage of humidity in several ways such as conducting firing operations while humidity is low or by finishing firelines at night when humidity is high. Failing to recognize the effects of humidity can also work against the firefighters. Many firing operations have been outright failures because late afternoon or nighttime humidities prevented even grasses from burning cleanly, and firefighters found themselves faced with an incomplete burn which more than likely would roar to life with the heat of the next day.

Wind Velocity and Direction

Wind is simply a movement of air. The average person thinks of wind as generally horizontal air movement fast enough to be felt. That is only because a person is much less aware of the causes, than of the horizontal air movement one can feel and observe as a mover of light objects.

Over the face of the earth several major forces are at work unceasingly to stimulate air movement. First, there are the vast areas of heated earth surface producing rising air currents that return to earth in the cooler regions; then there is the gravitational effect of the turning earth upon these tremendous churning currents. The changing seasons alter the pattern of wind movement because the hot and cold regions of the earth are shifted. From this point on the wind (and with it all weather behavior) is modified by the effect of bodies of water and land masses, and then by the lesser features in each local area.

Wind reacts like a fluid and can be compressed under pressure, expanded and contracted with heat and cold, made moist or dry. It may pause unmoving and then spring in any direction with violent gusts.

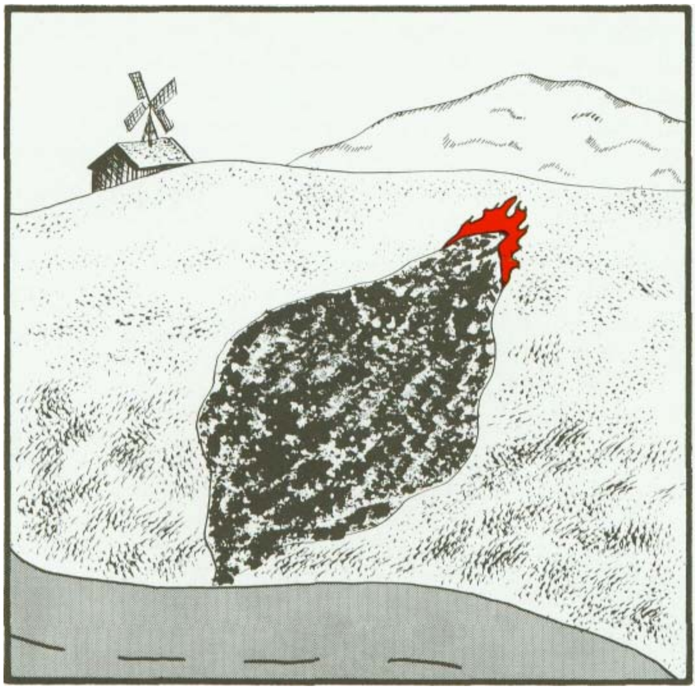
Wind movement is of vital importance to the firefighter. It would appear that the best approach to becoming master of such a flexible and untamed natural element would be for the firefighters to become acquainted with the air movement habits of one's own region. In the chapter on Fireline Safety, is information concerning the issue of weather, and why a lack of knowledge can be dangerous.

If fuel and topographic conditions do not alter the result, it can be said that a strong wind in one prevailing direction will cause a long wedge or elliptical shaped burn. This comes about not only from the driving force of the wind, but also because an augmented combustion will demand an indraft toward the fire from the flanks.

Winds may cause fires to jump prepared lines or natural barriers. Winds may drive a crown fire through tree tops when normally a lack of understory heat would cause a crown fire to subside.

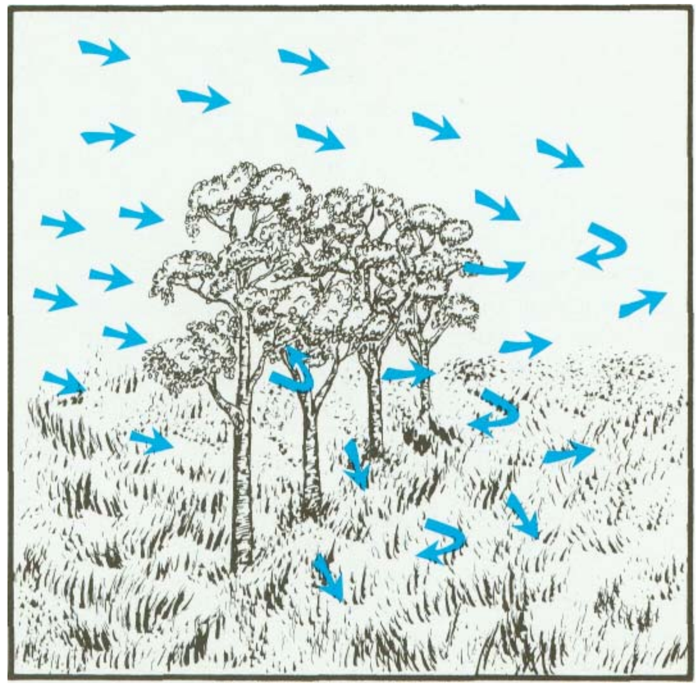
Large fires make their own local weather, especially in respect to air movements. Large convection up-drafts cause air currents along the ground toward the fire and sometimes cause downdrafts of importance out beyond the fire perimeter. Smoke clouds may shade the sun and alter the temporary radiation of solar heat toward and away from the earth.

Over broad areas such as plains or long wide valleys, the prevailing direction of the wind can be quite easily predicted throughout the year. But in irregular topography, the local wind courses may be quite different from the major prevailing conditions and also more changeable from time to time. Irregular topographic objects and vegetation act as a drag on ground wind movements.



2G — Elliptical burn pattern caused by strong winds

The common habit of winds changing direction or intensity throughout the day and night is well known. The particular condition in each locality will depend upon the temperature changes in and around local topography. Large bodies of water, such as the ocean and lakes, usually cause winds to blow inland as the sun warms the land area about midday. The wind blows outward when the land cools more rapidly than the water area at night. Isolated mountains draw air upward as in a chimney when the mountain slopes warm under the sunshine. The local effects of topography on wind are as varied as are the shapes of the topographic features. The directions and velocities of the wind, the time of day, the aspect (exposure) in respect to the moving sun, and many other influencing factors control the way surface winds blow. The gradient (general) winds blowing above the surface are the predominant element much of the time. But whenever these winds weaken in the presence of strong daytime heating and nighttime cooling, convective winds of local origin become important features of weather in areas of broken topography.

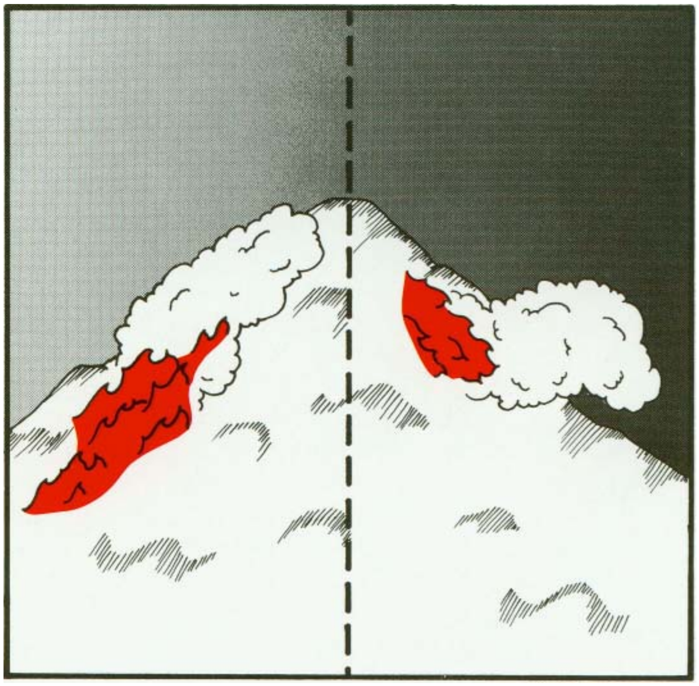


2H — Wind currents are changed when passing over obstructions.

The formation of cumulus clouds directly over peaks or ridges can have a marked influence on wind velocities and direction. As the cloud cell grows, strong indrafts are created that can increase upslope winds on the higher land surfaces nearby. After the thunderstorm cell has passed its most active stage, large volumes of cold air may be cascaded to the ground as a strong downdraft. Although usually only lasting a few minutes, these gusty winds can strike suddenly and violently with speeds up to 30 miles per hour and higher.

The passage of a cold front will invariably affect wind velocity and more often than not cause a shift in wind direction. Cold fronts will often give visible evidence of their presence in the form of high cloud cover. As these fronts pass over, there will usually be a marked increase in wind velocity followed by an abrupt clockwise shift in direction from 45 to 180 degrees.

The one general statement that can be made regarding expected normal wind movement in the mountains is that upslope winds will occur as the result of surface heating in the daytime and downslope winds will occur as the result of surface cooling at night.



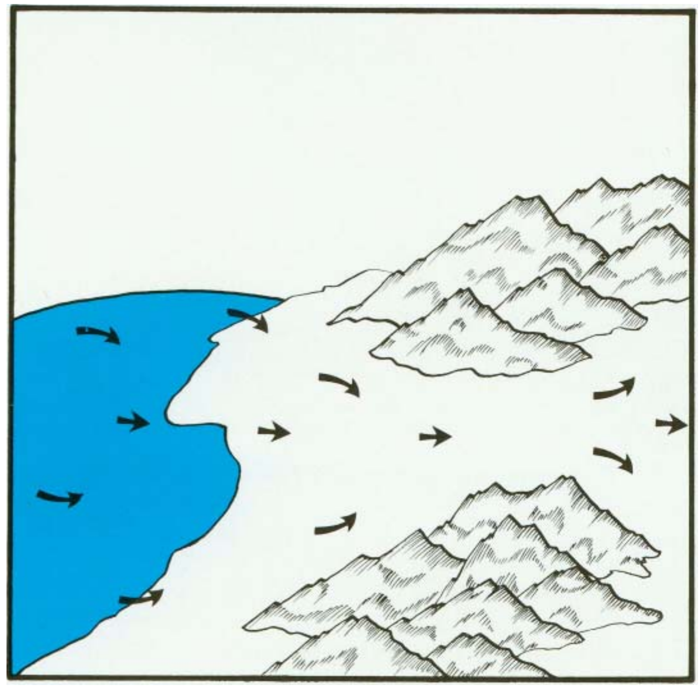
21 — Upslope winds in the daytime - downslope at night

Orientation of topography is an important factor governing strength and timing of wind flow. Upflow begins first on the east facing slopes as the sun rises. Other areas are affected gradually, soon after the sun strikes their slopes. The intensity of upslope wind increases as daytime heating continues. South and southeast and southwest slopes heat the most and therefore have the strongest upslope winds. Often velocities are considerably greater than those on opposite north slopes. Morning upslope winds flow straight up slopes and minor draws. The increased velocity of canyon winds later in the day turns the direction of upslope winds diagonally upcanyon.

The change from upslope to downslope wind will usually begin on those areas first shaded from the sun. First, the upslope wind will gradually diminish; there will be a period of calm and then a gentle downslope movement will begin. A large drainage can easily have varying degrees of this transition in process at the same time, depending upon exposure to the heating rays of the sun. When all areas are in the shadows, the downward movement of air strengthens until winds are moving in a 180-degree change of direction from daytime flows.

Strong upcanyon winds can be quite turbulent and will form large eddies at bends and tributary junctions. Fires burning in these locations will behave very erratically and may spread alternately one way and then another, but generally will move diagonally upslope.

It has been noted that strong daytime heating often produces rising convective winds that are capable of holding gradient winds aloft. In contrast, strong gradient winds can completely obliterate local wind patterns. The gradient wind effect will vary with the stability of the lower atmosphere. Stable layers, of which inversions are an extreme type, tend to "insulate" the local wind patterns from the gradient wind and thus minimize its effect. When the lower atmosphere becomes less stable, there is opportunity for more interchange between the gradient level and the surface layer and the gradient wind effects are greater.



2J — Marine Air Moving Inland

A gradient wind blowing toward the sea will reduce the sea breeze and if strong enough, may prevent the sea breeze entirely.

Along the coastal ranges of the west coast mountains, marine air intrusion complicates the firefighter's ability to forecast wind movement. All of the preceding discussion of convective winds would lead one to believe that downslope winds in the heat of a summer day are either non-existent or rare. Such is not the case. They do occur regularly and frequently. Marine air moving inland over the coastal mountains can often spill into EAST facing canyons or draws and flow beneath the locally created warmer upslope winds. Being heavier, the marine air will flow first through saddles and over low points and follow drainages and slopes closely, thus reversing ground wind direction from upslope to downslope. The change in direction can occur rather quickly. Cases have been recorded where the reversal took place within a few minutes with the downslope velocity considerably greater than the upslope had been shortly before. Needless to say, this sudden shift in wind direction can adversely affect fire behavior in the areas involved.

The behavior of wildland fires in the coastal mountains and valleys of California depends largely upon the depth, penetration, and modification of cool, humid marine air that develops over the upwelling coastal waters and moves inland during the summer and fall months.

Certainly the higher humidities found along the coast have proven themselves the friend of the firefighter on countless occasions.

However, in research done by the Pacific Southwest Forest and Range Experiment Stations in 1963, it was found that the full extension of sea breezes inland does not necessarily guarantee high humidities over the full wind range. In the study, done in August, the following was discovered:

On eleven days of a forty-six day period, the cool marine air penetrated less than 20 miles inland, even though the sea breeze front penetrated nearly 100 miles. On these days, the sea breeze that reached the coastal mountains and valleys was relatively warm. According to the research, as the marine air penetrated the coast and moved inland, it was warmed by inland temperatures and thus was modified in terms of its original moisture content.

This phenomenon no doubt has been responsible for disappointing firefighters, who, having heard the morning forecast for cooler humid air, found this air to be quite dry and capable of pushing fires toward the east with some persistence.

The research pointed out that for this modification to take place, the marine layer is rather shallow and on days when the layer is substantial, the humidity levels were more approximate to those found along the coast prior to moving inland.

There are numerous coastal mountain ranges that lie on an east-west plane, perpendicular to the shoreline. Here afternoon marine air flow is fully capable of pushing fires with considerable speed inland through rather unrestricted systems of canyons, ravines, gullies, and valleys.

Sea breezes occur because of the temperature difference between land and sea. As the summer morning sun warms the land, warm air rises creating a lessening in pressure. In an effort to seek an equilibrium, the colder sea air moves inland toward the lower pressure area. Thus the sea breeze establishes itself.

Wind of any kind has a marked influence on fire intensity and behavior. But the **foehn** winds that normally occur in the fall of the year have the most devastating and adverse effect on fires.

Foehn winds are known as north winds in northern California, Mono winds in the central Sierra, and as Santa Ana (also called Santana) winds in southern California. Such winds are capable of reaching extremely high velocities — 80 to 90 miles per hour across ridge tops and peaks. They are characterized by blowing downhill while hugging the land profile, being warm (at least warmer than they were at the same elevation on the windward side of the mountain), and becoming progressively more dessicating (drying) as they descend. They can blow unabated around the clock for several days.

A fire occurring under extreme foehn wind conditions can spread with such violence that control forces will be temporarily powerless to take control action except in the rear and flanks. Spot fires can occur in the dehydrated fuels a mile or more in advance of the main fire and become raging infernos on their own before being joined by the original fire front.

Such fires are capable of crossing both natural and manmade barriers not only through long distance spotting, but by direct contact with new fuels when winds literally flatten flame sheets horizontally.

Wind direction is generally responsive to the direction from which the greater pressure bears, as that dominant pressure is modified by local pressures and topographic wind channels. Wind speed is responsive entirely to the strength of the dominant force that causes a pressure to bear upon an air mass from any single direction at any single instant. The rules are rather simple. The result can be most complex, especially in the broken topography where so many wildland fires occur.

A knowledge of the change of local climate during the day and night is of vital importance to the firefighter. If unaware, the long quiet flank of the fire at dawn may suddenly become the fire's head when the usual afternoon wind shifts direction, and the firefighter may become more than embarrassed. Ignorance becomes responsible for an unnecessary disaster. Wildland firefighters who know and use the "Ten Standard Firefighting Orders," as well as have a working knowledge of the "Thirteen Situations That Shout Watch Out!" will be better able to use information on current and expected weather conditions to an advantage.

Wind not only affects fire behavior, but creates related problems for firefighters. Perhaps the most common is eye injury from wind blown material. In addition, specialized equipment such as aircraft will find limited use. Airtankers and helicopters lose effectiveness when wind speeds reach 20 to 30 MPH, and above 30 **MPH,** air tankers will normally be grounded due to their ineffectiveness and for safety reasons.

Fuel Moisture

WATER DOES NOT **BURN.** We have considered water vapor in the air (measured as humidity) and we have considered the effect of temperature on fire behavior. Actually, neither relative humidity nor air temperature have any effect upon the flame, or if they do, it is too technical a matter to be discussed here. What really concerns the firefighter is the condition of the fuel that will feed the fire.

Whether that fuel will be flammable depends on the proportion of its moisture content. Moisture in the fuel will not burn; it must be converted to steam by heat and driven away before combustion will take place. Air moisture is absorbed into dry fuel or taken away from the fuel by dryer air during Nature's eternal striving to set a balance.

While many parts of the country are subject to considerable rainfall, it is almost a forgotten element in a discussion of fire behavior. If rain is the firefighter's friend that goes elsewhere during the long, dry summer, it nevertheless has provided quantities of moisture to soak into the fuels during winter. By delivering water to the soil reservoir, it sets the length of the growing season for vegetation, thus controlling the moisture content of living fuels.

As the storage of rain moisture is dissipated into the air through growing leaves, or by evaporation from logs and litter, cumulative water loss can be measured from the fuels. This moisture loss can easily be measured as a loss in weight of the fuel particles. Eventually, the lighter dry fuels will lose their stored winter moisture and then reflect only a change in moisture content as air humidity causes water vapor to move into and away from the body of the fuels.

Heavy fuels such as logs will give up their moisture slowly and they will absorb it slowly. Dry leaves and grass will respond quickly to the relative humidity of the air and will vary from houi to hour and day to day. Green, living leaves naturally respond in accordance with the complex transpiration habits developed by each species.

The fuel that will not burn in a midnight or early morning backfire will probably be ready to roar when the decreasing air humidity of midmorning or afternoon arrives.

A great deal of the chaparral vegetation of California may be actually dry and dormant during the hot summer. These plants have passed the wilting point but nature has provided them with a rigid green structure. Unfortunately, too many strangers to our outdoors mistakenly believe that green leaves simply will not burn.

Later, fuel moisture as it relates to greenbelt planting around individual homes or communities will be discussed.

Nature's Danger Signals

Lightning does hit twice in the same place. In fact, where it is common, it strikes in a pretty well established pattern. It is not the rapid build-up of a potential lightning storm that offers the greatest unpredictable nuisance to the firefighter. It is sudden gusts of wind or violent changes in force and direction that can quickly upset the firefighters' best plans. As a matter of fact, lightning most often is born of the same natural phenomenon that can cause most local air turbulence — the convection upsweep of the cumulonimbus cloud.

Cloud Forms

Clouds are simply moisture particles in the air (which may be ice crystals when high enough). They form when a mass of relatively warm air containing water vapor has its temperature lowered by one means or another to the point where the water vapor condenses into fog, rain, hail, or snow. When the fog or mist rises above the ground it is called a cloud. Clouds may form on a grand scale in a tropical monsoon, or in the solitary miniature cloud cap where warm ascending air is chilled when it reaches the tip of a snow peak.

Clouds are generally segregated into families occupying a relative height above the earth. The drizzly mist that drifts over the hills in winter is cousin to the pale sheet clouds of warmer weather; they are of the stratus family and they generally indicate stable air conditions. Certainly the high stratus sheet clouds of summer are friendly to the firefighter. They indicate a * lack of turbulence at their elevation and they reduce the penetration of heat rays from the sun. Also they counteract the violent upheaval of cumulus updrafts that may be forming below them.

When a mass of warm air containing a relatively large ' amount of water vapor moves upward in a convection current, the cumulus cloud is born. This happens when the warm air reaches an elevation where the | temperature is capable of condensing the air moisture. This condensation point most often occurs at a rather precise elevation and thus the flat under-surface of the cumulus cloud is formed.

If the strength of the updraft is powerful enough, the rising air (now visible as beautiful, rounded cloud billows) in seeking a state of equilibrium reaches the height and temperature where the vapor turns to ice particles. The cloud is now a potential rainmaker and it is a fully formed cumulonimbus. Thereafter, it may degenerate into the high cirrus or low altocumulus formations, or even disappear if the temperature aloft changes enough to absorb the moisture particles. Most likely the familiar thunderhead (sometimes called anvil or cauliflower) will develop and rain or hail and lightning will strike the earth.

Oftentimes, a summer rain is a welcome event for firefighters. In the absence of new fire starts from lightning, many firelines have been cooled down and even drenched with the passage of such thunderstorms. However, this is not always the case;

firefighters, often wringing wet themselves, are faced with intensely active fire perimeters. Strong winds can be experienced as a thunderstorm of this variety passes overhead. The tremendous convection updraft is generally confined to small areas and movement upward is known to have reached one hundred miles per hour in some storms. This, of course, will mean that the wind will blow toward the bottom of an approaching storm and then change directions to the observer as the storm passes by.

The downdraft that flows away from these cumulus clouds is another disturbing element surrounding the clouds. Extremely strong and erratic winds can occur where these downdrafts pancake against the ground surface.

In general, winds will be strongest in the direction of cloud travel and fire may be driven rapidly and in complete disregard for terrain features. Obviously, a dangerous situation may arise when the fire is situated between the thunderstorm cell and the firefighters.

Downdrafts will be extreme during hotter days because the downdrafts are markedly heavier than the warm layer of ground air. Since downdrafts are said to move radially away from the cell, winds will hit the fireline from different angles as the cell moves past. For instance, if a thunderstorm moving to the east passes along the northern edge of a fire, winds will first be westerly, then northwesterly, northerly, northeasterly, etc. In this changing situation, firefighters may find new heads being formed as well as different spread direction along the perimeter. Large wildland fires send up a warm column of air that often cause a true cumulus cloud to form over them. Here, too, a downdraft will be a natural phenomenon, but fortunately it can be expected to reach the earth well beyond the fire perimeter.

Small, separate cumulus cloud tufts or "cotton balls" are called fair weather cumulus. Nevertheless, they are the result of convection updrafts and the firefighter should expect to find turbulence around the area as they pass overhead. The glider pilot searches them out because the rising air is there to support his craft. When any of these clouds become shredded or elongated like cigars, it is because strong winds aloft are acting upon them. That is a sign that soon the air near the ground will be affected by the same turbulence. It is a danger signal for the firefighter. Virga or moisture streamers beneath cumulus clouds are another visual warning that adverse winds may soon be expected on the ground.

Dust Devils and Mirages

Dust devils are small whirlwinds that always indicate an unstable condition of the atmosphere with a readjustment soon to come. They are most prevalent during the middle of the day when the sun has heated air near the ground to the point where expansion caused by heat is out of balance with the density of atmosphere above the ground. At this point, a small triggering action can create turbulence. This becomes a reality as warm surface air movements are interrupted by a rock or haystack or a small updraft in a gully. Friction and confusion upset the even flow of air that begins to whirl around and upward until it expends its energy in a crazy gyration.

The uneven burning effect of scattered patches of fuel on a large fire can develop the same type of whirlwind. Here it is potentially more dangerous than a flamethrower. It may also generate enough of a convection current to cause a blow-up over the smoldering fire area. Utmost caution should be observed when the surface air is capable of producing dust devils.

Not all whirls are composed of dust or are small in size. Whirlwinds carrying visible flame in their great revolving trunks reach tremendous heights and have awesome wind turbulence capabilities.

It is true that during any hot day there is danger of turbulent air movements that could create treacherous fire behavior. The safety valve is, of course, a reasonable adjustment of pressures and tensions in nature that do not react so rapidly as to cause a situation which man cannot control or, at least, predict. Inversion layers of atmosphere are said to be stable enough. It is the violent rupture of the inversion boundary under pressure that can cause the trouble for firefighters. Normally, on a hot day, warm currents of air will move upward. A low flying airplane over irregular topography and different vegetation often gets a rough ride through these convection chimneys. Often, too, a very great change in temperature is felt at definite elevation levels in the air. These are the inversion blankets interfering with the upward dispersal of the convection currents. Such indications are prime danger signals for the firefighter on the ground.

The same potentially unstable air condition over warm earth that produces dust devils may also produce mirages. These are familiar as "lakes of water" that disappear when one approaches them or changes observation points. The illusion is caused by refraction or bending of light rays through layers of air of different density. The "lake" is probably the reflected sky. This thin and very warm layer of ground air should be rising and losing its heat, but air of somewhat higher density presses down upon it from above. With enough turbulence in the vicinity this low blanket of warm air would have an opportunity to seek an area of equilibrium at a higher elevation. The proper triggering action could cause air turbulence near the earth, very probably in the form of sharp convection updrafts.

Turbulent air movements near the ground create difficulty in fire control as well as a serious hazard to life and property. The hazard is found not only in the existing disturbed weather conditions but largely in the treachery of sudden and unexpected shifts from gentle to violent local weather behavior. This occurs when natural forces under tension move abruptly toward a state of equilibrium.

The visible behavior of some natural elements will warn those capable of reading the signs that the apparent calmness or normalcy of surface weather is not trustworthy. The firefighter should be aware that the unusual behavior of fires burning on some days of apparently normal weather could very well be the logical but unhappy result of the abnormal or highly unstable local weather conditions that were failed to be observed.

Investigation of wildland fires where fatalities have occurred substantiate the fact that while the situation at the scene appeared to be quite docile, mother nature was conjuring up a mixture of ingredients to outwit the firefighter who failed to recognize telltale signs.

Fire Whirls

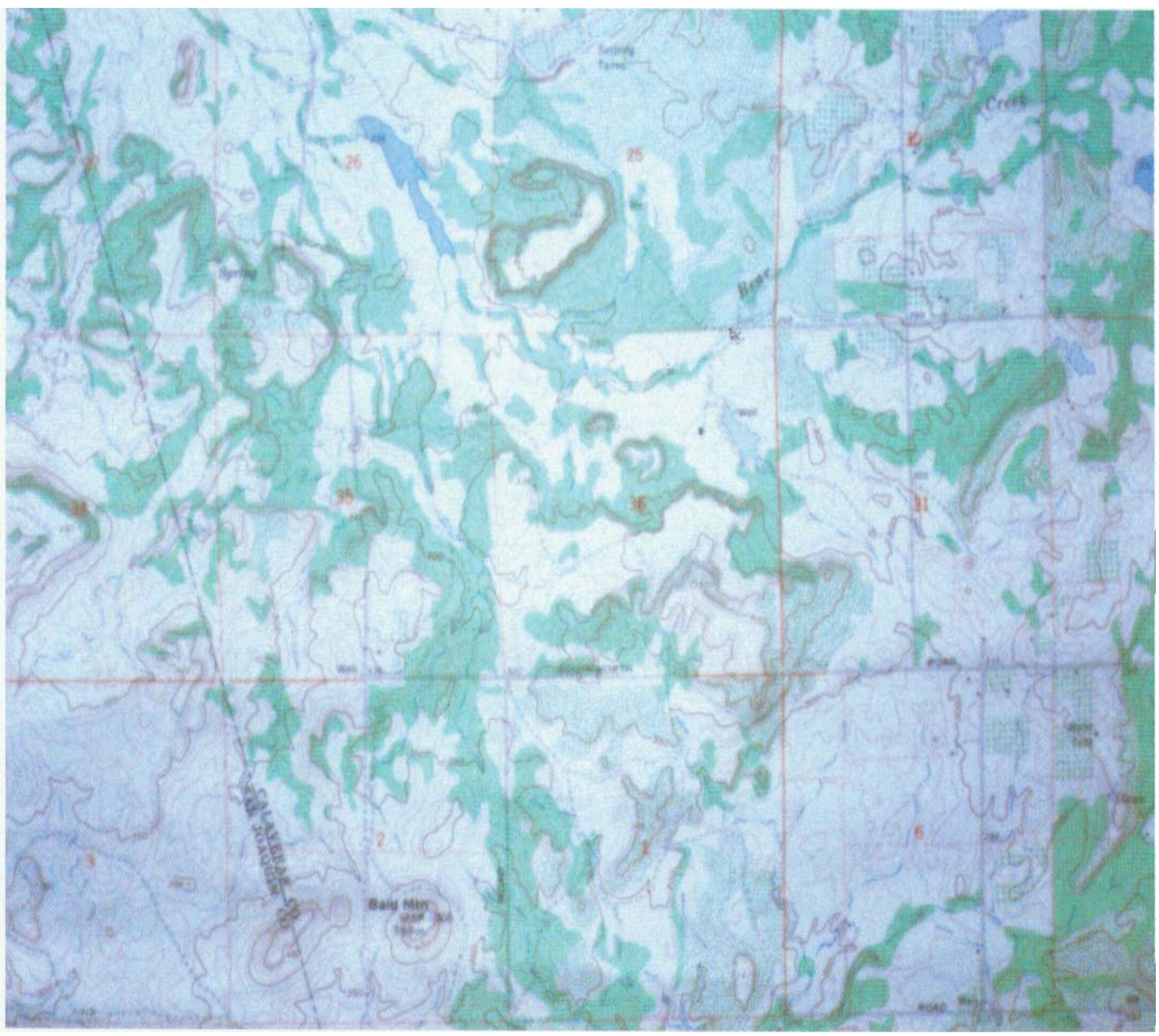
Fire whirls apparently are dependent on several factors, including existence of opposing air currents. In the illustration below, such an opposition is created by converging thermal and ambient wind currents. Also, such air currents can result under natural conditions in situations where eddies tend to develop.

2K – Development of Fire Whirl

WILDLAND FIRE FIGHTING

CHAPTER 3

TOPOGRAPHY



Of the three major factors influencing wildland fires — weather, topography, and fuel — topography is the most static, but quite often the most dramatic in terms of fire behavior. The word topography refers to the earth's surface in relation to the shape of all land forms and waterways. Simply, topography means the lay of the land.

Weather can change by the hour. Fuels, due to actions such as fires, land clearing, agriculture, and timber harvesting, can change from time to time. Annual changes in rainfall can increase or decrease the amounts of fuel available for fire. Topography, however, changes very slowly. It is a known geological fact that mountains wear down. Others are formed by uplifting, and the shifting of the earth crust causes other changes. However, as far as the wildland firefighter is concerned, topography will actually be considered a static or non-changeable element.

To most firefighters the term rough topography is clearly understood in general terms. Fire behavior is largely the result of local weather and fuel. The effect that topography has on these two important factors will be discussed in detail in this chapter and other portions of the book.

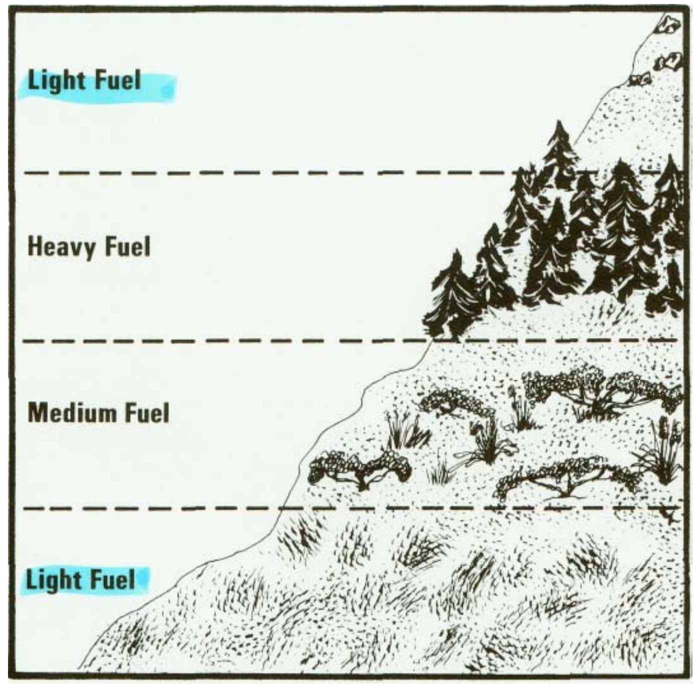
As noted before, fuel moisture and weather are subject to change on an hour-to-hour or day-to-day basis. However, in topography, we can deal with a relative constant whose form can be clearly identified by both the eye and the use of detailed topographic maps. In a given area, topography strongly influences fuel types and densities, direction of the fire's spread, the physical motion of the fire, micro-climates and quite often, important natural barriers in the fire's path.

This portion of the book will now deal with basic components of topography as they affect the firefighter. These are elevation, thermal belt, exposure, slope, and distinct topographic features that have a strong influence on fire behavior.

Elevation

Elevation has an effect on fire behavior both in relation to local changes in elevation in relative terms, and by changes in elevation above sea level in general terms.

On a summer's day, going from a valley bottom of 1,500 feet above sea level to a mountain meadow of 5,000 feet elevation points out some dramatic weather and fuel changes.



3A — Change in elevation and fuel

Generally, the temperature will drop as elevation increases during the heat of the day, and fuel may change from grass to timber. The changes in elevation cause dramatic fuel changes, and as elevation increases, rainfall also increases. The snow pack in the mountains also has a distinct influence on burning conditions and fuel types.

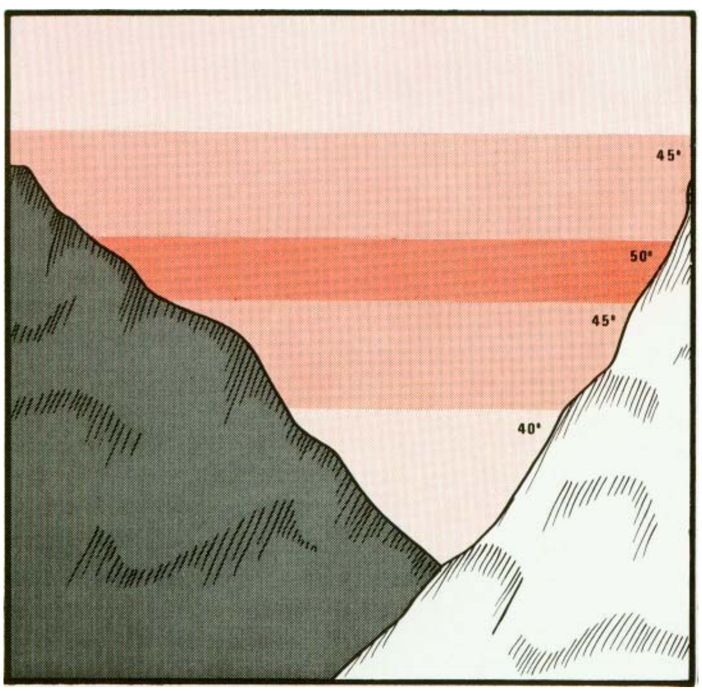
Elevation has a strong influence on the length of the fire season. The lower elevations have a longer fire season than the higher ones. The higher elevations also have a strong influence on the movement of air between the valleys and the mountains.

The elevation at which a fire is burning in relation to the surrounding topography must be considered. Depending on the fire location, it may be influenced by strong local effects under stable overall weather conditions. It is important for the firefighter to understand the topographic influence on local weather as it changes by day and night. Under settled, mid-summer atmospheric conditions, a daily interchange of airflow occurs between the mountain tops and the valley bottoms.

The heating of the air which is in contact with the ground during the day and cooling of the air during the night is responsible for this important air movement and hence fire movement process. During the day the air in the canyon and valley bottoms becomes

relatively warmer than the air at higher elevations. Warm air rises, causing upcanyon and upslope winds. The time of day that the upslope winds start is usually predictable. If the air is rapidly warmed, the rapid upslope wind may cause eddies and general turbulence.
At night the situation is reversed. When the heating of the lower elevations by the sun stops, the rising air becomes heavier and no longer rises. The sun sets and the slope surfaces automatically start to cool. The air above the now cool slopes takes on the temperature characteristics of the ground below it. Gravity then comes into play, and the heavier air from the relatively cooler elevations starts its down slope flow. Because the air is cool, the flow is in layers (laminar) and moves smoothly down the slope. As a result of this airflow interchange, temperatures in the valley bottoms normally become cooler than the surrounding ridges and slopes. These changes in air flow and temperature, caused by elevation, can be predicted by the firefighter. Obviously for tactical and safety reasons, the placement of ground attack forces should be such to take advantage of these changes. Due to these topographical and meteorological interplays, a basic rule of thumb should be restated. Generally winds blow up canyon during the day and down canyon at night.

Thermal Belt



SB- Changes of air temperatures involving thermal belt.

Between the valley and canyon bottoms and the mountain tops and ridges is a thin topographic area, called the thermal belt, that has a distinct effect on fire behavior. In this thermal belt fire conditions are usually more severe than in any other area. There are several reasons for this. The nighttime settling of cold air in the canyon bottoms creates a temperature inversion. The warm air mass that was in the canyon bottoms becomes displaced and is layered above the cooler air at lower elevations. Over a 24-hour period the thermal belt generally has the highest temperatures, the lowest average humidity, and the lowest average fuel moisture. During the fire season this topographic zone has the highest average fire danger. The effects from the thermal belt are dependent on the general topography and daily weather changes. The firefighter should quickly recognize the topographic features and weather patterns that can create a thermal belt. As fires move upslope, they can develop into adverse fire behavior patterns once they enter the thermal belt. Fires often remain quite active at night when they are burning in this belt.

Exposure (Aspect)

3C — Exposure relation to sun

Exposure is the lay of the land in relation to the sun. Exposures are generally given cardinal names such as north exposure or south exposure. The degree of exposure is determined by the steepness of the slope in relation to the angle of the sun's rays as they strike the earth's surface.

In the northern hemisphere the sun's rays strike most directly upon a full southern exposure and therefore deliver considerably more heat to that exposure than to any other. Southwest exposures generally receive about the same amount of heat, essentially because of the cumulative heating of the atmosphere and the land surface throughout the day as the sun progresses in a westerly direction. Southeast and western exposures are each subjected to approximately an equal degree of solar heating. The difference in the quantity of heat and duration of sunlight delivered to these southern exposures, as compared to the northern exposures, causes a set of physical interactions evolving into significant differences in vegetative cover and soil makeup.

