

Case Study
of the
Wildland/Urban Interface Fire
that destroyed 44 homes
and other structures
near Boulder, Colorado,
July 9, 1989

BLACK TIGER
F I R E

Black Tiger Fire Case Study

Prepared by the



National Fire Protection Association

Sponsored by the
National Wildland/Urban Interface Fire Protection Initiative

Members *of the* Initiative:

United States Department of Agriculture
Forest Service

National Association of
State Foresters

United States Department of Interior
Bureau of Land Management

National Fire Protection
Association

Cover photo by David P. Gilkey, *Boulder Daily Camera*
Design by Anne Aylward, NFPA

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Black Tiger Fire Case Study

ABSTRACT

A human-caused wildland fire starting on July 9, 1989 in a scenic part of the Rocky Mountains near Boulder, Colorado, swept through residential areas nestled among the trees. Within the first five to six hours after ignition, 44 homes and other structures were destroyed and many others were damaged. The fire was not completely extinguished until four days later, after burning almost 2,100 acres. Loss estimates of homes and natural resources amounted to \$10 million, and the cost to control the fire was another \$1 million. More than 500 fire fighters from local, state and federal fire agencies worked to eventually contain the fire and protect the numerous other homes built in the rustic surroundings. Some of the fire fighters' own homes were threatened or destroyed by the fire. Only a few minor fire fighter injuries were reported and one resident was hospitalized from burns.

The result of this wildfire, especially the loss of the homes, represents an increasingly common example of the risks of building homes in what is called the wildland/urban interface, the term for a border zone where structures-mainly residences-are built in wildland areas that by nature are subject to fires. This fire, which soon outran the fire defenses in difficult terrain, demonstrated the predictable effects of a combination of factors: lack of rainfall; prolonged heat spell; wind; sloping topography; buildup of forest fuels; construction factors affecting the susceptibility of the home to fire; use of combustible construction materials; poor site access for emergency vehicles; and lack of a home's site maintenance for fire protection. These factors plus the number of homes that were quickly threatened compounded the problems for the fire fighters.

The Black Tiger Fire was the worst wildland fire loss in Colorado history, but the conditions that led to it are still prevalent in many parts of Colorado as well as in other states. The trend of building combustible homes in the flammable wildlands continues. In many of these areas the potential for similar or worse disaster currently exists, needing only an ignition source and the unfortunate development of hot, dry, windy weather conditions that come with dangerous regularity every year.

For several years fire protection agencies have been attempting to warn affected homeowners nationwide of the risks of these wildland areas, but most homeowners remain not fully aware of, or insufficiently concerned about, the problem. Many publications also offer guidance for homes in the wildland/urban interface (see the Appendix for a sampling). Proposed NFPA 299, *Protection of Life and Property from Wildland Fire*, will be a national standard that will present fundamental planning and design criteria for fire agencies, planners, architects, developers and government for the protection of life and property. It includes information on procedures and practices for safe development in areas that may be threatened by wildfire. To assure that it will be an acceptable document, it-as are all standards developed by the National Fire Protection Association-is being prepared by a committee of those who would be most affected: homeowners; interested individuals; architects; urban planners; and fire officials from local, state and federal agencies.

Black Tiger Fire Case Study

ACKNOWLEDGMENTS

This report has been prepared by the National Fire Protection Association (NFPA) at the request and in cooperation with the Boulder County Sheriff's Department. The project was sponsored by the National Wildland/Urban Interface Fire Protection Initiative to further the goals of the Initiative established in 1986. Those goals are to create general public awareness of the wildland interface problems, to encourage the formation of partnerships among problem-solvers and interest groups, and to focus on the development of local solutions to wildland/urban interface fire problems. The Initiative is sponsored currently by the U.S. Department of Agriculture Forest Service, U.S. Department of the Interior, the National Association of State Foresters, and the National Fire Protection Association. Contact information for each of these organizations is provided in the Appendix.

As part of achieving the goals of the Initiative, an analysis of the Black Tiger Fire was undertaken. The purpose of the analysis was to document the fire, determine to the extent possible the variables causing the destruction, and make recommendations on how to prevent similar occurrences. Thomas Klem, Director of NFPA's Fire Investigations Division, served as project manager and technical advisor. William Baden, Senior Fire Service Specialist, NFPA, served as the technical advisor for the project. Dr. John R. Hall, Jr., Director, Fire Analysis and Research Division, NFPA, specifically contributed the section "Statistical Analysis of Factors in Damaged Homes."

The information from this report can be used to assist planners, local officials, fire service personnel and homeowners in Colorado and in other parts of the country in developing firesafe homes and communities in the wildland/urban interface, a term referring to the geographical area where two diverse systems—in this case, wildland and residential—join and affect each other.

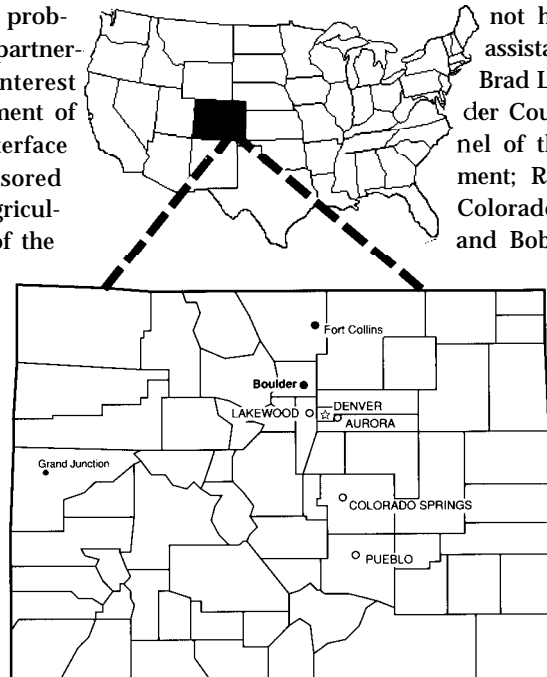
This wildland fire is only one of many that occur throughout the world each year. Under the sponsorship of the Initiative, the National Fire Protection Association will review, analyze, and document additional wildland/urban interface fires that cause destruction to homes and structures.

The preparation of this report would not have been possible without the able assistance of the following people: Sheriff Brad Leach and Sgt. Larry Stern of the Boulder County Sheriff's Office; Chief Ruth Ravelle of the Sugarloaf Volunteer Fire Department; Ron Zeleny and Dave Parker of the Colorado State Forest Service; Shelly Nolde and Bob Wilmot of the Arapaho/Roosevelt National Forest; Brooke B. Smith, Jr., Fire Protection Engineer, Aspen Engineering, Inc.; and numerous other people from the organizations listed above who contributed to this report.

In addition, the on-site assistance and technical guidance provided to NFPA personnel by Al Roberts, U.S.D.A. Forest Service Regional Office in Denver, greatly enhanced our ability to prepare this report. Next, technical assistance and input to the fire growth and intensity analysis of the report were provided by Dick Rothermel, U.S.D.A. Forest Service Intermountain Forest Range Experiment Station in Missoula, Montana. Each of these individuals has made significant contributions to the technical accuracy of the report. The methodology used for the project and approach used in the analysis is described starting on page 37.

Laurie Ruszcyk, as project secretary, served numerous functions throughout the project including coordination of technical reviews, procurement of photos, and arrangement of the report for layout and printing.

Finally, Jerry Laughlin of Books On Fire served as technical editor and prepared the layout of the final document.



OVERVIEW

Fire officials across the nation are reporting dramatic increases in the loss of homes to wildfires. The 1980s have seen some of the most severe wildfires in this century. In 1985, for example, 1400 homes and other structures were damaged or destroyed in fires reported to the U.S. Forest Service. Every year since 1985, more than 300 homes have been lost to such wildfires, but the tragic losses are not just to property-lives of homeowners and fire fighters are also lost every year. *In 1987, more fire fighters died fighting wildland fires than any other single type of fire.*

The fire danger to homes in the wildland/urban interface is affected by five major factors:

■ **People continue to move to the scenic wildlands and build homes there.**

This trend will continue to be influenced by the less desirable factors of city and suburban life, as compared to the desirable factors

associated with living in the wildlands.

The population density of most cities is extremely high. For example, Denver has approximately 4,200 residents per square mile; Los Angeles and Miami both have some 6,400 per square mile; and New York City squeezes in about 23,300 people per square mile. In addition, many city and suburban residents must contend with soaring property and rental costs coupled with reduced services. They say urban areas feature excessive taxes, too-restrictive regulations, and endless noise, crime and grime.

As a result, people are moving from cities to the less-crowded wildlands because they offer a scenic environment with generally lower property costs, more privacy, fewer regulations, less noise and less crime.

This new trend is made possible by the availability of a combination of services previously obtainable only in the cities and suburbs. Now good connecting highways allow people to retain their jobs in the cities but escape to live

A dream
homesite
can become
a nightmare
for the
unprepared.



Photo by NFPA

in and enjoy the aesthetics of a home in the woods. Extending outward with the highways, generally good communications and other utilities have provided important bridges between the urban world of work and the rural world of new homes. Some other basic services-education, for example-are also now more readily accessible in rural/wildland areas.

Indeed, one of the basic but erroneous assumptions made by people relocating to wildland residential areas is that seemingly most of the services they enjoyed in the cities and suburbs are equally available in the new areas. But the shock comes when it is time to pay for the relatively high level of services desired, because the typical lower population density in the wildlands means there are fewer people to share the costs of the services. Thus, per capita costs rise.

To keep costs lower, rural communities may decide to provide minimal services, or choose not to expand the current level of services. The result is often that, in an emergency, residents discover that critical services taken for granted in city life may not be available in the new rural setting. If available, they may not be *quickly* available.

But fire is one type of emergency that is very likely to occur-and develop quickly-when combustible homes are built in close proximity to the combustible vegetation found in forests and other wildland areas. Unfortunately, development of these rural areas has easily outpaced wildfire hazard awareness on the part of homeowners and governments.

□ **BLACK TIGER FIRE**

In Colorado an estimated three million of the state's 22 million acres of forested land are dotted with homes. Boulder County has 18,000 people living in the rural mountains in 6,000 buildings. Homes found in the area of the Black Tiger Fire ranged from shacks for pan-time use to large, expensive homes on the most scenic sites. One residential structure was a remodeled railroad caboose. One was an old bunkhouse for

a long-defunct mining company.

1 **Wildfires continue to ignite and threaten homes in the wildlands.**

To a city resident, a forest may represent only a beautiful environment, its quiet punctuated by the soothing sounds of birds or rushing streams or leaves rustling in the wind. But to a fire, the forest represents tremendous fuel.

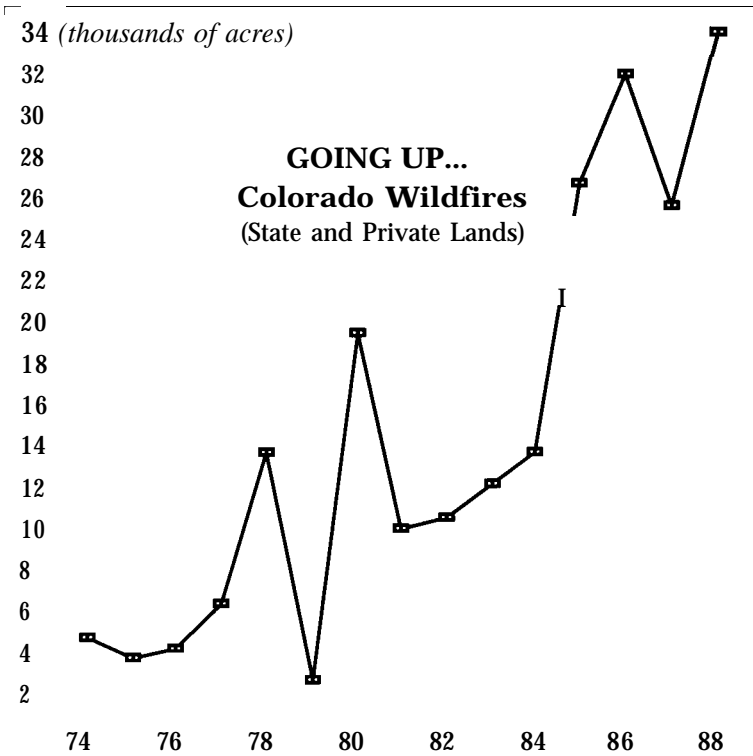
Fire is a fact of life in a forest. Taking a naturalist's view, fire serves a "cleaning" function and helps recycle nutrients. Frequent small fires-started naturally by lightning, for example-assure that fallen leaves and limbs are periodically removed and recycled before the fuel builds up to a quantity that, if ignited, would threaten the forest itself. On a longer-term period, as the forest ages and decays, fire inevitably burn out large areas that are subsequently replaced by new forest stands.

Lightning is not a phenomenon controllable by humans. Thousands of lightning discharges strike the earth each day with the electrical characteristics needed to start a fire. Although most will not find the necessary combination of fuels and dryness for ignition, weather conditions experienced every year do provide dangerous combinations of prolonged heat, wind and dryness. Then, any lightning strike in the forest, brush or grasslands could produce a rapidly spreading fire.

Where nature fails to ignite a fire, humans are capable of igniting fuels-whether accidentally or intentionally. Nationwide, a great majority of wildfires are caused by humans. And while some areas of this country have a greater fire problem than others, no area is immune to dangerous wildfires.

□ **BLACK TIGER FIRE**
In the area of the Black Tiger Fire, the U.S.D.A. Forest Service has wildfire protection responsibility on national forest lands. The county sheriff in Colorado is the official agent responsible for suppressing wildfires on private and unincorporated lands. No other state has a similar organization. Local volunteer fire depan-

Fire is a fact of life in the forest. It removes litter and recycles nutrients.



ments provide the first line of response but transfer control to the sheriff on large fires. The state forester can also assume the control duty with concurrence of the sheriff. Radio communications are controlled at the county level in Boulder County.

These wildfires continue to present particular problems to affected fire protection agencies.

Established procedures for controlling wildland fires-sacrificing some acres by preparing a perimeter firebreak and "backfiring" to remove adjacent fuels and starve the main fire, for example--conflict with the necessity for direct intervention to protect individual homes. At the same time, committing available personnel to an intensive battle to protect individual homes may result in not being able to control the main wildfire itself.

Fires threatening homes in the wildland/urban interface area (defined in box at right) may generate initial emergency response from either a wildland fire agency or a structural fire department, depending on which one is closer. However, wildland fire fighters are not always equipped or trained to fight fires in structures, and structural fire fighters are not always equipped or trained to fight wildland fires. Therefore, the first-responding fire fighters may not be able to quickly handle the fire at hand. Funding and manpower limitations faced by both types of agencies suggest that this problem will not be quickly eliminated.

In addition, many wildland homes are built along narrow roads and on cul-de-sacs that present access difficulty for larger emergency vehicles. The Black Tiger Fire area is characterized by many small private ownerships arising from old gold-mining claims (Black Tiger was the name of one of those early gold mines) overlapping on federal lands. Most of the existing narrow and winding roads originally served the mining claims in the late 1800s. The danger of fire crews becoming trapped and unable to turn their vehicles around



Wildland/Urban Interface

This describes the geographical areas where formally urban structures--mainly residence--are built in close proximity to the flammable fuels naturally found in wildland areas, including forests, prairies, hillsides and valleys. The results can be aesthetically desirable.. or disastrous. We can better achieve the desirable aspects by better understanding the potential danger and preventing or preparing for them.

on these roads can force them to leave some individual homes unprotected at critical times. Another problem occurs when roads are too narrow to allow simultaneous evacuation of threatened residents while large emergency vehicles move in the opposite direction.

Wildfires occurring during hot, dry and windy conditions find fuels prepared for easier burning and rapid fire spread. When moisture levels for some typical fuel types are reduced from 25 to 20 percent, the rate of spread factor can double. A moisture reduction from 25 to 10 percent in these same fuel types can result in a rate-of-spread factor increasing seven times.

Fire intensity is perhaps even more important. One fuel modeling system considers fuel types and converts flame front energy and rate of spread into a number expressed in Btu (heat) per foot (of fireline front) per second of burning. A rating of 500 represents the theoretical, or "rule of thumb," limit of control by any organized means. Beyond 1,000 Btu/ft/sec, a fire can be expected to feature dangerous spotting, firewhirls, crowning and major runs with high rates of spread and violent fire behavior. (These numbers are useful for comparison purposes but they remain theoretical calculations based on best estimates usually made after the fire from computer models.)

Spotting has particularly difficult implications. Spotting occurs as wind-borne burning embers are carried far ahead of the main fire front and land in receptive fuels. The embers can fall on the roofs of homes or woodpiles and start new fires while fire fighters are occupied elsewhere with the main fire.

Across the Black Tiger Fire area

For every 100 feet of distance, the land rises an average of 23 feet

To make matters worse, if the embers fall on untreated wood shingle or shake roofs, the new spot fires can develop even more rapidly. Yet, building code regulations to prevent the use of combustible roofing are not often in place or enforced in wildland areas.

□ **BLACK TIGER FIRE** State law in Colorado requires a county to contact the Colorado State Forest Service for comments on developments in wildlands, but some counties don't bother. Colorado fire officials are frustrated that some mountain subdivision covenants actually require shake-shingle roofing to maintain the perceived rustic charm of the community.

Boulder, however, became the first county in Colorado to mandate fire-retardant roof shingles, effective May 4, 1989. The greatest limitation of this requirement—as well as similar ones elsewhere—is that it covers only new construction. All existing homes are unaffected, which means they may be quite vulnerable to wildfire. Fire officials would like to see tougher laws, but they will only be created and passed if homeowners and local officials better understand the problem.

▮ **Lack of good vegetative management predisposes areas to wildfires.**

Arrangement of natural fuels is an important factor affecting the type of fire that could occur in an area. This includes not only the amount of forest litter and the density of the trees, but also the heights of adjacent fuels. Grass fires do not easily ignite tree canopies. But so-called ladder fuels can allow flames to escalate from grass to bushes to lower tree limbs. Clearing ladder fuels is a prime objective of prescribed or controlled burning. This term describes the knowledgeable application of fire to a limited land area under controlled conditions by forest management experts to accomplish specific objectives. In addition to removing litter, prescribed fires may also be intended to thin out competing vegetation or to prepare an area for the natural growth of vegetation more resistant to ignition and fire spread.

However, when people move to the forests, land management officials often have more difficulty conducting prescribed burning because of the opposition of residents to the smoke and possible risk of fire escaping control.

Other fuel management programs seek to limit the quantity of highly flammable fuels. On an individual basis, homeowners could remove fallen limbs and other flammable debris

A safety
zone of low
fuel density
all around the
home offers
important
protection.

that builds up on the ground. Homeowners could also manually thin out thick stands of brush and trees to reduce the intensity of any fire approaching a structure. Total clearing of all vegetation from the ground is not preferred because this could lead to erosion problems. However, homeowners could plant greenbelts, which are aesthetically pleasing zones of low flammability vegetation that help protect a home and also hold the soil. These irrigated, landscaped and regularly maintained areas act as a fuel break.