Some species of vegetation require the amount of heat that develops on the southern exposures, whereas others cannot survive in it. However, the requirements for moisture levels are probably more important than heat and sunlight in determining the type of plant species, growth rate, and size of each species. Higher temperatures and generally prevailing southwest winds remove the moisture more rapidly from the southern exposures both from evaporation from the soil and ground litter, and also from transpiration from the plants. The result is that the vegetation that adapts to these southern exposures is dryer, sparser, and more flammable than the vegetation that grows on the northern facing slopes. Rainfall on both slopes may even be equal, but the deeper soil on the north slope, coupled with less sunlight and heat, will produce a remarkably different micro or highly localized climate. This climate and soil difference will produce a heavier vegetative cover on the north slopes.

Due to the drier, sparser, flash fuel types that grow on the southern exposures, the potential for fire ignition and rapid fire spread is more predominant than on the north slopes. Also, south exposures are generally more prone to spotting than north exposures. The weather and fuel conditions combined with the inter-reactions of people have caused a unique cyclical affect on the southern exposures.

The laws of mathematical chance coupled with vulnerable fuel would naturally account for more fires starting and becoming large on the south slopes. There has also been a strong human factor at work, probably since the days of Spanish occupation, that changed vegetation into more valuable browse, and this has caused the more flammable south slopes to be subjected to more intentional fires set for this purpose. This is not the place to discuss the very broad subject of Chaparral Management accomplished through the use of prescribed fire and the application of artificial seeding, nor for that matter, the possible economic improvement in range values following fire without any scientific treatment to the land.

The point under consideration is this: past fires have had a strong influence upon the creation of presently existing vegetation, and most of all, upon south slopes. More fires have started and grown larger upon south slopes, especially in the hotter, drier locations, than upon northern exposures.

An important link in the chain of reactions mentioned above is soil erosion. The lighter, drier, flash fuel vegetation on the south exposures burns more easily, more numerous and larger fires also occur on the southern exposures, thus leaving the soil exposed. Soil erosion is increased due to the denuding of the vegetation. Less moisture can be held in the remaining soil due to limited or non-existent ground litter and leaf mold.

Continued erosion decreases soil quality which in turn limits the vegetative growth.

Generally, the southern exposures present the greater fire hazards. However, the northern exposures, at times, can produce a far greater fire control problem than the southern exposures. Late in the fire season the north exposures start to dry out. As the earth turns on its axis, the direct sun rays move farther north, and the north exposures receive more heat, so additional drying takes place. During the fall the gradient foehn winds blow generally out of the north and east causing the northern exposures to dry at a rapid rate. When the heavier north slope fuels dry out and come under the influence of the northeasterly winds, the north slope fuels become highly flammable. The physical force of the wind with its increased supply of oxygen combined with high fuel volume can cause some of the most adverse fire behavior that a firefighter may face. The difficulty of control is also increased due to the acceleration in flame length and heat production and fireline construction problems related to heavy fuels. Under these conditions the southern exposures may be the best place to maximize the ground and air attack efforts.

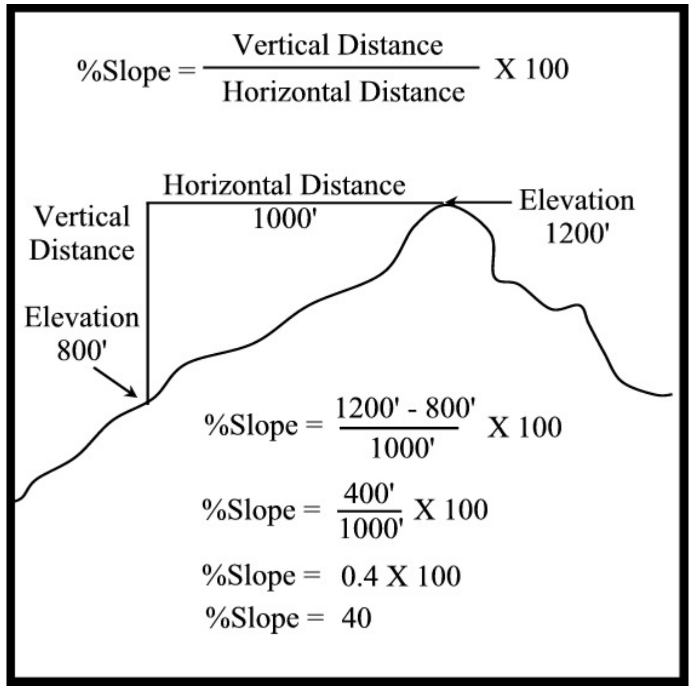
There are several important factors that influence vegetation regardless of the exposure that it grows on. For instance, vegetation on the broad slopes of a high mountain will probably show greater changes in vegetation than the opposing exposures of smaller hills. Generally, steeper slopes show a greater change in vegetation than ones of gradual slope. Where areas are strongly influenced by some dominating factor in local or regional weather, the vegetation will become highly responsive to these factors.

There may be little or no changes in vegetation or burning conditions. An example of this is the dry desert regions, the very moist coastal timberland, or the rolling, grassy woodland areas. Another extreme in the areas of little vegetative chan_ge is found on the Monterey Coast. There, the small gulches cut deeply into steep mountain faces are alternately influenced by damp fog and hot sun. These minute exposure changes have produced the moisture requirements that permit redwoods and desert cactus to grow literally within a few feet of each other.

Where prevailing rainstorms approach a mountain range in the same direction, a higher percentage of the moisture will fall on the windward side, causing a "Rain Shadow" on the leeward side. The abrupt changes in rainfall cause abrupt changes in vegetative types. A good example may be found in the Sierras where little rain falls on the Eastern exposure of this large mountain range.

Slope

The degree or steepness of a slope is quite a different factor influencing vegetation, fire behavior, and rate of fire spread, but as in most areas of firefighting, there is a strong inter-relationship between slope and the other physical factors affecting fire behavior. Slope is usually expressed in percentages. A 5% slope means a 5 foot rise in elevation for each 100 feet of horizontal distance. To figure slope, simply divide the horizontal distance into the change in elevation. Example: If the elevation rose 40 feet in a distance of 200 feet we divide the horizontal distance 200 feet into the vertical change 40 feet. This gives us a slope of 20%. It is most important to remember that slope is expressed in percentages and not degrees of angle.



***3D** — How to compute slope %*

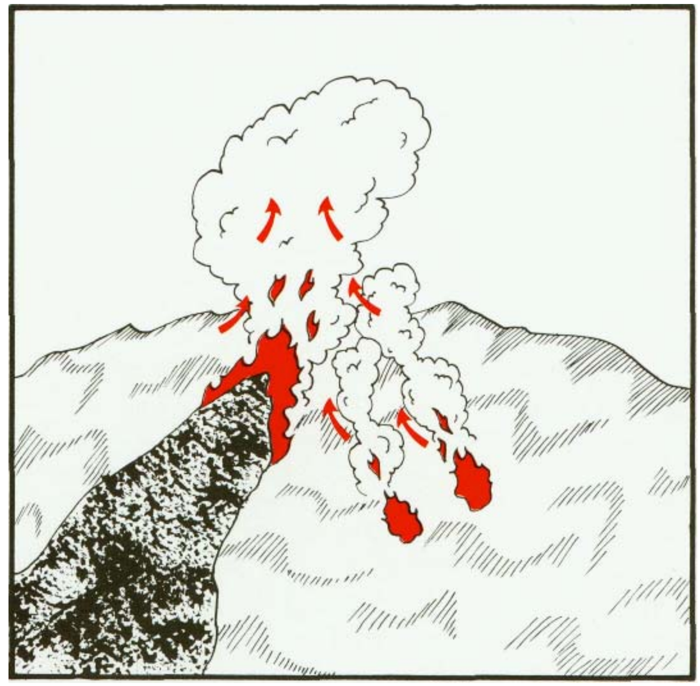
A 45-degree angle is a slope of 100% because for each foot we increase the horizontal distance we increase the vertical distance.

It is a basic rule in wildland firefighting that all things remaining unchanged, a fire will burn faster uphill and more slowly downhill. For every 20% increase in slope the given rate of spread of a fire will double; but why do relatively minor changes in slope have such a strong effect on the rate of spread? The changes in slope have a distinct effect on two methods of heat transfer: convection, and radiation and two of the important elements of combustion: heat and oxygen.

3E — Flames on steep slope

As a fire burns upslope the angle of the flames is closer to the fuel than during a fire burning on a lesser slope or level ground. The radiation of these flames on the increased slope removes the fuel moisture and preheats the unburned fuel.

The connective effects of heat transfer cause the hot air and gases to also rise thus providing additional heat to the unburned fuel. The connective heat of a fire, as evidenced by the size and shape of the smoke column, also picks up and supports fire brands that in turn may fall out ahead of the main fire and cause spot fires. These spot fires, like the main fire, require large amounts of oxygen. This oxygen is supplied from the area near the fire and may also be preheated thus increasing the rate of combustion. Because of indraft effect, the spot fires and main fire will tend to draw toward each other at an increased rate. Extreme examples of adverse fire behavior can take place under these conditions.



***3F** — Spot fires being drawn to main fire*

Winds generally blow upslope during the day and downslope during the night. If the downslope winds are strong enough, their pressure may completely offset the factors governing the upslope spread of fire and may actually cause a fire to burn downhill at an accelerated rate at night. A knowledge of these local winds and micro-climates is of the upmost importance to the firefighter.

In areas of broken or high aerial fuels, a fire of low intensity may cross into an unburned drainage and slowly burn downhill. As the fire burns downhill, its pattern is usually highly irregular. This irregular pattern is caused by the rolling of burning material downslope and a generally slow rate of spread. This quite often happens at night, and the fire leaves an unburned canopy of dried-out preheated fuel. Under such conditions a dangerous reburn of the same area may take place. Strong safety precautions, including the clear identification of escape routes, must be taken to insure firefighter safety.

Distinct Topographical Features

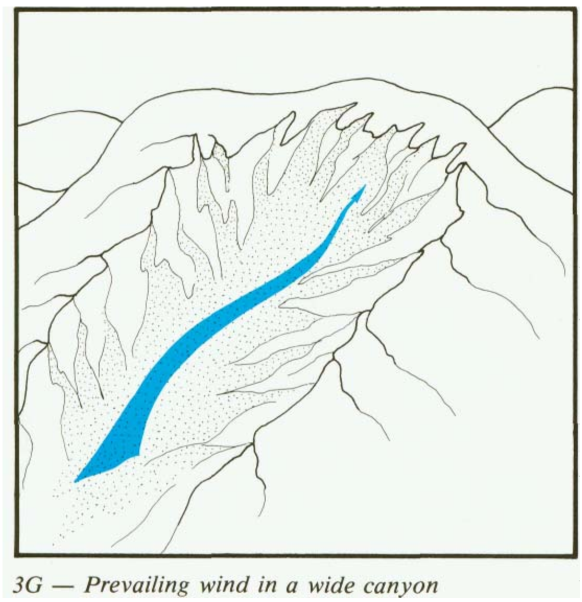
There are several distinct topographical features that have a strong effect on fire behavior and control methods.

Wide Canyons

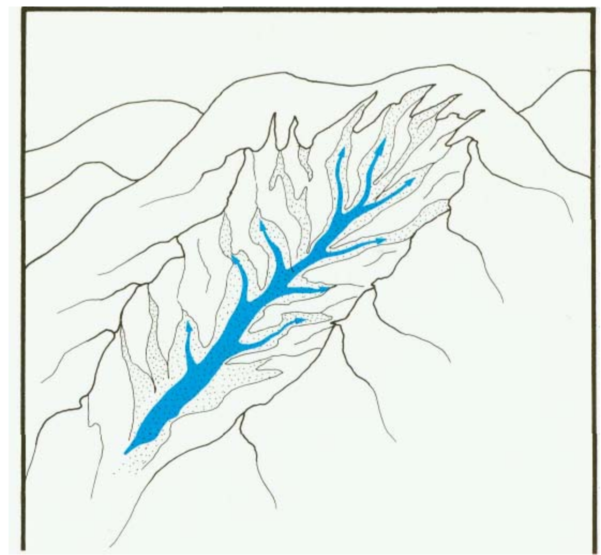
The prevailing wind direction will not be affected by the direction of the canyon. The wind will not be deflected by any sharp up or down drafts. Due to distance, cross canyon spotting is not common except in high winds. Exposure has a strong effect on fuel and fire behavior conditions

Narrow Canyons

Narrow canyons normally have more independent wind currents than wide canyons. The wind usually follows the direction of the canyon. Sharp breaks and forks in the canyon may cause strong eddies and turbulent drafts. Due to relative distance and stronger more turbulent wind conditions, spotting is more common. Exposure has little effect on changes in fuel conditions in the bottom of narrow canyons.



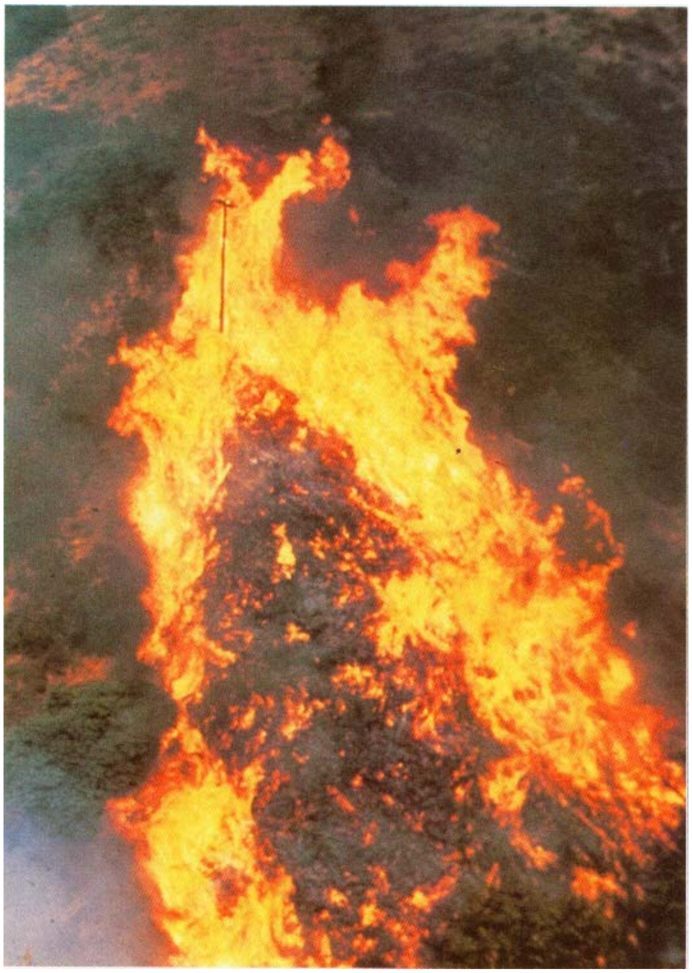
3G – Prevailing wind in a wide canyon



3H — Independent wind currents in narrow canyon

Steep Slopes

The steeper the slope, the more likely a fire will drive upward in a wedge shape, forming a narrow head. The rapid movement of the fire may cause strong indrafts on the flanks. Spotting in front of the main fire is likely.



31 — Wedge shaped fire in steep topography

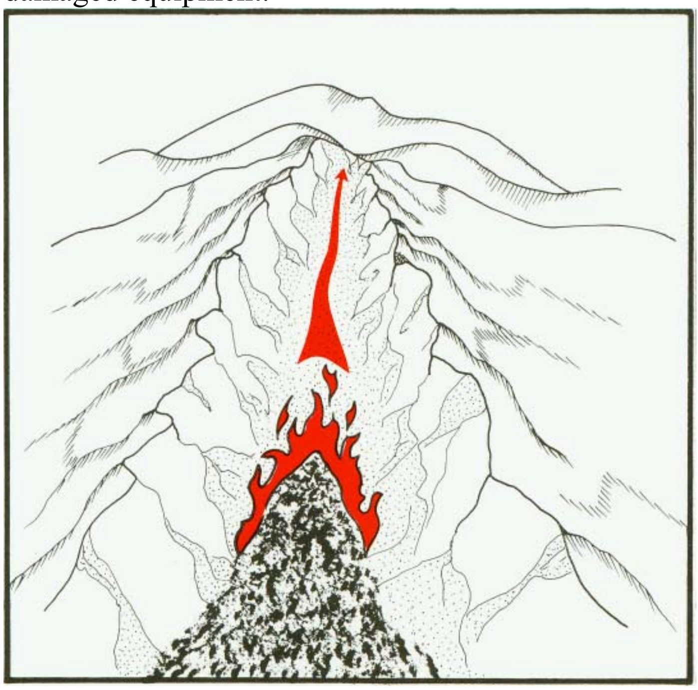
Ridges

Quite often, as a fire reaches a ridge top, it meets an opposing airflow (upslope) from the other side of the ridge. Such condition will slow the spread of the fire, but may also cause adverse fire behavior. The topography and opposing winds will cause eddies and turbulence

3J — Opposing air flow over ridge top

Chimneys

A chimney, as the name implies, depicts topographic features that form narrow draws and gulches that are actually minute box canyons. These chimneys draw the fire, as does an actual chimney from a stove. Strong upcanyon winds are drawn into the topographic features of the chimney and confined to the shape of the chimney by its steep side slopes. Firefighters have been trapped at the head of chimneys with resulting loss of life, injuries, and damaged equipment.



3K — Wind flow in a chimney canyon

Even a shallow chimney of ten feet in depth and a hundred feet long can cause an increase in the rate of spread and intensity of the fire. Additional information concerning this important subject is covered in the chapter pertaining to Wildland Fire Safety.

Physical Barriers

Barriers can have a significant influence on the spread of wildfires. Barriers, either natural or people-made, often become aids that help control portions of the fire. Natural barriers include rock slides and other barren areas, lakes, rivers, dry stream and river beds, and the ocean. Areas containing vegetation that is wet, such as some agricultural zones and river bed vegetation, may also slow or stop the spread of a fire. Also, certain types of fuel may not burn at different times of the year, such as grassland in winter or spring. The vegetative zones can be used as a natural
fire barrier.

Topography has a strong influence on how a fire burns. It also has a very important influence on the type of fire attack methods and equipment that are used in wildland firefighting.

Artificial barriers are people-made changes in topography, such as major highways and other road systems, fire breaks, fuel breaks, power line clearances, reservoirs, housing developments (discussed in the chapters on Urbanization and Fuels Management), and land clearing. Changes of natural vegetation to agricultural use may help or hinder the control of a fire. Each of these barriers may affect the spread of the fire directly through the absence of fuels or indirectly through the modification of relative humidity, local winds, and other fire weather conditions.

3L — A natural barrier

WILDLAND FIRE FIGHTING

CHAPTER 4

FUEL

Fuel is one of the three major elements affecting fire behavior, the others are weather and topography. Fuel is one of the three parts of this Fire Triangle and is a necessary element in order for combustion to take place. Fuel is any organic substance, either living or dead, that will ignite and burn. Fuels are nothing more than different species of vegetation. There are many different biological classifications of such vegetative types. However, this chapter will only identify and classify fuels as they relate to wildland firefighting. The fuel types will be discussed in terms of flammability and burning characteristics.

In wildland firefighting, fuels are not strictly limited to either growing or dead vegetative types. In areas of urbanization contiguous to or surrounded by wildland fuels, human structural improvements provide fuel for wildland fires and not only affect firefighting tactics but actually affect fire behavior.

For identification purposes various fuels are referred to as directly related to the fire suppression effort. Therefore, wildland fuels are grouped in reference to their position on the ground or in the air, as to their size, the relative rate at which they burn, compactness, continuity, volume, and moisture content.

Fuel Quantity and Availability

Measurements of fuel quantity often are expressed in tons per acre and refer to the burnable fuel available. These quantities can range from 1 ton per acre for some grass types to 100 plus tons per acre for heavy slash areas. In actual fire situations estimations are usually made by trained observers in order to establish guides for the difficulty of control. From time to time actual samples are measured to verify casual observations.

When dealing with a fire in the suppression stages, fuels are divided into three (3) main categories: light, medium, and heavy. This broad classification is generally sufficient for firefighting operations. Light fuel usually consists of grass and mixed light brush, usually two to three (3) feet in height. Medium fuel consists of brush six (6) feet high or less and growing in fairly thick stands. Heavy fuel refers to thick brush above six (6) feet, timber slash, timber if the fire is crowning and various hardwood stands.

It is important to remember that the fuel that is actually burning determines the fuel quantity designation to use. A pine needle or grass fire of low intensity, burning on a forest floor, would be considered a fire in light fuel even though it is burning in a timber covered area. It is generally better to use relative terms than numerical designations when dealing with fuel quantities.

4A Grass

4B - Brush

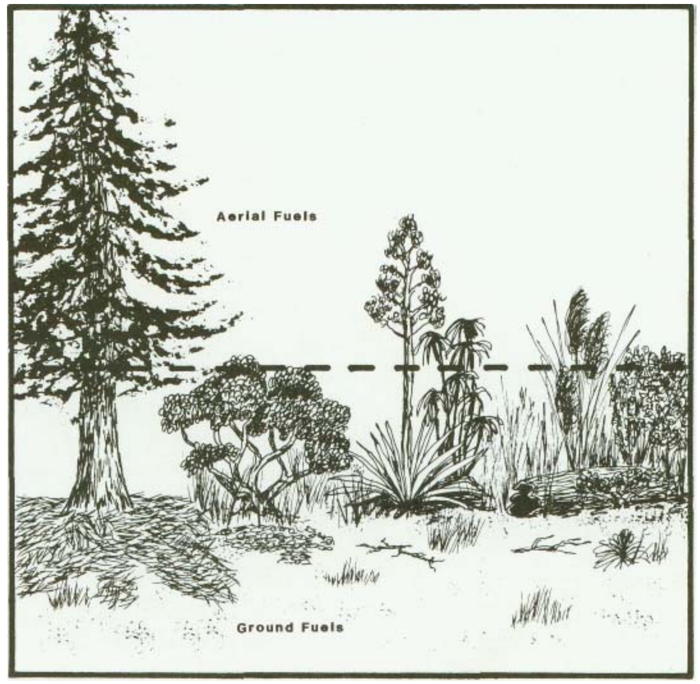
4C — Timber

Fuel availability refers to the proportion of fuel, usually finer fuel, which will burn in a wildland fire. In a grass fire it is quite easy to determine fuel availability due to the fact that almost all of the available grass fuel burns during a fire. In other fuel types, brush and forest, fuel availability varies widely with fuel moisture conditions and with the thickness of the fuel itself. Fuel availability also varies with the duration and intensity of the fire. Therefore, fuel availability is determined by the amount and type of fuel consumed under a specific set of burning conditions.

Ground Fuels

Generally ground fuels, whether living or dead, are fuels that are in the ground such as roots and buried logs, on the ground as in the case of leaves twigs and pine needles, or in close proximity to the ground such as grass and brush.

However, the distinction between ground fuels and aerial fuels is probably more difficult to define because some of the more prominent fuels fit in both classifications. Such fuel is given the broad name of brush or chaparral. Brush is a generalized fuel term whereas chaparral refers to dry Mediterranean climate type vegetation. It is dominated by chamise, manzanita, and scrub oak. Mature plant species of the brush type range in height from only a few inches to more than 20 feet above the ground. The differences depend upon the individual species and growing site. The major value in any segregation of fuels is the creation of a general reference term for fuel types having similar burning tendencies. The compactness of fuel particles and their size regulate the transfer of heat and the availability of oxygen to the fuel itself.



4D — Ground & Aerial fuels

These two factors allow for great differences in the burning characteristics of various brush type fuels.

When low aerial fuels or the ground fuels are in such condition that they offer easy ignition, burn rapidly, and combustion is relatively complete, they are called flash fuels. Among the different vegetative types listed as ground fuels are grass, sage, and other perennials. Any low brush growth that does not allow for the easy movement of air through the foliage would be considered a ground fuel, including small conifers growing as reproduction timber.

The nonliving ground fuel includes downed logs, heavy limbs, and smaller twigs, leaves, needles, bark, duff, and cones. Timber slash is a prime example of a ground fuel. In some areas this slash can be four to eight feet deep and fuel weight can exceed 100 tons per acre. Fires in slash pose some unique and very difficult suppression problems.

Some types of ground fuels pose additional problems due to their ease of ignition. Punky logs or any type of pulverized wood material allow for quick ignition when exposed to sufficient radiant heat, sparks, or firebrands. Large logs, particularly if their surface is not punky or splintered, may resist ignition, and once burning may not aid the fire's spread. However, if a group of logs at a mill sight or at a log deck catch fire, the close proximity of the burning logs to each other can cause a tremendous heat buildup and spread fire through radiation, convection and by spot fires caused from firebrands.

Large limbs will burn more easily when dead needles are attached. Pine slash will pose this hazard for several years while fir limbs will usually drop their needles after the first year.

Several types of needles and leaves become ready firebrands when lifted into the fire's convection column. Eucalyptus, because of the oil content in the bark and leaves and the aerodynamics of each, can cause a major spotting problem. In parts of Australia that have burning and fuel conditions much the same as the western states, eucalyptus firebrands have caused spotting for a distance of several miles ahead of the main fire.

Grass is a fast burning ground fuel type in its cured state. Due to its density and thickness, it allows a maximum amount of oxygen to be available for flame production. In other than early season fires when certain grasses still maintain some moisture, combustion is usually complete. Grass fires are relatively easy to suppress and once out, provide a safe area for firefighters to retreat to if necessary. Grass is also an easy fuel to construct fireline in, and it is a good fuel to use in backfiring operations. It should be well understood though that a fast moving grass fire can be extremely dangerous to firefighter safety. A change in wind can cause a rapid change in the fire's direction. Firefighters have been killed and injured while fighting grass fires because they underestimate the potential of this light flashy fuel.

Unlike grass where changes in seasonal rainfall may affect fuel quantity quite dramatically, the quantity of fine fuels in many mature brush fields and forest covered areas remains relatively stable. This is true unless temporarily reduced by fire or increased by such factors as a severe snow (snow down), insects, wind storm, drought, or logging operations (slash).

The rate at which leaves, bark, twigs, and other fine fuel material are deposited on the ground varies according to the type and density of the parent fuel. The rate of decomposition depends on several variables, most important of which are fungi and microfauna. The presence of these two elements depends on climate and the environment of the litter bed itself. As this litter bed breaks down and begins to decompose, it is referred to as duff. Fires in duff, although not spectacular, can cause many fire control problems if firelines are not properly constructed.

A fire in duff can creep along for long periods of time and escape established control lines. Therefore, duff fires must be completely mopped up to prevent "rekindles."

Another problem created by ground litter is that it is used by pack rats to form nests. These nests are usually about three feet high and three to six feet in diameter. They are filled with thousands of twigs and small branches and are tinder dry. Spot fires can easily ignite in this material, and once on fire are difficult to extinguish and mop-up.

Sawdust is a ground fuel that produces a slow-burning smoldering type fire with little or no active flame production. Sawdust fires are very difficult to extinguish and very seldom does the extensive use of water suppress this type fire. The material must be separated and allowed to burn itself out or be extinguished by extensive hand work and mop-up operations. Some sawdust piles have been known to burn for months. There is a safety hazard present when working a sawdust fire in that the fire will burn underneath the surface and cause burned out areas that are not visible. These burned out areas produce large caverns and sink holes containing hot material.

Aerial Fuels

The classification of aerial fuels is considerably less complex than ground fuels. They consist of snags, tree crowns, branches, and the higher brush canopies. Aerial fuels are physically separated from the ground and from each other. Their placement is such that air can freely reach and circulate around the available fuel.

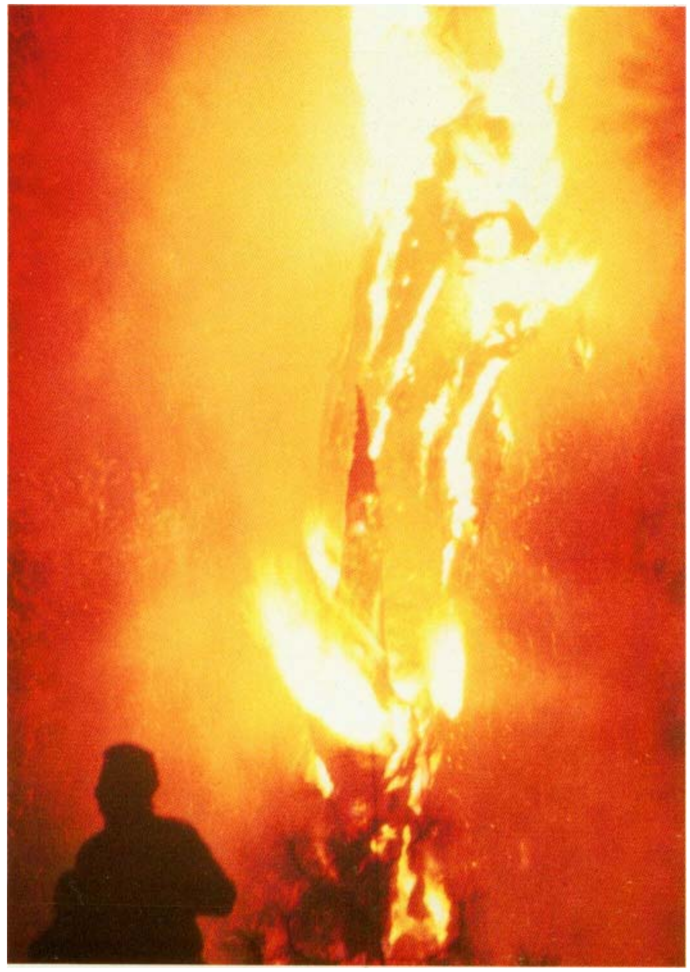
Living and dead leaves and needles are considered aerial fuels while located above the ground as are bark, lichens, moss, and vines such as poison oak. The needles of most evergreens and the leaves of some hard woods are highly flammable due to the availability of air, exposure to higher level winds, and high oil or sap content.

Dead tree limbs near the ground or in the proximity of hot burning ground fuels can provide a ladder for a fire to reach the aerial fuel or crowns of certain types of trees. Once the fire is established in the crowns of a few trees radiation and convection can sustain a crown fire.

Snags are dead standing trees that cause a multitude of problems for the firefighter. Snags are caused by the natural death of the tree from drought, disease, insects, animals, and quite often previous fires. Burning embers can quickly ignite in a snag, and once burning, can spread fire for some distance. Extinguishing a fire in a snag is most difficult because in most cases the snag must be cut down before the fire can be completely extinguished. Obviously, cutting down a burning and weakened snag can pose serious safety problems for suppression personnel.

High brush is classified as an aerial fuel when it is distinctly separated from the ground fuels. Most brush above ten feet will fall into this classification. Tan oak, madrone, and manzanita are representative of this group.

Obviously, there are several fuel types that fall into both classifications or under certain conditions will be classified as a ground fuel, and under more favorable growing conditions be considered an aerial fuel. The important factor is to learn the burning characteristics of both ground and aerial fuels under various weather patterns and topographic features.



4E — Burning snag, Marple Cone Fire, Monterey County Calif.

Structural Fuels

Many profound textbooks and training manuals have been written on the burning characteristics and behavior of structural fires. However, this book will only deal with structural fuels as they directly relate to wildland fires. Structural development and encroachment into previously underdeveloped wildland areas is taking place at an ever-increasing rate. Wildland firefighters must learn how to protect structures from wildland fires, the extinguishment of structural fires once they ignite, and how structural fire fuels interrelate with a wildland fire.

Structural fuels are a high volume fuel and produce large amounts of radiated and convective heat. Once a structure becomes involved, it can quickly spread to other nearby structures and uninvolved wildland fuels. The heat generated in a structural fire tends to remove the moisture from fuels for some distance.

Due to the fact that an involved structure will burn for some time, it provides a long term source of ignition to other fuels.

The biggest problem that structures cause is due to their roof construction. Many homes, cabins, and resorts in wildland areas have roofs constructed of wood or shake shingles. These roofs provide a ready place for spot fires to start and once ignited are difficult to extinguish.

Burning shingles are rapidly uplifted into the convection column and can travel great distances before they land on the ground to start new spot fires. During the Bel Aire Fire of 1961 in the Los Angeles area, burning shingles traveled some two to three miles to start a series of fires that developed into the Brentwood Fire. These shingles can easily spot across fire lines to not only start new fires but endanger firefighter safety. This topic is covered in detail in the chapter on Urbanization of the Wildlands.

4F — Wood shingled roofed railroad station. Riverside County, Calif.

Fuel Arrangement

The arrangement of the available fuel and the placement of individual pieces of fuel in relation to one another should be considered in relation to the three means of heat transfer. Radiation is more important in the spread of fire when fuels are basically horizontal to each other when than dealing with fuels in a vertical arrangement.

The two major factors affecting fuel arrangement are the continuity of the fuel and the actual compactness of the fuel. These two factors determine the actual burning conditions under other given circumstances.

Continuity refers to the distribution of fuel particles to each other and their relative distances that may or may not allow the transfer of heat from one fuel particle to another. The rate of a fire's spread and the total heat generated over any area is dependent on the continuity of the fuel. Areas that have some distance between fuel particles such as in deserts or high alpine areas are termed patchy fuel areas. Rocks, plowed land, wet drainages, green herbs, and other nonflammable objects also produce areas of patchy fuel. Generally areas of patchy fuel favor firefighting efforts. However, some areas of patchy fuel can cause problems for the firefighter; sparse fuel may cause backfiring operations to be difficult or totally ineffective. Rocky areas are difficult to use mechanized equipment in and the construction of fire line in such areas is slow and tedious.

Areas of uniform fuel consist of fuel stands that evenly and continuously cover a sizable location. This uniformity relates to the continuity of the fuel rather than to the pureness of the stand of a specific species. With other fire behavior variables remaining constant, it is fairly easy to determine rates of spread in a uniform fuel cover.

Compactness refers to the proximity of fuel particles to one another in respect to the unobstructed flow of air around the particles. Compactness is an opposite characteristic from continuity in that close continuity produces faster and greater heat spread. Compactness could mean less heat generation and the discouragement of combustion because of lack of sufficient oxygen to sustain an active combustion process.

A grain field fire is a good example of a fire in fuel of uniform continuity. Usually these fires burn hot and produce a relatively rapid rate of spread. In contrast, a fire burning in leaf mold, a fuel of great compactness, tends to burn with little flame production and produces a relatively slow rate of spread.

Both the continuity and compactness of fuels vary from high to low combustion rates as local weather conditions take effect. For instance, an area may be so thinly covered with scattered fuel that normally its poor continuity (patchy fuel) will reduce both the chances of a fire starting and the possible spread of a fire once it did get started. Desert brush growing in a mountain rain shadow would be a good example of such a fuel, yet a strong dry wind out of the northeast could produce a hot burning fire that would increase the rate of combustion and tend to bridge the gaps in the available fuel. The expanding fire would produce more intense flame production and at the same time the strong wind would be pushing the convection heat through the available sparse desert fuel in a leeward direction.

Suspended pine needles on timber slash may be so uncompacted that fire would not move along the clumps on a high-humidity day, but the same fuel is adequately compacted to carry fire with a slight breeze on a dry day. Fir, juniper, or chamise needles on the ground will nearly always be less flammable than pine needles or oak leaves at the same place and time. This is because the nonpine needles rest together so compactly that not enough oxygen is available for rapid combustion.

The vertical arrangement of fuel in relation to the size of the fuel's crown will often influence fire spread. Thick pure stands of some brush species will have very little growth near the ground surface. Therefore, except under severe burning conditions, fire will not sustain itself in the crowns.

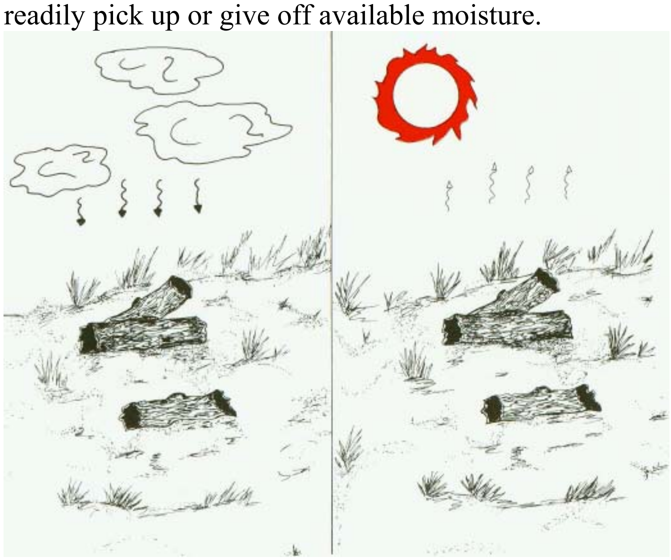
Using the terms as defined and described in this section of the book, the most serious possible fire problem exists in areas of moderately compacted aerial and ground fuels of uniform continuity in a mixture of many size particles.

Fuel Moisture

Fuel moisture is a most important factor in determining the burning capability of different wildland fuels. It is the measured amount of moisture available^ in various fuels. It is measured by the weighing of a sample type fuel stick and the fuel moisture is expressed in a percent. Fuel moisture readings of below 10% indicate that available vegetation is in a burnable estate. During fhoen wind conditions (Santa Ana -North wind), fuel moisture readings have been recorded as low as *Vi* of a percent. When fuel moisture is low, fires start easily because the ignition source has very little moisture to evaporate from the fuel. The applied heat quickly causes flammable gases to vaporize and ignite. When fuel moisture is high, many ignition sources such as sparks, tobacco, exhaust, carbon, and others may cool down before the water vapor is removed from the fuel and flame producing gas starts to vaporize. Generally as fuel moisture increases, rate of spread decreases and as fuel moisture decreases, rate of spread increases. However, if fuel moisture is already low, a further reduction will cause the rate of spread to increase five to six times.

Fuel moisture is controlled by two major factors:
weather and the curing stage. Weather considerations that influence fuel moisture consist of temperature, relative humidity, wind speed, and precipitation. The curing stage factors that affect fuel moisture consist of the type of vegetation, time of year or season, and days since new growth. These factors combined with seasonal weather will determine if the fuel is green, curing, or cured.

To express the moisture content of plant fuels relative to their combustibility, the following descriptive adjectives can be used: green curing, dry, and dormant. Fuel moisture changes are much more rapid in dead (hydroscopic) fuels such as cured grass and twigs than in live fuels such as growing brush and timber. The reason for this is, once the moisture and sap leaves a fuel during the curing process, the fuel becomes porous and can readily pick up or give off available moisture.



4G — Moisture exchange in dead fuels

Where sufficient ground moisture is present, such as in irrigated agricultural areas, stream channels, dry gulches and washes (underground moisture), certain types of otherwise flammable vegetation may retain high levels of fuel moisture and remain quite resistant to combustion. Also under the protection of dense forest cover, very high moisture fire resistant plants including ferns, moss, and leichens will survive. Major changes in fuel moisture also occur due to aspect, elevation, time of day, and season of the year.