□ **BLACK TIGER FIRE** The principal vegetation across the Black Tiger Fire area was tall grass under open ponderosa pine. Pockets of dense lodgepole pine and Douglas fir were found on shaded slopes and along riparian zones—areas of high-moisture vegetation around lakes, streams or ponds that serve to reduce fire intensity.

The fire danger in this part of Colorado was made worse by the recent effects of tree-killing insects such as budworms and beetles. The spruce budworm larvae feed on the needles of spruce trees, killing them slowly while building up a thick carpet of needles on the ground. In the past ten years the Black Tiger area had been ravaged by mountain pine beetles, which left many of the pine trees dead. The Douglas fir beetles were also in those remaining trees, entering the bark and damaging the internal water distribution system of the trees. In the previous winter, a deep freeze followed by a quick thaw weakened many trees and made them even more vulnerable to the insect damage. Dead and downed fuels had been removed on some areas but remained on others.

■ **Unless specific preventive measures are taken by homeowners and local governments, homes will continue to be lost and people's lives will continue to be in danger.**

When the owners and builders place their primary emphasis on aesthetic values and economic considerations without regard to fire protection, the potential for catastrophic loss increases. In the eyes of fire protection officials, these homes are built to burn. Homes in the wildlands that are at special risk usually share several dangerous traits:

Combustible vegetation

An approaching fire will ignite surrounding vegetation in a step-by-step attack on a home. A safety zone of low fuel density all around the home offers important protection. So does

removing fallen leaves and limbs from roofs, boxing eaves and screening vents. Landscaping with fire-retardant plantings can actually help protect homes by repelling fire or giving it no place to burn.

Combustible exterior walls

Radiated heat from a nearby fire can ignite wooden walls without actually touching them. Wooden decks are also vulnerable. Similarly dangerous is the placement of combustible material such as woodpiles under decks, too close to walls, or immediately downhill from the home.

Untreated wood roofs

This is a major risk factor for wildland homes. Wind-carried burning embers can ignite these roofs far ahead of the main flame front. A test has been developed to measure the relative ability of roof coverings to withstand ignition from different size brands. A Class A roof protects against larger brands (weighing over 4 pounds) than a Class C roof (withstanding brands weighing only 1/3 ounce). Untreated wood shingle and wood shake roofing will not withstand Class C brands. This means that a brand half the size of a kitchen match will ignite a weathered wood roof under the wind and weather conditions accompanying most conflagrations. Burning wood roofing then gives off more burning brands. New treatments can successfully improve the ignition resistance of wood roofing, but only if the treatment allows the roofing to be certified as passing fire tests for at least a Class C rating.

Untreated wood shingle roofs are a major factor for wildland homes.

Home located on a slope

Sloping hillsides provide for scenic views and are some of the most desirable sites for homes in the wildlands. Slopes, however, create natural wind flows that increase the spread of a wildfire. Slopes with gulleys can create chimney effects that further increase a fire's rate of spread. Compared to level ground, a 30 percent slope will double fire spread rates while often cutting fire control efforts in half. The survivability of the home is further reduced when there are large glass windows or a wooden deck or unprotected wooden support piers facing the downslope.

Remote location

Homes a greater distance away from fire protection equipment will obviously take longer to reach. Homes with poor access for larger emergency vehicles are in greater danger, as are those hidden by vegetation and with poor or no markings to help fire fighters locate the home. Steep, narrow trunk roads also slow emergency response and evacuation for residents.

Lack of water

Piped water systems with sufficient pressure and hydrants for fire fighting are usually a product of higher population densities and may not be available in areas. Ponds and cisterns can provide additional options for fire departments, but they may be dry in the worst conditions; fire tanker trucks are seldom enough. In the Black Tiger Fire area, homes were usually served by individual wells with small pressure tanks that stopped functioning during the fire when burned poles and falling wires cut off the electricity.

Black Tiger Fire Time Line: Sunday, July 9, 1989

12:35 pm	Approximate time of fire origin
12:35 - 12:40	First structure (mobile home) involved (approx.)
12:40	Fire discovered by residents and extinguishment attempted
12:43	Fire alarm received by Sugarloaf Volunteer FD. Estimated size: 40 x 10 feet
12:55	First fire fighters arrive on scene. Estimated size: 40 x 100 feet
12:59	Crown fire
12:59	Fire fighters on scene request equipment assistance
1:00	Estimated time of steady state burning.
1:00	Fire fighters on scene request mutual aid departments
1:04	First request aerial tanker support
1:05	Additional mutual aid departments requested
1:30	First evacuations begun (approx.)
1:00 - 1:39	Fire spread 78 ft/min average
1:59	Radio confirmation of second structure
1:39 - 2:10	Fire spread 25 ft/min average
2:10 - 2:30	Fire spread 57 ft/min average
2:30	Type 1 interagency fire management team ordered mobilized
2:30 - 3:30	Fire spread 55 ft/min average
3:30 - 6:00	Fire spread 45 ft/min average
6:00	Last home lost
6:30	Fire area: 1,500 acres
Overnight	Bulldozers cut 120-ft line
July 10	Greater state and federal fire fighting assistance arrived
July 13	Final control announced

BLACK TIGER FIRE



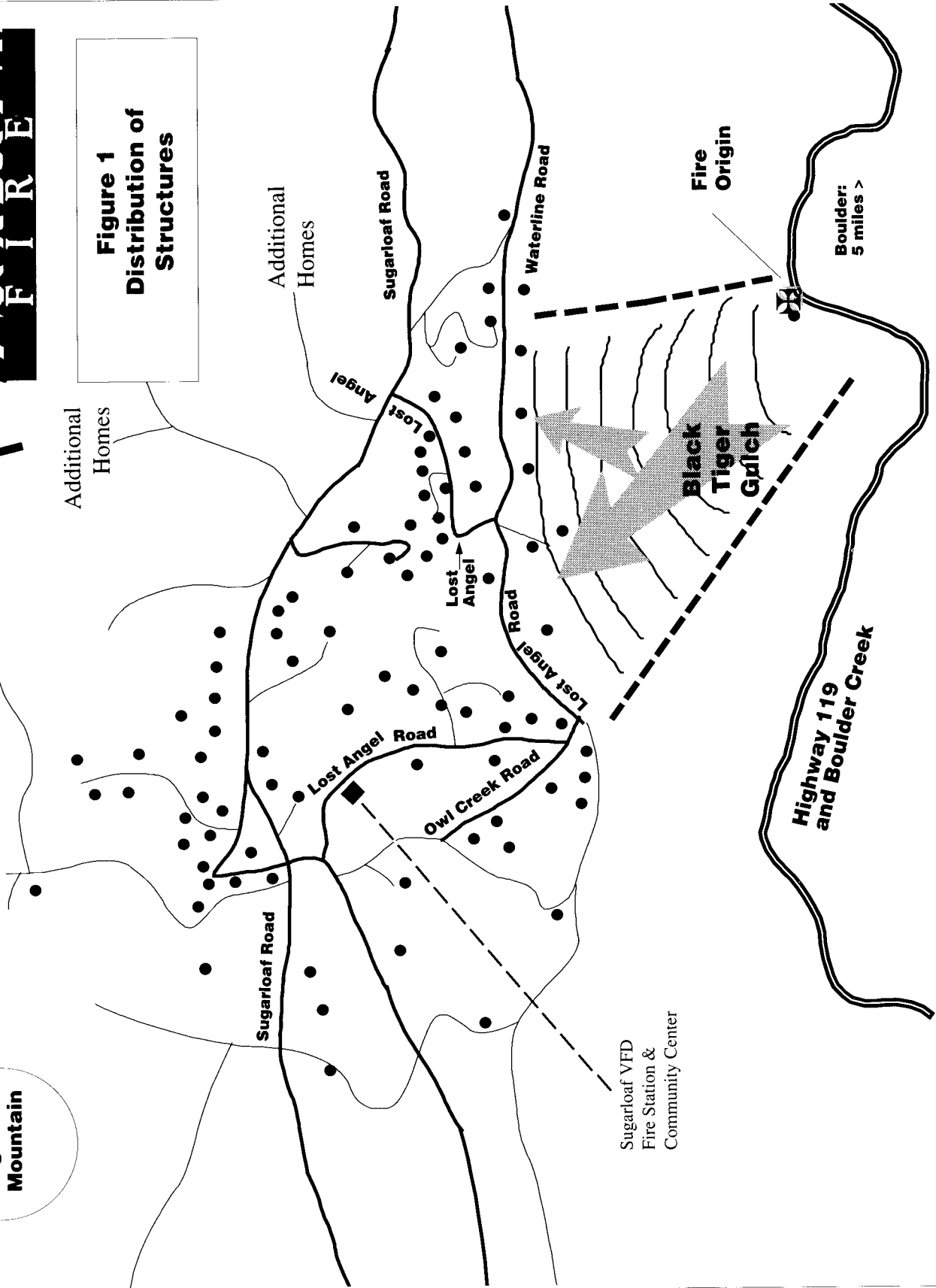
Distance from fire origin to top of Sugarloaf Mountain is approximately 2.5 miles.



**Figure 1
Distribution of
Structures**

Additional
Homes

Additional
Homes



Sugarloaf VFD
Fire Station &
Community Center

Highway 119
and Boulder Creek

Boulder:
5 miles >

Black Tiger Fire Case Study

THE FIRE

Weather Conditions and Topography

The conditions on Sunday, July 9 in that part of Colorado had all the elements in place for a dangerous fire, lacking only an ignition source.