In grass and other light fuels, conditions affecting combustion can develop that are not described by any of the previously discussed conditions. They are caused by rainfall but are not reflected in terms of fuel moisture.

Late spring rains falling on grass in the curing stage can be detrimental to both the stockman and the firefighter. These rains can cause a leaching action in the curing vegetation that renders it less palatable and nutritious to the stock. The rain also causes the grass to become lifeless and matted close to the ground. Such grass can catch fire easily, and because of the fuel compactness, is harder to extinguish.

Rains in the late summer period will wash off a cover of dust that tends to somewhat protect roadside grass fuels from ignition. The isolated rains will increase the fuel moisture in the short run, but this moisture rapidly dissipates after a few hours of wind and sunshine.

Fuel Temperature

Fuel temperatures influence both the chance of a fire starting and the rate of spread after a fire starts. Air temperature and direct sunlight are responsible for corresponding fuel temperatures. As fuel temperature rises, a less amount of heat is needed from an ignition source to start a fire. Most wildland fuels will ignite in a range of from 400 to 700 degrees Fahrenheit. During the night the temperature of a fuel might drop to 50 or 60 degrees; this same fuel could rise to a temperature of some 150 degrees on a hot day. Most of us have experienced this higher than air temperature factor when touching a steering wheel after the vehicle has been parked in the sun for some length of time.

The rate of spread will increase at a greater rate than a proportioned increase in the fuel temperature. For instance, if a fuel temperature of 61 degrees causes a rate of spread factor of 1, a rise in fuel temperature to 100 degrees will result in a spread factor of 2 or twice as fast if all other variables remain constant. The effect of temperature is quite evident when we realize most wildland fires start and spread the fastest during the heat of the day, usually from 1000 hours to 1600 hours.

Since it is impractical to measure fuel temperatures while fighting a fire, some general guidelines should be remembered.

A. The rate of spread factor is doubled long before the fuel temperature is doubled.
B. Fine fuels are more quickly and easily heated by air temperature and direct sunlight than heavy and compacted fuels.
C. During the hottest part of the day, all fuels on the south and west facing exposures will have higher fuel temperatures than those on the north and east facing slopes.
D. Heavy fuels will usually have a lower fuel temperature than the surrounding fine fuels in the daytime, and the reverse is true at night.
E. When fuels are exposed to direct sunlight, ground fuels will usually have a higher temperature than aerial fuels.

The behavior of a wildland fire will vary as it consumes different types and amounts of fuel under varying weather and topographic conditions. An understanding of how a fire will react to all fuel types and the other major factors affecting wildland fire behavior must influence the strategy and tactics used to control a wildland fire.

WILDLAND FIRE FIGHTING

CHAPTER 5

FIRE BEHAVIOR

If all of the factors that influence fires were known and understood, the behavior of any given fire could be precisely predicted. Yet, because of the complexity of factors, this is not possible. Although large fires appear to behave differently, with many more aggravated problems than small fires, they are each reacting to environmental influences that are present at that particular time and place. Therefore, certain generalizations can be made.

General Fire Behavior (Small and Large Fires)

As discussed in previous chapters, fuels, topography and weather are found to have varying influences on fire behavior. Any one of these may be dominant in influencing what any individual fire will do, but usually the combined strength of all three dictates the fire's behavior. The particular topography does not -change, of course, but wind movements are influenced by orientation of topography and hence the direction that fires will burn. The actual shape of topography will similarly have its effect. For instance, a saddle or low point in a ridge will act as a funnel, tending to draw a fire in its direction.

Severe tunneling action often occurs on steeper slopes, as rising air currents are forced upward through narrow, chimney-like ravines or gullies. Even with very sparse vegetative cover, fire is capable of moving long distances in extremely short time. Fatalities have occurred within chimneys when the superheated air alone, rising from fire downslope, actually seared the lungs and depleted the oxygen supplies of firefighters. It has long been established that it is dangerous to work above wildland fires. The danger factors must be multiplied many times when personnel are at the top of, or within chimney-like terrain.

Fires will burn very rapidly upslope, but (in the absence of other strong influences) will usually burn slowly downslope. Fires burning in the upper portions of steep slopes or backing downhill often spread themselves rather quickly by means of rolling pieces of flaming fuel. Pine cones are noted for this because of their rounded shape. Those lying on the ground are loosened as they burn and will then roll downslope into unburned fuel.

Except for relatively small areas which are devoid of fuel, California wildlands are well covered with unbroken stands of vegetation. Hence, fire, in relation to fuels as they exist must be considered. Theoretically, a fire burning in any type of flammable vegetation on flat ground, with no wind, would create a perimeter in the form of a circle with flames and smoke leaning toward the center. But fuel varies in size, shape, arrangement, amount of dead material, and relative flammability. Given opportunity, the small fires will become larger. Certain portions will burn more rapidly than others, and soon an unsym-metrical shape in the fire perimeter will develop. Eventually a prominent bulge will influence an adjacent portion of the fire, and the intervening fuel will burn out rapidly.

Fires spreading upslope or with the wind assume a wedge-like shape. The point of the wedge is the head where the most rapid spread is occurring. The flanks of the fire will gradually widen with the passage of time. That portion of both flanks immediately behind the head will unquestionably be influenced by an indraft caused by the convection column at the head. A shift in wind will, of course, cause a greater movement of the leeward flank and probably change the direction of the head.

Should the head of this theoretical fire be suddenly stopped, the rate of spread of the flanks will increase. If the wind is strong, or the slope is steep, the original forward impetus of the fire remains unchanged. It is probable that the fire will now progress with two new heads (on either side of the old) until they join, or until one becomes dominant.

Depending on fuel type and condition, spot fires can occur ahead of small fires as well as large. Burning embers are carried with the wind in the convective updrafts with the smoke and are dropped in unburned fuel in advance of the main fire. Embers will nearly always come from the underside of the heaviest smoke concentration. Flying embers can also originate from burning snags or trees with punky pockets on fire, and again the spots will occur downwind. The rapid spread of a fire up a steep slope to a ridge crest will often result in spot fires on the opposite downslope or even on the upslope of the next ridge in advance. Spotting can also be expected downwind when individual trees "crown out" or when large piles of dead material such as slash are burning at peak intensity.

A small fire is not necessarily safer to work on than a larger fire. Small grass fires have overrun many engine companies and personnel have sustained serious burns. Regardless of fire size, it has been determined that fatalities are most likely to occur during docile periods of fire behavior and under innocent appearing overall conditions. A study of California and other national fatality fires has provided several other facts that will be described in the chapter on Fire Fighting Safety.

When the relative humidity descends below about 30 percent, the situation is becoming favorable for wildfire. **For every 20-degree increase in temperature, the humidity is reduced by one half**. As the humidity drops, the chances become greater for a smaller fire to reach large size unless an adequate suppression force is available.

Spread Definitions

- **Low** (slow) - very little spread; spread of no consequence.
- **Moderate** spread is less than one mile per hour.
- **Dangerous** spread is 1-3 miles per hour.
- **Critical** fire spread is over 3 miles per hour.

The following data gives us some clue as to why early morning backfires often fail, and why fire starts tend to favor mid-day and mid-afternoon hours. Note that at 10:00 A.M., humidities have not yet returned to the low level recorded at 4 P.M.. Many small fires simply stop burning by themselves in the early evening rising humidities, and scores of large fires are finally contained through the help of higher humidity levels at night.

Spotting

One of the characteristics of a small fire that is frequently difficult to handle, is spotting. Spotting is an important eventuality on many wildland fires.

Spotting occurs when wind and convection columns broadcast hot "firebrands" into the green ahead of the main fire. The use of lookouts can sometimes expedite quick attack on spot fires, although in many instances, the embers evade discovery until a later time, when sufficient smoke begins rising above the green canopy. Patrol crews often are the first to detect hot material outside the line.

Although spotting is often related to such firebrands as wood shakes and ash from burning brush and

Average Relative Humidity by Time Periods

1941 -1970

	4 A.M.	10 A.M.	4 P.M.	10 P.M.
January	89	85	70	86
February	87	79	61	76
March	83	68	52	76
April	80	58	43	72
May	80	50	36	69
June	77	47	31	64
July	76	47	28	61
August	77	50	29	63
September	76	50	31	64
October	79	57	39	70
November	86	75	59	81
December	90	85	70	86
Annual	**82**	**63**	**46**	**73**

(U.S. Weather Bureau Records)

timber, there are other causes as well. Small animals, such as rabbits, have been observed carrying fire into unburned fuel (green). Although burning grass seems to often be completely consumed by fire, spots can and do occur in the green well ahead of the main fire, such as across several lanes of freeway. Spotting occurs more easily across narrow ravines than wider ones, and given favorable conditions, quickly spreads to become fire problems themselves.

A fire moving from timber-brush mix into grass will triple in spread speed.

As a fire burning in brush enters an area of grass species, firefighters can expect the rate of spread to double.

Spread characteristics of each fire determine the shape of the fire and depend on many criteria, including steepness of slope and wind.

The National Wildfire Coordinating Group categorizes wildland fires as being "large" as follows:

Timber — 30 acres or more, or
Brush — 300 acres or more, or
Woodland and/or Grass — 1500 acres or more, or
3000 Person Hours — expended on fire suppression

For purposes of describing a wildland fire in terms of its organizational needs, fire complexity and the amount of time required to control it, wildland fires are divided into three distinct categories:

INITIAL ATTACK FIRE — (First Alarm)

An INITIAL ATTACK FIRE is one in which the fire is generally CONTAINED by the first dispatched attack units (first alarm) without a significant augmentation of reinforcements within two hours after first attack action, and full CONTROL is expected within the FIRST BURNING PERIOD. (From time a fire starts until 10 a.m. the following day.)

EXTENDED ATTACK FIRE — (Multiple Alarm)

An EXTENDED ATTACK FIRE is one in which the first dispatched attack units must be substantially augmented by additional ground and air attack units and is CONTAINED during the FIRST BURNING PERIOD with full CONTROL expected during the SECOND BURNING PERIOD. The only exception would be a small fire in heavy slash (i.e., redwood) requiring several days for full control.

MAJOR FIRE — (Major Emergency)

A fire that is CONTAINED during the SECOND OR FOLLOWING BURNING PERIODS and requires extensive forces for CONTROL. At least one BASE CAMP is established.

Work should begin on the flank with the greater potential, keeping in mind the necessity of protecting important exposures and holding the fire to a small size. Many small fires, and resulting larger ones, have their origins along roadways from a number of causes. The roadway serves as an excellent anchor point from which to begin work along the chosen flank.

Smaller fires in brush may dictate use of a "hot-spotting" team, whose job it will be to pass up dormant or slower burning portions of line in order to knock down portions with greater activity. Hot spotting can be employed by either an engine company or a handcrew, as a delaying tactic until arrival of additional forces. Hot spotting, if successful, and it has been on thousands of smaller fires, can save the day in terms of avoiding a long duration battle with an extended or major fire. This tactic also has use on large fires.

Smaller fires can be quite damaging to improvements such as fences, outbuildings, and homes due to the fact that the fire burns generally untouched from the time of its origin until the first-in company arrives. Thus, even a small one-acre grass fire will have had sufficient time to move into an area of improvements and lacking attack by locals, do considerable damage. Of course, on many such fires near residential areas, the locals can and do knock down many potentially dangerous fires. Because many fires start near or in populated areas, the first-in companies can expect traffic congestion, dense smoke, confusion and fire ingress problems.

Small, hot running fires can be knocked down successfully by an alert, well trained company, providing access to the fire is known and available. When fencelines and other security measures are present, access can be very restrictive to firefighting efforts.

Small does not mean easy, when it comes to firefighting. Because of the intense aggressiveness utilized to hold such a fire at small size, most any nozzleperson will tell you that it was hard, very hot work along the fireline and that although the action may be short-lived, it was nip-and-tuck for a period of time.

Large Fires

The tendency is for a large fire to beget a larger fire. In California at the present time, the efficiency and economy of maintaining crews ready for prompt attack upon a fire is well understood by all fire officials, and fortunately, by many elected officials responsible for appropriating necessary funds. Statistics show that 95 percent of the reported fires have been kept from growing large. The other 5 percent could be reduced by more pre-suppression expenditure, or more effort at the proper place, or by less human carelessness at the improper time. Yet, many of the large fires are the result of adverse conditions of weather or topography.

Adverse may mean too tough for the strength of the initial suppression forces at that particular time and place, or it may mean a condition worse than the average bad condition for which preparations can be made with the funds provided. Both amount to the same thing. The point is that if natural conditions were essentially the cause of the fire getting large, it is reasonable to assume that the same conditions would allow the fire to get even larger. That is why it has been mentioned elsewhere in this writing that the initial attack crew should have as its primary objective the prevention of the expensive large fire.

Adversities are not limited to the effects of weather and topography; **people** also enter into the scheme. The urbanization of the wildland areas greatly complicates the control of a fire.

As a wildland fire approaches and enters a populated area, such as a subdivision, firefighters must turn their attention to the saving of homes and other improvements. The delegation of wildland fire control efforts to the protection of specialized exposures often outdistances the capabilities of available personnel and equipment. Engine companies, hand crews, bulldozers, and even retardant-dropping aircraft must concern themselves, not with a primarily overall strategy situation, but rather, a large number of specialized and individualized strategy situations. If the reinforcement of forces is inadequate, the control of the wildland fire may be greatly hindered.

If weather is to blame for the small fire becoming large, then the odds against the firefighter increase as the weather becomes more adverse. It has been stated that a doubled wind speed may quadruple the fire spread. Reducing fuel moisture by half (when it is already low) may cause fire spread not twice but five or six times as fast.

Added to whatever adversity may exist in the shape of topography or weather, there are characteristic habits of large fires within themselves that mean trouble for the firefighter. There are the tendencies to crown and spot ahead because of the build-up of convection currents over large fires. Also the effect of upslope radiation is increased as the intensity of the fire increases.

On the other hand, unless unusually heavy and dry winds from one general direction overwhelm the effect of local broken topography, a large fire can be expected to subside considerably when it reaches ridge tops. This will result from the heavy in-draft demanded by the large fire running uphill.

The development of strong convection columns over large fires, with smoke rising thousands of feet into the air, is one of the most striking differences between small and large fires. The essential cause of this difference is, of course, found in the difference in the concentrated heat mass.

Consider the several steps of cause and effect in respect to the single matter of spot fires caused by firebrands originating in the main fire. If the air mass over the fire is stable, that air will resist the development of a strong convection updraft in the form of heavy smoke column.

Consequently, the fire will burn less intensely than it would under a strong updraft. Unstable air is more conducive to the development of a strong convection column and a more intense fire. The stronger updraft naturally has more carrying capacity for burning embers. But it should be noted that the longer time period in the stronger updraft will allow many of the potential firebrands to lose most of their heat. Also, when they reach their height and fall out of the smoke column they probably are entering cooler atmosphere than that at the ground level.

Should a force of wind aloft be brought to bear upon each of these fire conditions, tilted convection columns will result. The column occurring in unstable air will be stronger and will carry firebrands higher and higher. On the other hand, the less intense updraft will drop firebrands sooner, closer, and hotter, and in a more concentrated pattern in front of the advancing fire.

Long distance spotting will more than likely occur on the right flank of an advancing fire because of the tendency of the smoke column under the influence of wind to rotate in a clockwise direction with increased height.

A convection column is not a "chimney" in the sense that all the air must flow into the bottom of the convection coil. Most combustion takes place near the ground, and naturally the oxygen requirements are most intense there. Nevertheless, some combustion of gases occurs in the rising heat columns. To supply needed oxygen, and undoubtedly because it is entrapped in the rolling updraft, outside air is gathered into and along the vertical exterior wall of the rising convection column.

Normally, a general in-draft into the convection column can be expected from all sides. If there is a prevailing wind, wind speeds on the leeward (advancing)

Ing) side of the column will usually be less than on the windward side of the flanks. But occasionally, pronounced out-drafts (winds moving away from the column at a greater velocity than the free air movement) have been observed on the leeward side. No guides can be given as to their occurrence since there appears to be no correlation with fire size or intensity, or with weather conditions. Several instances have been observed when winds in advance of the fire were double or even quadruple the velocity of winds along the flanks or rear. In any event, fire control personnel should be alert to the occurrence of this phenomenon. The possibility that the wind velocity may increase two to four fold in advance of the fire front could drastically change fire suppression strategy.

Another important difference between small and large fires is the relative unimportance of size, distribution, and arrangement of fuel particles in favor of total fuel volume in the high intensity fires. Under extreme conditions, larger size fuels will burn faster and hotter, producing temperatures up to 2,650 degrees F. This intense heat results in large areas being rapidly consumed with extreme violence and nearly total consumption of all combustible material.

The isolation of fuels from each other can be beneficial in reducing the total fuel volumes available to a fire. Fuel breaks and firebreaks transverse many wildland areas. Fuel modification is helpful in reducing the tons-per-acre volume of heavy fuels, as in the case of establishing grasses where brush once was dominant.

As pointed out earlier, topography is important in the rate of spread of all fires. Generally speaking, the steeper the slope the greater the increase in fire spread uphill. Considering the vast area usually encompassed by high intensity mass fires this generality could be misleading. It has been noted that rate of spread in mountainous topography is rapid for sustained periods of from two or three hours. Mountainous country has as many downslopes (where fires burn more slowly) as upslopes. On the other hand, rate of spread on flat or rolling topography can be sustained periods of 12 to 24 hours. This is due to lack of retarding steep downslopes.

Area Ignition

The logs in the cold fireplace were giving out a desultory smudge when a merry blaze was in demand. A crumpled newspaper was then ignited and pushed toward the throat of the fireplace. Suddenly the gaseous smudge around the logs burst into flame and the logs began to crackle with combustion.

What caused the outburst of flame in the fireplace?

Two vital sides of the fire triangle had been strengthened where the fuel was situated although the action that caused it occurred elsewhere. No doubt the most important action was the creation of a convection updraft in the chimney, thus pulling in more oxygen for the fuel. More specifically, a sharp indraft against the flank of the fuel facing the open room was created. Secondly, heat radiation from the burning newspaper raised the temperature of the flammable gas around the smoldering fuel to the extent that it was ready to ignite in the richer air brought in by the convection updraft.

This principle of augmented ignition and combustion from an adjacent source of heat has long been appreciated by experienced firefighters. However, its full significance from the standpoint of potential destruction seems to have been rarely scientifically considered until the occurrence of "fire storms" created in large cities by wartime bombing.

The phenomenon of increased intensity of conflagration due to multiple adjacent points of combustion is termed area ignition. The same incentive produced by the burning newspaper in the fireplace can be compounded outward in geometric proportion as the individual sources of fire act upon one another in an open area.

The tendency of a large fire is to beget a larger fire. It was intimated that this is true because adverse conditions around a fire act to make bad things become even worse. Part of the resultant trouble may be due to the effect of Area Ignition as it occurs in a natural manner during the progress of the wildfire. However, this phenomenon is much more likely to occur outside than within the perimeter of a large fire. This would happen when a number of spots outside the fire area flare up together in fuel that is highly flammable. This, of course, constitutes an added hazard for the firefighter.

Aside from spot fires and concentrated lightning strikes, a great quantity of the vegetation burned as a result of the area ignition process is by human design. The arsonist has made use of it as well as the backfiring specialist and the stockman who uses controlled fire to eliminate unwanted vegetation.

When a number of fires are ignited in such relation to one another that the heat of each one affects the other, the following situation develops. Radiant heat prepares large amounts of unburned vegetation for easy ignition at approximately the same time. If we could look down upon such a condition of multiple fires at an early stage we might observe perhaps one-tenth of the area in flames. This would leave some nine times the flaming area in a state rapidly approaching a readiness for ignition. While this is going on the individual convection currents are thursting hot air upwards. Each creates in-drafts at its base.

Soon the convection updrafts begin to mingle and multiply the dimensions of the invisible "chimney." A constantly and dynamically increasing supply of air generates numerous fires into one massive flame front. A blow-up has been created. Whether it has been created intentionally or otherwise, the blow-up can be a fire of such intensity that it is difficult to hold it within prescribed lines.

It is obvious that this condition should not normally be expected from a fire moving outward from a central source, actually flaming for the most part at the perimeter and leaving behind only the ashes of the fuel it has consumed. If quantities of fuel are bypassed, either unburned or smoldering, the powerful forces of multiple ignition may be suddenly unleashed at one critical moment when heat, air and the crucial spark of ignition are ready.

Area Influence

The effects of fire burning large areas in a relatively short period of time can extend for a considerable distance from the actual flames. This may influence fire behavior in other areas, sometimes with adverse effect. It is, therefore, quite important for firefighters to be aware of rapid fire occurrence on any part of the fire and be alert for possible dynamic changes resulting in their own areas.

Dynamic fire spread can adversely affect "firing out" operations. (Backfiring and burning-out are discussed in the chapter on Fire Tactics and Strategy.) Particular care should be taken when firing is conducted down long ridges where major bends in the control line are unavoidable.

Ideal firing operations are conducted from the top of a ridge moving downhill into the intended burn with no wind or only a light and favorable wind. With such favorable conditions, firing along the line should proceed rapidly in order to take advantage of the situation before more critical burning conditions develop. Caution, safety must be never compromised.

However, it should be remembered that a major run of the main fire or the backfire near the top of the ridge can change the wind flow and adversely affect the backfire elsewhere. For example, if there is an sharp bend in the line near the newly developed back fire, the combination of topography and wind change at this point could become quite serious. Under no wind or light wind conditions, indrafts into a large fire can affect wind flow for a considerable distance downslope from the fire area.

Two major convection columns burning in close proximity to each other will usually result in a very rapid and violent burnout of the intervening vegetation.

Fire Whirls

A fire whirl can be described as a violent, noisy tornado of fire, shaped like an elongated inverted funnel. The phenomenon spins at an extremely high velocity and emits a loud roar that is best compared to the sound of an aircraft engine. Size can vary from a few feet to several hundred feet in diameter and from a few feet to 4,000 feet in height.

Fire whirls are usually associated with large fires, although they have also occurred on small fires. This is probably due to the fact that some of the conditions (unstable air is one) condusive to whirlwind formation are also factors in the creation of large fires.

The cyclonic action (rapidly whirling fire around the outer perimeter of a center cone of air or gas) can pick up debris, sometimes including small logs, and raise it to great heights. A central "tube" is present whether or not it is always visible.

Topography plays an important part in fire whirl occurence. Although fire whirls have been known to happen in flat terrain, by far the majority occur in mountainous areas. Some generalities can be stated regarding possible locations and conditions that these whirls are likely to occur. But there have also been notable exceptions observed that have little or nothing in common with these general rules of behavior.

The majority of whirlwinds observed by firefighters have generally occurred on the leeward sides of ridges, near the top. The shearing action upon wind flowing over the abrupt edge of a ridge has been found to be present in the formation of dust devils.

All of the theories on whirlwind formation include air stability as an important factor. Some, however, advance the belief that it is a local thermal instability caused by the fire and not the degree of upper air instability that has the greatest effect. But others point to the extremely unstable upper air conditions known to exist when large destructive fire whirls have occurred. Unfortunately, in the past, too little attention on the part of firefighters has been paid to upper air instability as an indicator of potentially violent fire behavior.

Heat supplied by the fire provides the "trigger" to set the whirl in motion when all of the other factors are present. Sometimes a mass of fire is required and this usually results in a rather large whirl. At other times, relatively small whirls have formed along a moderately burning fire edge with no noticeable increase in fire intensity prior to their formation.

The intensity of the heat source seems to control the position and length of life of many whirls. Numerous examples have been noted wherein the whirlwind, once generated by an intense fire, remained stationary and active at one location until the largest volume of the fuel was consumed. One observer of a small whirl reported that he was able to move it downslope by rolling debris against the hottest portion of the fuel.

On the other hand, another instance was observed in which a small fire whirl (10 feet wide and 150 feet high) formed itself at a fire edge in brush cover, then moved away from the main fire finding fuel sustenance in its path as it moved. It traveled about 300 yards into fine grass fuel before dissipating.

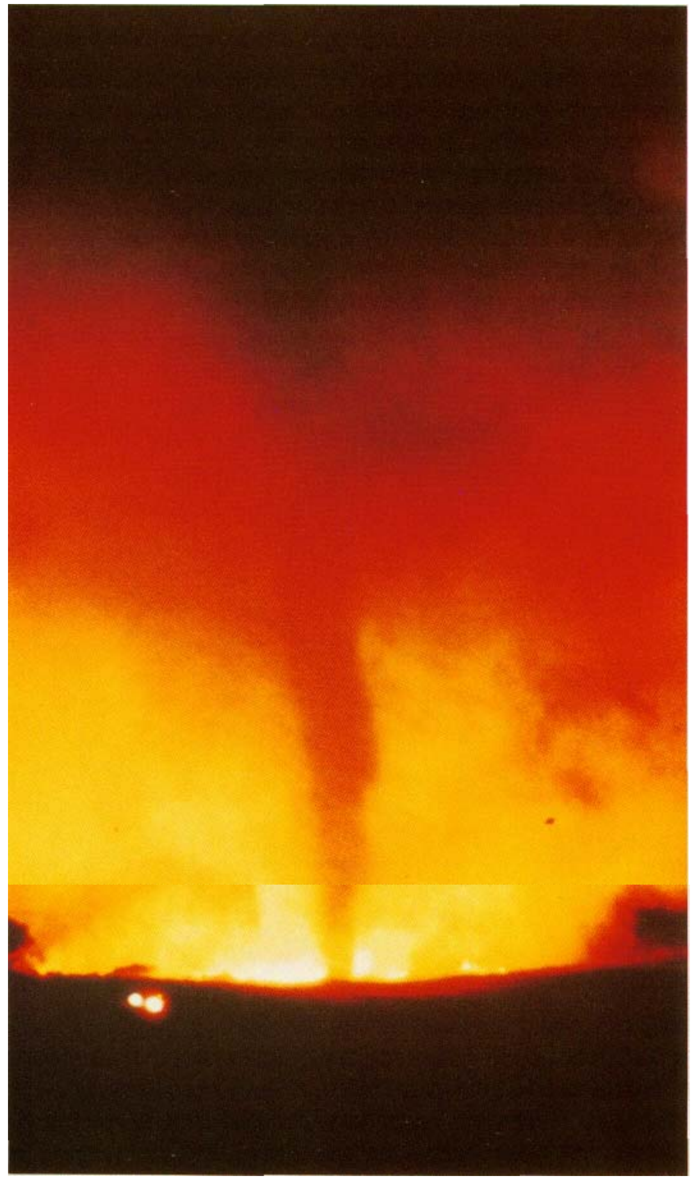
Other notable exceptions to the above generalizations have occurred. On one fire in southern California, giant whirls occurred repeatedly in or near the bottom of a deep canyon. One of these whirls began when one head of fire traveling upslope met another head moving downslope in the adjoining drainage. Undoubtedly the fire moving downslope was under the influence of a marine air intrusion.

The resulting large fire whirlwind formed itself around a prominent point on a ridge that contained not only ranch structures, but a number of firefighters and fire engines placed there to protect them. These firefighters could well be the first human beings to view a fire whirl from the **inside.** If this honor is somewhat dubious there can be little question of their particular good fortune in emerging unscathed from such an unusual situation.[2]

In yet another case (Pole Line Fire, San Bernardino, 1957), a very large whirl developed and became the head of the fast moving brush fire in moderately rolling topography. The whirl continued as the head of the fire, moving with the prevailing wind for a considerable distance. It advanced one and a quarter miles in six minutes.

As if to prove the old saying among southern California firefighters that a 13 month fire season exists in that portion of the state, a very destructive fire whirlwind occurred near the end of the winter of 1960-61 in Santa Barbara County. Moderately strong foehn winds were driving the fire downslope when many small whirlwinds suddenly formed into one large one. As it moved from the main fire its flaming path of destruction led through homes, barns, and avocado orchards. Then the whirl lifted to travel overland toward the Pacific Ocean.

As spectacular as the large fire whirl might be, in terms of safety, the more common smaller variety is



***SB** — Fire Whirl*

worthy of careful scrutiny as it moves across the burn. The use of goggles can prevent eye injury, and a strategically located lookout can watch for spot fires in the green. Whirlwinds of all types and sizes are indicators of unstable weather conditions.

[2] In August, 1949, Len Chatten witnessed this frightening phenomenon from outside the fire whirl on the De Luz Fire, San Diego County.

WILDLAND FIRE FIGHTING

CHAPTER 6

GROUND ATTACK

This chapter and the following chapter explain in general terms the various types of equipment that are available to the wildland firefighter.
Wildland firefighting equipment has been divided into four overall components consisting of engines, hand crews, bulldozers, and aircraft. Each one of these components consists of a variety of equipment and personnel.
Before we define the function of the three ground attack components — engines, hand crews, and bulldozers — we will discuss the basic tools, some of which are used by all three components.

6A — Basic hand tools

Hand Tools
Possibly the first wildland fire suppression tool used by man was a hand tool in the form of a stick or branch. As with the early hand tools, today's tools are merely an extension of the human arm. After the sophisticated equipment such as aircraft and engines has done its work, hand tools are still necessary to completely extinguish the fire. Hand tools are used for cutting, scraping, and throwing dirt.
The **round point shovel** is the most familiar and versatile of the hand tools. It is used to throw dirt at the base of the flames, scrape the fire line to mineral soil, cut small branches and plants, and dig out deep-seated fire.
The **axe,** both double and single bit are used basically as cutting tools but can scrape line in a limited fashion. Another tool, the **pulaski,** is used for cutting in that it has an axe blade on one end, and a thick hoe-type cutting edge on the other end. It is used to scrape and grub out roots.
The **brush hook** is designed to cut brush off just above ground level. This tool is very effective in chapparal fuels.
There are several raking and scraping-type tools that generally accomplish the same task. Some are hoe-like on one side and rake-like on the other - such as the **Mcleod** and **barren tool.** Others can only perform the function of a rake or hoe.
There are a series of hand tools that are used for special fuel types or in certain parts of the country. These consist of such implements as the wire brooms, fire swatters, Swedish brush hooks, and adze hoes. Crosscut saws are still in limited use in fire control work but have been for the most part, replaced by chain saws.

Power Tools
The most commonly used power tool is the power chain saw. Chain saws save many hours of labor, especially when working in heavy fuels such as slash and timber. Some chain saws can be fitted with a brush bar that enables the saw to be used in brush fuels. The chain saw does have several drawbacks. First, the operator must be highly skilled in the use of the tool as it can cause injury to the operator and others if not handled properly. Also, extra fuel must be carried to enable prolonged operation.
Several other types of power tools have been developed for fuel removal, but few have proved operationally effective in fire control work.

Portable Pumping Equipment
There are several types of portable pumping equipment that have been developed for wildland fire control operations. The back pump is the most widely used portable pump in the fire service. It carries from three to seven gallons of water and applies water by a hand operated trombone-like piston pump. Back pump tanks are made of metal, fiberglass, or rubber. They are highly efficient in their application of water, but cause fatigue to firefighters due to their weight which averages 30 to 60 pounds.
There are several types of power driven portable pumps. All are designed to draft water from a static source, such as swimming pools, streams, or lakes. Some are small enough to be packed on a firefighter's back; others are able to float on the surface of the water; and still others, of larger size, can draft considerable amounts of water. In areas where fire

***6B** — Engine in action*

water supply systems are scarce, portable pumps are of a great aid in both direct suppression and in refilling apparatus water tanks.

Engines

Of the various types of apparatus, both air and ground, the fire engine is the most versatile. It can fight fire both day and night, and is not greatly restricted by visibility as is the case with aircraft. It can deliver water on a fire at various capacities and transport a crew of personnel to a fire with their equipment. Its crew can construct hand line, and the unit can be used to fight structural, vehicle, and other types of fires.

There are many types of wildland fire engines;
however, most maintain some of the same basic characteristics. An engine should be able to both static and mobile pump. Therefore, most wildland engines have power take off units that enable them to pump and roll, or a self-powered slip-on pump unit. Some units have both a power take off unit that provides static pumping and a small auxiliary pump with engine that provides for a mobile pumping attack.

A wildland engine should be able to pump from 250 GPM to 500 GPM. These pumping capacities enable one unit to pump multiple lines and also protect and extinguish structure fires in the wildland areas.

The water tank capacity should enable the unit to make a successful attack in most small wildland fires and provide sufficient capacity for sustained operations. The water tank size must be capatible with the truck chassis. Tank size should be no smaller than 300 gallons or much larger than 700 gallons. If greater water supplies are needed, water tenders should be utilized.

Wildland engines should have short wheelbases, high ground clearance for off road use, be of rugged construction, and carry a complement of necessary firefighting equipment. A pump of at least 250 GPM and a water tank of 500 gallons is considered adequate. The unit should be able to function with a four to five person crew. Due to the long responses and durations involved in wildland firefighting, the entire crew should be able to sit while riding. If the crew seating is open or partially enclosed, fire blankets of a fire resistive material should be provided. When firefighters sit on the back of a unit, a roll bar is also recommended. Seat belts and restraints should always be used.

The wildland engine may be a conventional or a four wheel drive. Both have advantages and disadvantages. Terrain features, response criteria, and maintenance costs should determine the type of unit to use.

The wildland engine should carry the following equipment. The engine should have a complement of 1,000 to 1,500 feet of 1 *Vi"* hose and 800 to 1,000 feet of 1" hose. This hose should be lightweight of both fabric and couplings. The unit should have two hard lines with a minimum of 150 feet of hose on each reel. A full complement of nozzles and adapters is also necessary. Various hand tools and backfiring equipment is also considered standard complement. Engines that fight rural structural fires may also carry breathing apparatus, ladders, and forcible entry equipment.

The wildland engine company can be used to make hose lays, perform a mobile attack, construct hand lines, and protect and fight structural fires. Due to their mobility and communications, they can be quickly moved to various tactical assignments. Engines can be grouped together to perform specific tasks such as a major hose lay operation or structural protection. They are also complementary in working with hand crews, bulldozers, and supporting air drops. In most significant wildland fire operations, engines are made an integral part of the total wildland suppression forces.

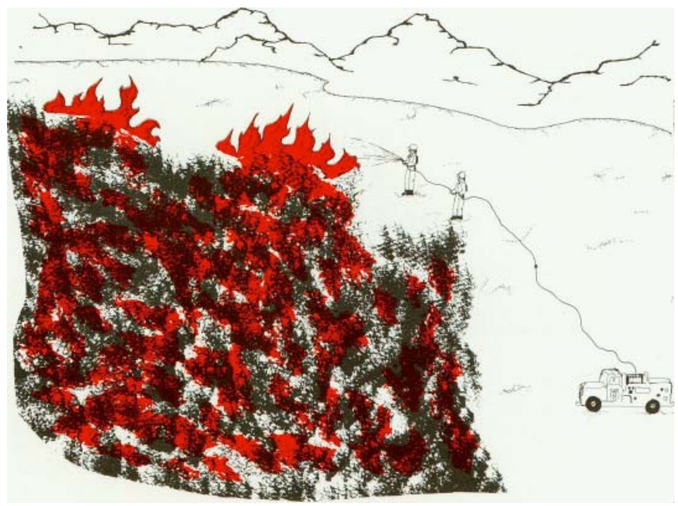
Considered under the same broad category as engines, but of significant different tactical design and use, are pickup pumpers and water tenders. A pickup pumper is usually a pickup truck operated by one firefighter. This type unit is used for fire prevention and patrol type work. Its water capacity is usually less than 150 gallons and carries a small pump and limited tools. It is effective on a small fire but of little value on an established fire.

One of the major tactical functions of a wildland engine company is to make hose lays. Hose lays can be used in a variety of configurations and prove highly effective in hot burning fuels involving terrain that is non-transversable by wheeled vehicles.

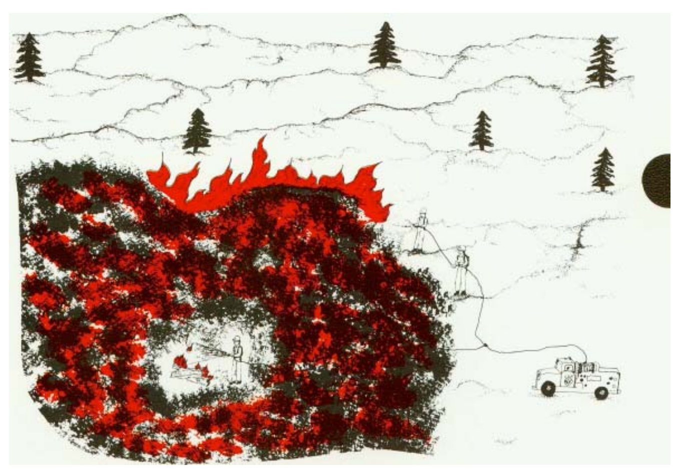
The following drawings depict a simple or point-to-point hose lay and a progressive hose lay with the use of "tees" and "laterals."

Ideally, \Vi" hose in 100 foot lengths and combination nozzles are used. On hot burning fires, gallonage discharge should not be less than 30 GPM. Hose lays should start from the heel of the fire, have an anchor point, and work along the fire's flanks. The fire should be approached with a charged line, and a straight stream should be used to knock down flare-ups in front of the nozzle operator. A narrow angle fog can be used to complete the rest of the knock down. The fireline should be secured in that rekindles or flare-ups behind the nozzle can cause the hose lay and the fireline to be lost. Hand crews should be used to follow up the hose lay and construct completed firelines. Water usually has to be brought to the hose lay by engines or water tenders, so strict water conservation methods should be employed.

Water tenders are used to support engines in various operations. They should be able to carry in excess of 1,000 gallons and be able to volume pump in order to transfer water to the engines. They also need to be able to draft in order to fill their own tanks. Some water tenders carry a large supply of hose for support in extended hose lay operations



6C – Simple Hose Lay



6D Progressive hose lay, water is discharged as the hose is extended. Laterals are put in for hot spots and mop up.

Hand Crews

On any sizable wildland fire usually the largest portion of suppression personnel will be made up of hand crews. A hand crew, as the name implies, is simply a group of firelighters that are formed into a suppression component and use hand and power tools to fight fire.

The hand crew is the oldest used organized suppression force known. The Greeks, Romans, and others used civilians and military alike to fight Mediterranean chaparral fires. These personnel used hand tools and were often organized into units.

The hand crews usually contain from 12 to 20 firefighters and are designed to actively suppress low flame production fires and construct hand lines along the fire's edge (direct) or ahead of the fire for future holding action or for backfiring operations (indirect).

6E — Hand crew in action

They quite often have the toughest assignments as they are used to go where vehicles, including bulldozers, are unable to traverse.

A hand crew's tools should consist of those necessary to construct fireline in the affected type fuel. Thus, the type and ratio of tools will vary as greatly as fuel types do. Some essential items for all crews are adequate safety clothing, communications, water, rations, headlamps, tool sharpening equipment, and spare tools. The crew should have its own transportation and be in top physical shape.

The following information can be used by a fire manager to estimate the number of hand crews and the time necessary to perform a specific line assignment. Remember, these are only guidelines and such variables as slope, weather conditions, flame production, crew fatigue, and morale must be taken into account.

For simplicity, fuel types have been divided into four basic categories: grass, medium brush, heavy brush, and extra heavy brush or slash. Grass fuels usually require a three-foot wide line to handle a fire. Brush fuels of medium density require a six-foot line, heavy brush requires a nine-foot line, and extra heavy brush or slash may require a 12-foot line. The line should be scraped to mineral soil and permit no overhang or canopy. A general rule of thumb is to construct the line one and one-half times as wide as the fuel is high. Thus, six-foot tall heavy brush may require a nine-foot wide line.

Some guidelines for crew production for various fuels using a 15 person crew:

Fuel	Ft. of Line per Hour	Width of Line
Grass	900	3
Medium Brush	450	6
Heavy Brush	300	9
Heaviest Brush/Slash	225	12
SOURCE: California Dept. Forestry Field Tests – Lake County 1969		

Crew production will decrease as the length of shift increases. Hand crews must be properly supported both tactically and logistically in order to maximize their effectiveness.

Most hand crews are used as ground attack crews. However, some crews are specially trained to descend from helicopters or parachute from aircraft. Whatever their means of transportation, the mission on the ground is basically the same, fire suppression and line construction by using hand tools and handheld power tools.

Bulldozers

The use of bulldozers in conjunction with the other ground and air attack components provides for a tactically balanced and integrated fire suppression force. Bulldozers are divided into three broad classes and are used in basically two types of tactical modes. The three classes of bulldozers are light, medium, and heavy types. The lights are generally of the D4 Caterpillar, Case 450 or International TD6 types. The

mediums vary greatly in size and transport capabilities and are considered to be of D6 (Caterpillar), HD11 Allis Chalmers. Usually, due to size and maneuverability, the heaviest type of dozer to be used should be no larger than a D8 or possibly D9 or equal.
Most fire departments that have wildland fire responsibilities use the D6 and D7 size bulldozers. These units can be transported without the use of Jeeps (extra wheel support units) and can traverse most rural roads. They are easily unloaded from a low-boy or tilt-bed transport by one operator. Some fire agencies use the D4 size or equal bulldozer units and find them quite effective in grass and other light fuels.

6F — Dozer in action

Many wildland fire agencies in the United States use dozers that drag or employ a plow device. These suppression units are very effective in generally level topography and certain soil and vegetative types.
The two types of tactical modes consist of fire department owned and operated with attack dozer units and rental by hire units. Although the actual mission of both departmental and hired units is the same, the deployment is quite different.
Fire service bulldozer units should consist of three vehicles: the bulldozer, the transport or prime mover, and the dozer tender. The bulldozer should have a canopy brush cage, radio, fire blankets or shelters to protect the operator, hand tools, and a short duration breathing apparatus. The transport may be either a tilt-bed or low-boy. It should be radio equipped and carry some basic fire tools and personal gear for the operators. The dozer tender provides the necessary support items for the dozer. These include fuel, lubricants, a compressor, welding equipment, and various mechanical tools and spare parts.
Rental equipment should be inspected to meet minimum safety standards. Due to the fact rental dozers usually have no radios, they should be placed under close fire line supervision. Fire service dozers can be used with considerably more leeway but must be supported in order to obtain tactical accomplishments. Support consists of fuel and other logistical items and the coordination of other suppression components such as engines, aircraft, and hand crews.
Bulldozers are used to construct firelines either directly along the fire's edge (direct attack) or construct predetermined lines ahead of the fire that may be used to stop the fire's spread by backfiring or holding with other ground and air attack forces. Bulldozers should work in tandem and be closely controlled and supported. There have been all too many incidents where bulldozers have been overrun by fire with resulting deaths and injuries to firefighters.
This chart gives the fire manager some broad guidelines for the production rates of bulldozers. Such rates may vary greatly depending on the fire's intensity, soil types, age and condition of the bulldozer, and most important, skill and motivation of the operator.

Rate of Construction — Yards Per Hour

(Fire Service Dozers)

Light Vegetation						
Percent Slope	Light Dozers			Medium Dozers		Percent Slope
	Down Grade	Upgrade		Downgrade	Upgrade	
0	1485	1485		1750	1750	0
10	1600	1400		1900	1470	10
20	1785	975		1930	1130	20
30	2012	675		1830	850	30
40	2060	350		1500	700	40
50	1900	250		1015	635	50
Medium Fuels						
0	1250	1250		1000	1000	0
10	1300	800		1080	885	10
20	950*	340		1115	650	20
30	1100	250		1085	470	30
40	1500	150		970	333	40
50	1575	100		650	217	50
Heavy Vegetation						
0	450	450		700	700	0
10	500	400		740	600	10
20	600	300		783	417	20
30	710	260		933	350	30
40	725	250		1217	300	40
50	500	100		1000	200	50

Source: California Department of Forestry 1967 Bulldozer tests.

6G - Average production consists of 885 yards per hour for a medium dozer and 935 yards per hour for a heavy dozer. These averages are based on a single pass fire line one blade wide.
The bulldozer is an extremely valuable tool to the fire manager. However, it should be used with caution in areas that are ecologically sensitive. There have been cases where uncontrolled bulldozer use caused more resource damage than the actual fire.

* based on one dozer pass only - not an average.

WILDLAND
FIRE FIGHTING

CHAPTER
7

AIR ATTACK

During a training session with a group of firefighters, the subject of fire apparatus, specifically, the history of apparatus development, was discussed. One firefighter presented his observation that the fire service "had come a long way," while an opposing viewpoint was stated by another, who said she only saw one major technological advantage - replacing the horse drawn pumper with a mechanical contrivance. Perhaps the greatest change resulted with the advent of fighting fire from the air. The air programs as we know them now, will surely become even more sophisticated and more remarkable in the future.

History of Firefighting Aircraft

At the close of World War II, various forest protection agencies received numerous unsolicited suggestions to use military bombers to attack forest fires. The responsible fire specialists had not been unaware of this potential new tool. In fact, the use of military planes for fire control observation and transportation in 1919 probably saved the embryo air unit of the Army from complete disintegration.

Between the two wars, numerous experiments had been made by Canadian as well as American military and forestry specialists and a few private pilots in the dropping of liquid in volume from aircraft, both in containers and as free fall liquid.

The results were not at all promising as measured in effect upon burning ground fuels, and the personnel safety hazard was most formidable. Yet the experiments were continued.

Then testing the bulk release of water from a torpedo bomber on the Jamieson Fire in Orange County, California in 1954, gave renewed hope of technical success. This occurred during a joint agency experiment known as Operation Firestop, that was conducted at Camp Pendleton. There had been no original intention of making the drop on an actual wildfire. Concentrated testing of techniques and equipment thereafter soon assured the practical use of liquid drops from airtankers. It yet remains a hazardous undertaking, requiring great personal skill on the part of the pilots and thoroughly adequate equipment.

During the early stages, aircraft use gained in popularity and even the most skeptical firefighters probably acknowledged the benefits of this new fire control tool. For some, the program was even visualized as a separate entity, apart from the traditional forces on the ground. Present day thinking, however, is that air attack complements ground attack. Even though integrated and correlated, air attack is actually considered to be supplemental to ground attack because of the flight limitations during periods of darkness, low visibility, or high winds, and because ultimately the ground forces put out the fire.

As with ground attack units, the greatest value is gained during initial attack on small fires. Aircraft are a limited duration support tool for the Fire Boss or Incident Commander.

Great care must be taken to assure desirable cost-benefit ratios. Because of a rather complex, but necessary system of use-control within the wildland fire agencies, special handbooks were written to deal with policies governing the utilization of all types of aircraft.

It was mentioned earlier that aircraft are tools to be used by the Incident Commander. Naturally the Incident Commander must know how to use such a tool effectively.

Aircraft types have changed since the first ones worked the fireline. Type availability is often dependent upon procurement of craft from the military or through contractual arrangements with private vendors.

For this writing airtankers are classified by the retardant payload capacity.

Type 1	800 - 1000 gallons
Type 2	1000 - 2000 gallons
Type 3	2000 + gallons

"Immediate initial attack will be made on wildfires occurring in remote areas under weather conditions where the spread of a fire is expected to be so great that normal initial attack ground forces would be unable to effectively contain the fire without air-tanker assistance."

Aircraft Deployment

The preceding paragraph contains several important and separate points. First, the response should be immediate, whenever possible. Air bases are situated strategically in California; any wildfire that will occur is but 20 minutes flight time from the nearest base. Second, the aircraft should be utilized while the fire is small, in its initial attack stage. Third, a reference was made to "remote" areas. The urbanization of California's wildlands surely will continue to reduce many backcountry areas formerly considered as remote. In addition to urban sprawl, whole subdivisions now sit in the middle of remote sites, creating a fire control nightmare for ground attack and air forces alike. The use of aircraft adjacent to such subdivisions is not uncommon. Fourth, the assumption is made that air attack will be used when the fire cannot be handled by the normal initial attack ground forces. If the aircraft are not already on scene, the Incident Commander, likely to be an Engineer or Captain on a first in company, will have to immediately decide whether the aircraft will be needed. Then the necessary orders must be given for cancellation or reinforcement.

It is worth repeating that aircraft, like ground units, are most efficient on initial attack fires. Thereafter, as a fire grows to an extended attack, and perhaps on to major fire status, all efforts are somewhat diminished, or scaled down in size. For instance, a single 500 gallon fire engine is better used on a quarter acre grass fire than on a 25,000 acre grass fire. And, one retardant drop from an airtanker on a one-acre brush fire is more significant than a dozen on an inferno, now in its second or third burning period.

The California Department of Forestry holds over 95 percent of its wildland fires to sizes that accommodate the best use of aircraft, a statistic resulting, in part, from the very effectiveness of the aircraft themselves.

Many fires are controlled as small fires through the immediate use of aircraft in initial attack situations. When aircraft are not needed, ground attack units hold many fires to smaller sizes also.

Tactical Use of Aircraft

Each fire has a different set of circumstances that can only be effectively evaluated by the people at the scene. The Incident Commander and the Air Attack Supervisor (Air Coordinator) must work as a team to obtain the most effective and economical use of firefighting aircraft. Advantage must be taken of

7A — C-119 Salvo drop

favorable weather conditions and information so that unnecessary drops are not made. Air Attack Supervisors and Incident Commanders continuously evaluate the need for further air drops. Under the most critical fire conditions, the number of airtankers that can be utilized effectively will provide one drop every five minutes, using whatever size aircraft is available. On fast moving fires with a broad front the most profitable use of airtankers will probably be through attacking active flanks. This is to say that without successful ground holding action, any contribution on a hot front may be wasted, while the same retarding effort on the flank can result in a secured piece of line. If a fast moving head is narrow enough, several drops may be adequate to stop the forward drive of the fire.

7B — Air Attack Supervisor

Prior to the availability of airtankers, it was a generally accepted axiom that rarely anything except a hazardous position could result from taking action against the face of a fire moving up a steep slope, even in relatively light fuel.

Usual action was to attempt to hold the fire at the ridge with the resulting sacrifice of the broadening flanks. In many cases the most logical strategy with air drops was to pretreat a ridge or bench where both retardant material and natural decrease in fire intensity will have the most beneficial result. On the other hand, the possibility of greatly reducing fire intensity, or even eliminating the active fire spread, with airtankers used on the upslope, offers a new dimension to the strategy of fire control. Success in this action should be expected, however, only if the frequency of drops can dominate a rate of fire spread that could cause the fire to outflank the retardant line.

The effectiveness of airtankers increases as the following conditions are approached: as grass or light brush fuel predominates, as wind movement decreases, as topography becomes less steep, as the time of fire incidence passes mid-afternoon, as the distance to the fire from the airport decreases within the 20 minute maximum ideal first attack striking limit.

During critical periods of backfiring operation, an orbiting airtanker may be desirable to furnish immediate action on spot fires.

If there are a series of separate fire starts occurring almost simultaneously in the same general area, air-tankers can normally be most profitably used on the small and isolated fires.

Aircraft Limitations

It should be recognized that certain conditions may seriously limit the use of airtankers. Fire managers should recognize that:

(a) Steep topography seriously reduces airtanker effectiveness. Deep canyons may rule out their use entirely for certain fire targets.

(b) Winds over 20 MPH sharply reduce airtanker effectiveness. Shifting and high velocity winds (over 40 MPH) and turbulent air may restrict or exclude airtanker use.

(c) Early morning and late afternoons are periods when airtankers may be less effective. Deep shadows are produced by the sun on certain aspects of topography that make it difficult for pilots to see fire targets or ground obstructions.

(d) Dense smoke may make airtanker operations both hazardous and ineffective on part or all of the fire area.

(e) Airtankers cannot be used at night - a period when a fire is normally expected to become less **active.**

(f) Tall dense timber and snags may require airtankers to make drops higher than desirable and may intercept most of the retardant before it reaches the fire.

Aircraft Capabilities

Most airtankers are capable of dropping retardant in three patterns:

- **<u>Salvo</u>:** Total load at one time and place. All tanks open.
- **<u>Trail</u>:** Overlapping series of from 2 to 8 tanks in tandem.
- **<u>Split</u>:** Single drop from one tank at a time at widely spread intervals, or 2 to 8 times on the same place.

Often, air drops are made on a fire prior to the arrival of ground forces. Such a "delaying tactic" pays big dividends when the drops are successful in holding the fire to initial attack size.

Airtankers generally operate under the direction of an Air Attack Supervisor, who constantly works via radio communication with the Incident Commander on the ground. The following is a typical sequence of events one might observe at the fire scene.

The Incident Commander has a need for an airdrop on a ridge that cannot be reached by the fire engines. The Incident Commander calls the Air Attack Supervisor on the radio and describes what it is the airtanker is to accomplish such as to "have one air-tanker drop a salvo load on the right flank. Advise the airtanker to be careful of a powerline near the ridgetop." The Air Attack acknowledges, and directs the airtanker by radio.

Air Attack evaluates the effectiveness of the drop and converses with the Incident Commander as to further needs. Firefighters from handcrews, or from the engine companies will be immediately sent by foot up to the ridge to work on the fireline which, hopefully, is burning with less intensity following the retardant application. Often, ground crews are working on the fireline when retardant drops are made.

Aircraft Safety

The safety bulletin that follows will help ground personnel avoid possible serious injury due to weight and force of the falling retardant payload. While aircraft do fly at sufficient altitudes to permit the falling retardant to disperse in the form of a rain or heavy mist, occasionally the payload does not break up, and personnel have been hurt and equipment damaged. When the retardant hits in a mass, it is capable of tearing brush out of the ground, kicking rocks into the air, or knocking personnel off their feet.

Sometimes, fire conditions along the line become untenable or pose potential threat to ground personnel. In such cases, it is not uncommon for them to ask for a protective retardant drop. The point to be made concerning such a request is this: if asked, any air officer would probably say that the very conditions that threaten the ground crews are also obscuring the situation from the visibility of the pilots.

The aircraft may be unable to locate the crew in time to help them. Even with the brightly colored fire resistant clothing worn on the ground, it may be difficult to pinpoint the area of need and to establish a proper drop pattern, because of the dense smoke. Therefore, a dependence on aircraft to perform such a function should not take the place of escape routes, communications, lookouts, and other preventative measures. Airtanker movement adjacent to the fireline can fan a dormant section suddenly into life, or can force a change in spread direction. Both contingencies are detrimental to firefighting efforts and accentuate the relative immobility of ground personnel. Vortex turbulence from low flying airtankers, a turbulence consisting of a pair of minature whirlwinds trailing from the wing-tips, must be evaluated carefully by ground personnel.

*7C — **Vortex***

The more heavily loaded the aircraft, and the lower and slower it flies, the stronger the vortex turbulence will be and the more likely to reach the ground. The vortex may strike the ground with velocities up to 25 MPH, sufficient to cause sudden and violent changes in fire behavior on calm days in patchy fuels.

Wind gustiness and surrounding high vegetation will

Aircraft Types and Capabilities

TYPE	Min Air Strip Req.	Loaded Speed Drop/Cruise	No. of Doors	Min. Rel. Gallons	Total Capacity Gallons	*FT. of Trail Drop
Type 1						
• S2F	3500	120/190	4	200	800	400
• PBY5A	4000	100/135	2	500	1000	500
Type 2						
• Super PBY5	4000	100/150	2	700	1400	700
• C119	5000	125/195	6	330	1900	900
• C119J	4000	125/195	6	300	1800	900
• B17	4500	115/175	4	450	1800	900
• DC-4	4000	130/195	8	250	20000	1000
Type 3						
• S-PB4Y-2 (Super)	4500	120/200	8	300	2400	1200
• DC-6	5000	150/250	4, 6, 8		3000	1500
• DC-7	5000	160/250	8	400	3200	1600

*Notes:
Usable trail drop distance is 2 gallons for 1 foot.
Usable salvo drop distance is 4 gallons for 1 foot.
Number of available drop combinations can be determined from the following columns: Number of doors, minimum releasable gallons, and total capacity.

tend to break up or diminish vortex intensity.
The firefighters should be alert for trouble during airtanker drops when:

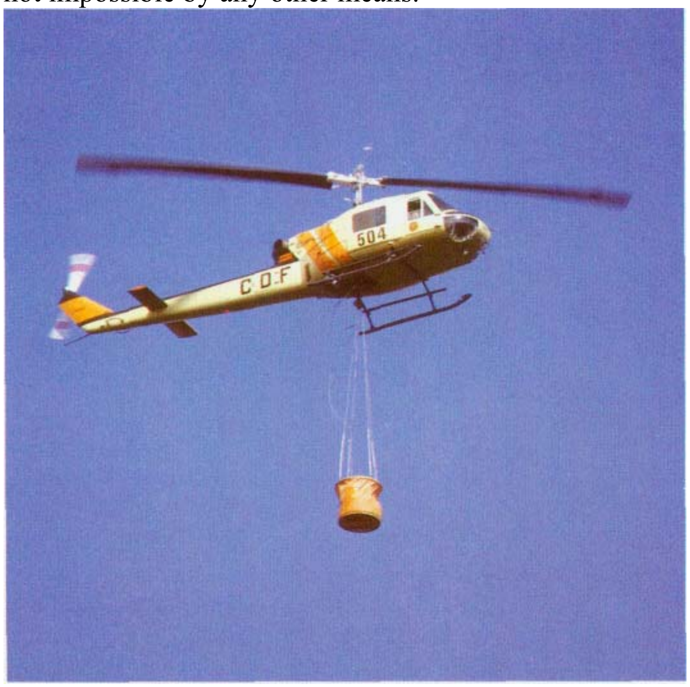
(a) The air is still and calm.
(b) The fire is burning in open brush or scattered timber.
(c) The airtanker is large or heavily loaded.
(d) The airtanker is flying low and slowly.

The airtanker pilot should be aware of the problem the aircraft can cause. The pilot may know the effect of vortex wakes on aircraft, but may not know the effect on a fire. The pilot can abide by the following rules during situations of possible danger from vortex wakes:

(a) By not flying parallel with the fireline more than necessary.
(b) By remaining high, except when making the actual drop.
(c) By assuring that ground personnel are alert to the presence of the airtanker and/or the pilot's intentions.

Helicopters

One of the principal advantages of a helicopter is its ability to operate from locations near to, and on the fireline. Its vertical take-off and landing characteristics make it a valuable piece of equipment for close support action for ground based and other aerial operations. Various accessory attachments are available that permit a helicopter to perform certain jobs that would be difficult if not impossible by any other means.



7E — Helicopter

Helibases are main bases of operation serving a fire. They should be located near a good access road. **Helispots** are sites of temporary use located on or near the fire perimeter for the purpose of delivery or return of personnel and equipment. Depending upon terrain and the ease of vegetation removal for safe takeoff and landings, helispots can be constructed in meadows, on mountain peaks, or on ridge tops and saddles. On some fires of longer duration, helispots may be used for the stockpiling of sleeping bags, lunches, drinking water, backpumps, and extra tools. Handcrews are flown into these helispots to work a shift, and then perhaps return to the site for supplies and to spend the next shift sleeping in a designated area adjacent to the helispot. A miniature "fire camp" is thus created that can be advantageous in reducing the number of ferrying trips to and from the line. The procedure also allows for a longer period of fireline construction because travel times are not involved, and it eases the logistical requirements of the planning section. Helispots are identified by name or number on maps for easy location by personnel. Pilots approaching helispots are able to confirm identification from the air because the helispot is marked with a large plastic sign or by other means.

Helicopters may also be used for the application of liquids, such as water or retardant chemicals, over key fireline targets. Because of their ability to hover, they can be directed precisely via radio communication with ground personnel. Some helicopters carry a collapsible canvas or rubberized water tank which can be strategically placed on the fireline. A portable "floto-pump" is placed in the tank, which is filled by helicopters using water containers. Ground personnel are then afforded some of the benefits of having a fire engine in un-drivable terrain at their disposal. The floto-pump includes a complement of fire hose, adapters, nozzles, and hose clamps.

Helicopters are useful in transporting injured firefighters, including burn victims, who will be flown to pre-designated hospital burn wards. Helicopters have often served dramatically to evacuate persons stranded or threatened by fire.

Most agencies supplying and coordinating helicopters require certain data on each load of personnel and equipment. Manifests are routinely filled out prior to each embarkment. Fire tools are secured in groups and each firefighter is weighed to assure that the weight limitations of the ship are not violated. Logistically, it is desirable, but often most difficult to keep track of a crew once it has been dropped on the fireline at a helispot. The handcrew that is scheduled to return to the pickup point may end up in quite a different location. The reasons are several, including reassignment to another section of fireline, necessity for various reasons to walk the crew out rather than fly, easier access to another helispot, etc. As is the case in so many fire operations, good communications can help prevent misplacement of personnel and equipment even on remote sections of line.

All fire control personnel are subject to assignment with or around helicopters. They should have at least a general familiarity with the type of work that can be accomplished as well as the limitations. Those employees who will be engaged directly in some activity involving the craft must, of course, have a thorough understanding of the part they are to play. All personnel who may possibly be working near or transported by helicopters, should be familiar with safety practices, and they shall observe such precautions at all times.

WILDLAND FIRE FIGHTING

CHAPTER 8

TACTICS & STRATEGY

This chapter is divided into two major sections, one dealing with the concepts of fire management and strategical objectives, and the other with the actual tactical deployment of suppression resources. Strategy deals with the major objectives of managing a fire, while fire tactics involve the actual number and the individual designation of the units that are to accomplish the identified strategies. For example, during the planning stages of a fire suppression objectives may be to minimize all structural losses and to prevent the fire from crossing a specific highway. These two major objectives are considered part of the fire strategy.

In order to successfully identify and implement the strategies and resulting tactics necessary to accomplish control and extinguishment of a fire, the fire manager must have a working understanding of the four major components of sound fire management. These components are equally applicable on a small grass fire requiring only three or four engines as they are on a major fire requiring hundreds of suppression units supported by complex planning, logistical, and financial functions.

Many times firefighters start suppression operations on what they determine is the immediate requirement of the situation. They then augment their resources based on what the fire is doing. Their organization grows with little concern for long term objectives and the command and suppression structure becomes chaotic with overall poor results. Such management, if it can be called that, results from a reactive rather than a proactive approach to proper and cognitive fire management.

Fire management consists of the proactive consideration and intelligent use of four basic elements:

Planning, Organizing, Directing, and Controlling. The firefighter must formulate a **plan** of action, build an organization to accomplish the objectives and strategies as outlined in the plan, **direct** the organization by communicating the strategies and tactics to the necessary members of the organization, and finally **control** the identified fire organization with adequate systems so the fire management staff can meet the objectives as outlined. Successful fire management must incorporate planning, organizing, directing, and controlling.

A plan is formulated based on consideration of the past, present, and future factors that affect the fire. A plan is an ordered sequence of events over a specified period of time.

The fire suppression planning process consists of three separate elements: an information gathering system, an information evaluation and prediction system, and a constant re-evaluation system. These elements provide the basis for size-up that will be *A* covered in detail in this chapter. ^

In wildland fire situations the information gathering system may consist of: facts gathered from pre-fire plans, observations and radio traffic from the first-in companies, information from the Dispatch Center, and communicated observations from aircraft, such as air attack and helicopters. Information is also gathered from recon personnel and the personal observations of the command officers. The information evaluation and predictions system consists of the fire ground commander and various staff members.

The re-evaluation system is a never-ending process. *A* With good firefighters and command officers, ^ effective planning is a dynamic and ongoing process. A good plan is constantly being adjusted based on new significant data that will affect overall action on the fire and pro-action of the suppression forces.

Ideally, fire control operational plans should be based on facts alone. Actually, however, beliefs sometimes alter facts. What one sees and hears is often influenced by experience, or lack of it. Attitudes, sentiments, values, and, therefore, planning conclusions are not always based on facts alone. Successful firefighters objectively rather than subjectively view data in order to develop effective control plans.

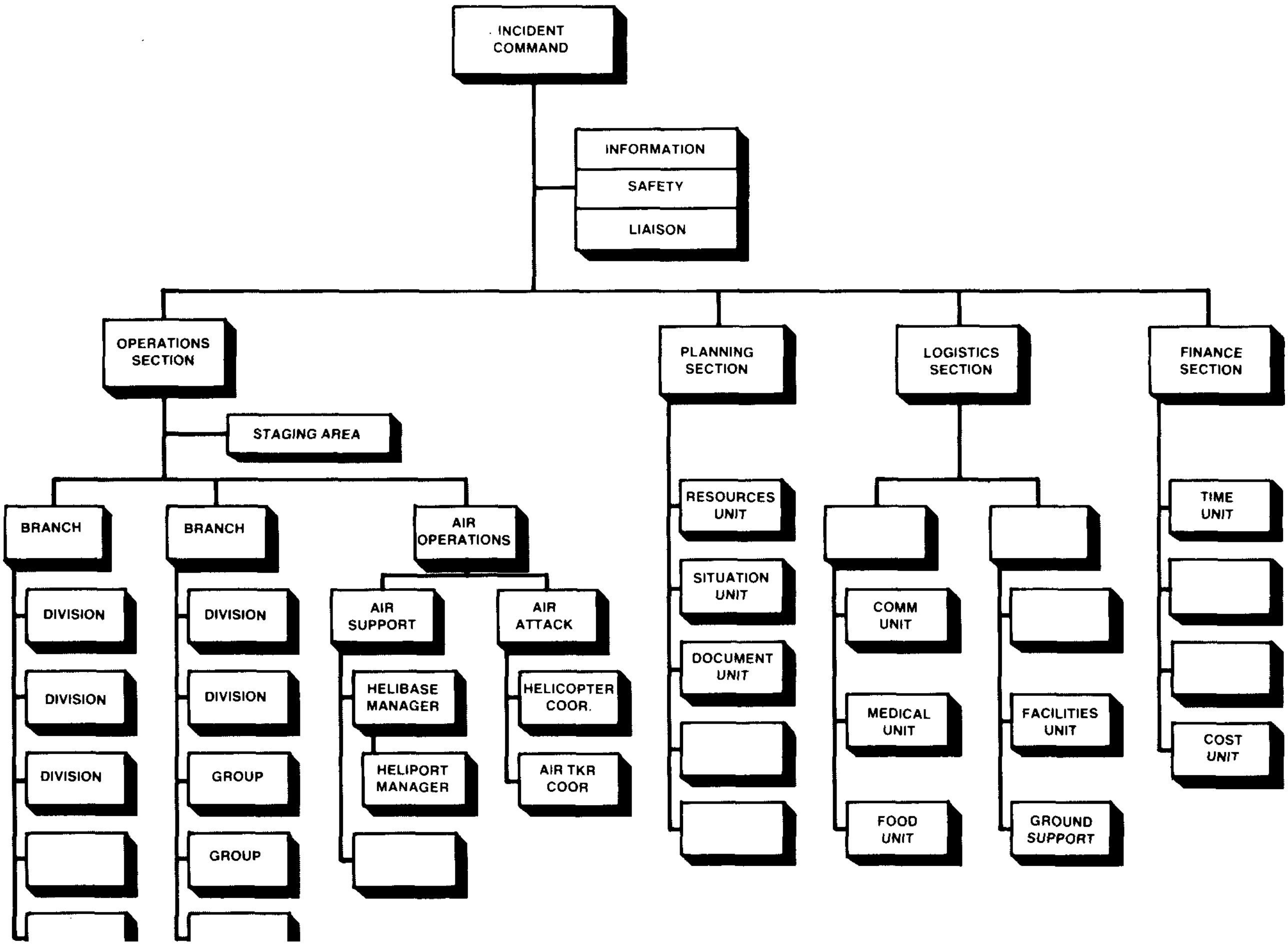
A fire organization, simply stated, is a group of firefighters working together to achieve a common objective. To be effective, the organization must include the following elements: a system of authority and responsibility, a system of direction and communication, consolidated action toward identified objectives, and a system of maintaining acceptable norms and standards.

The system of authority and responsibility is usually outlined by the legal basis. The fire service functions by the operation and organizational guidelines and orders that are developed by each department. *A*

This system is communicated through an organiza- ^ tion chart and supplemental position descriptions. The accompanying chart is typical of one used to staff a major wildland fire.

The organization must maintain a system of direction and communication. This system can consist of face-to-face contacts, written messages, and radio and telephone communications.

An important key to a successful organization is the coordinated action toward specific objectives. This coordinated action is based on how well the forces are organized and how realistic the objectives have been *A* identified. ^



ICS Organization Chart

The system of maintaining acceptable norms and standards or effective fire suppression production is based on past successful performance in like conditions. Chapters #6 and #7 cover these standards.

The important elements of a fire suppression organization to be considered are span of control, unity of command, clear definition of authority and responsibility, and unity of objective.

Span of control relates to the number of people or units a manager can effectively direct or control. For example, management unit is an individual (firefighter), or a unit such as a hand crew, that reports directly to one supervisor. Generally in a fire organization, the span of control should not be less than three nor more than seven.

Proper unity of command dictates that each firefighter should have only one supervisor. Although almost all fire officers agree with this concept, it is the one most violated on the fire ground.

A clear definition of authority and responsibility is paramount to fire suppression efforts. Each person should be given clear authority^ to carry out the responsibilities assigned to that individual.

The unity of objective must be clearly understood and pragmatically pursued in order to accomplish the overall goal of putting the fire out.

The third element of fire management involves direction. The issuing of directives during the fighting of a moving wildland fire requires a clear understanding of the process of human communications under stressful conditions and the necessary parts of a proper and effective directive.

A directive is simply a communication that involves some specifics as to the accomplishment of a task. In order for a directive to be clear and effective, it should provide the following information:

WHO is to perform the work.
WHAT is to be done.
WHEN is it to be done.
WHERE is it to be done.
WHY is it to be done.

Sometimes the "WHY" is implied or understood and does not have to be fully explained in the directive.

The following is an example of a proper fireground directive that meets the requirements of providing "WHO, WHAT, WHEN, WHERE, and WHY."

"Engines 28 and 72, upon arrival at the fire, start a progressive hose lay on the right flank. This hose lay is needed to tie in with the dozer line that is progressing on the left flank."

When finishing your directive be sure to ask, "Do you have any questions?" Good directives involve two-way communications and are best handled on a face-to-face basis.

Planning, organizing, and directing elements of proper fire management have been defined now, the fourth and final segment of fire management is controls.

Controls are methods or systems designed to inform the manager of progress and breakdowns in the operations so the system may be adjusted and corrected to meet the objectives as identified in the fire plan. To insure a proper set of controls, a fire organization must contain several important elements.

These elements consist of visual control by actually observing what progress is taking place. Periodic reporting from different suppression units and field commanders can pass along pertinent information. The monitoring of radio traffic and face-to-face meetings with responsible members of the fire control organization can provide timely controls. Also, aircraft, both fixed and rotor wing can provide important rapid and timely information to field commanders.

The previous sections of this chapter have covered the concepts of fire management and the development of strategical objectives. The second major portion of this chapter will cover fire ground tactics, suppression methods, and the deployment of fire attack resources.

Size-Up

SIZE-UP*, an *estimate of the needed actions and resources required to extinguish a fire.

FIRE SIZE-UP IS MADE AT FIVE TIMES

1. Upon receiving call

2. While enroute to the fire

3. At first site of the fire

4. Upon arrival at the fire

5. During entire life of the fire

8A —

Before any strategical objectives can be identified or any suppression companies put to work, one all-important process must take place.

Fire departments exist to combat fires. This fact should not be forgotten. Although it is true that fire service administrative procedures are important, the fire service does not exist solely for the purpose of being well-run. Administrative, financial, and political decisions can be reached after considerable counseling and conjecture and can, and often are, revised if found inappropriate or lacking. However, fire ground decisions must be made quickly. The fire ground situation does not allow the first-in officer the luxury of consultation and calculated deliberation.

The officer's initial decisions are usually irreversible and the consequences of error can quickly compound and become disastrous. Unlike staff officers in the fire service and executives in industry, the fire ground officer must base all important decisions on hastily obtained information gathered under the most stressful conditions.

This process of hastily gathering important information is called **size-up.** Size-up is the basic foundation for subsequent firefighting decisions and operations. The old saying that a building is no stronger than the foundation it rests on has a direct application to fire size-up.

Size-up should start long before the fire actually starts. Firefighters should be familiar with the fuel types, topographical features, exposure problems, and daily weather patterns in their areas of responsibility. Having this basic information can provide a foundation for future observations. When the alarm sounds, each firefighter should know the general fire behavior that can be expected, the location of the fire and the types of physical factors that are present:

fuel, topography, road access, structural exposure, water supplies, natural or manmade barriers, and the number and type of suppression resources dispatched.

Once the fire is actually viewed, hopefully from several vantage points, the specific size-up consisting of three general interrelated mental evaluations may start.

1. **What has happened?**
   EXAMPLE: The fire has burned five acres of grass and two small out buildings.
2. **What is happening?**
   EXAMPLE: The fire is spreading rapidly on the right flank and is moving into medium brush. It is starting to spot. It is within 200 feet of a barn, ranch house, and stock pen.
3. **What will happen?**
   EXAMPLE: If no suppression is taken:
   a. The fire will continue to move into the medium brush,
   b. The spot fires will increase in size, c. The ranch house and barn will catch fire as will other structures in the path of the fire.

Size-Up Steps

These six steps must be considered in all wildland fire situations; however, all of them may not apply in every case.

1. **Pre-Arrival Considerations**
   Prior to your arrival at the fire or even prior to dispatch, there are several facts you should take into consideration.
   a. Fuel-Topography. What effect will the existing fuel and topography have on current and expected fire behavior? How will these factors hinder or aid fire control?
   b. Weather. What effect will the key variable to wildland firefighting have on the fire behavior?
   c. Time. Are we just starting into a burning period with conditions that will become more adverse to control or is it late in the day and the fire danger is dropping?
   d. Type of Fire. Is it grass, brush, timber, or exposures. What types of equipment are necessary to effect control? e. **General Location.** What effect does the location have as to access, exposures, natural barriers, water supplies and effectiveness for air attack?
2. **Where is the fire?** What is the exact location of the fire? Check maps, talk to locals, obtain information from air attack units.
3. **What is burning?** What is actually burning — grass, brush, timber, or combinations.
4. **What will burn?** Consider all previous factors and determine what will soon become involved in the fire — heavier fuel, structures, recreational areas.
5. **Life Hazards.** Always consider life hazard from the time of initial dispatch. It is axiomatic to state that rescue takes precedence over firefighting. However, after going through the previous four steps, you will be better mentally prepared to plan the rescue actions and subsequent attack operations.
6. **Resources Situation.** Consider whether the initial dispatch is sufficient to handle the fire based on the information gathered in the previous five steps. Consider available personnel, apparatus capabilities, water supply, fire defense improvements, logistical support and resistance to control.

Remember — no fire is static; therefore, your size-up should not be static. Many fires have been lost even though the Incident Commander made a good initial size-up but failed to reappraise the situation. Continue your size-up throughout the confinement, extinguishment, and mop-up process. Many fire-fighters have been killed or injured due to sudden changes in weather and resulting fire behavior.

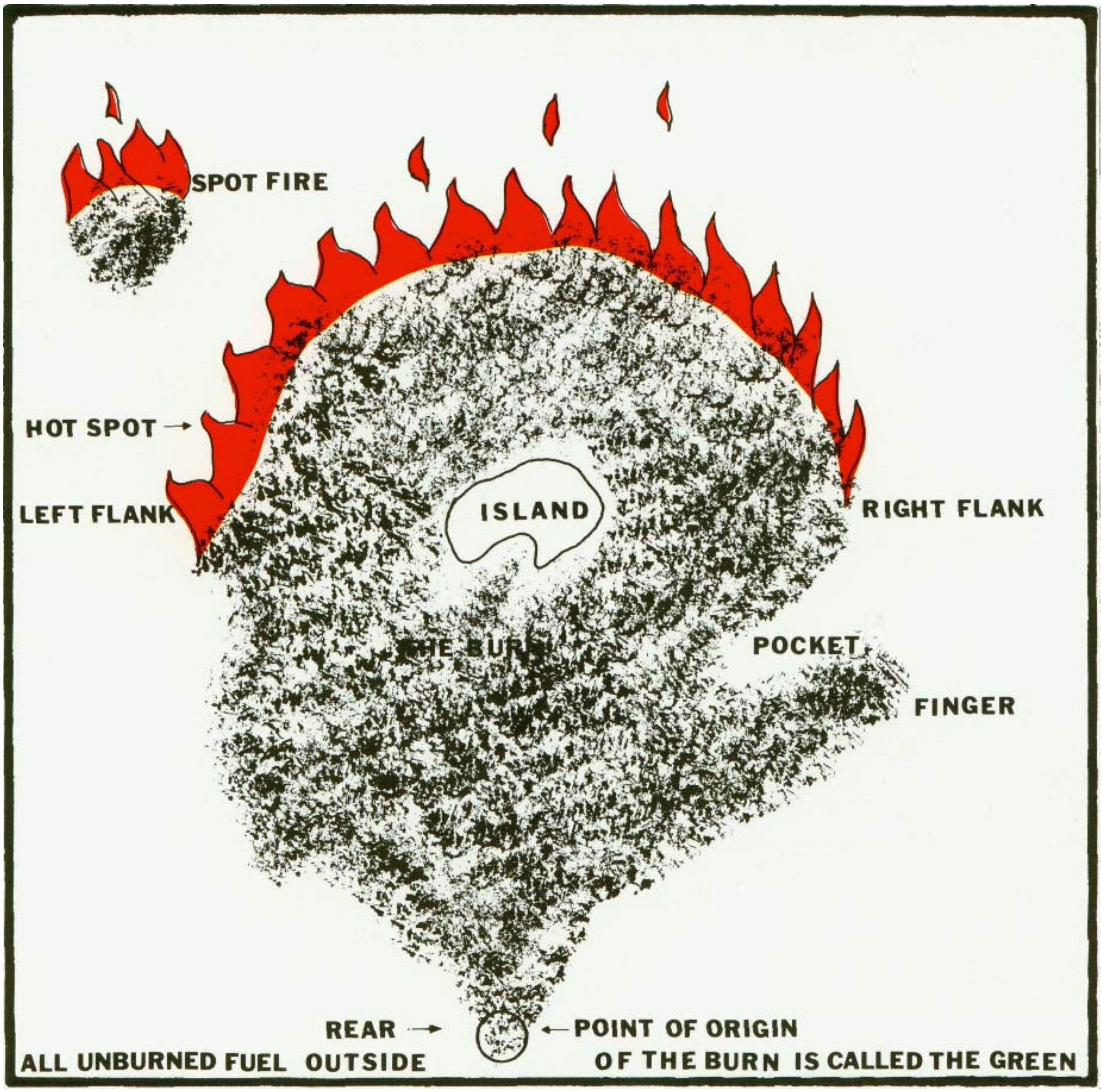
Wildland Fire Tactics
Now the tactics for putting out the fire will be considered.