Rain had not fallen for at least 30 days during an extended period of high temperatures. The dry conditions were long term; snow pack the previous winter was only 25-75 percent of normal. On Sunday, July 9, the temperature was again near 100 degrees. Humidity in the previous week was reported to be in the single digits, although at the nearest official weather station three miles east of the fire the reading at 1:00 p.m. on July 9 was 24 percent.

Dry winds were blowing up the Black Tiger Gulch with greater force than usual. Fire fighters on the scene estimated the upslope wind speeds in the early stages of the fire to have been varying between 15 and 25 miles per hour. At the weather station mentioned above, observations at 1:00 p.m. indicated a wind speed of 8 miles per hour.

The distance from the point of origin to the northwest terminus of the fire at Sugarloaf Mountain is 2.5 miles. Along the first 3,000 feet northward from the point of fire origin, Black Tiger Gulch rises 720 feet, for an average slope of 24 percent. Parts of this area slope as much as 35 percent.

At the top of Black Tiger Gulch the slope becomes less steep further northward for approximately one addi-

tional mile approaching the Sugarloaf community. Then the slope increases to about 34 percent from the base to the top of Sugarloaf Mountain, with an elevation of 8,917 feet above sea level. The slope over the total distance of the fire averages 23 percent.

Weather

Report:

Hot, Dry

Windy

Fire Origin

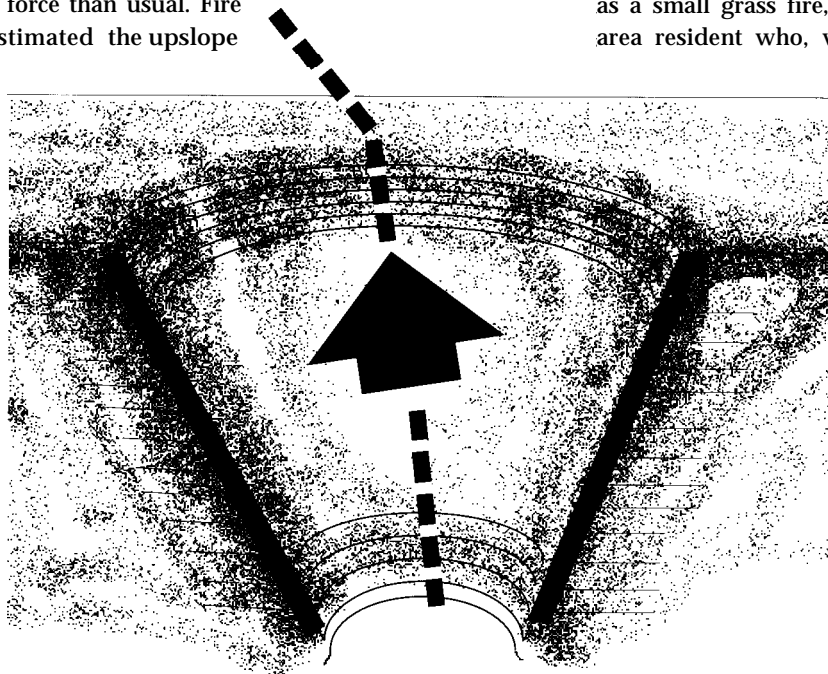
The Black Tiger Fire began on private property along Highway 119 in the Sunnyside area about seven miles west of Boulder, Colorado, around 12:35 p.m. on Sunday, July 9, 1989.

The county sheriff determined that the fire was accidentally set-probably by a carelessly discarded cigarette. The fire was first reported as a small grass fire, 40 feet by 10 feet, by an area resident who, with the aid of other residents, unsuccessfully attempted to extinguish the fire.

Sugarloaf Volunteer Fire Department personnel were available at the station preparing for a community picnic when the first radio alarm from the county was received at 12:43. The alarm notification also included the U.S. Forest Service and the Colorado State Forest Service. This message indicated that there was a "possible Wailer endangered at that location."

Arriving on the scene at 12:55, Sugarloaf VFD personnel reported, "The fire is spreading and looks like it is covering about 40 by 100 (feet)."

By 12:59 fire per-

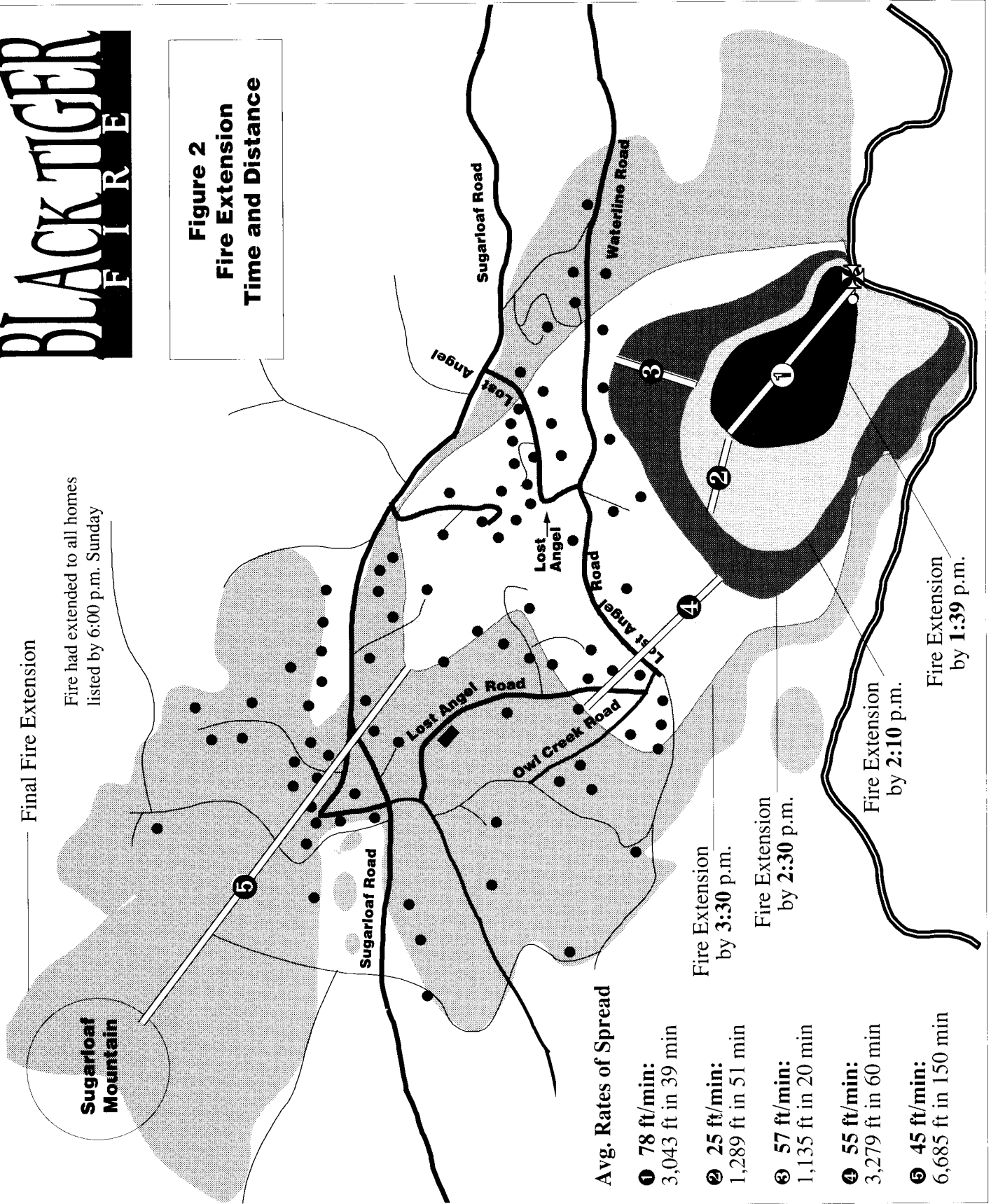


Sliced Coffee Cup

Black Tiger Gulch can be visualized by comparing it to a sugar bowl or coffee cup sliced down the middle. The result is a side that slopes upward and outward toward the top and also curves around. Heated air at the bottom naturally funnels up the slope and accelerates over the ridge.

BLACK TIGER FIRE

Figure 2
Fire Extension
Time and Distance



sonnel on the scene had requested more tankers, a portable pump and as many portable containers as possible for collecting tanker water in the field, adding that they had some structures that were exposed. A storage trailer adjacent to where the fire started was the first structure to be lost to the fire. (Figure 1 shows the approximate distribution of structures in the affected area.) The fire burned through the grass into the forest and spread up the steep hillside.

One minute later-at 1:00 p.m.-the first requests began for mutual aid from nearby fire departments. This is also the time estimated for a condition of steady-state burning used in fire spread calculations. At 1:04 the requests for assistance escalated to inquiries about needed response from air tankers to drop fire retardant chemicals, and helicopters for aerial reconnaissance and water drops. Aerial support was not immediately available. The nearest air tanker base was 16 air miles away, but the air tanker stationed there was already working another fire that threatened structures in southwestern Colorado. (As the number of homes threatened by the Black Tiger Fire grew, however, the air tanker was diverted to Black Tiger, a distance of 260 air miles.)

Additional fire departments were requested at 1:05. A nearby department preparing to respond with mutual aid asked for clarification at 1:09 about which type of apparatus was needed: "Would you ask Sugarloaf whether they want forest fire-brush fire equipment or structure protection, or both?"

The answer was clear: "Respond all the equipment you can."

Fire Intensity and Growth

Fireline intensity is the best indicator of the fire's destructive force and resistance to control. The intensity is computed by multiplying the rate of spread by the energy density for the particular fuel type found in the area.

To determine rates of

Why one
home is lost
and another
survives:
many variable
factors.



Photo by Jerry Cleveland, *The Denver Post*

spread in different areas, the timed progress of the fire was noted from aerial observation, as shown in Figure 2. Measurements were taken of the distance of fire spread and this was divided by the minutes of travel.

Energy density is a number describing the energy released by a square foot of a particular fuel. Ponderosa pine had an energy density of slightly more than 1,000 Btu/ft². Mixed conifer fuels had an energy density near 2,000 Btu/ft². Dry meadow areas had energy densities between 100 and 200 Btu/ft².

Calculation of fireline intensity for specific areas of this fire demonstrates that two different types of fire can have the same resistance to control:

- a fire spreading rapidly through fuels with low energy density, and
- a fire spreading more slowly but through fuels with higher energy densities.

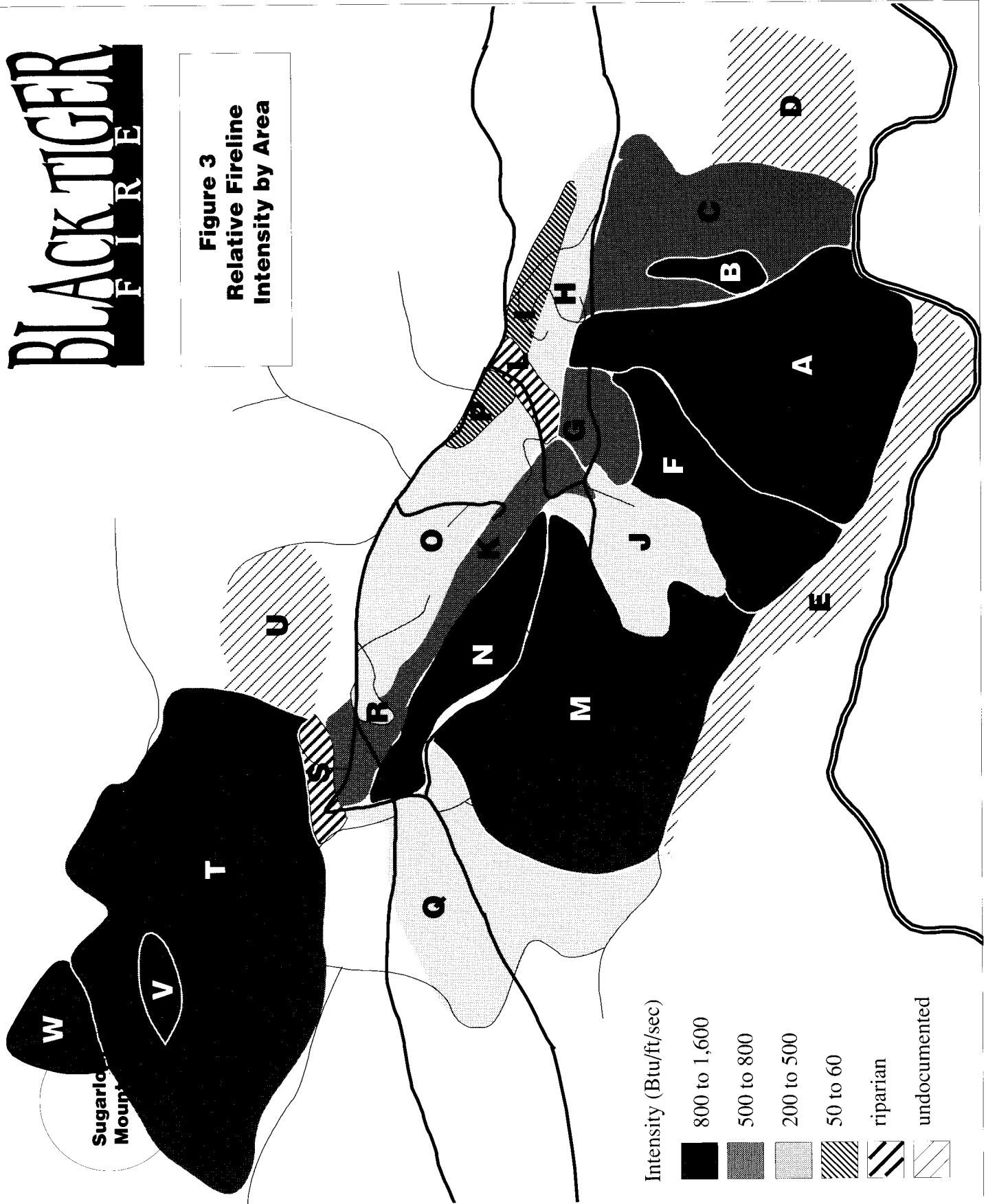
If either calculation exceeds a fireline intensity 500 Btu/ft²/sec, control is not considered possible by normal organized means.

Figure 3 shows the different fireline intensities at the Black Tiger Fire. The fire started and made an initial rapid run up Black Tiger Gulch, shown as area A. The heat from the burning brush and fallen tree debris served to ignite ladder fuels until this became a crown fire among the predominate ponderosa pine. Radio confirmation of the crown fire came at 1:10 when the fire commander reported: "We need all the help we can get as quick as you got it. We're crowning out rapidly here." At that time nothing in the terrain offered a major obstacle to slow the fire and help protect the homes uphill in the path of the fire.

Crowning generally is a two-step process. Accumulated ground material, including downed limbs and trees, burned and created intense heat to further dry out and ignite tree canopies. Where the fire burned into timber stands with tree canopies touching or intermingled, crowning occurred. Crowning could not be sustained if the ground

BLACK TIGER FIRE

Figure 3
Relative Fireline Intensity by Area



fires ran out of heavy ladder fuels. Where canopies were not touching, the crowns generally did not burn although they were usually scorched to the top. In general, however, crowning occurred in all map reference areas except I, J, L, P, Sand R. (Areas D, E and U were not as completely documented with timelines. Due to the generally lower intensities in these areas it is probable that the areas were burned by either flanking, backing or originating spot fires.)

The steep terrain and rate of spread upslope made direct fire attack on the fire's head from the point of origin impossible. No roads provided access to the area immediately above the point of origin. The fire simply outran the fire fighters who were on foot in difficult terrain, putting them into a defensive mode from the earliest minutes. Indirect attack on the flanks was not an option due to the speed of the fire and structural threats ahead of the fire.

Areas B and F were of different fuel cover type (mixed conifer), but they burned rapidly and with similar intensity to area A.

As the fire burned into more ponderosa pine-but in different topography-at areas C and G, it slowed somewhat. At a calculated fireline intensity usually above 500 Btu/ft/sec, these areas were still impossible to control.

The next defensive position was determined by the next available roadway crossing the area that would provide some ready break in the fuel and allow access by the fire equipment. Fire fighters began to race around the fire and up to Waterline Road (see Figure 1), following a ridge, which also gave them access to the first homes to be threatened by the fire. Running along the ridge top, Waterline Road connects with Lost Angel Road.

Waterline Road, however, was too narrow to allow two fire trucks to pass side by side, and it featured close-in trees and brush on both sides. Although smoke obscured the size of the fire, fire fighters could hear its roaring and determined that the fire intensity approaching them was high.

These fire fighters made a quick decision that Waterline Road was not a defensible position, due to the size of the approaching fire and the danger of having fire crews and equipment caught and overrun by the fire before they could maneuver to escape. One fire officer was almost trapped near where Waterline Road meets Lost Angel Road; he had to drive to safety through fire burning on both sides of the road.

The narrowness of Waterline Road meant

Fuel types
and their
proximity to
structures
determined
where de-
fenses might
be possible.

that its effectiveness as a fire break would be inadequate. Fire crews fell back to the next road, Sugarloaf Road. Evacuation of homeowners began, affecting about 100 homes.

All homes along Waterline Road were ultimately lost. The first radio confirmation of a destroyed home came at 1:59, the victim of fire spotting ahead of the main conflagration. Meanwhile, valuable time was gained to set up defenses for the homes along portions of Lost Angel Road and Sugarloaf Road.

Fuel types and their proximity to structures determined in large part where defenses might be possible. In areas of highest fireline intensity the fire break would have to be so wide as to be impractical with limited numbers of fire fighters. Figure 4 shows fire characteristics for fuels in areas that would be controllable by hand crews, controllable by bulldozers clearing wider breaks, and areas not controllable by any immediate means. Table 1 presents fire behavior information in a matrix form.

Reaching the eastern crest of the gulch, the fire slowed further at area H, and the fireline intensity decreased.