Diagram 8B lists the significant parts or locations of a fire. This is most important because it gives a common set of reference terms.

Firefighters have a choice of three major methods for combating wildland fires — direct attack, parallel, and the indirect attack methods. Quite often the method chosen is determined by fuel types, exposure problems, fire behavior, and suppression resources available. The safety requirements for the personnel involved should be considered first when choosing a method or combination of methods.

The direct attack method involves working directly on the fire's edge. This type of suppression action would involve laying hose and spraying water on the fire's edge, constructing hand lines along the direct edge of the fire, making air tanker or helicopter drops to support firefighters working on the perimeter, and having bulldozers construct line along the edge of the fire.

This method has several tactical advantages. The applied suppression resources instantly produce results in the amount of fire controlled. (Refer to 8C.)

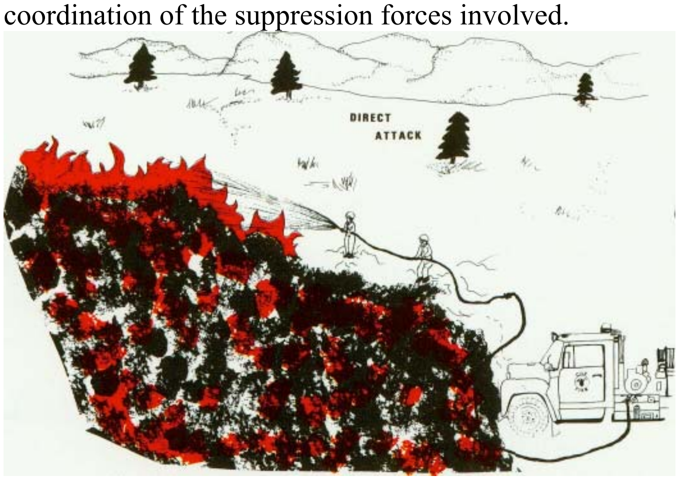


8B — Parts of a fire

This method requires a continuous and finished line. The line should be started from an anchor point such as a road, plowed field, or other manmade or natural barrier. The direct attack will limit the fire building up momentum and eliminates the need for backfiring or firing out. It is generally used on fires in the initial attack phase and can be used on the flanks and head. The main objective is to stop the spread of the fire as soon as possible.

The advantages of the direct method consist of:
holding the size of the fire to minimum acreage, taking advantage of portions of the line that have gone out due to lack of fuel or poor burning conditions, eliminating fuels at the fire's edge, providing for direct operational control and higher levels of crew safety, and reducing loss of resources caused by backfiring or allowing the fire to run to predetermined control lines.

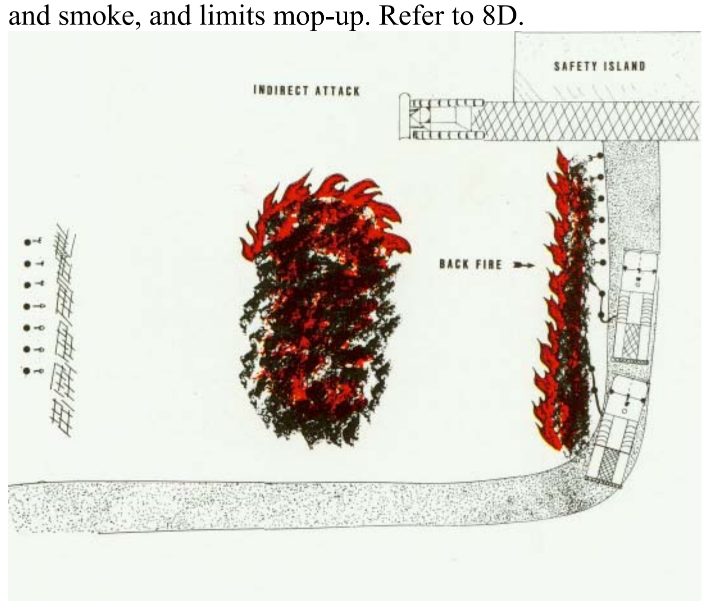
The disadvantages of the direct attack are: it might not be effective against an intensely hot or fast moving fire; results in an irregular and thus, longer amount of fireline to be constructed; exposes firefighters to direct flame and smoke; does not normally take advantage of natural or manmade barriers in the fire's path; and requires additional mop-up. Direct fire attack requires close coordination of the suppression forces involved.



8C — Direct Method of Attack

The indirect attack method consists of fighting a wildland fire by constructing control lines at a considerable distance ahead of the main fire. It is used when the fire is burning too hot and rapidly to employ direct attack methods or when sufficient suppression forces are not available for the employment of direct attack methods. The pre-constructed lines put in ahead of the fire are either fired out or held by ground and air forces and become the final control line.

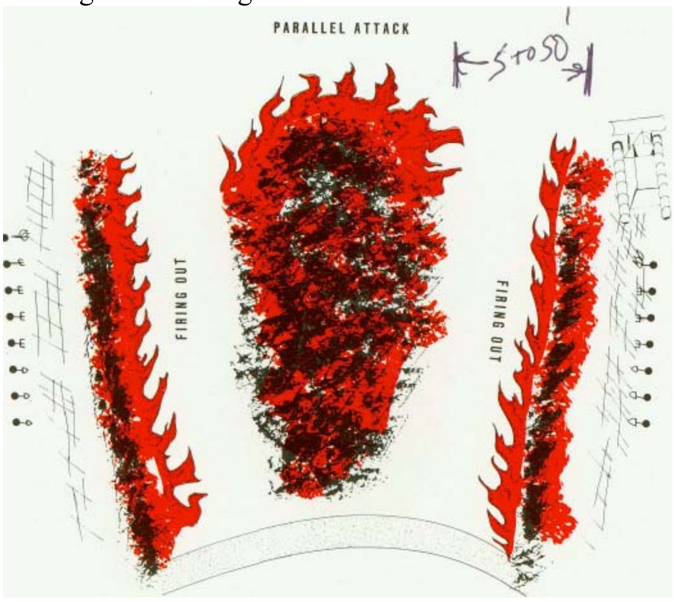
The advantages of the indirect attack method are: the burned area can be determined by a pre-constructed line that can often be completed with less suppression resources, the amount of total fireline is limited, firefighters can work away from large amounts of heat and smoke, and limits mop-up. Refer to 8D.



8D — Indirect Method of Attack

The disadvantages of the indirect method consist of:
no fire is put out while the control lines are being constructed, additional acreage is sacrificed, portions of the fireline that may have gone out aren't used, places firefighters in front of an advancing fire, may require secondary lines to be constructed, and requires a frontal stand with firefighters and/or a successful expected backfiring operation.

The parallel method consists of constructing a continuous line from five to fifty feet from the advancing fire's edge. In this method, the basic principal is to remain close to the fire's edge; however, freedom is allowed for dropping back to avoid intense heat and smoke, to cut straight across indentations in the fire's edge to save labor and later safely conduct burning out operations. The parallel method is also used to straighten or shorten lines, drop back from snags, encompass burning logs into the main portion of the fire, and improve line location. The major difference between the indirect method is that the parallel method is performed considerably closer to the main fireline and that the final control line becomes a general extension of the original fire's edge. Refer to 8E.



8E — Parallel Method of Attack

The major advantage to the parallel method is that it allows control of the fire on a predetermined line and reduces the total amount of line to be constructed. The major disadvantage is that the firefighters must work near the fire in unburned fuel and thus it is the most dangerous of the three methods.

Application of Attack Methods
No one method must be totally followed throughout the suppression of the fire. More often, on any sizeable fire, all three methods will be utilized. On one flank it may be possible to use dozers and engines on a direct attack, using line construction and hose lays on the other flank. Parallel line construction involving burning out might be the selected tactic while dozers and hand crews might be constructing the line well in advance of the fire's head to be backfired and held at a later time.

8F — Burning Out (Firing Out)

Firefighting Operations
Firefighting operations consist of the tactical deployment of air and ground forces in the suppression of wildfires. These operations involve the three methods of attack: direct, indirect, and parallel. To employ these methods we may use backfire or burning out action, tandem action, pincer action, flanking action, or total envelopment action.

Backfiring and Burning Out Actions
There is a distinct difference between backfiring and burning out. These two terms have been used inter-changeably with resulting confusion for many years. The term burning out sometimes also called firing out, refers to removal by fire of residue fuel that remain between a constructed line and the edge of a dead fire. The term also refers to the burning of fuel to protect structures or other improvements. Refer to 8G.

Backfiring is an indirect fire control action typically used against a rapidly spreading fire. The fuel between the pre-planned control line and the active fire's edge is intentionally fired to eliminate fuel in advance of the fire. This widens the control line to possibly change the fire's direction and to slow the fire's progress.

8G — Burning Out Around a Structure

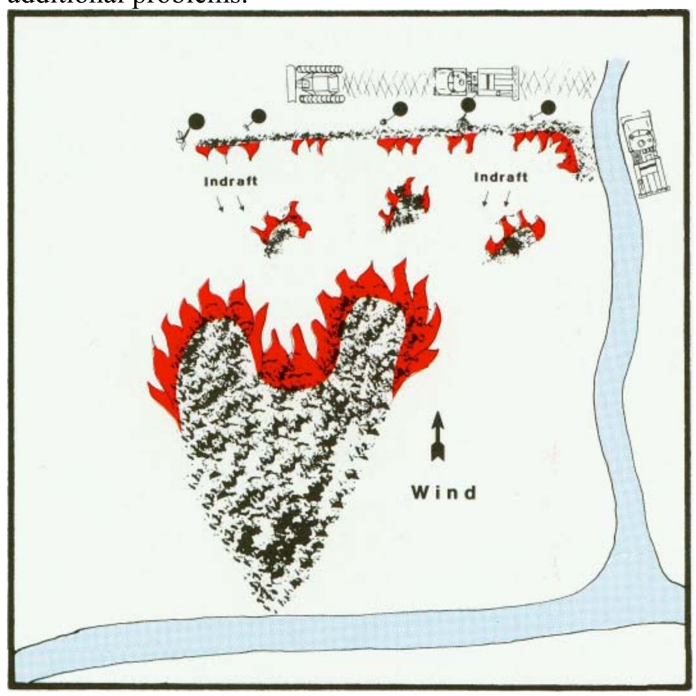
Planned backfiring often involves considerable planning, organizing, and physical preparation. The decision to backfire should be made by the command function communicated through line channels and executed at the division level by strike teams or individual increments. Under special circumstances or in emergencies, line personnel may be forced to backfire and then notify higher command levels concurrently.

Safety considerations must take first priority. No backfiring operation, regardless of how important the strategical values involved, is worth risking one human life. The calculation of probabilities of both success and failure must be considered by command personnel as any backfire may result in the loss of the fire and resulting compounded damages.

Knowledge of when and how to properly conduct a backfiring operation is essential in that such operations can control a major fire rapidly with relatively limited suppression resources. Overall fire strategy and resulting tactics must be understood by all personnel involved in the backfiring operation since the fire behavior on other portions of the control line is likely to be affected.

Backfiring should be directly correlated to the behavior of the fire. If the main fire is burning intensely and moving at a rapid rate of spread, backfire quickly enough to prevent the fire from jumping the prepared or proposed control lines.

When weather, fuel, topography, and sufficient suppression forces are favorable to a backfiring operation it should proceed without delay. Many fires have been lost due to indecision on the part of ground commanders and many backfires have only created additional problems because time was wasted and burning conditions changed to less than favorable causing the back fire to "lay down" or go out. At times, these same indecisions and burning conditions can cause backfires to escape and result in additional problems.



8H — Backfiring

Backfiring and Fire Behavior

Active fires, whether the main fire or intentionally set backfires, produce conditions that draw other fires. The larger and more intense a fire grows, the more it affects local weather conditions, thus greatly influencing additional fires at greater and greater distances. Noticeable wind direction and intensity changes have taken place at more than a mile away from a fast moving fire in heavy fuel.

Once a decision to backfire has been made, there are several important guidelines that should be followed:

1. Backfiring operations should always be directed by an officer who understands fire behavior and knows how to take advantage of favorable topography, fuel, and weather conditions. The officer must know the overall fire strategy and keep constantly informed on

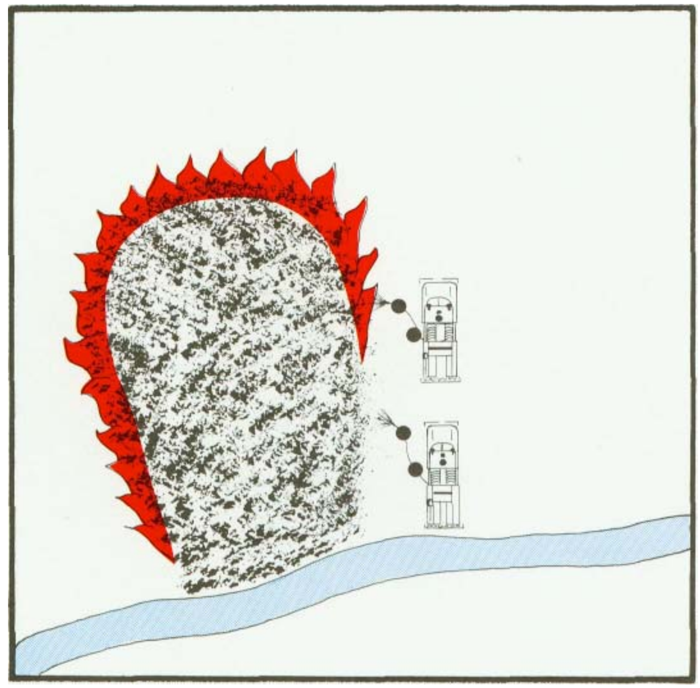
the progress of the main fire. The officer should have considerable experience on other firing operations.

2. When the fire danger is extreme, backfiring is most hazardous and may fail. Suppression action on the flanks may prove to be more effective.
3. A backfire should be started as close as possible to the main fire, balancing the time needed to establish an effective line against the rate of spread of the main fire. Always provide for a margin of time.
4. Once backfiring has started, it is essential that all fuel between the backfire and the main fire be burned.
5. Backfiring should be conducted by a group of highly experienced firefighters under experienced leadership.
6. Sufficient forces should be committed to hold the line created by the backfire.
7. The main fire and the backfire should meet a safe distance from the control line as intense and erratic fire behavior is common as the two fires meet.
8. Weather conditions, both current and predicted, should be noted at all times.
9. Never start more fire than can be controlled by personnel assigned to the holding operation. However, once started, the backfire should gain maximum depth in the shortest amount of time.
10. **Remember, there will always be a calculated risk when backfiring!**

Tandem Action

A tandem action is a form of direct attack arid involves like suppression units working together or in tandem. It is often used on a fast-moving fire and is effective for flank control. A tandem action can rapidly develop into a pincer action once the movement of the suppression forces becomes faster than the spread of the fire and it is determined that the head of the fire can be pinched off.

The key to a tandem action is the combining of suppression units producing more fireline control than the sum of the units working individually. Also, greater control is established and units in a mutual supporting role provide for a greater margin of safety.



81 — Tandem Actioh

Pincer Action

A pincer action may be conducted on any size fire; however, it is most often used on small size fires. The objective of a pincer action is to move along both flanks of the fire and eventually have the flanking forces move closer together finally pinching off the head and encircling the fire.

The forces used in a pincer action may be hand crews, bulldozers, engines, aircraft or a combination thereof.

Flanking Action

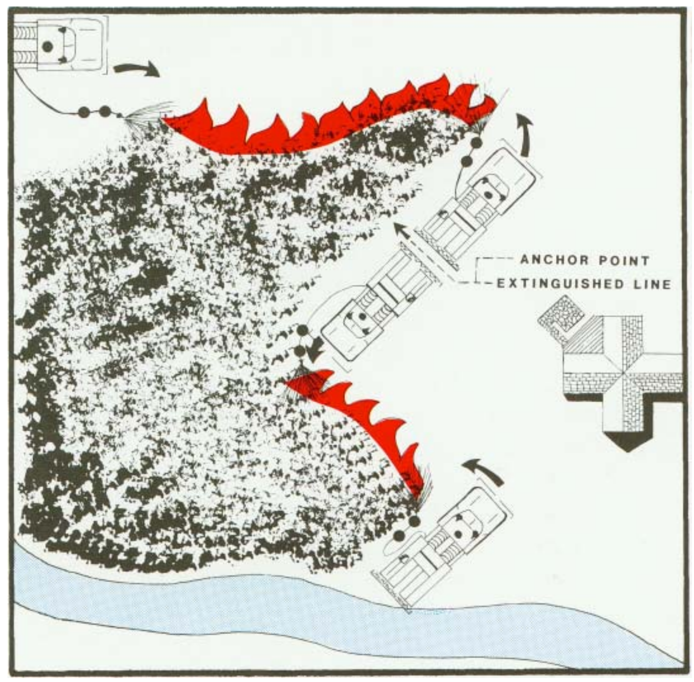
A flanking action can be conducted by any type of ground or air suppression resources. The objective of a flanking action is to prevent the fire from spreading on a given flank and thus threatening some exposure such as heavier fuel, a recreational area, or an area of structural development. Usually, most forces are concentrated on an identified flank

Envelopment Action

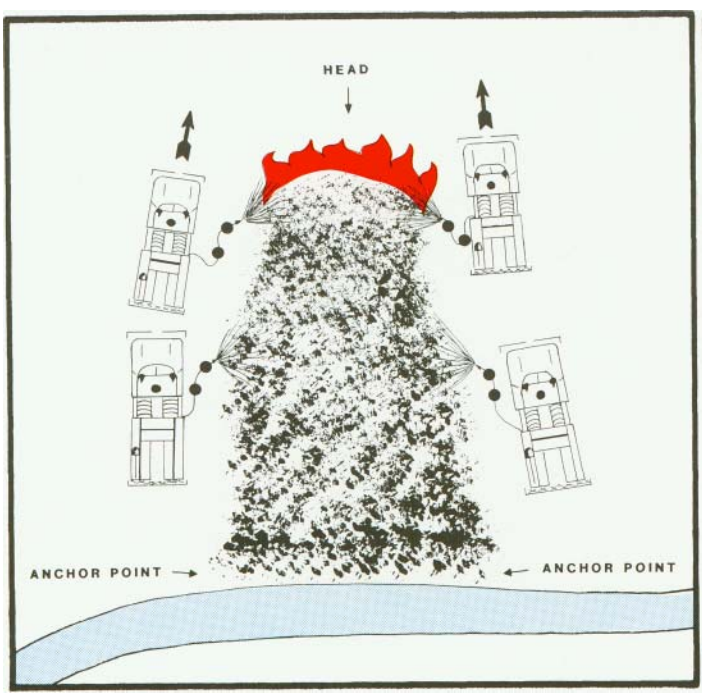
An envelopment action consists of taking suppression action on a fire at many points in many directions, at the same time. It provides for a rapid attack and if coordinated properly, can be highly effective on smaller size fires.

It requires a large amount of suppression to be committed and close command must be established. Units taking part in this type of action should be experienced and aggressive

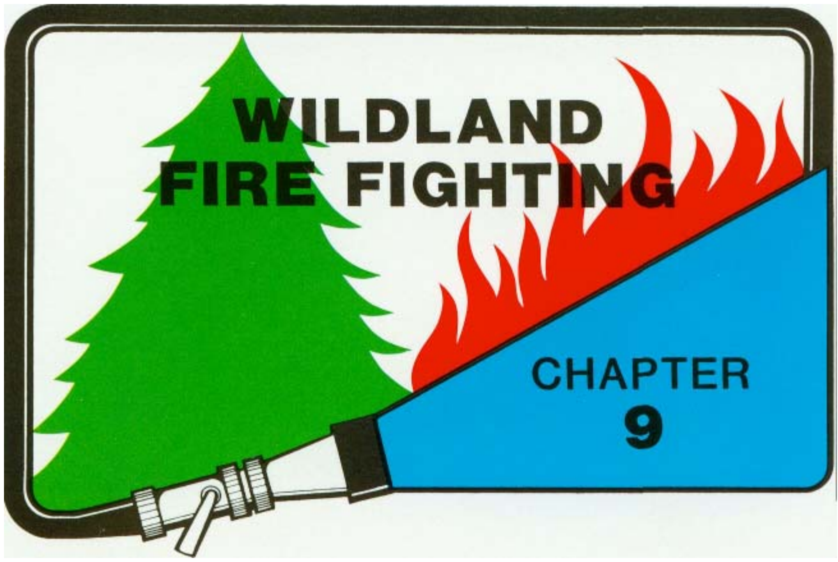
8J — Pincer Action



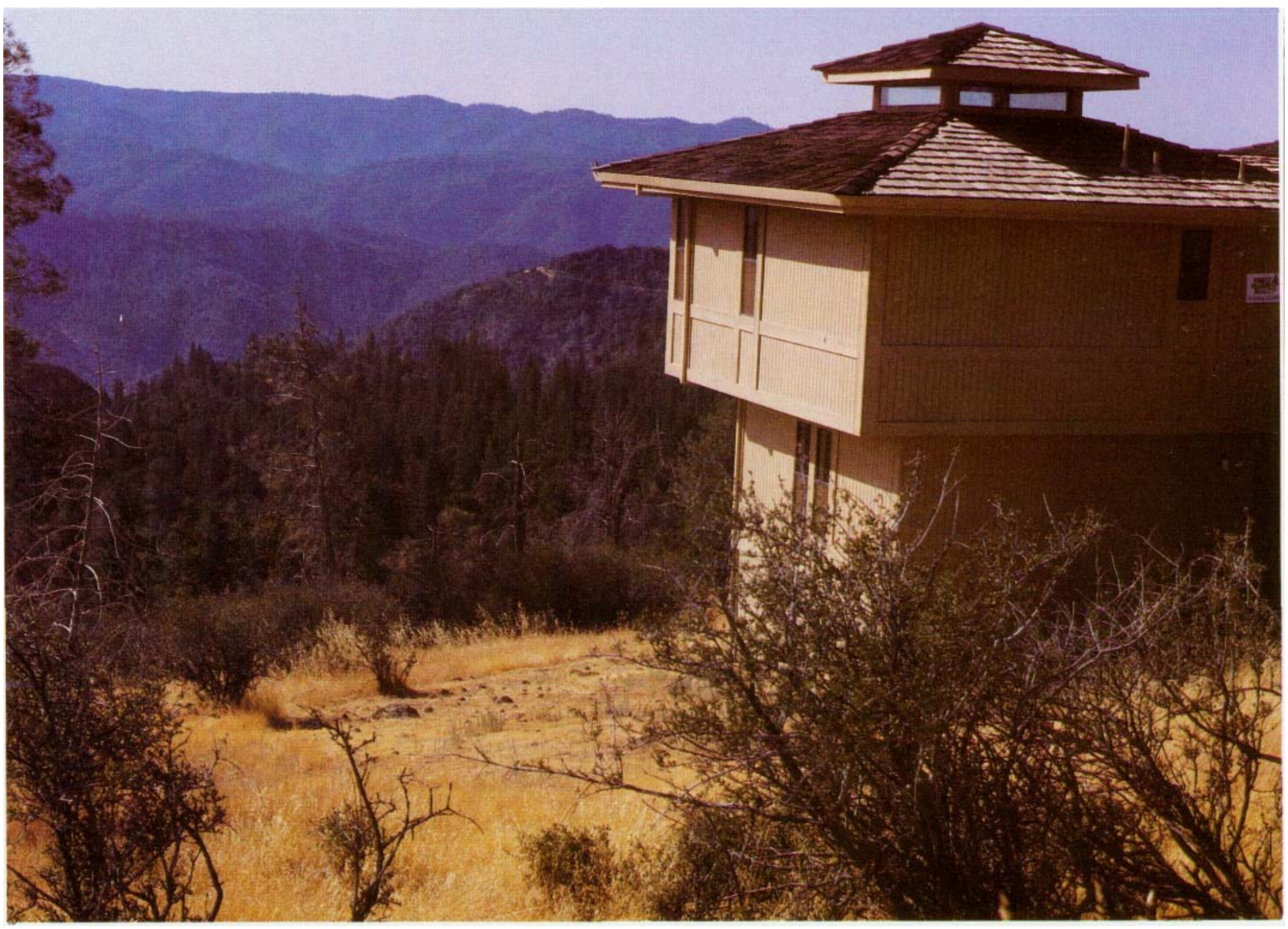
8L — Envelopment Action



8K —^Flanking Action



URBANIZATION OF THE WILDLANDS



In our discussion of wildland fire, we considered three primary influences of distinct importance — fuel, weather, and topography. These influences, are natural influences and they exist at the burning of every wildland fire.
The introduction of human-made fuels has drastically altered the suppression considerations on many of today's wildland fires. Each year, hundreds of homes and other structures in or adjacent to the "natural" fuels of the wildlands have burned, multiplying suppression complexities and driving the dollar loss figures upward.
The Urbanization of the Wildlands is a curious blend of people and nature, with precariously little in the way of protective separation between the two when wildfire strikes. The construction of homes and other structures on grass, brush, or timber covered lands is not a new phenomenon, but rather a rapidly accelerating one.
In itself, the term "wildland urbanization" does not imply either a good or a bad situation. Persons from diversified backgrounds could point to numerous qualities, both good and bad, concerning any particular housing situation. Unfortunately, for those communities unprotected from fire, the bad qualities suddenly come into sharp focus for everyone. Losses in personal property and human life extend to every citizen through the vast network of social and economic relationships.
Before discussing suppression, the how and why of building construction within the wildlands should be discussed.
First, there is a traditional American dream to own "a little place in the country." As the problems and complexities of metropolitan life multiply, many choose to pursue that dream of country living.
Second, nature's landscape is an integral part of the country, and we will go to great lengths to preserve that setting. To that end, homes are literally built within the landscape, often to later become the cornerstone for disaster. The aesthetics of living within that brushy canyon or on top of that forested ridge, are overwhelming goals for many people.
While "flat-land" architects are satisfied to cram homes onto postage stamp sized lots, quite the opposite is true in the country. There is a challenge in using that "unusable" wooded cliff for a home site, to erect a structure worthy of partnership with nature.
Most buildings are of wood frame construction, with several inherent drawbacks in terms of withstanding fire. Untreated wood shake roofing constitutes a major deficiency in this building type. Easily ignited
and fast spreading under windy conditions, fire often exposes the ridgepole and rafters, thus the attic space, in a matter of a few minutes. In addition, the fire is capable of leaping from one rooftop to another, thus spreading through a community and doing so in spite of whatever vegetative fuels might have been available at ground level. During such fires, water supplies, both domestic and fire reserve often are depleted by scores of homeowners attempting to knock down roof fires with garden hoses.
Carried aloft by strong convective currents, burning shakes have been responsible for new fire starts miles from the buildings from which they originated. If sufficient resources are available, there may be an advantage to assigning patrols to watch for spot fires ahead of the fire and generally beneath and beyond the angle of the convection column as it leans with the wind.
Generally speaking, buildings ignite quite easily, given sufficient exposure to fire or radiant heat, regardless of the exterior wall covering material in use. Even the metal siding on mobile homes easily disintegrates, having too little substance to absorb the tremendous heat buildup. Further, metal structures often fail, through collapse, sooner than other types of structures, once the construction members become plastic at about 900 to 1000 degrees.
Eve openings and large expanses of glass door and window openings also can be conductive to fire spread to a building's interior. Buildings with debris such as leaves and pine needles catch fire easily when accumulations of this fuel ignite in rain gutters and on roof tops.
One of the most vital of necessities for firefighters hoping to protect a structure, will be the vegetative clearance available. Even on flat terrain, lack of clearance often will prevent approach by engine companies, which need a safe zone in which to park and operate. The company commander will sometimes be forced to make the decision as to whether or not to protect certain structures when insufficient clearance is available for the safety of the equipment and the crew.
The California Public Resources Code stipulates that certain fire protection measures be taken to protect from wildfire.
Chapter 3. Mountainous, Forest, Brush, and Grass-covered Lands
"4291. **Reduction of Fire Hazards Around Buildings.** Any person that owns, leases, controls, operates, or maintains any building or structure in, upon, or adjoining any mountainous area of forest-covered lands, brush-covered lands, or grass-covered

lands, or any land which is covered with flammable material, shall at all times do all of the following:

(a) Maintain around and adjacent to such building or structure a firebreak made by removing and clearing away, for a distance of not less than 30 feet on each side thereof or to the property line, whichever is nearer, all flammable vegetation or other combustible growth. This subdivision does not apply to single specimens of trees, ornamental shrubbery, or similar plants which are used as ground cover, if they do not form a means of rapidly transmitting fire from the native growth to any building or structure.

(b) Maintain around and adjacent to any such building or structure additional fire protection or firebreak made by removing all brush, flammable vegetation, or combustible growth which is located from 30 feet to 100 feet from such building or structure or to the property line, whichever is nearer, as may be required by the State Forester if he finds that, because of extra hazardous conditions, a firebreak of only 30 feet around such building or structure is not sufficient to provide reasonable fire safety. Grass and other vegetation located more than 30 feet from such building or structure and less than 18 inches in height above the ground may be maintained where necessary to stablize the soil and prevent erosion.

(c) Remove that portion of any tree which extends within 10 feet of the outlet of any chimney **or** stovepipe.

(d) Maintain any tree adjacent to or overhanging any building free of dead or dying wood.

(e) Maintain the roof of any structure free of leaves, needles, or other dead vegetative growth.

(0 Provide and maintain at all times a screen over the outlet of every chimney or stovepipe that is attached to any fireplace, stove, or other device that burns any solid or liquid fuel. The screen shall be constructed of nonflammable material with openings of not more than one-half inch in size.

(g) The State Forester may adopt regulations exempting structures with exteriors constructed entirely of nonflammable materials or conditioned upon the contents and composition of same, he may vary the requirements respecting the removing or clearing away of flammable vegetation or other combustible growth with respect to the area surrounding said structures.

No such exemption or variance shall apply unless and until the occupant thereof, or if there be no occupant, then the owner thereof, files with the State Forester, in such form as the State Forester shall prescribe, a written consent to the inspection of the interior and contents of such structure to ascertain whether the provisions hereof and the regulations adopted hereunder are complied with at all times."

Roof Coverings

In most areas in the United States, roof coverings are classified as to their ability to withstand fire exposure. They are as follows:

Class A covering: Effective against severe fire exposure. Coverings of this class are not readily flammable and do not carry or communicate fire. They afford a fairly high degree of fire protection to the underlying roof deck, do not slip from position, pose no flying-brand hazard, and do not require frequent repairs in order to maintain their fire-resisting ability.

Class B covering: Effective against moderate fire exposure, are not readily flammable when exposed to moderate exposure, and do not readily carry or communicate fire. They afford a moderate degree of fire protection to the roof deck, do not slip from position, possess no flying-brand hazard, but may require infrequent repairs in order to maintain their fire resisting ability.

Class C covering: Effective against light fire exposure. Under light exposure, not readily flammable and do not readily carry or communicate fire. They afford at least a slight degree of protection to

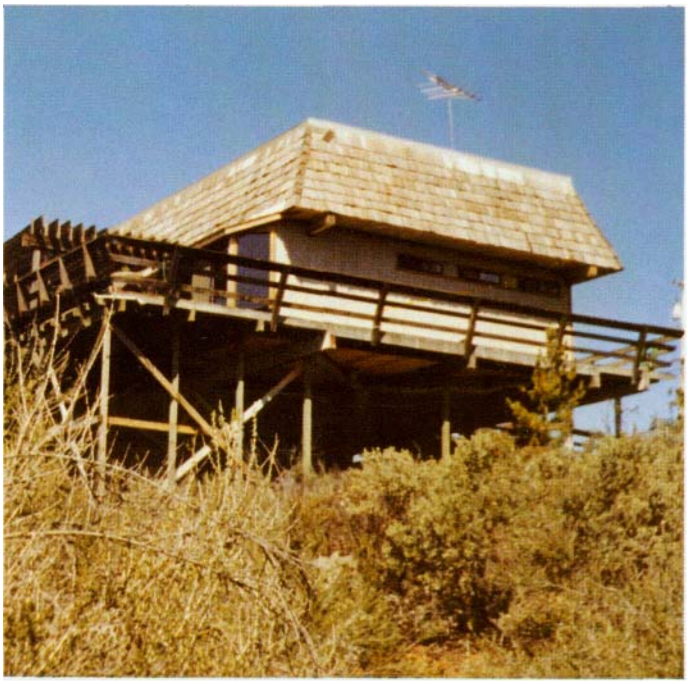
9A — Burning Roof

the roof deck, do not slip from position, possess no flying brand hazard, and may require repairs or renewals in order to maintain their fire resisting properties.

Unrated coverings: Untreated wood shake shingles are ineffective against even light fire exposure. They are readily flammable and easily carry and communicate fire. Afford no degree of protection to the underlying components, such as ridgepole and rafters and stringers. Wood shakes constitute a menace in their ability to become flying fire brands.

Due to the less substantial underroofing of a shake-covered building, fire easily gains access to the structure interior via the attack space. Loss of the roof truss support leads to ceiling collapse and further downward destruction. The use of Class "A" coverings of a cement or other base is an option to wood shakes, and the resistant types can be purchased in shake imitation form.

Stilt construction offers fire a large surface area on which to obtain a hold. Once the fire burns beneath the structure, its upward travel becomes somewhat restricted and longer duration flame impingement takes place. Stilt construction homes need a considerable clearance of flammable vegetation to survive a fire approaching from below.



9B — Stilt Construction

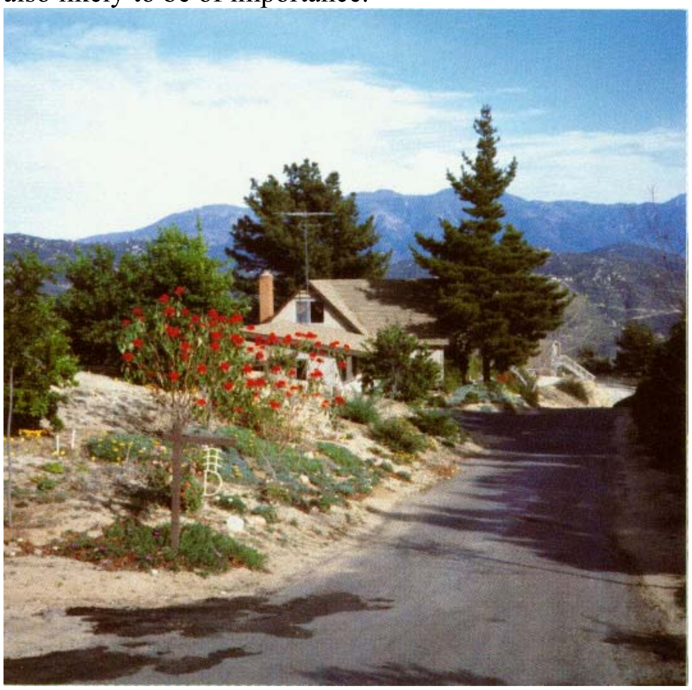
When insufficient vegetative clearance exists around a building that is situated on a slope, the problem of tactic efficiency and safety is compounded even further. The popular use of wooden sun decks often necessitates removal of natural vegetative fuels, but of course, the decks provide no relief from ignition themselves from a wildland fire.

In addition to the positive features of adequate building clearance, some communities provide further protection by means of a firebreak, or firebreak/fuel break combination, or sometimes, by maintenance of a landscaped greenbelt. Such zones help to isolate the community as a whole from the wildland fuels, but should not be relied upon for replacement of the individual building clearances. The reason is, that on very large lot sizes, considerable grass and brushfields may exist within the community interior, and the fire that is able to cross the exterior firebreak or greenbelt will find ample fuel once inside the community itself.

9C — Greenbelt Community

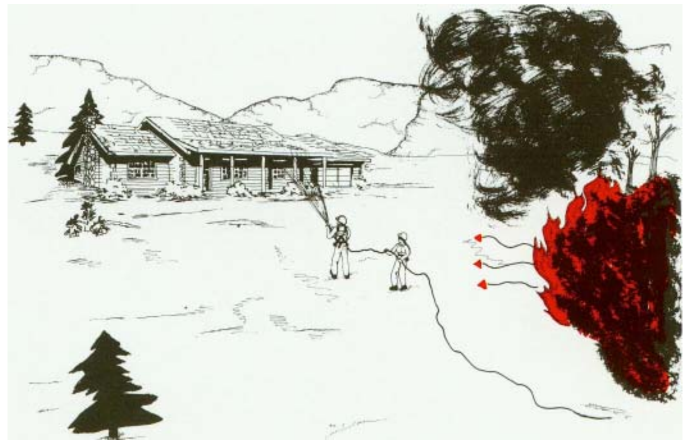
First-in companies who have knowledge of greenbelt equipment access may be able to put these zones to more effective use. Oftentimes, there is but a single access road to the greenbelt, perhaps from an interior cul-de-sac. Sometimes, engine companies have been able to widen the capabilities of the firebreak or greenbelt by firing out between the structures and that area. The use of airdrops along the exterior borders of such subdivisions have proved valuable in the past, although careful watch must be made for power lines and the aircraft so notified. Damage to structures, either temporary or permanent through coating by the retardant, is a district possibility, but is decidedly better than allowing such structures to burn to the ground.