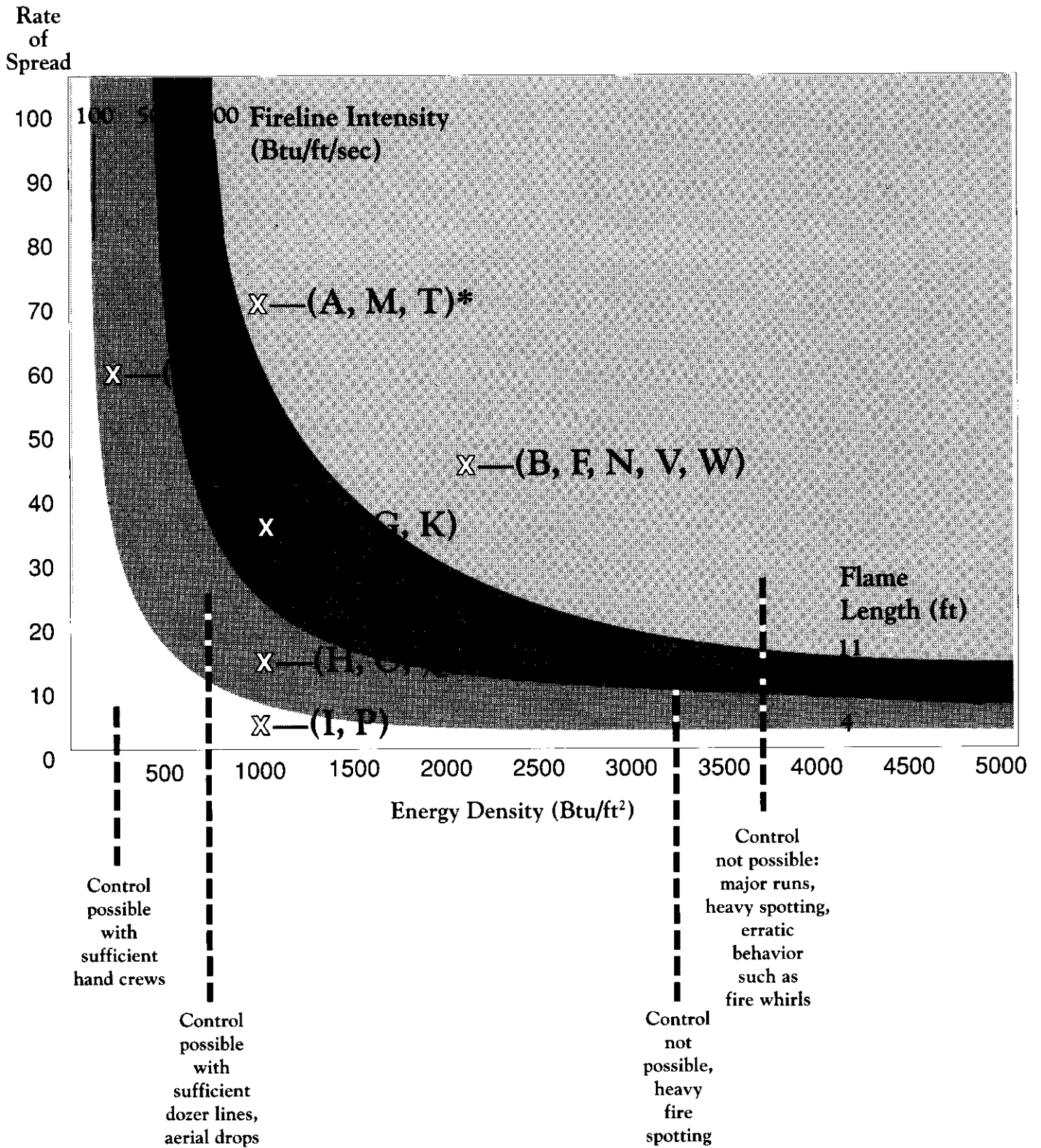
Area L represents a riparian zone of either no burning or reduced energy density. Fire extension to areas I and P beyond this riparian zone occurred from spotting over area L.

A wind shift at the top of the ridge sent the fire in a northwesterly direction. This helped lower the fireline intensity at area 0 and allowed fire fighters to protect some of the homes in the area.

More mutual-aid fire equipment arrived and was set up to fight the fire. Communications became more complex as additional units began operations. A third major stand was attempted on the east flank of the fire along Sugarloaf Road; if the fire extended far past the road, another hundred homes would have been at risk in other residential areas. Fire fighters had a chance to hold here because the area was out of the main path of the high intensity fire up Black Tiger Gulch and on up to Sugarloaf Mountain. Some homes were saved and some were lost. The outcome was often influenced by a home's location, whether construction features aided or resisted the spread of the fire, and whether human intervention was available at the critical moment. Homes farther from Sugarloaf Road and those at the end of long dead-end driveways were at a greater disadvantage and many were destroyed.

Back in the center of the main fire front, area J shows a decreased intensity due

Figure 4
Fire Characteristics Chart



* See Figure 3 for the location of these fire intensity areas.

to the lighter, dry meadow fuels found there. However, the rate of spread was increased by wind in the flashy grass fuels.

Moving again into ponderosa pine fuels with high energy density and higher rates of spread, area M shows increased fireline intensity equal to the level of area A up Black Tiger Gulch. These areas were not controllable.

For the third time, fire crews had to pull back and re-group, but the news at 2:18 was that the ETA for the closest aerial tanker was only another 10 minutes. Then at 2:21 one unit reported: "I've been advised by the [spotter] aircraft that we've got erratic fire behavior. We've got a crown fire making a run on Sugarloaf Road at this point. If you could have Nederland [Fire Department] send up their gear we're going to need it for structural protection."

Area N was similar to areas B and F, with mixed conifer fuel cover but continuing high fire intensity beyond control by available fire agencies.

In area K the fuel was again ponderosa pine but the topography and wind shift toward the west slowed the rate of spread. As in similar areas C and G, the intensity here was beyond possible control.

Area R was more dry meadow grasses with a high rate of spread but lower energy density.

Meanwhile, a Rocky Mountain Interagency Type 1 fire management team was ordered mobilized by 2:30 along with seven 20-person fire fighting crews. An additional five crews came later, and more bulldozers were brought in to cut an additional fire line. Help also came in the form of contract planes dropping fire retardant and helicopters dropping water.

Another riparian zone was at areas, where a higher proportion of homes survived than

any other area, but again spotting from areas N and K allowed the fire further to spread into ponderosa pine at area T (Sugarloaf Mountain) at an uncontrollable fireline intensity. Areas W and V showed similar intensities but were in mixed conifer fuels.

By now some 40 fire departments had responded, some from other counties. The rapid growth of the fire and the numerous mutual-aid departments made coordination and communications especially difficult. Some departments in the Boulder County Fire Association had trained together, but this fire was larger than anyone had anticipated. One result was that many fire companies were operating independently.

After 6:00 no more homes were burned. The last two homes lost were obscured by vegetation, and mutual-aid fire crews unfamiliar with the area did not see the homes until it was too late or feared that the excessive vegetation would compromise the safety of fire personnel as it began to burn. By 6:30 the fire had covered 1,500 acres.

At nightfall the fire was at the base of Sugarloaf Mountain. Three bulldozers cut one line 120 feet wide along the back side of Sugarloaf, and nighttime weather conditions contributed to a slowing of the fire's spread.

Although no more homes were lost after Sunday, the fire continued to burn hot on Monday, advancing very little. Greater state and federal fire fighting assistance on Monday helped efforts to contain the fire, as did rain showers on Tuesday. Final

control was announced on Thursday, July 13.

Figure 5 shows the location of saved and destroyed structures in relation to the areas of similar fireline intensity. Figure 6 shows the location of saved and destroyed structures in relation to the timeline of fire spread.

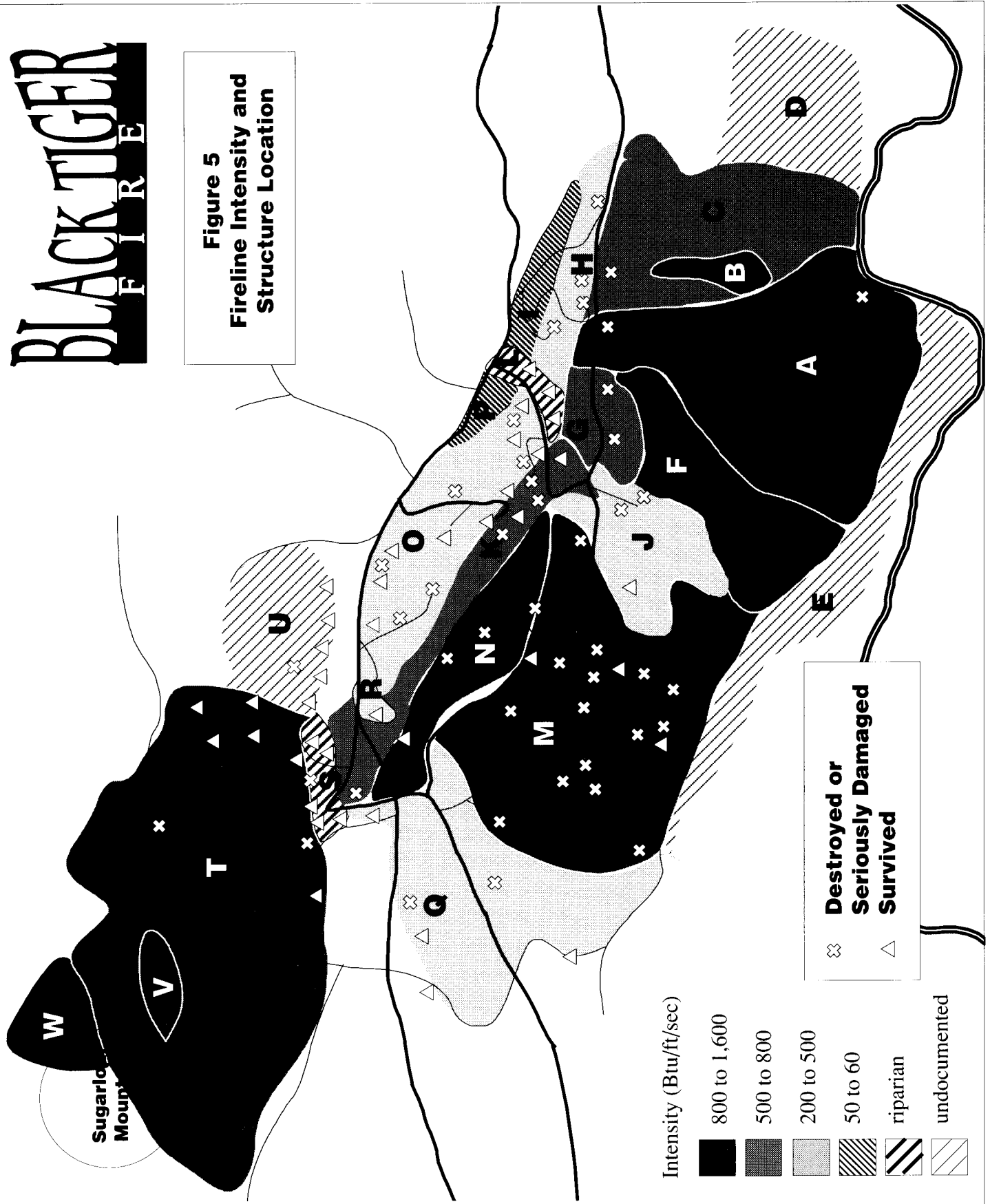
Narrow escape

The timing of this fire provided for the greatest possible number of available volunteer fire fighters on the scene in the shortest possible time. But a Sunday afternoon meant that more people were at home and at risk from a fast-spreading fire. The evacuation load was higher. One resident was burned enough to require hospitalization when he delayed his escape too long. Several others experienced the terror of a wildfire from unexpected close range.