First-in companies should be familiar with the access provisions for both the greenbelt, driveable or not, and the driveable firebreak area. Location of fire hydrants and ability to gain access to individual home backyards are also likely to be of importance.



9D — Ornamental shrubbery surrounding buildings can be protected from ignition by "limbing up" the lower branches. When other flammable vegetation is available at ground level, fire will rise into the canopy of shrubs and trees and then transmit to the structure itself.

Exposure protection can best be accomplished by applying the water directly onto the exposed building. Water curtains sprayed into the open space between the two buildings are not as effective because radiant heat is not well absorbed by that process.



9E — Exposure Protection

Following is a discussion of how the firefighters might contend with a wildfire as it approaches, enters, and attempts to consume the rural community.

Based in part, upon the report of conditions from the first-in crew, an adequate force must be quickly mobilized, and before too much time has elapsed, both wildland and structural considerations will have been assigned adequate attention.

Initially, the demands upon firefighting forces to protect life and personal property are often considerable, to the point that wildland fire control efforts are often delegated to the saving of products of urbanization. The wildland fire often is "guided" through the developed area, but actual efforts to stop the head may suffer due to insufficient forces.

Another chapter focuses upon the requirements for fire engines, both wildland and structural. There are differences in control methods. Some firefighting agencies are trained to handle either type of major fire. Such flexibility permits the Incident Commander to use the forces at his/her disposal on exposures that he or she deems priority. The wildland engine company may be assigned to protect homes in one area, while a municipal type company will be utilized to hold a grass or brush fire along a particular roadway. For an agency this ability is important, for the most efficient use of people and equipment will be during the initial attack stages. First arriving companies that cannot move from a structural situation to a wildland situation, and back again, would seriously hamper control and protection efforts.

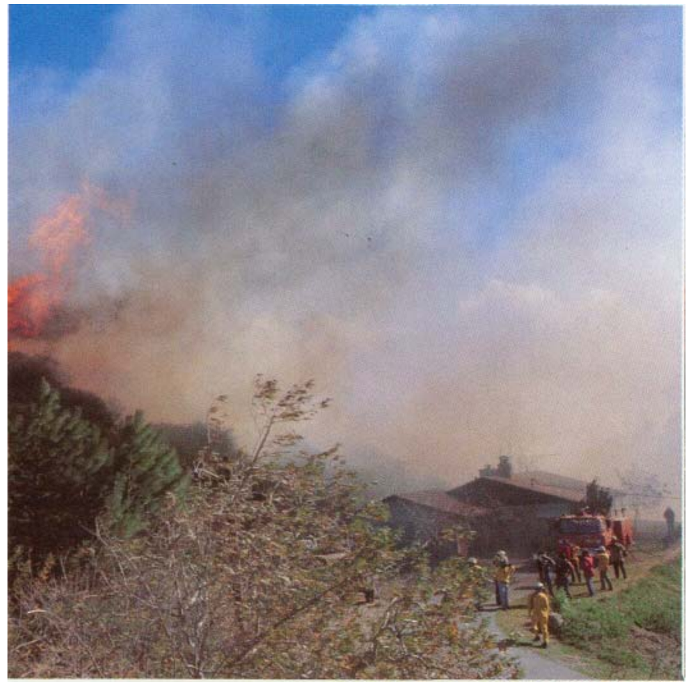
Many agencies, in addition to being "cross-trained," routinely operate both types of fire engines. There are many buildups that incorporate the individual characteristics of both engines — such as a short wheel based engine, that has a rated pump, yet can negotiate truck trails. Often, as the fire moves from an initial attack stage to an extended attack stage, "strike teams" will arrive at the scene. Usually consisting of five engines and an officer, strike teams move together as a unit and can be assigned to many types of tasks. If the strike team is used to protect structures, that assignment may free up engines that are needed to halt the wildland fire itself. Wildland strike teams can be used for any assignment that the Incident Commander wishes. As each task is completed, the strike team moves together to a new assignment. Many times, strike teams are pooled in a "staging area" for a resource in the event they are needed for immediate response. The type of strike team needed must be correctly ordered, i.e., a structural type for structure protection, a wildland type for structural protection, etc. For example, a strike team ordered from a municipal department for structure protection, may inadvertently arrive at the scene with a truck company such as a snorkel buildup, and be useless for protecting smaller, single story homes.

Saving a home from an approaching wildfire may be difficult. If firefighters can safely work in the area, and there is sufficient time, it may be possible to construct a narrow fireline around the structure from which to fire the vegetation between the line and the approaching fire. Although not the most ideal of situations, airtankers sometimes can be used adjacent to homes to help cool down the approaching fire.

With sufficient water supplies, the structure itself can be wet down, and windows and doors shut to prevent entry of sparks and other firebrands.

On any wildland fire, an organization of personnel and equipment must be brought to bear against it. With this in mind, consider the additional complexities of such a fire as it approaches the wildland community. Decisions must be made by that first-in engine crew, decisions and some built-in flexibility. Without decisions, size-up considerations cannot transform into a plan of action, and flexibility as an important tool for change in those plans.

Rarely, in the initial arrival of forces, on a moving fire, will firefighting strength and versatility be able to cope with both wildland and structural exposures **on a**



9F — Structure Protection

simultaneous basis. The protection of life and property may dictate a shift from wildland fire suppression to the protection of these higher values.

Experience has shown that the protection of structures from wildfire is the most demanding situation a firefighter is likely to face.

9G — Fire Advancing Toward Homes From Below

Improvements, such as homes, do not reduce the danger of working within, or above a gully, ravine, or canyon.

Firefighters attempting to protect homes from fire approaching from below may be hard pressed to do so in a safe manner. The rising convection column will preheat the fuels upslope and it is likely that an almost instantaneous flareup will occur.

Firefighters must consider how fuel, weather and topography are likely to affect the fire, and how the dual considerations of wildland and structures will fit into the situation. Fire engines and crew-carrying vehicles are as vulnerable to heat and flame as are persons on foot. Personnel and equipment should never be positioned within, or above chimney-like gullies or ravines. Many firefighters have died in such terrain when superheated air, even lacking flames, overtook them.

For many firefighters, grass fields that surround buildings may not appear menacing. This is a mistake however, because grass constitutes a hazardous flash fuel no matter what its location. Even a two-foot growth of dry grass on a canyon wall below a house is a potential danger.

Special Protection Hazards

In addition to building construction, there are other considerations for the firefighter. For example, nearly every garage contains a flammable pesticide or a can of gasoline, and the fire hydrant in the front yard probably disappeared early in the spring beneath a geranium bush.

In many rural communities, propane tanks of various sizes will be found adjacent to homes. Approach such tanks from the sides, never the ends, and apply water to the vapor (upper) sides of the tank, being careful not to extinguish the flame burning at the relief-valve port. It is normal for a heated tank to expel vapor from a pressure-relief valve. Cherry red spots developing on the metal or a sudden pronounced, shrill noise from the relief valve spells trouble. Everyone must evacuate to a distance of not less than 2000 feet, for a rupture may be eminent.

Newer subdivisions may have all utilities located underground. However, in many areas, power lines are supported on creosote-treated poles which burn and collapse the lines. Utility companies have trained crews to deal with this hazard; remember, the vehicle interior is the safest place to be when there is a threat of falling power lines.

9H — Propane Tank Next to Structure

A crew's ability to successfully guide fire around a structure, or extinguish it, often depends on the amount of vegetation clearance available. Even with clearance, radiant heat may become overwhelming to the crew. Often, under windy conditions, within canyons or on ridge-tops, flame sheets will impinge directly on the structure. High winds may distort hose streams and intense heat can turn even a large fog into ineffective vapor.

Mobility, even when protecting and fighting structure fires, is advisable. Crews need to be available to knock down a flare-up, to aid citizens in reaching safety, or to help another crew pull out a hoseline. To become hopelessly immobile reduces overall effectiveness; it destroys flexibility. That is not to say that a crew should become so diverse that no single task is safely and properly completed. Strategy changes constantly as a fire expands.

When extending hoselines, the vehicle should be at the curb closest to the side that the work is being done. This will prevent damage when other vehicles pass. If a hose must be laid across a street, it should be protected with hose bridges or lengths of 2x4 tied on each side of the hose line.

A fire running through a community is nightmarish. During the daytime, the sun is transformed to an unforgettable red-orange disc, and visibility becomes poor. At night, flame fronts dance along ridges and the skeletons of homes protrude along the skyline, abandoned after a futile fight to save them.

- Wildfire cost taxpayers millions of dollars each year. In the absence of sound community planning, firefighting agencies take up as much slack as they can.
- A publication titled, "Protecting Residences From Wildland Fire, A Guide For Homeowners, Lawmakers, and Planners," discusses problems and solutions to wildland urbanization.
- Excerpts from **Protecting Residences from Wildland Fire**
- 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 plan 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. Also 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 made with a fire-retardant material.
- 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 all yards, gardens, landscaped areas, ^ and fire protection clearances.

•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.

•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 occupants.

•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.

•Design and install patios, sun decks, and balconies in ways that enhance the fire safety of the building.

•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 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 fire.

•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.

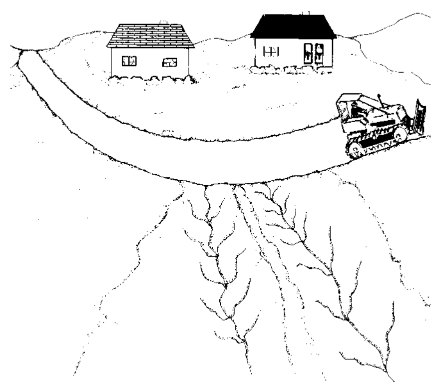
•Treat and continuously manage vegetation fuels on all wildlands that may become fire threats so as to reduce the conflagration hazard and facilitate fire control.

•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 that 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 organizations and associations.

Urbanization of the wildlands means more people using the wildlands, hence a correspondingly higher degree of fire starts. Most of these fires are discovered quickly and are extinguished at a small size although even a small fire can destroy unprotected buildings. The 5 percent or so that become large fires have an ability to damage or destroy even more buildings because of the horizontal extension through populated areas.



91 — When community or individual homes have no fire or fuel break, or greenbelt area, bulldozers can be used. The width of the break on a slope will need to be wider than one on the flats.

WILDLAND FIRE FIGHTING

CHAPTER 10

FUELS MANAGEMENT

This chapter differs from the others in this text because it turns the emphasis from the physical dynamics of wildfire and the equipment and methods used for its control. It deals with the modification and reduction of wildland fuels to facilitate fire control operations. The information contained herein will give the reader an overall basic knowledge of the concepts of fuel management. Fuel management programs quite often are highly complex and require the coordination of many scientific disciplines.

Fuel Break and Fuel Volume Reduction

Fuel management is divided into two general classification areas — the removal or conversion of fuel for the construction of fuel breaks and fuel volume reduction. Fuel breaks are simply what the term implies, a break or a change in the natural vegetation which will impede a fire's progress and allows firefighters to take action from pre-planned fire defense areas. Fuel breaks are quite often confused with firebreaks. A firebreak, as noted earlier, is a control line that is put in during the fire's process to aid in suppression efforts. Its placement is based on the current and predicted behavior of the fire in progress and is cleared to mineral soil.

Fuel reduction is a process where fuel is systematically reduced, usually by the use of prescribed fire, to protect existing vegetation types, to conduct slash and understory burning and to reduce total fuel volume in order to mitigate large fire potential.

Objectives of Fuel Management

The two major generalized objectives of fuel management are fire protection facilitation and ecological management. Fire protection in wildland areas can be greatly enhanced by the construction of fuel breaks. This concept is nothing new and was recommended by the California State Board of Forestry in 1886. The Board recommended that "waste" areas be established to prevent the spread of fire into valuable resources. The Diamond Match Company constructed fuel breaks some 200 to 400 feet wide but considered the visual esthetics and ecology by leaving selected ground vegetation and trees in place.

Fuel breaks are designed to prevent or impede the spread of fire into a predesignated area, such as a high-value watershed or areas with homes. They are also designed to prevent fires from escaping high-fire risk locations such as camping areas, major roadways, railroads and dumps. Because fire is a natural part of most ecological systems, a fire will generally happen in any given area “sooner or later." In order to aid the wildland firefighter in this inevitable chain of events, fuel 4 reduction is conducted, mainly by the use of prescribed fire in which preplanned areas of grass, brush, and timber are broken up into smaller units. The objective of reducing fuel volume, and thus reducing major fire potential, is a very important part of overall wildland fire protection.

While the objective of this text is to aid the wildland firefighter in the management and suppression of fire, ecology is an important consideration in all firefighting operations, and especially in fuel management. These considerations involve wildlife habitat, water yield, soil erosion, vegetation changes, and a ^ myriad of complex interrelationships between the fl forces of man and nature. Before any fuel manage-ment program is started, thorough studies should be conducted to minimize damage to the environment.

Pre-Suppression Planning

The planning of a fuel break system and areas to be burned to reduce fuel volume is an essential part of wildland pre-suppression planning. The fuel management portion of any pre-suppression plan must be based on sound fire control strategy and realistic ecological considerations. Simply constructing a fuel break because the terrain is favorable or doing prescription burning because the land owner is willing, causes the development of a disjointed and economically wasteful program that adds relatively little to the overall pre-suppression efforts.

The fire control strategy needs must be based on sound and attainable objectives. An example of such might be to prevent fire from reaching a specific mountain cabin area or reducing the fuel age to 20 years for a major drainage area.

Once the goals and necessary strategies have been developed, a fuel management plan can be started.

The plan should consider the fire protection problem ^ and then cover the best method to mitigate the « problem. The plan should consider fire history, existing man-made breaks such as freeways and major roads, bodies of water such as reservoirs, lakes, streams, and rivers. Man-made changes in vegetation such as property development and agriculture use can also be used in planning. Once all existing favorable changes or breaks in fuel have been identified, then the firefighter can plan when to construct fuel breaks and conduct prescribed burning to meet the goals of the overall plan.

Fuel break construction and fuel volume reduction by prescribed burning are the two most important parts 4 of wildland fuel management. These two wildland fuel management facets must be interrelated. For example, a fuel break system designed to aid in fire suppression can also serve well when used as an establishing line for prescribed burning. The planned and systematic burning of areas contiguous to fuel breaks can reduce fuel, increase water yield, improve game habitat, and greatly increase the functional ability of a fuel break to aid in the suppression of wildfires.

The reduction of fuel in the wildlands has been widely promoted as a feasible way to reduce the conflagration potential of high fire hazard areas. This reduction of fuel and construction of fuel breaks when planned and conducted in harmony can greatly aid in the effectiveness of air and ground suppression efforts.

Fuel Removal

Actual methods of fuel reduction and removal will be discussed before the actual construction of fuel breaks is explained.

10A — Hand Reduction Methods

Normally the hand reduction method is conducted by organized hand crews made up of either inmates or seasonal firefighters. Hand operations are conducted with the normal array of hand and hand held power tools used in wildland fire control operations. Hand clearing has several advantages. First, it can be conducted in very rough topography that would be inaccessible to motorized equipment. Also, it causes a minimum amount of disturbance to the site of the fuel break. Most importantly, it does not remove the uppermost layer of duff and soil which occurs when a bulldozer is used. Hand crews are also effective in pruning trees and selectively leaving certain types of vegetation in the fuel break construction area.

Hand methods are also preferred adjacent to structural areas, rather than using disruptive track-laying vehicles. Hand crews also can selectively pile cut fuel in locations that will provide for safe burning at a later date.

Major disadvantages to removing fuel by hand methods involve the high labor cost, the large number of people needed, and the relatively slow progress. Hand clearing is rarely used when large acreages are to be type converted or cleared because of these drawbacks.

The cost and personnel requirements for large clearing operations can be readily appreciated when on an average it requires: 15-person days per acre for light brush, 25-person days for medium brush, and 35-person days for heavy brush.

Hand clearing methods are most favorably used on fuel breaks that are rocky and traverse steep topography. This method should also be considered for areas that are ecologically or politically sensitive.

Machine methods involve a variety of vehicles, usually track-laying, and a variety of implements that are attached to the vehicles. Machine methods, although expensive, are considerably less expensive than the previously mentioned hand-cleaning methods. Mechanical methods are relatively fast but do cause severe problems.

Mechanical removal of fuel can cause deep soil disturbance and leave unsightly scars. There are many old fire areas that show little residual damage from the original fire but clearly show the outline of dozer lines that were used in the fire's control. Also, mechanical equipment cannot be used on steep terrain or on rocky topography.

The bulldozer, the most often used piece of mechanical equipment, can be fitted with a variety of implements for fuel clearing. The dozer blade, the most utilized attachment, is effective in many direct fuel removal operations. Dozers can be fitted with brush rakes — large steel teeth that replace the dozer blade — to uproot vegetation. Heavy disks pulled by a dozer are highly effective on level or rolling type terrain. They work well on light to medium height fuels such as buckwheat and chamise because the fuel is left broken and partially buried. The disk is useful in maintaining existing fuel breaks because it minimizes soil disturbance and will crush new vegetative growth rapidly. In specific areas where all fuel must be removed, the disk can mulch under annual grasses and causes a minimal amount of soil disturbance.

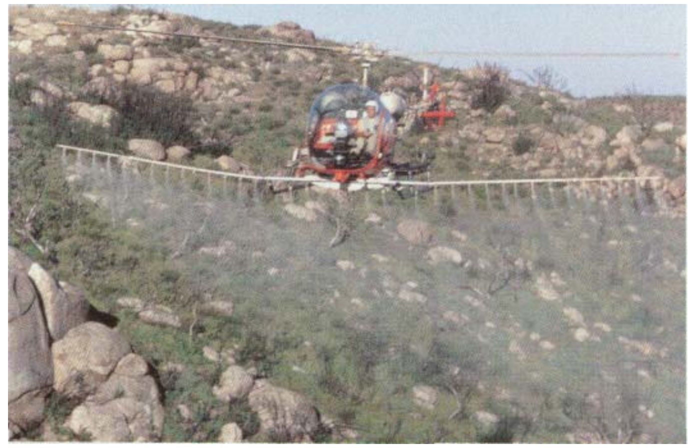
10B — Bulldozer using a ball and chain

The use of a heavy anchor chain with two bulldozers working in tandem can crush large amounts of fuel in relatively short time periods. The fuel then dries out and is burned during a safe weather period.

There are many other mechanical methods being tested. These involve machines that grind and chew up fuel, much like the cutters that tree trimmers use and various drags.

Chemicals in the form of herbicides, desiccants, defoliants, and sterilants have been used for years to kill both large tracks of vegetation and reduce or eliminate growth on existing fuel breaks. Chemicals may be applied by aircraft, tank and hand sprayers, and in solid pellet form.

Because of the problems and ecological sensitivities involved in chemical vegetation reduction and removal, careful studies should be conducted before they are used.



10C — Helicopter with a spray boom.

Fuel Volume Reduction

The process of fuel volume reduction is generally accomplished by the use of controlled fire. The fire is started under a set of specific guidelines and therefore is called prescribed fire or prescription burning. The object of prescribed burning is to reduce the fuel volume, and in doing so reduce the fire potential in a defined area. Prescribed burning may also improve livestock and wildlife access to forage, water yield, tree growth, and do away with unwanted plant species.

Extreme care must taken with prescribed fire. Miscalculations on the time of year to burn or the present weather conditions when burning can cause a destructive fire that yields little ecologically and could allow a faster burning species to replace the existing vegetation. Also, there is always a possibility of a fire escape, with resulting damage and civil liability problems.

Prescribed fire, when properly used, can be a great benefit to the wildland firefighter by lessening control problems on wildfires and providing areas that are only slightly susceptible to large fires for several years.

Reducing the age of chaparral fuel reduces its ability to carry fire in two ways. First, the live fuel is so greatly reduced in volume that it may take several

10

D — Helitorch on a prescribed fire

Fuel Loadings per Acre

	Age (Years)	Total Load (Tons)	Dead Fuel % of Total
Grass	1	3	100
Mixed Brush	10	15	10
	20	24	16
	30	30	23
	40	35	35
	50	38	52
Chamise	10	11	10
	20	19	16
	30	24	23
	40	29	35
	50	32	52

10E — Fuel Loadings Per Acre

years to sustain fire of any consequence. And second, the dead fuel that provides for high heat production, rapid fire spread, and spotting is usually totally removed by prescribed fire. The following chart notes age, total loading of both live and dead fuel, and the percent of the total that is dead.

Depending on the percent of dead fuel in the stand, the following general guidelines are used to set the prescription for the prescribed fire:

Fuel Moisture - 6 to 15 percent Relative
Humidity - 25 to 35 percent Wind - 4 to 10
MPH

The percent of the fuel to be removed by fire can be generally regulated by the prescription parameters. A "clean" burn may be highly undesirable for certain plant and animal species and a dirty or unclean burn **may** not accomplish the established fire control and ecological objectives.

While fire intensity is directly proportional to the amount of burnable fuel, it is possible to conduct a **low** intensity fire in heavy fuel if the burn is carried out when only a portion of the fuel is ready to burn or weather conditions are not critical.

Fuel reduction should be started before all fuel is fully dried out. Sometimes canyons and north facing slopes may have too high a fuel moisture to burn on a given day, thus allowing for a desired mosaic effect. If it is necessary to burn deep canyons and north slopes they can be fired when control lines are secured and conditions are more favorable for a higher intensity fire. Previous burning in the adjacent lighter fuel will also reduce the chances of fire escape.

The following factors should be considered when planning and conducting a prescribed fire:

1. Fuel moisture.

Fuel moisture, as noted in a previous chapter, is dependent on previous seasonal weather and current humidity conditions. The fuel moisture will vary considerably depending on slope, height, and aspect. Drier slopes and exposed ridges should be burned when conditions will allow a fire to go out in heavier or moister fuels. Such burning also reduces the amount and size of control line required.

2. Wind.

The forward rate of the fire's spread, with other variables remaining constant, will square as the wind speed doubles. Current and predicted wind speed should be monitored before, during, and after the burn.

3. Fuel.

The quantity, size, arrangement, and ratio of living to dead fuel is important in determining the severity of the prescription to be followed and the percent of fuel that is to be removed.

4. Slope.

As the slope doubles, the rate of spread will quadruple. The firing pattern for the prescribed fire can be set to take advantage of the topography and can be adjusted to accomplish the desired amount of fuel removal. A lower intensity fire can be set a short distance from a ridge with additional strip fires set down slope if a cleaner burn is desired. The fire can be set considerably downslope or at the bottom of the slope to allow for a hotter uphill run.

5. Atmospheric stability.

Stable and unstable air condition will have a marked influence on a prescribed fire. Inversion layers, thermal belts, thunderhead activity, and diurnal flows must be considered prior to initiating any prescribed fire.

Once all prescription considerations have been identified, the fire manager should seriously consider local fire history, local fire behavior, and predicted weather conditions.

WILDLAND FIRE FIGHTING

CHAPTER 11

ORGANIZATION

Generally speaking, the problems involved in controlling a wildland fire become larger and more complex as the fire increases in size or as the rate of spread increases. Fires burning in, or adjacent to structures of all types pose even greater challenge to any particular firefighting force. The essential characteristics of a good organization, especially a firefighting organization, are clear lines of authority, consistent responsibility, and unity of effort. If all organizations were primarily successful, there would be considerably less written about them in terms of the lack of proper levels of authority, responsibility, and effort. As fires become larger and more complex, the organization's weak spots become more prevalent. During multi-jurisdictional fire operations, "organizations" must become singular in nature to assure unity of effort.

Given the fact that there are individual firefighting agencies for many communities, as well as Federal and State entities, the need to develop a higher degree of "similarities" becomes pronounced. For example, there are several variations of radio code in use. And, because terminology differs sufficiently between some agencies, problems have, and continue to arise. The potential for lack of coordination can occur with some frequency as larger fires burn in two or more jurisdictions, or threaten to do so.

In California, and other parts of the nation, an effort is being made to increase the effectiveness of both single agency efforts and multi-jurisdictional incidences through the **Incident Command System.** The ICS system provides a common plan which fire protection agencies can utilize at the local. State or Federal levels. ICS is designed to be used for all kinds of emergencies, and is applicable to both small day-to-day situations as well as large and complex incidents. The following are basic system design operating requirements for the Incident Command System.

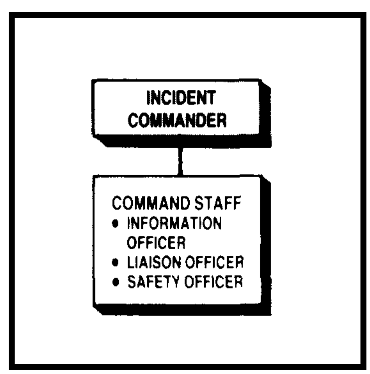
1. The system must provide for the following kinds of operation:
   (a) single jurisdiction/single agency,
   (b) single jurisdiction with multi-agency involvement,
   (c) multi-jurisdiction/multi-agency involvement.
2. The system's organizational structure must be able to adapt to any emergency or incident to which fire protection agencies would be expected to respond.
3. The system must be applicable and acceptable to users throughout the country.
4. The system should be readily adaptable to new technology.
5. The system must be able to expand in a logical manner from an initial attack situation into a major incident.
6. The system must have basic common elements in organization, terminology, and procedures which allow for the maximum application and use of already developed qualifications and standards and ensure continuation of a total mobility concept.
7. Implementation of the system should have the least possible disruption to existing systems.
8. The system must be effective in fulfilling all of the above requirements and yet be simple enough to ensure low operational maintenance costs.

Modular Organization

The structure develops in a modular fashion based on the kind and size of an incident. The organization's staff builds from the top down with responsibility and performance placed initially with the Incident Commander (Fire Boss). As the need exists four separate sections can be developed, each with several units which may be established. The specific organization structure established for any given incident will be based on the management needs of the incident. If one individual, such as a Fire Captain on an engine, can simultaneously manage all major functional areas, no further organization is required. If one or more of the areas requires independent management, an individual is named to be responsible for that area.

The Command Staff:

In the Incident Command System, a command staff may be initiated. The command staff consists of:



11A — Command Staff

Incident Commander — The Incident Commander is responsible for incident activities including the development and implementation of strategic decisions and for approving the ordering and releasing of personnel or equipment.

Information Officer — The Information Officer, a member of the Command Staff, is responsible for the formulation and release of information about the incident to the news media and other appropriate agencies and organizations.

Liaison Officer — The Liaison Officer of the jurisdictional agency, a member of the Command Staff, is responsible for interacting, by providing a point of contact, with the assisting and cooperating agencies. This includes other fire suppression agencies. Red Cross, law enforcement, and public works and engineering organizations.

Safety Officer — The Safety Officer, a member of the Command Staff, is responsible for monitoring and assessing hazardous and unsafe situations and developing measures for assuring personnel safety. The Safety Officer will correct unsafe acts or conditions through the regular line of authority, although the Officer may exercise emergency authority to stop or prevent unsafe acts when immediate action is required. The Officer maintains awareness of active and developing situations, approves the Medical Plan, and includes safety messages in each Incident Action Plan.

For the purpose of acquainting the reader with command, in its simplest form, envision a fire prevention patrolman who detects a smoke, arrives at the scene, and extinguishes the fire with a backpump. The patrolman, acting as the Incident Commander, was able to simultaneously manage all the functional areas and no further organizational development was required. He or she handled the command function, and was also able to handle the control of the fire.

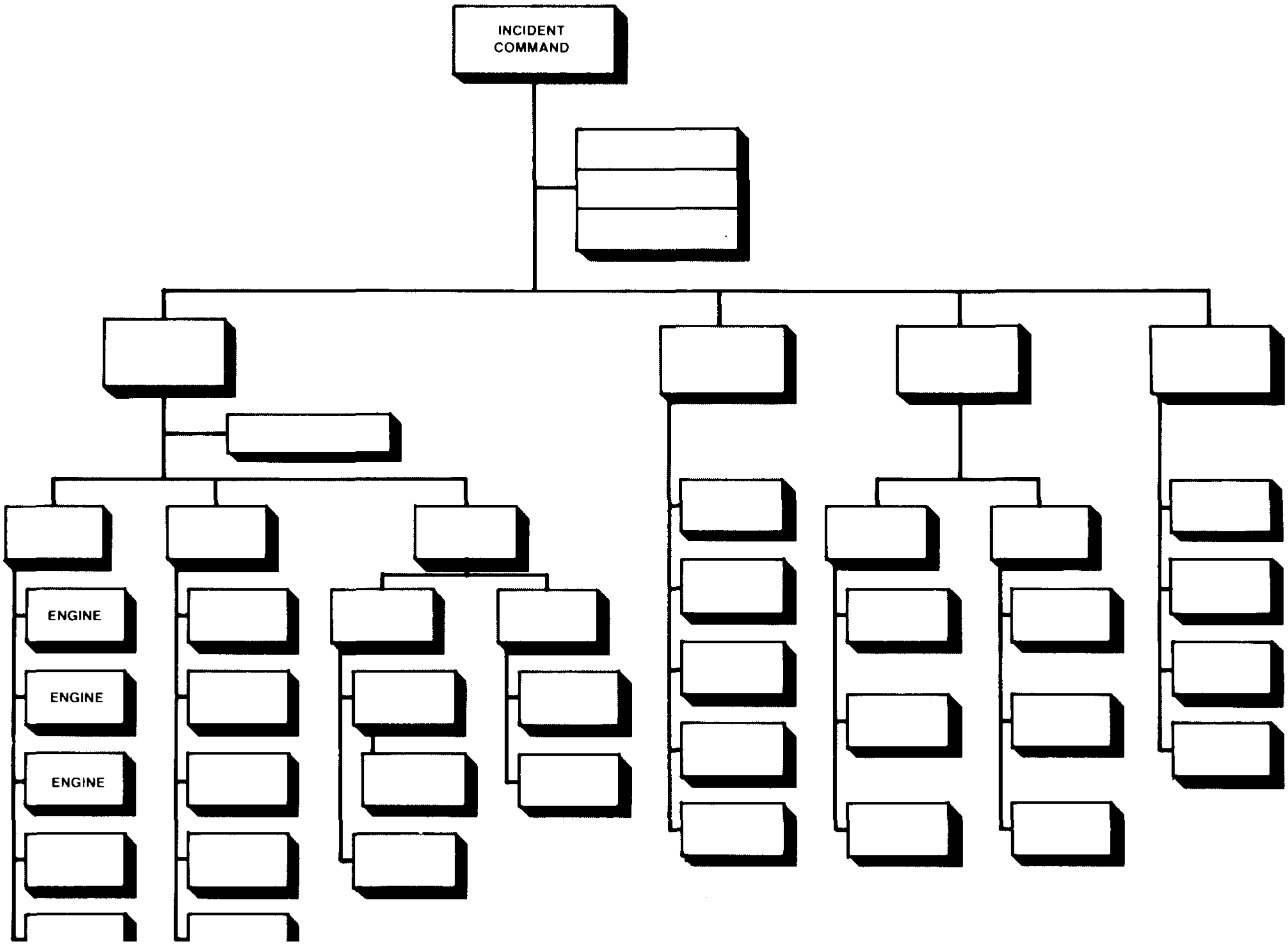
Going one step further, let's describe the first-in of several engine companies on a grass fire or small brush fire. Arriving at the scene, the Captain or Engineer responsible for the engine assumes the role of Incident Commander, (and he or she will retain that role until formally relieved by a higher level of authority). Upon arrival of the other engines, the Incident Commander will direct activities, possibly coordinate information about exposures ahead of the fire with an air contact, perhaps order a bulldozer, and address the other fire needs. Thus, the initial attack resources are being managed by the Initial Attack Incident Commander, who will perform all command and general staff functions. The incident is not complex enough to warrant expanding the organization to include a separate person as Safety Officer. In addition, There are functions that are not necessary, such as the expansion to a logistics section to monitor the number and type of ground units or to provide feeding facilities for the firefighters. On a small incident, the Initial Attack Incident Commander is still able to manage the ground units he or she requires. And, at this stage, no plans are yet under way to establish a food preparation facility.

Of course, if the fire gains in size or complexity, the Initial Attack Incident Commander will begin the process of addressing the organization of need to cope with the situation. Probably, the Initial Attack Incident Commander will ultimately be grouped with other fire engines and the task of incident command will be passed to another person who will manage the organizational needs of the more complex situation, and the new person now becomes responsible for the overall situation. Thus, the organization builds from the top down. The Initial Attack Incident Commander is moved downward in the organization as he or she is replaced at the top end or "command" end of the organization. And, there is lateral expansion, because the new Incident Commander, having formally relieved the Initial Attack Incident Commander of that duty, may now find a need to order additional resources to help the first-in group which can no longer cope with the expanding fire perimeter.

By using organizational charts, the ICS system develops from an initial attack organization and progresses to extended attack. The Initial Attack Incident Commander is designated as 2389 on the charts. This person, having been relieved of his incident command position because of the fire's increasing complexity, is subsequently shown on 11B as a single resource. That is, the engine is being used as a single, separate company. This, in comparison with the five engines shown on 11C which are assigned as members of a strike team. This is just one hypothetical assignment possibility.

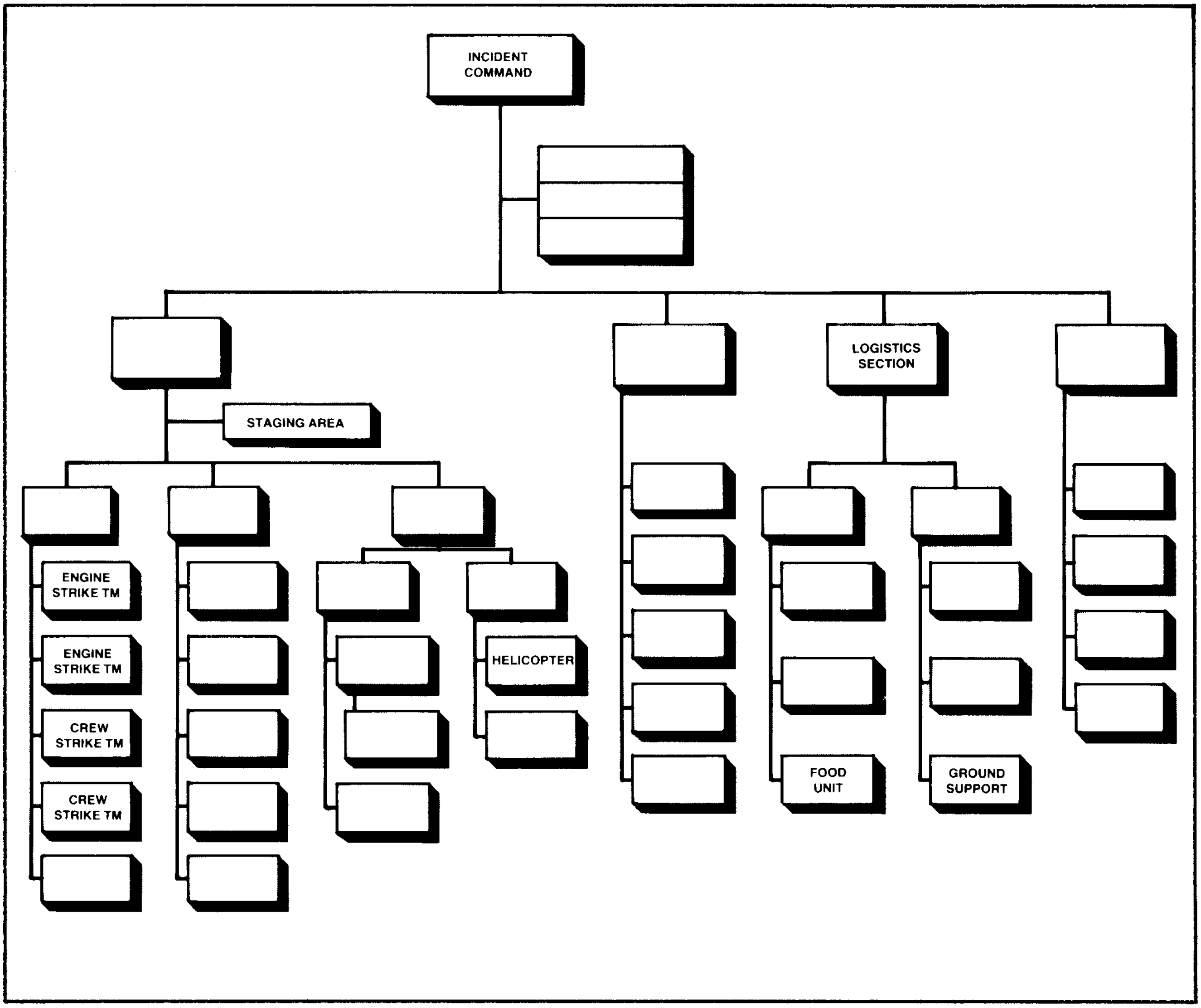
Strike teams are discussed elsewhere in the chapter.

Example #1 — Initial Attack Organization
Initial attack (first alarm) resources are managed by the Initial Attack Incident Commander who will perform all Command and General Staff functions.