"I barely got my - - out of there, "said one resident quoted in the newspaper. "First I smelled smoke, and then I saw flames. When I left, there were flames on both sides of the road. I was choked with smoke, and once I had to wait for a wind to blow the smoke away because I couldn't see the road. I cried like a baby when I got to the end of the road. "

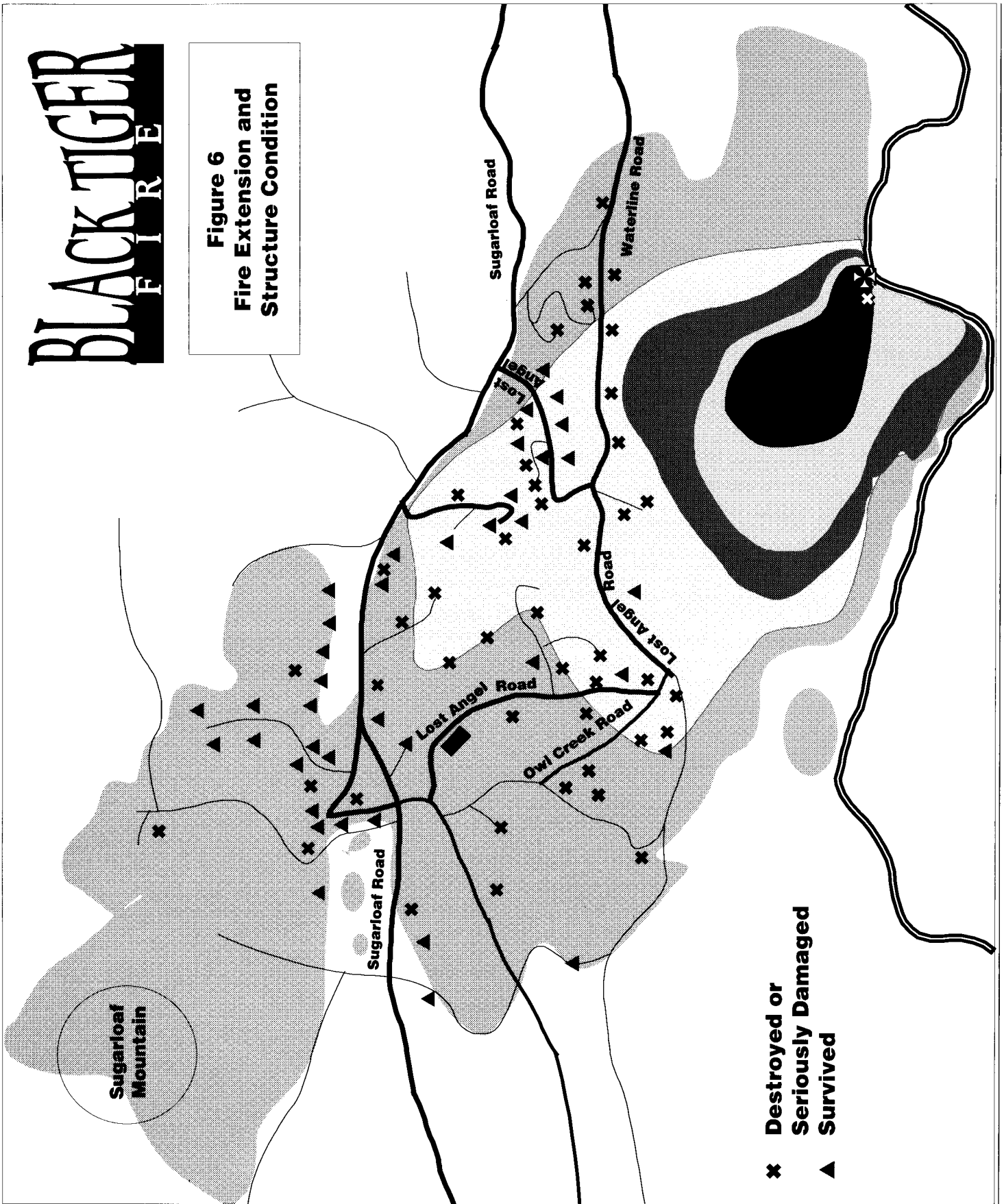
BLACK TIGER FIRE

**Figure 5
Fireline Intensity and
Structure Location**



BLACK TIGER FIRE

Figure 6
Fire Extension and
Structure Condition



**x Destroyed or
Seriously Damaged**
▲ Survived

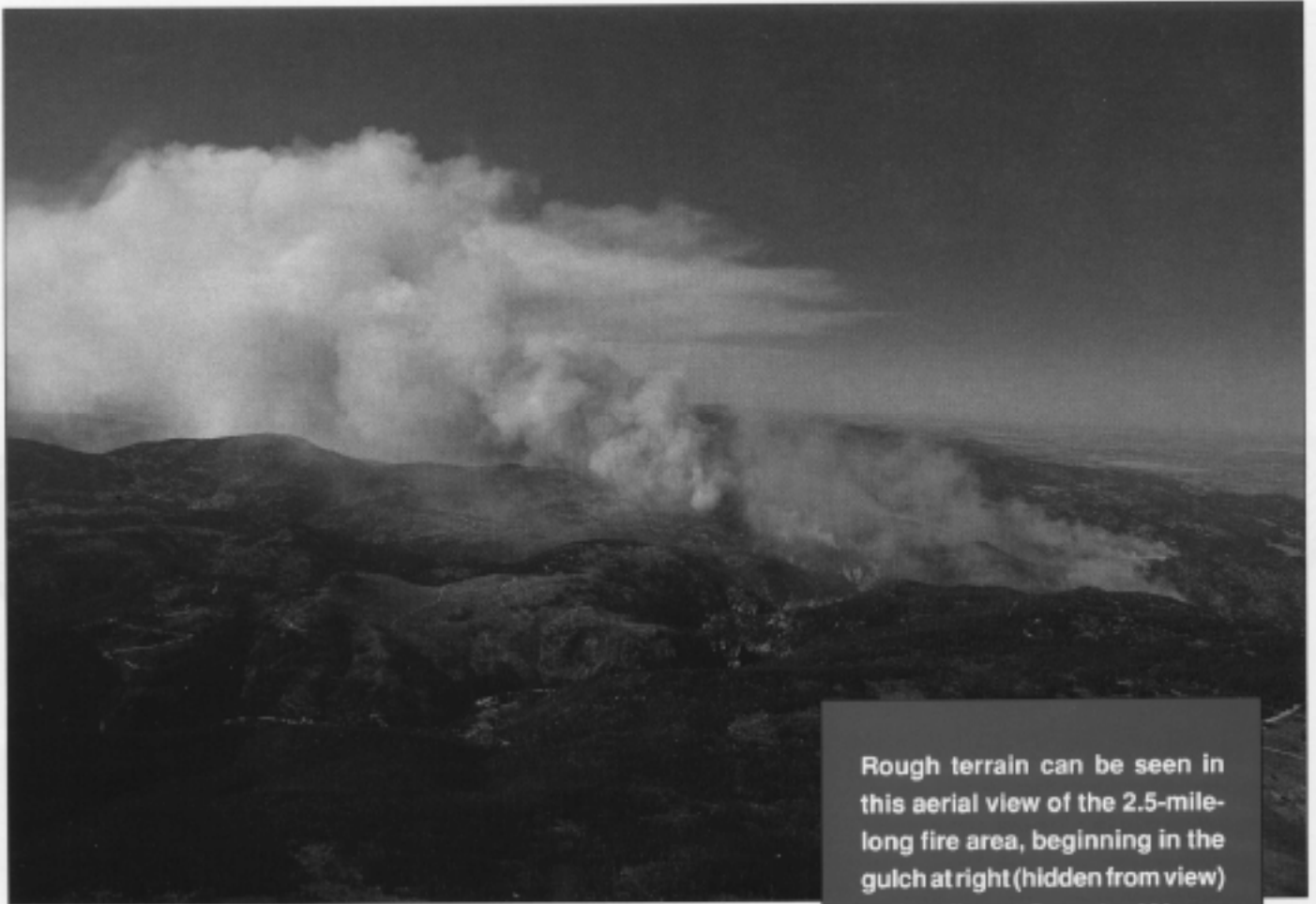


Photo by Shaun Stanley, *The Denver Post*

Rough terrain can be seen in this aerial view of the 2.5-mile-long fire area, beginning in the gulch at right (hidden from view) and ending at Sugarloaf Mountain to the left.