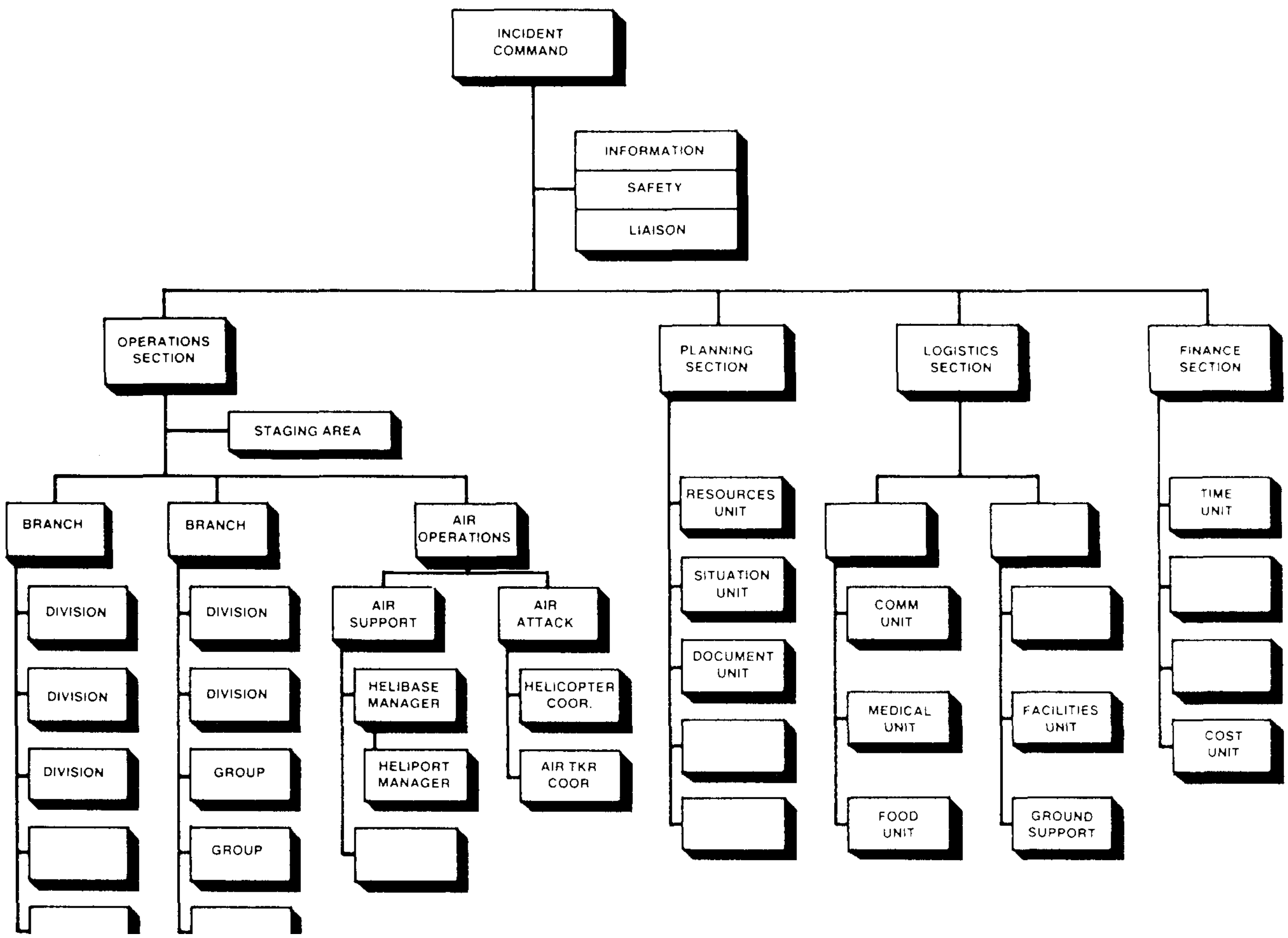
11B — Initial Attack Organization

Example #2 — Extended Attack Organization
In the extended (multiple alarm) attack situation the new Incident Commander manages all resources. The 1C has now designated a Staging Area, a Logistics Section Chief, and two Units within the Section.



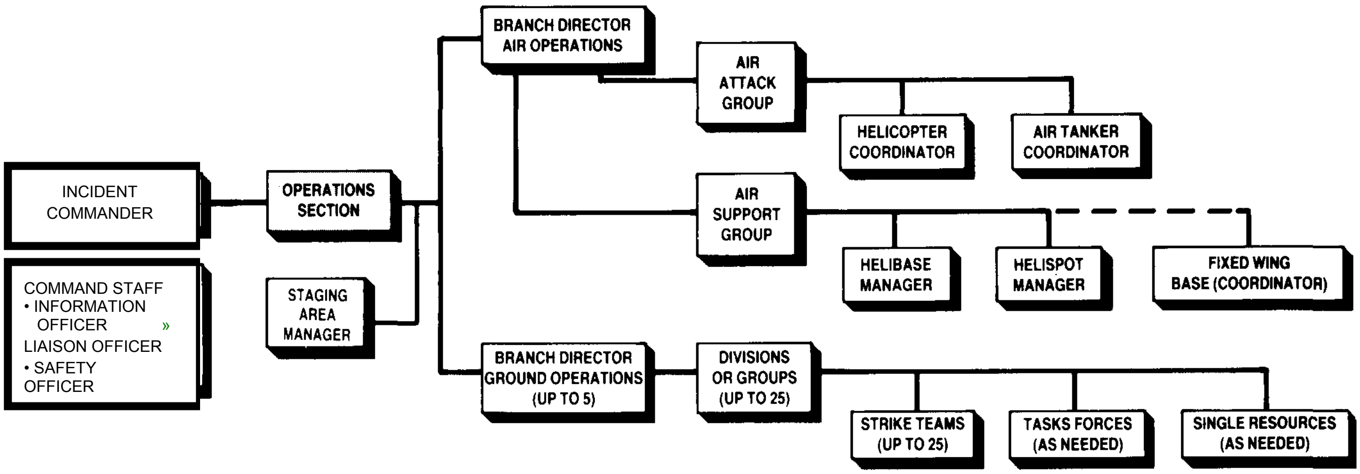
11C — Extended Attack Organization

Now, the fire organization has expanded to meet the needs of a major fire situation. 11D contains many positions that will not be discussed here. As the reader moves forward to the section concerning the operations section, and then, right on through the remainder of the ICS organization, be reminded that ICS has been adopted for use in many areas of the United States, and by all indications will expand over even greater areas in time to come. ICS is one approach to fire organization; one which strives to address the complexities of multi-jurisdictional as well as single jurisdiction incidents of all types.



11D — Major Fire Organization

The following sections contain some of the position duty statements and pertinent organizational charts.



11E — Operations Section

Operations Section Chief —

The Operations Section Chief, a member of the General Staff, is responsible for the management of all operations directly applicable to the primary mission — that of field operations. The Chief activates and supervises suppression and rescue organization elements in accordance with the Incident Action Plan and directs its execution. The Operations Chief also directs the formulation and execution of subordinate unit operational plans, requests or releases resources, makes expedient alterations to the Incident Action Plan as necessary and reports such to the Incident Commander.

Staging Area —

Staging areas are established for temporary location of available resources. Staging areas will be established by the Operations Chief to locate resources not immediately assigned.

Branch Director —

The Branch Director, when activated, is under the direction of the Operations Chief, and is responsible for the implementation of the Incident Action Plan within the Branch. This includes the direction and execution of Branch planning for the assignment of resources within the Branch.

Division Supervisor —

The Division Supervisor reports to the Operations Section Chief (or Branch Director when activated) and is the top level of tactical line supervision. The Supervisor is responsible for the implementation of the assigned portion of the Incident Action Plan, assignment of resources within the Division, and reporting on the progress of control operations and status of resources within the Division.

Strike Team Leader —

The Strike Team Leader reports to a Division Supervisor and is responsible for performing tactical assignments assigned to the strike team. The Leader reports work progress, resources status, and other important information to a Division Supervisor, and maintains work records on assigned personnel. There are three primary types of strike teams — engine, handcrew and dozer.

Task Force Leader —

Task Forces are a combination of resources put together for an assignment of a temporary nature. The task force leader, usually in a separate vehicle, and with common communications between all resource elements, commands a very versatile unit, once the need no longer exists, the leader and his or her resources are disbanded, to be released or reassigned perhaps as single resources.

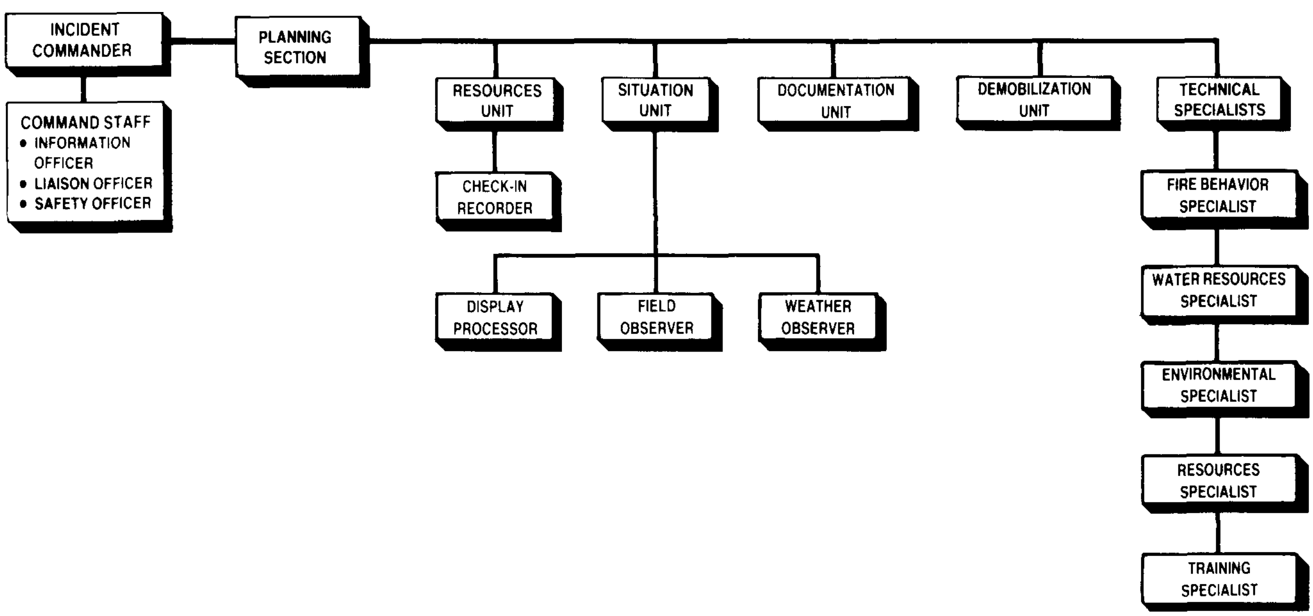
Air Operations —
Air operations, which is ground-based and is established by the Operations Chief, is primarily responsible for preparing the air operations of the Incident Action Plan. The plan will reflect agency restrictions that have an impact on the operational capability or utilization of resources (e.g. night flying, hours per pilot). After the plan is approved, the Air Operations Director is responsible for implementing its strategic aspects — those that relate to the overall incident strategy as opposed to those that pertain to tactical operations (specific target selection). Additionally, Air Operations is responsible for providing logistical support to helicopters operating on the incident and maintaining liaison with fixed-wing air bases.

Air Attack Supervisor —
The Air Attack Supervisor is primarily responsible for the coordination of aircraft operations when fixed and/or rotary-wing aircraft are operating on an incident. The air attack Supervisor reports to the Air Operations Director.

Air Support Supervisor —
The Air Support Supervisor reports to the Air Operations Director, and concerns him/herself with the Helibases, Helispots, and fixed-wing bases. The Air Support group is responsible for all time keeping for helicopters assigned to the incident. The Air Attack Supervisor position is established as a separate position whenever both helicopters and fixed-wing craft will simultaneously operate within the incident air space.

Helicopter Coordinator —
The Helicopter Coordinator is primarily responsible for coordinating tactical or logistical helicopter missions at the incident. The Coordinator can be airborne or on the ground operating from a high vantage point. The Coordinator reports to the Air Attack Supervisor. There may be more than one Helicopter Coordinator assigned to an incident and activation of either is contingent upon the complexity of the incident and the number of helicopters assigned.

Air Tanker Coordinator — The Air Tanker Coordinator is primarily responsible for coordinating assigned air tanker operations at the incident. The Coordinator, who is always airborne, reports to the Air Attack Manager. Activation of this position is contingent upon the need or upon complexity of the incident. There may be more than one Air Tanker Coordinator assigned to an incident.



11F — Planning Section

Planning Section Chief —
The Planning Section Chief, a member of the Incident Commander's General Staff, is responsible for the collection, evaluation, dissemination, and use of information about the development of the incident and status of resources. Information is needed to 1) understand the current situation, 2) predict probable course of incident events, and 3) prepare alternative strategies and control operations for the incident.

Situation Status Unit —
The Situation Status Unit, a member of the Planning Section, is responsible for the collection and organization of incident status and situation information and the evaluation, analysis, and display of that information for use by ICS personnel and the Operations Coordination Center (OCC).

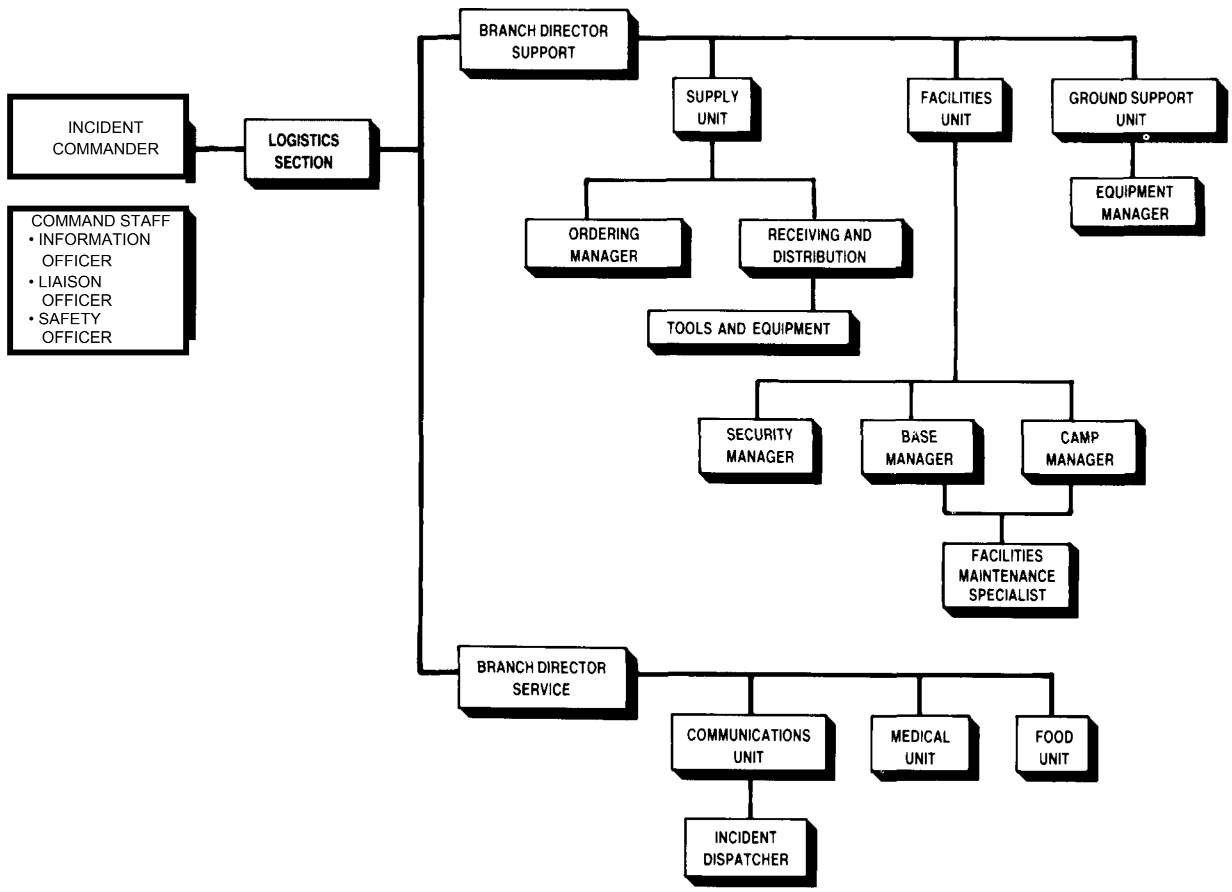
Resource Status Unit —
The Resource Status Unit is primarily responsible for:
1) the preparation and processing of resource status change information, and 2) the preparation and maintenance of displays, charts, and lists which reflect the current status and location of suppression resources, transportation and support vehicles and personnel, and 3) maintain file of check-in lists of resources assigned to an incident.

Documentation Unit —
The Documentation Unit, a member of the Planning Section, is responsible for: 1) maintaining accurate and complete incident files, 2) providing duplication services to incident personnel, and 3) packing and storing incident files for legal, analytical, and historical purposes.

Demobilization Unit —
The Demobilization Unit is responsible for developing an Incident Demobilization Plan. The plan should include specific demobilization instructions for all overhead and resources which require demobilization. (Note that many city and county agencies do not require specific demobilization because they are local.)
The Demobilization Unit must also ensure that the Plan, once approved, is distributed both at the incident and to necessary off-incident locations. It is appropriate for Demobilization Planning to begin early in the incident, particularly in developing rosters of personnel and resources and to obtain any missing information from the incident check-in process.

Technical Specialists —
The ICS is designed to function in a wide variety of incidents. Within the Planning Section is the capability, in addition to the four designated Units, to have Technical Specialists which may be called upon depending upon the needs of the incident.
Technical Specialists assigned to the Planning Section may report directly to the Planning Section Chief;
may function in an existing Unit (e.g., a fire behavior specialist and meteorologist could be made a part of the Situation Unit); or may form a separate Unit within the Planning Section depending upon the requirements of the incident and the needs of the Planning Section Chief. It is also possible that Technical Specialists could be reassigned to other parts of the organization (e.g., to Operations on tactical matters or Finance on fiscal matters).
Generally, if the expertise is needed for only a short time and will normally be only one person, that person should be assigned to the Situation Unit. If the expertise will be required on a long-range basis and may require several persons, it may be advisable to establish a separate Unit in the Planning Section. For example, if an extensive amount of fire behavior planning will be required for several days, Technical Specialists consisting of fire behavior specialists and a meteorologist may combine to form a Fire Behavior Unit.
The incident itself will primarily dictate the needs for Technical Specialists. Listed below are examples of the kinds of specialists which may be required:

- Fire Behavior Specialist
- Meteorologist
- Environmental Impact Specialist
- Resource Use and Cost Specialist
  (e.g., crews, plows, bulldozers, etc.)
- Flood Control Specialist
- Water Use Specialist
- Toxic Substance Specialist
- Fuels and Flammables Specialist
- Nuclear Radiation Fallout Specialist
- Structural Engineer
- Training Specialist



11G — Logistics Section

Logistics Section Chief —
The Logistics Section Chief, a member of the General Staff, is responsible for providing facilities, services, and material in support of the incident. The Section Chief participates in development and implementation of the Incident Action Plan and activates the Units and Branches within the Logistics Section.

Support Branch Director —
The Support Branch Director, under direction of the Logistics Section Chief, is responsible for development and implementation of logistics plans in support of the Incident Action Plan. The Support Branch Director supervises the operations of the Ground Support Unit, the Facilities Unit, and the Supply Unit.

Ground Support Unit —
The Ground Support Unit, under the direction of the Support Branch Director, is primarily responsible for:

1. The maintenance and repair of primary tactical equipment vehicles and mobile ground support equipment.
2. Time reporting on all incident-assigned ground equipment.
3. Fueling of all mobile equipment.
4. Providing of transportation services in support of incident operations (except air).
5. Implementing the Incident Traffic Plan.

This unit also maintains a transportation pool on major incidents and provides the Resources Unit with up-to-date information on the transportation vehicles.

Facilities Unit —
The Facilities Unit is responsible for establishing, setting up, maintaining, and demobilizing all facilities used in support of incident operations. The Unit is also responsible for providing any facility maintenance required and for providing security services at the incident.
The Facilities Unit will set up the incident command post, the incident base, and camps as well as trailers and/or other forms of shelters for use in and around the incident area. The Unit also sets up the feeding, sleeping, and sanitation/shower areas.

Supply Unit —
The Supply Unit is responsible for ordering, receiving, storing, and processing of all incident-related resources, personnel, and supplies.
The Unit has basic responsibility at the incident for all off-incident ordering. This will include:

1. All tactical and support resources (including personnel).
2. All expendable and non-expendable supplies required for incident support.

Where required, the Supply Unit is responsible for handling tool operations, including storing, disbursement, and servicing of all tools.

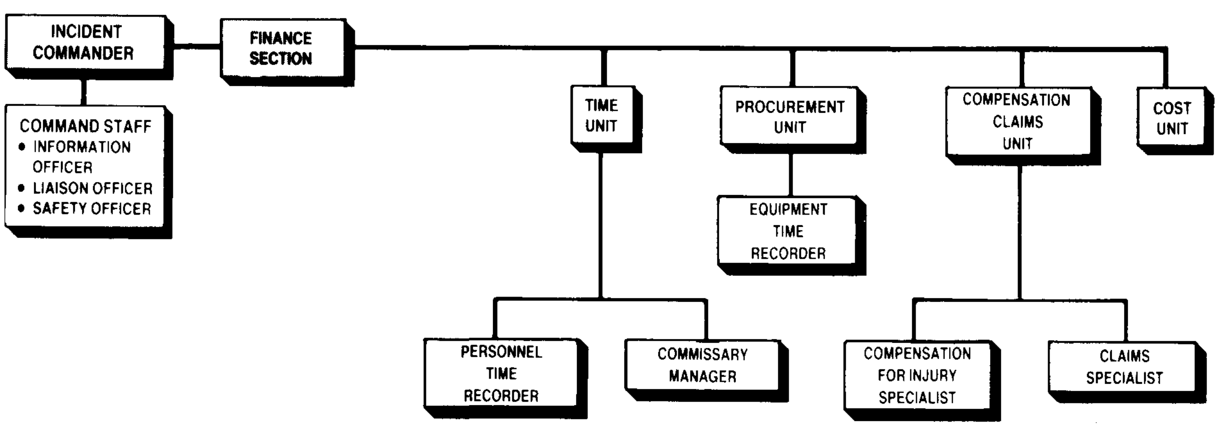
Service Branch Director —
The Service Branch, when activated, is under the supervision of the Logistics Section Chief and is responsible for communications, medical, and food units.

Communications Unit —
The Communications Unit is responsible for the developing of plans to make the most effective use of communications equipment and facilities. The Unit has a major responsibility for effective communications planning, because of potential multi-agency use of the ICS.

Medical Unit —
The Medical Units are responsible for:

1. Developing the Incident Medical Plan.
2. Developing procedures for handling any major medical emergency involving personnel.
3. Providing medical aid and transportation for injured and ill personnel.
4. Assisting in the processing of related paperwork.

Food Unit —
The Food Unit is responsible for determining food and water requirements, menu planning, food ordering, and general maintenance of the food service areas. The Unit will be responsible for supplying the food needs for the entire incident, including all remote locations.



11-H Finance Section

Finance Section Chief —

The Finance Section Chief will determine, based on present and future requirements, the need for establishing specific Units. In certain of the functional areas (e.g., Procurement), a functional Unit need not be established if only one person would work in the Unit. In that case, a Procurement Officer would be assigned rather than designating a Unit.

The Finance Section Chief should be designated from the jurisdiction/agency which has the requirement, because of the specialized nature of the Finance functions.

Time Unit —

The Time Unit is primarily responsible for ensuring that daily personnel time recording documents are prepared and compliance to agency(s) time policy is being met. The Time Unit is responsible for ensuring that equipment time reporting is accomplished in the Logistics Section-Ground Support Unit for ground equipment, and in the Operations Section-Air Support Unit for helicopters.

If applicable, (depending upon the agencies involved) personnel time records will be collected and processed for each operational period. The Time Unit Leader may desire to have one or more assistants who are familiar with respective agency(s) time recording policies. Records must be verified, checked for accuracy, and posted according to existing policy. Excess hours worked must also be determined and separate logs maintained.

Procurement Unit —

The Procurement Unit is responsible for administering all financial matters pertaining to vendor contracts. The Procurement Unit will coordinate with local jurisdictions on sources for equipment, prepare and sign equipment rental agreements, and process all administrative paperwork associated with equipment rental and supply contracts.

Note that in some agencies, certain procurement activities will be accomplished as a function of the Supply Unit in the Logistics Section. The Procurement Unit will also work closely with local cost authorities.

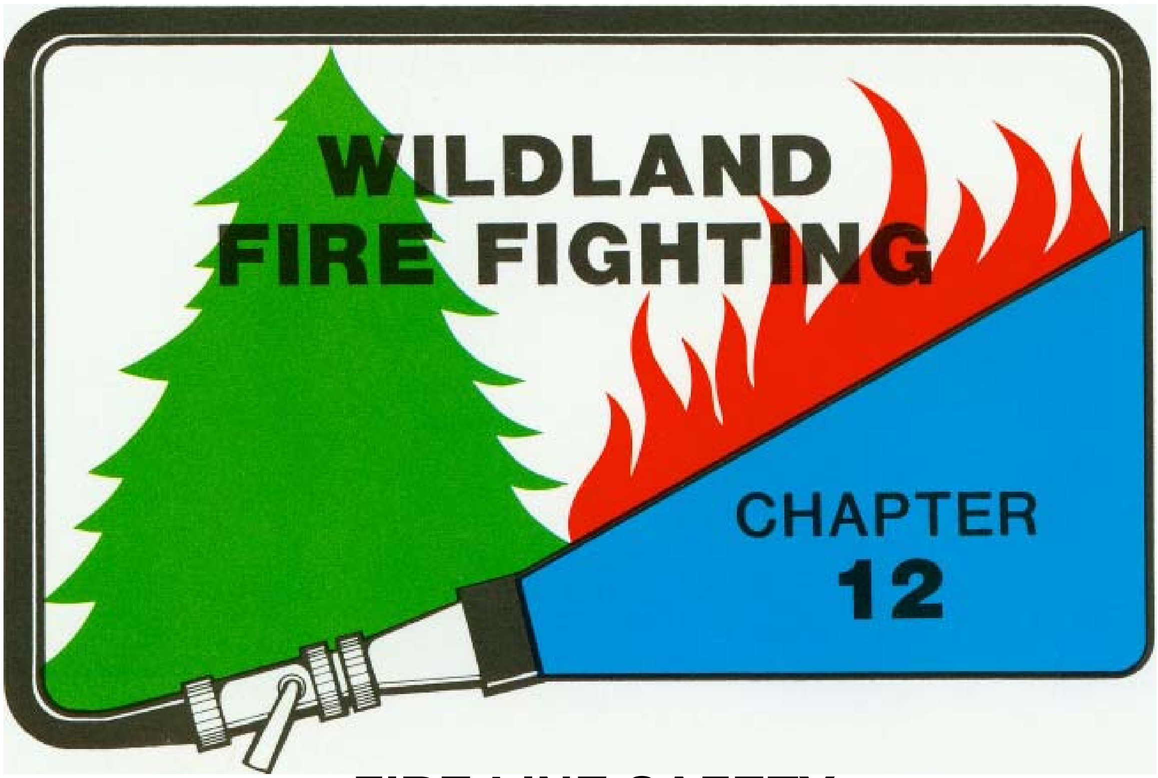
Compensation/Claims Unit —

In the ICS, Compensation-for-Injury and Claims are included together within one Unit. It is recognized that specific activities are different, and may not always be accomplished by the same person. Compensation-for-Injury is responsible to see that all forms required by workers' compensation programs and local agencies are completed. The person performing this activity is also responsible to maintain a file of injuries and illnesses associated with the incident and to ensure that all witness statements are obtained in writing. Many of this Unit's responsibilities are done or partially done in the Medical Unit, and close coordination with that Unit is essential.

The Claims function will be responsible for handling the investigation into all civil tort claims involving property associated with or involved in the incident. The Unit will maintain logs on claims, obtain witness statements, document investigations and agency follow-up requirements.

Cost Unit —

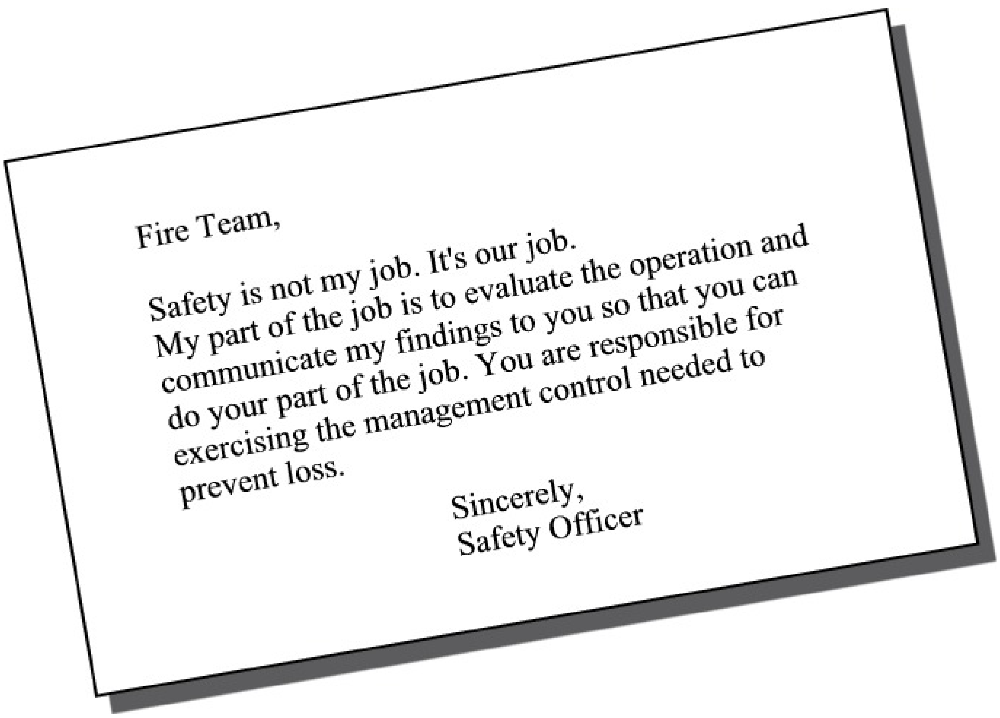
The Cost Unit is responsible for providing cost analysis data for the incident. The Unit must ensure that all pieces of equipment and personnel that require payment are properly identified; obtain and record all cost data; analyze and prepare estimates of incident costs; and maintain accurate records of incident costs. The Unit must maintain accurate information on the actual cost for the use of all assigned resources.



FIRE LINE SAFETY

"Fight fire aggressively, but make safety your first consideration." While firefighting is recognized to be among the more dangerous of occupations, a concerted effort by each person on every fire can reduce the likelihood of injury or death. From past experiences, most of the contributing factors that can harm firefighters are rather well known and documented. Information is readily available from a variety of sources for the firefighter who would take a moment to read them. For example, during initial training sessions, recruits are given the advice to "keep one foot in the burn," to stay a minimum of ten feet apart when walking as a group on a fire, and to wear safety goggles when working in the vicinity of a helicopter landing area.

The Weather Service provides information regarding winds that can cause spotting, or cumulus buildups that may affect fire direction. Previous firefighting experiences show how to avoid many hazardous situations; the more experiences, the more complete the knowledge. More experienced employees can be useful in relating their own findings to the newer employees. There are hundreds, if not thousands of situations that might cause injury to firefighters. This chapter will review the "Thirteen Situations That Shout Watch Out" and the "Ten Standard Firefighting Orders" to follow when assigned to a wildland fire. Many of the large fire control agencies routinely provide a Safety Officer to oversee the entire fire operation from a safety standpoint.



Fire Team,

Safety is not my job. It's our job.
My part of the job is to evaluate the operation and communicate my findings to you so that you can do your part of the job. You are responsible for exercising the management control needed to prevent loss.

Sincerely,
Safety Officer

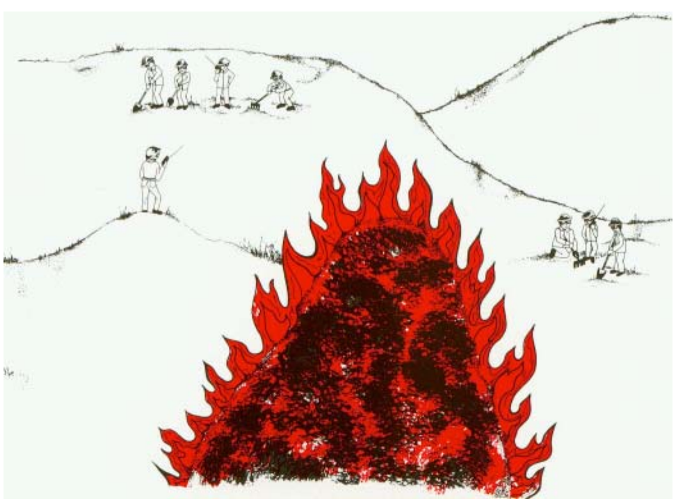
The 13 Situations That Shout "Watch Out!'

Situation:
You are building a line downhill toward a fire.

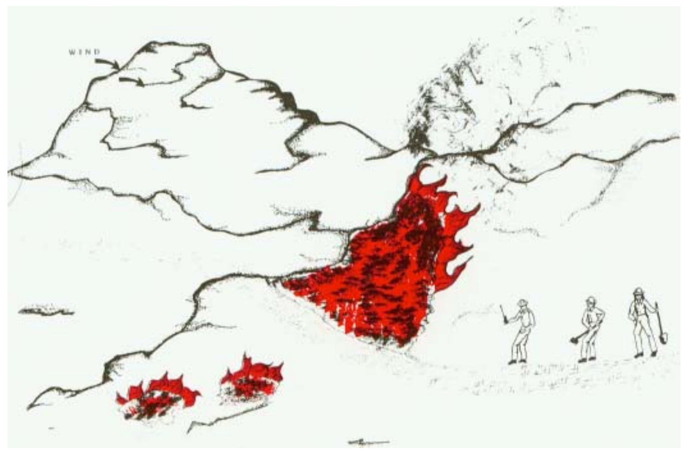
Fire normally burns faster uphill than it will downhill. Approaching from the uphill side of the fire places firefighters who may be constructing line or extending hose in a very precarious position. A person cannot outrun a fire uphill. Additionally, convected hot air will be rising through the areas above, making it difficult to breath or see. A crew working on a slope has poorer footing, no matter which direction the fireline goes. Definite escape routes must be established and each firefighter must be advised of the location of such routes. The crew must remain together and a lookout should be posted to assist in monitoring the fire situation.

The rising hot air currents previously mentioned will be forcing the fuels to give up fuel moisture and the more they give up, the closer they come to their ignition temperatures. Firebrands are likely to start spot fires; firefighters may suddenly find themselves between the fires, or within a cluster of fires. This situation may preclude use of the originally planned escape routes. The advancing flame front itself, lying parallel to the ground as it does most often on slopes, will extend quickly into new fuels. The advance may be so rapid as to easily cross hose lays, constructed hand lines or dozer.lines, as well as retardant treated areas. On steeper slopes, fire will likely drive upward in a wedge-shaped burn, but will often seek natural chutes or chimneys. More than one fire head can develop, and as the fire burns into different elevations or onto new slope exposures, it can be driven in new directions and at different rates of spread by the influence of wind.

A lookout should be posted to keep both crews advised as to what the main fire is doing and to watch for spots. Both crews should be in communication with each other.

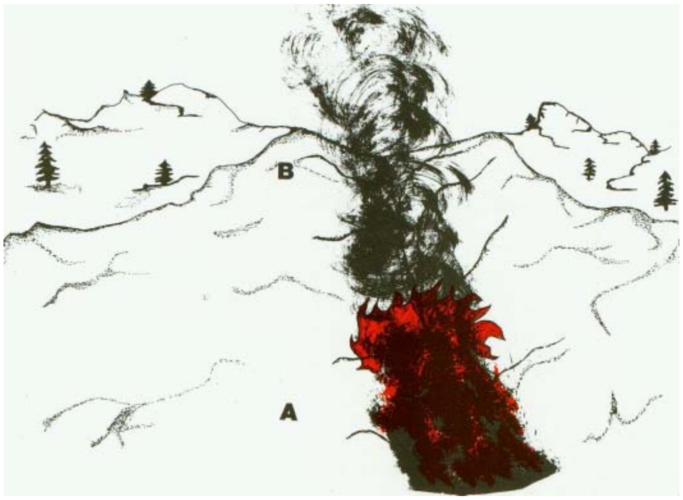


12A — Post a Lookout



12B — Watch out for spot fires

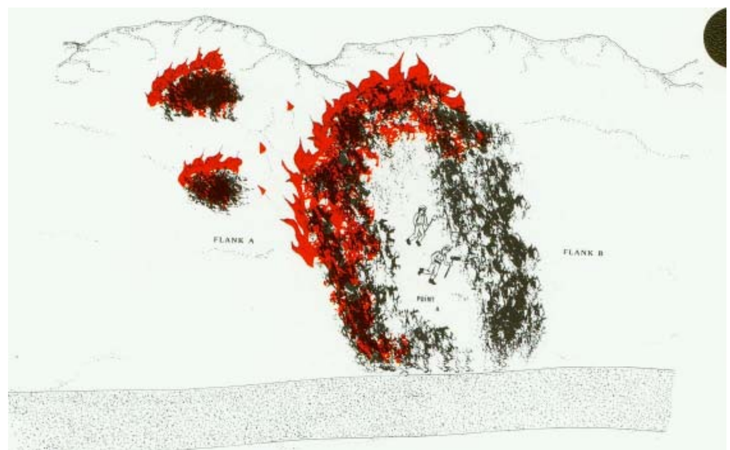
Although a handcrew approaching the main fire from below is taking the safest route, the existence or possibility of spot fires below the access route has to be seriously considered.



12C — Avoid downhill attack

In this situation, the fire is at the bottom of a ravine or chimney. The safest approach will be from point **A,** which will bring the crew in from a flank. In contrast, approach from point B will expose the crew to superheated air or direct flame in the event fire moves up the chimney. Approaching a fire from the uphill side is always dangerous; approaching it via a chimney has meant death for many firefighters.
Each of these possibilities can drastically affect the strategy-situation. As a fire burns uphill, it carries with it the effects of flame, smoke, heat, spread, speed, and the possibility of entrapment for the firefighter. Knowledge of who is working above and below, what their assignment is, and what type of equipment they have, can be of benefit. All ground attack increments are at a disadvantage, given the hazards of being uphill from a fire. Even bulldozers, which the reader might envision as being relatively impervious to fire because of their mass, are slow moving and susceptible to being overrun. In addition, bulldozers are driven by firefighters who have the same limitations as any other person on the fireline. Bulldozers when needed can construct safety islands, and these can serve as refuge for any persons near enough to use them. Sometimes, however, safety islands are impossible to construct, such as often occurs in very rocky terrain. Of course, time must be available to select the appropriate island location and additional time to construct it. Good communications within a crew and between crews will be important on all fires, and particularly so when working downhill toward one. Bulldozer swampers must also be kept informed because their assignment often places them in areas of poor overall visibility.

As a final emphasis, firefighters can and have suffered fatalities from just the superheated air alone that sweeps upslope from a fire below. This is especially so when fires are burning at the bottom of, or within a chute, or chimney, such as a natural gully or canyon. The fire itself may be hundreds of yards away, yet the rising convected heat can sear the lungs of any firefighter who may be in the path. Working downhill toward a fire is hazardous enough; it should never be accomplished via a vertical chute or chimney. Whenever possible, fire should be approached from beneath, or from the flanks.



12D — Firefighters should not attempt to outrun a fire upslope. Convected heat, smoke and flame will be moving uphill.

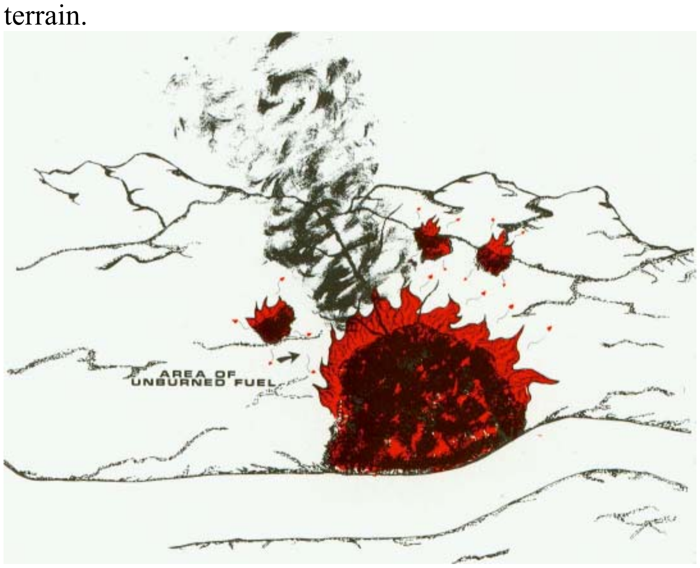
At any given time, either flank may become too hot or fast burning to work. This condition may arise suddenly, forcing choice of an escape route. The safest area generally will be inside the burn at point "A". However, if that route is not possible, firefighters should move toward the flank. Escape routes must be considered before the problem arises.
Flank "B" would be the least menacing because of the lesser flame activity on that side.

Situation:
You cannot see the main fire and not in communication with anyone who can.

The title of this situation contains two areas of danger — inability to see what is going on and a lack of communications.

Firefighters who cannot see the fire lack the ability to do something about the fire and to do it in a safe manner. Coupled with an inability to communicate spells potential trouble.

To gain access to the fireline, personnel and equipment will often be crossing expanses of unburned fuel via truck trails, improved roads, or even cross country. Access may be by vehicle or on foot. The dynamics of a moving wildfire demand the utmost attention of personnel who are attempting to approach it; lack of visibility will call for accurate assessments gleaned from earlier briefings, plus knowledge of local weather, fuel, and topography. Ground forces are relatively immobile in some situations, such as when on foot, or when in vehicles crossing rough or steep terrain.



12E — The green area lying between the main fire and spot fires can be susceptible to area ignition. The effect of radiant heat emanating from each fire, plus the possible pooling of flammable gases in low lying areas, can cause a sudden combustion of the green area.

Many fuels, such as the explosive chamise, are difficult if not impossible to penetrate because of the thicket characteristics of the plants. Remember, in most situations, the safest spot on a fire is right on the fire's edge. Access to the burn is handy, and personnel can keep track of fire progress. Once on the line, personnel should not venture into the green or otherwise lose the advantage of good fireline visibility and relative mobility of the fireline and burn. When spot fires outside the line require movement through the green, visibility also may become impaired. A separate "Watch Out" situation regarding spot fires will be found later in this chapter. Scouting may provide a vantage point to help the crew develop its own lookout and necessary communication. Supervisors must establish escape routes and make them known to others. The use of topographical maps may provide important information such as natural barriers, shafts, and the destination of jeep trails which transverse the area. In some instances, aircraft can assist in monitoring progress of the main fire and thus inform ground personnel.

Situation:
You are working in an area where the local factors influencing fire behavior are unfamiliar.

Fuel, weather, and slope or topography are important factors on every fire. To accomplish the task of effectively fighting a wildfire, an optimum situation would exist if each firefighter were familiar with the specific weather, fuel, and topography factors present at the burning of every fire. Unfortunately, many small fires and most large fires draw personnel from areas some distance from the fire scene; they have not previously spent enough time in the fire scene area to become familiar with the factors, indeed, some may never have been in that area before. Knowledge of local factors probably means a knowledge of all three factors, because they are each influenced to some degree by the others. For example, knowledge of local weather conditions must also be a knowledge of topography; how else would one explain the effect of an upcanyon wind as it passes through a saddle? Further, the spread of fire through that saddle will be effected by the fuels within it, and the fuels even beyond.

The notorious Santa Ana or Santana winds of southern California have widespread publicity, yet firefighters from northern California who have not fought fire in the south, may find burning conditions quite alien to them, even after reading numerous articles about the phenonmenon. Given a certain exposure to such foehn wind conditions, however, a firefighter begins to piece together the behavior of fires, as fire weather and topography play out their roles.

It stands to reason then, that when a fire is burning **in a** particular area, that people with first-hand information about that area should be utilized in the development of strategy for that fire. This is not always possible, however, for these people must be working the firelines for their knowledge to be taken advantage of. Such a person is valuable because of the familiarity with roads, natural barriers, types of fuel, including improvements, and wind characteristics.

Firefighters who are not familiar with the local factors, and who are not in communication with anyone who is familiar, must take steps to minimize this disadvantage. The posting of lookouts will serve to alert crews to existing and predicted fire behavior. Staying together as a crew, united under a specific plan of action, will assure that everyone knows what is to be done and what to do if the situation necessitates change. The supervisor who attended the briefing session back in base/camp and who paid attention to what was said there will be a more effective leader on the fireline. Radio communications can be an advantage only if each person knows whom to talk with and on what frequency.

Situation:

You have been given an assignment but the instructions are not clear.

To do an effective job of firefighting, individuals and teams of individuals must have a clear understanding of their exact assignment. Certainly, personnel with less experience can be expected to run across more tasks with which they are unfamiliar than their experienced counterparts. Yet, the most experienced of personnel often misinterpret instructions or, as supervisors, assign work to others without giving the subordinate all of the pertinent information he or she will need to do the job. Communication, whether written, oral or otherwise, must be a clear exchange of information. Both parties must come away with the same interpretation of what was said. Face to face communication is the most effective.

One way to reduce the chance of error is to write the information or instruction down, then repeat it to the person who gave it. A person should not let the opportunity slip by to secure all the information necessary. Once out on the fireline it may be too late to obtain timely clarification. The result can be both unproductive or downright dangerous. If the assignment is not clear, the first, most immediate thing to do is to simply say so.

This is not so easy at times, given the hustle and bustle of the situation surrounding many fires, but absolute clarification is mandatory. An example: You are with a strike team of fire engines assigned along a drivable section of fireline. You are to "work your *A* way" to a certain location as quickly as you can ^ before nightfall and tie in with another strike team of engines. What would you interpret this to mean? Merely drive along the fireline as quickly as you can and meet the other engines? Or, did "work your way" mean that the engines were to work the fire's edge, such as by pumping water on burning material, and to continue until tying in with the other engines?

This example is a very typical situation. Be sure to clarify the assignment while the person giving it is still available.

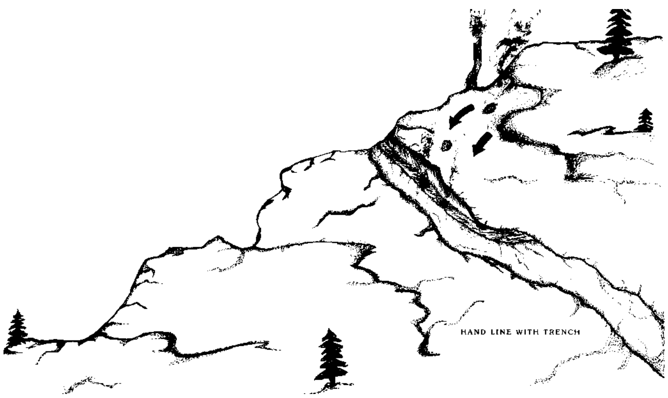
Obviously, part of the story is whether or not a *A* person has sufficient experience to know if additional information is, in fact, needed. However, no one should leave for any assignment until he or she knows exactly what is expected.

Situation:

You are on a hillside and hot rolling material can ignite fuel below.

This situation can occur at any time that the slope affords the opportunity to pine cones, logs, etc. In one case in San Diego County, the following happened: A lightning fire had ignited a small fire in rather light fuels on a ridge above a deep ravine through which a river flowed. Handcrews made up of personnel from several engines had all but tied in the line. The remaining fireline dipped down a steep slope which led to the river, and one crew was working this portion of line. Suddenly, a burning log worked loose above, and rolled past the crew into the green below and immediately, a new fire ran upslope toward the firefighters above. A second crew, nearer to the ridgetop was able to scramble to safety. For those who were working on the lower part of the fire, however, there was no time to reach the safety of the ridgetop. All reached the safety of the river and watched, from a wet vantage point, as both sides of the canyon burned off. The fire was finally controlled at several thousands of acres. One single log had changed the strategy situation from initial attack to major, and had the river not been available, it is certainly possible that some serious injuries might have occurred.

Pinecones roll even more easily because of their shape. During the daytime, these rolling materials normally will ignite fuels, which will burn upslope with rising convective currents. Sometimes, they will ignite spots that do nothing more than creep through the duff or ground litter. Smoldering, they lie waiting for sufficient oxygen to burst into flame. In gaining access to a smoldering fire when the route is through the green, it is important to construct a cleared line with handtools. This handline will permit egress if needed, plus serves as a locator for personnel on future work shifts. During the nighttime, when air currents normally flow downslope, fires caused by rolling materials may progress downhill and can do so at alarming rates under ideal burning conditions.



12F — Rolling material

All fires on slopes having undercut lines must be adequately trenched to catch rolling materials and prevent their journey into green fuels below. Such trenches must be properly constructed, with no rounded berm which only provides the material with a roller coaster ride across the line. The bottom lip of the trench should be vertical to properly catch material. The posting of a lookout can provide timely discovery of new fires and adequate communications to alert the crew is a vital necessity. Escape routes must be established before leaving the main fire to work on spot fires and the whole issue of rolling materials should be discussed before beginning work.

Personnel walking along undercut firelines must walk in the trench bottom rather than on the berm to prevent damaging the catching ability of the trenching effort.

Situation:
You are in country that you have not seen in daylight.

There is something quite different about the fireline at night. The shape of the land, the configuration of the vegetation, even the distances between points can present the firefighter with new and increased safety problems to consider.

It is likely that as a particular fire extends over several days, that the personnel who work the night shift will continue to work the night shift, and likewise, the day shift will always work the day shift. The point being, of course, that the night shift people will start their first shift with little or no opportunity to see the terrain, fuels, and exposures, and even after repeating the night shift, will perhaps not have all the information needed to work in a higher degree of safety. If per chance, the night shift can gleen some information from the day shift, then perhaps the situation will become a bit safer. Fire organizations work best when communication channels are open, and the sharing of experiences and accomplishments between crews who work opposite shifts, is probably the best way to find out about the work and fire progress during the previous 12-hour period.

Topographical maps are also helpful to the person who has not seen the fireline in daylight. Location of avalanche slides, mine shafts, stream beds, jeep trails, and other features will certainly be useful. Lack of visibility can be negotiated, in part, by artifical lighting, such as by firefighter headlamps. It is simple enough, provided every person is equipped with a light. Yet, on countless fires, quite often an entire crew will walk into a fire by daylight, and find itself, hours later in darkness, unable to work. The supervisor must make a last minute check with the subordinates for items such as headlamps which may well go forgotten when it is still daylight at a shift start.

Briefing sessions will often disclose other important bits of information, such as the types of fuel, including dangerous snags, location of cleared areas which can be used for emergency airlift by helicopters, and the access routes to spot fires which may be located well outside the fireline. While darkness does take away some of the visibility, the supervisor who obtains information through use of maps and through the eyes of others will certainly be able to assign work which can be accomplished with a reasonable degree of efficiency and safety.

Situation:
You feel the weather getting hotter and drier.

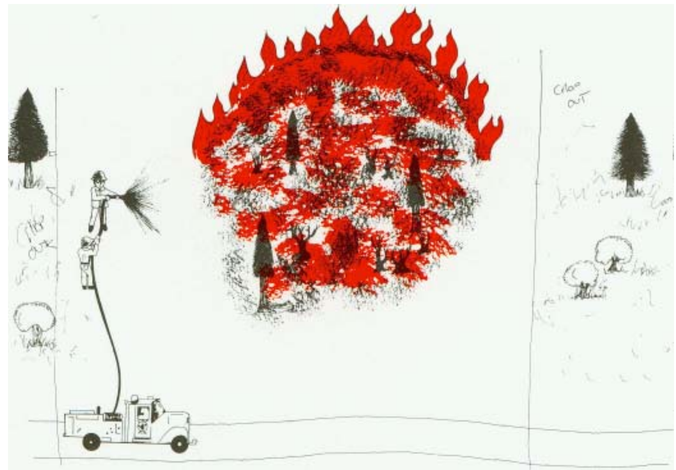
The fire that was less active during the night can be predicted to become increasingly active as the morning sun begins its heating process upon the land. Moisture, accumulated by fuels at night, was partly responsible for a more dormant fireline. Warmth from the sun will begin the process of extracting the moisture, hence the probable increase in fire activity as the day progresses toward mid-afternoon.

Generally, fireline personnel shift changes occur early in the morning to take advantage of the more favorable weather influences. And, in the very late afternoon or early evening, as the daytime influences give way, another shift change of personnel generally takes place.

All out efforts made during the period of high fuel moisture account for the containment and control of many large fires. Day shift personnel should be in place before the sun exerts much influence, hence the early morning shift change effort. The firefighters will note, as temperatures rise, that new smokes will appear within the burn; that smoldering duff now supports visible flame, and that the upcanyon winds now rustle through ravines and across the fireline. At midday, fuels will have given up most of their moisture and the fire may be on the move once again.

All personnel must be alert to the meaning of a hotter, drier period. Reductions in fuel moisture and an increasing wind can fan a hidden spot fire into life and convected currents of warm air flow upward through chimneys and across saddles. Flammable gases, which may be lying within a depression in the green, may suddenly avail themselves of an ignition source, immediately engulfing an area, sometimes of considerable size, in flame. The five foot fireline that sufficed the day before may become much too narrow to hold a fire that is now burning under hotter, drier conditions.

Flash fuels burn with extreme fierceness and even heavy, slow burning fuels become susceptible to ignition. Spotting across the line becomes more pronounced along with the danger of pursuing small fires starting within the green. Fire runs upslope may be almost simultaneous in nature, arriving at ridgetops quickly and just as quickly jumping across ravines and canyons on opposite slopes. With the arrival of hotter, drier weather, a new strategy-situation develops. Firefighters must take into account each of the signals that mother nature presents concerning the weather, and perhaps in particular, the signal of a hotter, drier day.



12G — Possibility of reburn in the crown

This engine company is in position to begin a progressive hose lay up the left flank. Because the fire burned primarily through the lower branches and duff, part of the canopy is unburned. The ignition of the canopy can initiate a fire run from within the burn itself and can place the crew in an unsafe situation with fire moving upslope toward them. Firefighters must be alert to the possibility of fire crowning in the canopy, even during what appears to be a mop-up situation.

With hotter, drier weather, the possibility of the fire crowning increases considerably.

Situation:
You are getting frequent spot fires over your line.

Spot fires are visible indicators of fire behavior which demand attention and evaluation. Strong winds, ground debris, snags, and low-fuel moisture are among the mechanisms which cause or encourage spotting. Remember fire brands, such as wooden shake shingles, have been responsible for spot fires not only from rooftop to rooftop, but for starting new conflagrations many miles away from their origination. Spot fires under most circumstances are indicative of the more extreme of burning conditions. Spot fires are, in reality, new fires; remember, nearly every fire is small in its incipient stage. Hence, spot fires can themselves become large fires. Spotting can suddenly isolate personnel and equipment between two or more fires, and fire engines, bulldozers, and personnel have been trapped and burned in this way. Spot fires that occur across a constructed fireline seriously jeopardize work and are often hazardous or impossible to reach. Spots can never be ignored because left alone they will continue to grow and perhaps require additional personnel and equipment to control. Firefighters on the line, whether engaged in fire control or patrol of a "cold;' line must be on the lookout for telltale smoke rising from the green beyond them.

In reaching these fires, fuel must be cut out along the access path to facilitate ready escape routes if the need should arise. Crawling through the underbrush to reach a spot is asking for trouble. Whether located upslope, downslope, or on flat terrain, a spot fire is capable of overrunning a crew. Because of the strong convective influences of the main fire, spot fires can suddenly be drawn toward personnel and equipment on the line, or toward those who are already within the green area enroute to work the spot fire.

In such a situation, or when conditions are such that the spot runs away from the main fire, it may be advisable to pull out of the area temporarily because of the tendency of a rapidly building spot fire to influence the rate of spread in the main fire. The intervening strip between the two can burn out in almost simultaneous action. When it can be accomplished with a degree of safety, spots should be attacked aggressively when first discovered. This, in part, is to reduce likelihood of two large fires rather than one. When the wind and other conditions mentioned earlier exist, the time has come to double check the location and alertness of the lookout, in order that he or she might reduce the discovery time on spots. When aircraft, including helicopters, are employed to work on spot fires, ground personnel will be well advised to keep in mind the turbulence on the fire and the possibility of multi-directional spread.

Situation:

You are in heavy cover with unburned fuel between yourself and the main fire.

The indirect method of firefighting dictates that work is accomplished at some distance from, and usually parallel to, the fire's edge. This procedure quite often presents a special safety problem of one sort or another, although it does allow firefighters to work in a somewhat cooler environment away from the approaching flames.

In terms of access to the burn, a most dangerous situation arises because firefighters are actually in the green, and they can be easily overrun by the fire as they attempt to move through the intervening strip between the constructed fireline and the fire itself. Because it is true that in the vast majority of cases, the burn is the safest place of refuge for personnel in time of danger, gaining access to that refuge by struggling through the green diminishes the very safety factor that we are seeking. This is the very point of course, because the indirect method does not allow firefighters "one foot in the burn," and to make things worse, they must now find their way, through heavy vegetative cover in the green, to the safety of the burn. Such a venture is sometimes impossible, if not downright unsafe. The supervisor must plan escape routes which can be used when entry into the burn is not possible.

In addition to the possibility of the main fire overrunning personnel who are working in an area where unburned fuel lies between them and the fire, spot fires can occur behind the crew, leaving them in a situation where the main fire is on one side and the spot fire is on another. Again, there may be no safe way to escape to the safety of the burn. A lookout must always be posted to keep a close eye on the exact fire location. Communication must be effective between the supervisor and the crew, and others along the line. Escape routes must be established and the handline construction must be extra clean. Although this situation subject refers to working in heavy fuels, one must never under estimate the flashy characteristics of lighter fuels, such as grass.

Situation:

You are in an area where terrain and/or cover make travel slow and difficult.

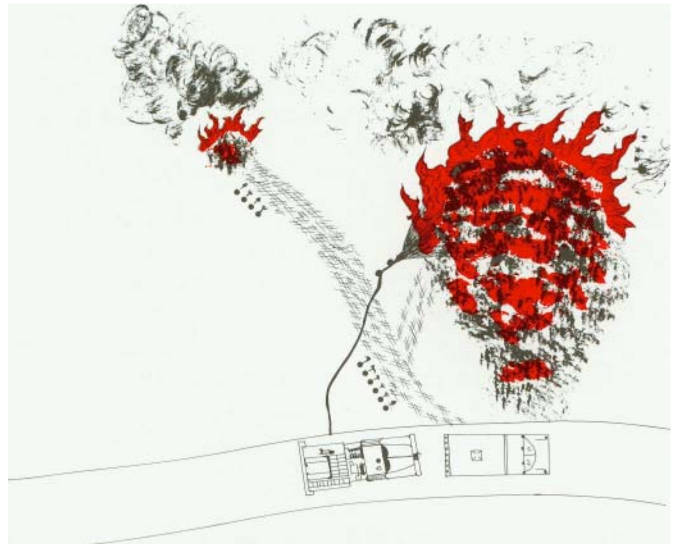
As we know, a crew walking or working on level ground must maintain at least ten feet of clearance between each person. This gives a margin of safety for swinging tools and throwing brush. On a slope, new hazards may be present, such as falling rocks and the potential for slipping. Of course, regardless of slope, all personnel must know exactly what their location is in relationship to the main fire. The rule "keep one foot in the burn" assures this, although in the indirect attack method, personnel are not immediately adjacent to the burn. Irregular terrain such as one encounters when traversing gullies and ravines, can put firefighters out of sight of other personnel, and, many fuels will restrict visibility and confuse travel routes. Oftentimes, a scout must be sent ahead, under the watchful eye of a lookout, to determine the best route for the crew to take. However, it may be a better choice to walk the longer route if that procedure will assure that personnel can exit directly into the burn. When fire slops below a ridge and is burning on steep terrain, no easy solution may be available. An undercut line will probably have to be put in, but personnel will, at some point, probably be walking or working in an area above the fire, an obviously dangerous situation. Sometimes, access to the fire, which is burning on a steep slope, can be gained by walking in from below. Or, it may be that rather than gamble on the safety of the personnel, the best decision will be to wait until the fire moves into negotiable territory. Even the most valuable of timber resources or watershed fuels must be left to burn if the probable trade off for suppression subjects firefighters to any danger. When walking down slopes, personnel must be staggered so that at no time will one person be directly above another.

Doing this will help prevent the dislodging of rocks by the person above and the resultant injury to the lower person. Personnel transversing such slopes above a fire are in a precarious position, for even in the case of a chimney which is void of all vegetation, superheated air rising from burning fuels far below have been known to sear the lungs and cause almost instant death.

Crews, which are attempting to gain access to spot fires in the green, should cut their way in to the spot to provide a safe escape route.

Access to such fires as lightning strikes or spot fires often necessitates travel through hidden terrain or heavy cover. Some vegetation is dense and cannot be traversed other than by crawling on hands and knees. This method is dangerous because the firefighter cannot see what the fire is doing. A better route should be investigated, or a handline should be cut to the fire to facilitate speedy withdrawal if it becomes necessary.

This situation calls for cutting away fuel to provide access to the spot fires. The procedure also provides an escape route back to the main burn in the event the spot fires become too aggressive.



12 H Safe access to spot fires

Whenever the fuels restrict visibility of the fire or make travel difficult, special safety considerations must be addressed.

To re-emphasize, access to a spot fire should be accomplished by cutting a handline from the main fireline to the spot. This procedure will allow speedy withdrawal should the spot fire become too hot to approach or if it makes a runs toward the main fire.

Situation:

You notice a wind change.

Of all influences on a fire's behavior, wind probably dominates in its ability to direct and spread wildfire. Wind flattens out the flames, facilitating ignition of new fuels and enhancing the speed of flame spread. A section of line which previously had favorable wind blowing from the green into the burn may suddenly reverse sufficiently to blow hot material or flames into new fuels. A change in the wind may necessitate a change in the attack and firefighters must remain flexible to meet any new situations, which may arise. Use of fire weather forecasting to predict wind change is an important consideration in developing strategy plans. Expect daytime upslope winds to change to downslope in darkness. The initial abatement of upslope flow can take place as soon as a particular slope becomes shaded from the sun. The shade may be due to the setting of the sun, or it may be due to shielding of the sun by terrain, such as a mountaintop. There are situations where two wind directions and/or speeds can occur simultaneously and at different elevations. A foehn wind, blowing from the north or east may be gradually surfacing along the upper mountain slopes, while at the lower elevations, a westerly marine flow exists. Expect change to a predominantly easterly flow as the foehn wind descends to the lower elevations. Foehn winds and other influences, such as cloud formations, are discussed elsewhere in depth.

It is important for the firefighter to utilize and fully understand predicted wind and wind changes, and to remain alert to both existing and altering forces. Wind often dictates the placement of personnel and equipment, attack methods, and other situations that have direct bearing upon the success of fire control and safety considerations.

Situation:
You are attempting an attack on the head of a fire with engines.

At times, a situation arises which calls for a frontal "stand " against an approaching fire. The decision to use this tactic can stem from several fire situations. A fire may have eluded a flanking attack because of its size or speed of spread. Or, accessibility problems may have precluded approach by personnel and the fire is now approaching an area where it can be dealt with. The primary dangers involved in a frontal attack involve the situation where personnel are "out front" of a wildland fire. The fire may overrun the most elaborate of counter forces, or it may spot well beyond them. Time is needed not only to move in the necessary forces, but to assure a reasonable degree of safety by such measures as safety island construction and briefing of personnel as to the plan of action and alternate plans of action. Many times in the past, such stands have been hastily, yet necessarily, enacted as a last effort to hold the fire at a particular road or other barrier before it moves into an area of habitation, remoteness or other aspect. This plan of action no doubt will be utilized many more times in the future; however, it does not allow development of as complete a plan as when some time is available.

Newer Engineers and Captains may not have sufficient depth of experience to safely react to a fire that is approaching them head on. Sometimes compared to a military stand, firefighters often must "dig in" and hope to hold a particular road or drainage. When sufficient time is available, and when a plan of action has been worked out well enough in advance, safety zones can be established and a plan with built-in flexibilities developed. If a plan is not worked out, several non-productive and potentially dangerous events can, and have, occurred. For example, while one crew has been busy initiating backfires, a second crew, or even aircraft, not aware of the situation, has been trying to extinguish it. Or, an engine company may find an easy access to the head, perhaps at a point where the fire may be easily picked up. If that engine gets between the main fire and a backfire, it can spell trouble.

The reader should be able to detect here, the importance of communication. Even the scantiest of communication is perhaps better than none; the point is that on a frontal attack, there are definite needs for explicit instruction, perhaps more so than needed for other firefighting procedures. Flexibility in planning, and planning far enough ahead of time can go a long way toward affording the Incident Commander or Line Officer enough time to build a plan and notify all the participants. When fire engines are to be placed in stationary positions, they should always be parked for the speediest of departures. Vehicles are best moved in a forward gear rather than in reverse, and they should be parked so that backing out is not necessary. The backing should take place when the vehicle is initially positioned, not when the fire necessitates its removal. If attack lines are to be used, they should never be less than I'/z" in size and they should be charged and ready for use. Hose tarps should be kept in place to provide protection for hose and ignitable equipment. A charged engine fire protection line should be checked for readiness.

When bulldozers are available, safe parking can be established to isolate the other vehicles from the green fuel lying between them and the head. Personnel and equipment should not be located at the top of any draw, ravine, or canyon, nor within a saddle, because of the tendency, even reliability of fire to choose these routes. All safety gear, including goggles should be in place and wet handkerchiefs may provide some relief from the smoke that is liable to blow across the area.

Situation:
You feel like taking a nap along the fireline.

To the reader, in comparison with the other twelve situations, it may seem that a discussion about sleeping along the fireline is elementary or "just common sense." Yet certainly there are times when the most alert firefighter reaches the point when he/she cannot go on and simply have to grab a quick wink. What is dangerous about a fireline nap? How does sleep fit into the firefighter's assignment? Every person on the line is a lookout and a sleeping firefighter can't be watching for spot fires. On some fires, a special fireline sleeping area may be needed to rest off shift crews on the fire itself. Seldom, however, will a regular work shift, night or day, incorporate an individual discretion to sleep on the line. The fire that springs up and makes an effort to cross the line; the flame that burns through the hoseline; can overrun a sleeping firefighter.

In summary, sleep, like any other fireline activity, is a function that is part of an overall plan. Supervisors authorize sleep when it is appropriate and in doing so, assure that fire control efforts do not suffer and that all safety considerations have been met.

In addition to the Thirteen Situations That Shout Watch Out!, there are Ten Firefighting Orders. Many of the orders are directly related to watch out situations; how many are evident?

Ten Firefighting Orders:

1. Keep informed on fire weather conditions and forecasts.
2. Know what the fire is doing at all times.
3. Base all actions on the current and expected behavior of the fire.
4. Plan escape routes for everyone and make them ~ known.
5. Post a lookout where there is possible danger.
6. Be alert, keep calm, think clearly, act decisively.
7. Maintain prompt communications with your crew, your supervisor, and adjoining forces.
8. Give clear instructions and be sure they are understood.
9. Maintain control of your crew at all times.
10. Fight fire aggressively, but provide for safety first.

For purposes of clarity and to emphasize the importance that the ten orders have on the overall wildfire safety plan, they can be broken down as follows:

Fire Behavior

1. Keep informed on fire weather conditions and forecasts.
2. Know what the fire is doing at all times.
3. Base all actions on current and expected behavior of the fire.

Safety

4. Have escape routes for everyone and make them known.
5. Post lookouts when there is possible danger.
6. Be alert, keep calm, think clearly, act decisively.

Operations Control

7. Maintain prompt communications with personnel, your boss and adjoining forces.
8. Give clear instructions and be sure they are understood.
9. Maintain control of personnel at all times.

Ultimate Goal

10. Fight fire aggressively but provide safety first.

Common Denominators of Fire Behavior on Tragedy and Near-Miss Forest Fires.
Wilson and Sorenson

The following information is based on analysis of 40 fires from 1926-1974 (136 deaths; average 3-1/2 *m* deaths per year).

1. Most of the incidents occurred on relatively small fires or isolated sectors of larger fires.
2. "Unexpected" or "unpredicted winds" were often given as the major cause of "erratic behavior."
3. Most of the fires were innocent in appearance in some cases the mop-up stage — prior to the "flare-ups" or "blow-ups."
4. Flare-ups occurred in deceptively light fuels.
5. Fires ran uphill in "chimneys, gullies, or on steep slopes."
6. Suppression tools, such as helicopters or air tankers, can adversely modify fire behavior. (Helicopters and air tanker vortices have been known to cause flare-ups.)
7. There are no erratic fire behavior situations. Our inability to predict fire behavior causes us to fall back on the term "erratic."

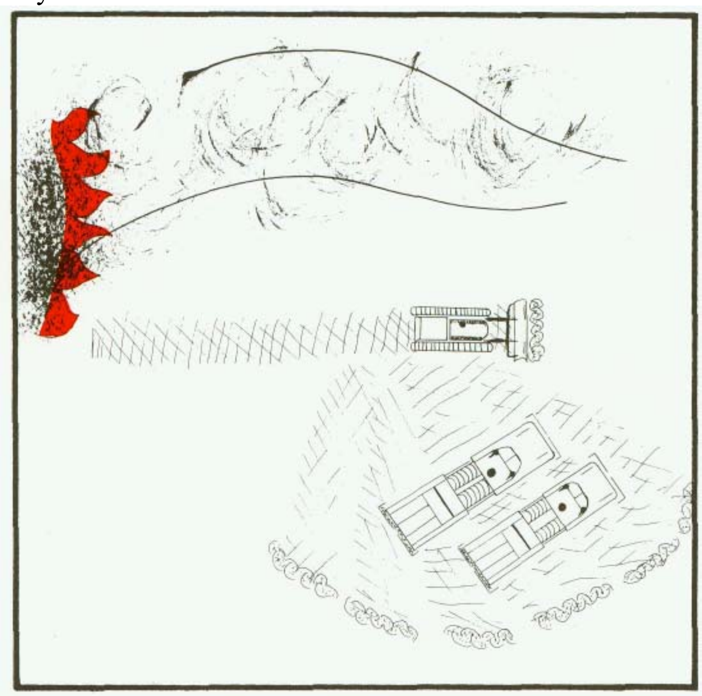
An analysis of 125 wildland fires which include 236 fatalities and 66 near-miss situations also involving a substantial number of personnel reveals that the tragedies or emergencies were precipitated by the | following basic fire behavior characteristics:

1. Fire ran upslope. ....…………………......*29.0%*
2. Sudden wind shift.............…………………....20.8%
3. Head made fast run. ....………………......... 13.6%
4. Fire spotted across line.....………………......... .9.6%
5. Fire ran downslope. ....………………..........6.4%
6. Concentrated fuel flare-up..………….............4.8%
7. Gusty cumulus clouds overhead (downdrafts).4.0%
8. Wake turbulence (aircraft). ......……………........0.8%
9. Equipment failures............………………….... .0.8%
10. Other (heart attacks, electrocution, etc.)….. .9.6%
^

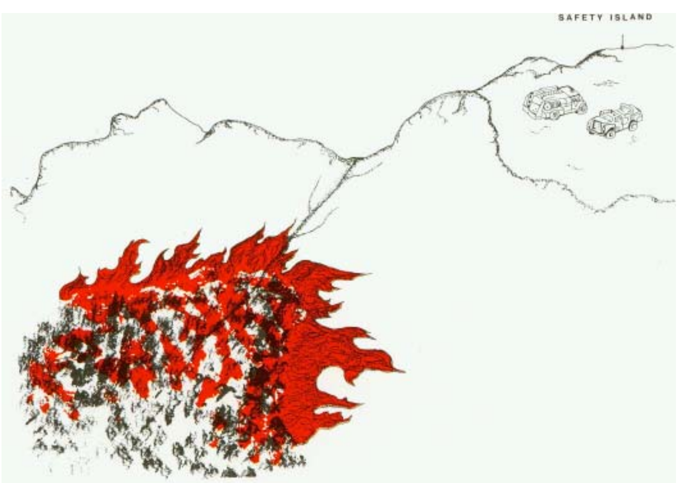
Vehicle Placement

Vehicle parking areas must be void of fuels that can transmit fire from vegetation to the vehicles themselves. If the area is not clear, the crew should clear it prior to initiating their assignment.

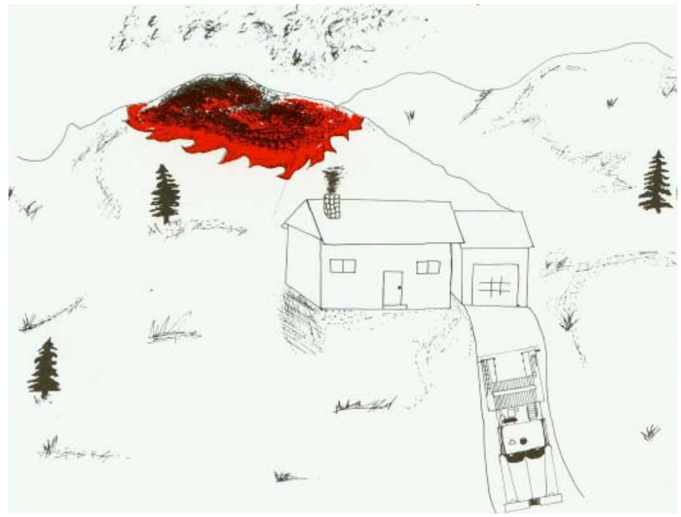
When vehicles cannot be parked parallel to egress routes, they should be backed in to facilitate evacuation.



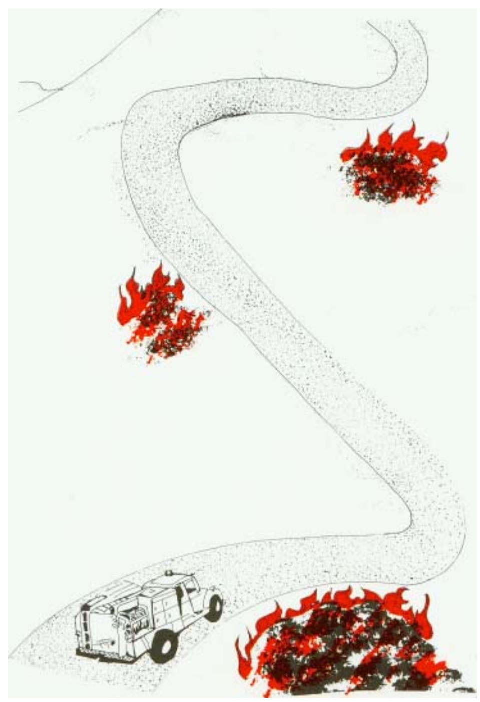
727 — *The location of safety islands must be known to all persons working in the area. These islands, cleared completely of vegetation, are located at safe and strategic places and are usually constructed by a bulldozer.*



12J — Vehicles should not be parked within the influences of saddles and chimneys



12K — The engine should be backed into place and parked in the direction of egress.



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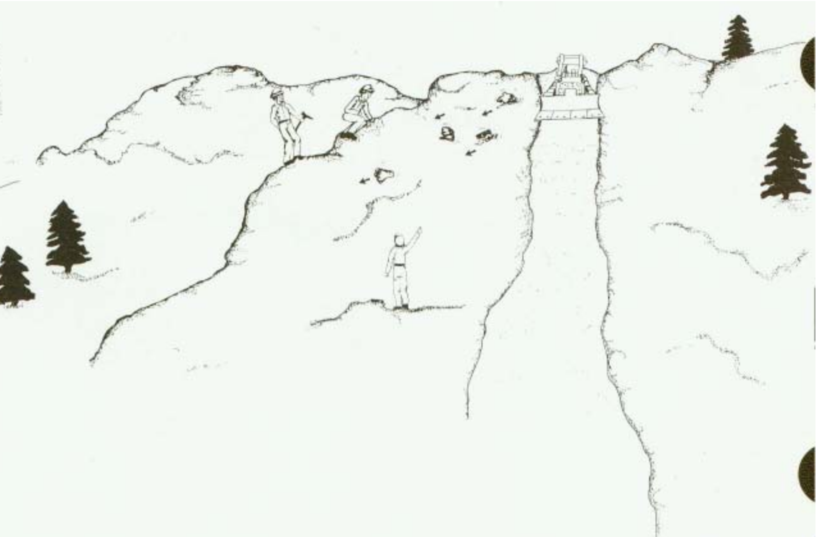
12L — In areas where firefighters will be driving vehicles on switchbacks some consideration must be given to the possibility of fire moving across the road.



12M — Although this engine company has begun work at an anchor point, it is in danger of being overrun by the fire should it become active. There is danger that the helicopter could trigger a flare-up

120 *— Dozer working above firefighters*
When the dozer has to work above where the engine and/or crew is working, the engine or crew is to be instructed to move out of the way until the dozer is by them. This is to avoid the danger of rocks rolling on the crew.

12N — Other Safety Considerations
Where larger trees once stood, root cavities often retain considerable fire and heat for long periods of time. The principal danger is that of accidentally stepping into, or falling into one of the cavities.
Generally, the telltale sign of these pits is a rather fluffy grayish ash in the pattern of the original tree trunk.
If a dozer and engine are working together on a hot fire with a hoselay, the crew should try to conserve water and let the dozer get as much as possible of the line construction work while the hand crew picks up the hot spots with water. This tactic conserves water and provides safety for personnel.

Wildland Safety Uniform

12Q — Wildland Safety Uniform

The only legitimate role of government is to protect and enhance the life of people.
We protect resources because resources protect people.
Life and quality of life are the real objectives.
It is not then reasonable to sacrifice people to serve resources.

FIGHT FIRE AGGRESSIVELY BUT PROVIDE FOR SAFETY FIRST