Lack of clearance between combustible wildland vegetation and combustible building materials is a frequent reason for the loss of homes in the wildland/urban interface.

Photo by NFPA

Air tanker drops fire retardant on the slope leading to a scenic homesite. The trees, slope and combustible exterior of many homes made defense impossible without major commitment of planes and other major equipment not always readily available.



Photo by David P. Gilkey, *Boulder Daily Camera*



Photo by Jerry Cleveland, *The Denver Post*

After the fire passed, the sloping terrain and what is left of the tree cover can be seen. A home—once nestled in the foreground trees—has been reduced to a minimum pile of ashes.



Bulldozers clearing fire breaks were an important asset in controlling the fire spread, although bringing them to the scene of a major fire can be time consuming.

Photo by David Denney, *The Denver Post*

Fire fighters on the ground were able to save this home despite its combustible roofing, exterior siding and open decks. The critical factors were a cleared defensible space facing the fire, good access for available fire fighters and sufficient water supply brought in by tankers. Take away any one of these and the home probably would have been lost.



Photo by David Denney, *The Denver Post*



A resident looks for something to salvage, but the high intensity fire in this area left behind very little except family memories.

Photo by David P. Gilkey, Boulder Daily Camera



Neighbor consoles neighbor. Most residents have said they will rebuild, but will the new homes be constructed with firesafety in mind?

Photo by Jerry Cleveland, The Denver Post

ANALYSIS

This wildfire resulted in the loss of more homes and other structures than at any other time in Colorado wildfire history. The significance of this fire is that similar conditions exist elsewhere in Colorado and in other states.

One of the most frequent comments offered by homeowners in explanation for not preparing for a wildfire is that the fire department will “handle” the fire. Once ignited and without immediate attack, however, a fire under the conditions found in Black Tiger Gulch on this July day would have been unstoppable by any available fire fighting forces.

The major factors contributing to this fire and the loss of structures are numerous:

Weather conditions. The hot, dry, windy weather lowered fuel moistures and prepared the area vegetation for easy ignition and rapid fire spread. These conditions occur seasonally in Colorado and elsewhere. Fire protection agencies can predict when these conditions present the greatest fire danger but cannot otherwise control them. Homeowners who wait for an announcement of high fire danger to prepare their properties have lost the time for appropriate and thorough preparation.

Topography. The steep topography of Black Tiger Gulch created a chimney effect that funnelled the fire toward homes at the top of the canyon. The direction of the prevailing winds, the direction of the slope, and the normal rise of heated air combined to increase strong upslope winds that pushed heat closer to unburned fuels ahead of the flames, pre-heating the fuels and accelerating the combustion process.

Fuel types and densities. Fuel types in the area contributed to the unmanageable intensity of the fire. Fuel types have been rated according to their relative wildfire hazard. Ponderosa pine, Douglas fir and mixed conifer are rated in the highest hazard category. The fire stated in an area where ponderosa pine

predominates. When the fire reached the next fuel type it was mixed conifer, which continued to feed fire intensities impossible to control. Table 1 and Figure 4 describe areas of fuel types and resulting fireline intensities.

Fuel arrangement. Fuel arrangement facilitated the conversion of a surface fire to a crown fire, The lack of small, natural, or controlled fires or vegetative management measures in the area resulted in a heavy forest litter buildup of dead trees, limbs and brush. These fuels, in conjunction with remaining low branches of live trees, formed ladder fuels. The dead forest litter was also more susceptible to drying out from decreased atmospheric humidity than live fuels. If this surface litter had been replaced with vegetation of low energy density, crowning would not have been sustained, (Note: Extremely dry live fuels could sustain a crown fire despite removal of combustible litter. Also, complete removal of needles and other vegetation could contribute to soil erosion.).

Fire spotting. Crown fires in dried fuels under windy conditions caused fire spotting ahead of the main fire front and further accelerated fire spread, as well as expanded the affected area. This exposed more homes to the fire while reducing the time available for fire fighters to respond to each new outbreak. The additional fires diluted the number of available fire fighters for each particular burning area. Fire conditions leading to spotting also reduced the effectiveness of firelines, roads and other fuel-free areas normally expected to help slow or stop a spreading wildfire. Aerial observation indicated that fire spotting occurred as far as one-third of a mile ahead of the main fire front.

Construction features. Homes in the path of the highest fire intensity were often not savable regardless of total fire suppression efforts. Given the quantity and type of fuels in the fire zone, the amount of radiant energy

Aerial
reconn-
aissance
indicated
burning roofs
a quarter-mile
or more
ahead of the
main fire
front.

**Table 1
Fire Behavior Matrix**

Map Ref. Area	Fuel Cover Type	Fire Type	Rate of Spread (ft/min)	Fuel Energy Density (Btu/ft ²)	Fireline Intensity (Btu/ft/sec)
A	ponderosa pine	crown	60-80	947-1220	947-1630
B	mixed conifer	crown	30	2010	1000
C	ponderosa pine	crown	30	947-1220	474-610
D	ponderosa pine	unknown	—	947-1220	—
E	ponderosa pine	unknown	—	947-1220	—
F	mixed conifer	crown	30	2010	1000
G	ponderosa pine	crown	40	947-1220	630-813
H	ponderosa pine	crown	15	947-1220	237-305
I	ponderosa pine	crown	3	947-1220	47-60
J	dry meadow	surface	60-80	103	103-140
K	ponderosa pine	crown	30	947-1220	474-610
L	moist riparian	—	—	—	—
M	ponderosa pine	crown	40-55	947-1220	630-1120
N	mixed conifer	crown	45	2010	1500
O	ponderosa pine	crown	10	947-1220	160-200
P	ponderosa pine	crown	3	947-1220	47-60
Q	ponderosa pine	crown	25	947-1220	390-510
R	dry meadow	surface	60-80	103	103-140
S	moist riparian	—	—	—	—
T	ponderosa pine	crown	45	947-1220	710-915
U	ponderosa pine	unknown	—	947-1220	—
V	mixed conifer	crown	45	2010	1500
W	mixed conifer	crown	45	2010	1500

generated could ignite combustible homes across normally recommended firebreaks. In most cases the survival or destruction of a home was affected not by a single factor but by the combined effects of multiple factors. For a more in-depth examination, refer to the following section, "Statistical Analysis of Factors in Damaged Homes."

Figure 7 shows the location of 28 structures selected for detailed study of multiple construction features and loss factors.

Table 2 shows the features of the 28 homes selected for detailed comparison. The most consistent factor associated with structure loss of the studied homes in this fire was the distance of the homes from adjacent combustible vegetation. In every case except one, the proximity of homes to wildland fuels was 20 feet or less. One structure (map reference number 171) had the advantage of an adjacent moist riparian zone, but combustible vegetation was allowed to grow to within 5 feet of the structure.

Table 2 also shows a high occurrence of wood exterior construction and open wood decks, porches or balconies, which can provide a ready source of easily ignitable fuel. Decks, porches and balconies can serve as an easy path for burning vegetation to reach structures, and they are vulnerable to wind-carried brands from the main fire front. Such decks become even more hazardous when the areas underneath them are used to store combustibles such as firewood.

The multiple-factor effect can be seen in several examples. Structures 5 and 6 in Table 2 had metal roofs, which provide an extra measure of protection compared to combustible roofing. However, in both cases combustible vegetation was only 5 feet away when the fire front moved through. Structure 5 was adjacent to dry meadow fuels that produced a relatively low fireline intensity, but the home had an open pier foundation that allowed rapid ignition.

On the other hand, map reference 3 was on a 10 percent slope adjacent to mixed conifer fuels that produced some of the highest intensity flame of the entire incident. The rate of spread was a rapid 45 feet per minute, and flame length was at 11 feet. Yet, unique among

the studied structures, this property owner had a cleared fuel break of 75 feet in front of the approaching fire. The roof was asphalt and was wetted down by the owner before he evacuated. Although radiant heat caused heavy damage, the structure survived.

Structures 17 and 28 were saved by fire department action along Lost Angel Road, where a stand was attempted after waterline Road had to be abandoned. Number 17 had a wood shingle roof but stucco exterior and no open deck. Although adjacent vegetation came to within 5 feet of the home, the fuel bed was a riparian zone and the approaching fire was on the ground, not in the crowns. The resulting fireline intensity was a manageable 100 Btu/ft/sec and good access allowed fire fighters to save the home with damage to the roof. Only

one studied home faced fireline intensities lower than 100 Btu/ft/sec. Number 7 shows a low fireline intensity of 60 with a rate of spread of only 3 feet per minute, but fire department action was at a disadvantage because the fire reached the area before full mobilization was possible and the long dead-end driveway discouraged entry by emergency vehicles. Furthermore, vegetation clearance was only 5 feet from a combustible exterior on a slope of 20 percent. As a result, the home was lost.

Number 27 showed the benefit of fire department and owner action. Its location meant that the fire did not reach it for

several hours, giving time for fire fighters to better organize defenses and bring in bulldozers to build firebreaks. A fireline was cleared 200 feet from this home and the owner stayed to extinguish spot fires. The owner had also prepared the site by removing trees and limbs killed by beetle damage, although some vegetation remained as close as 10 feet.

Fire department intervention was attempted at number 26, where another bulldozer began to clear a fireline. However, this was an area of the highest intensity of the fire (1500 Btu/ft/sec) and vegetation was as close as 5 feet from the structure, which also had open wood decks on two levels. The bulldozer had to abandon the line due to the high intensity and rapid spread of the fire. The home was destroyed.

-continued on page 30

Editorial

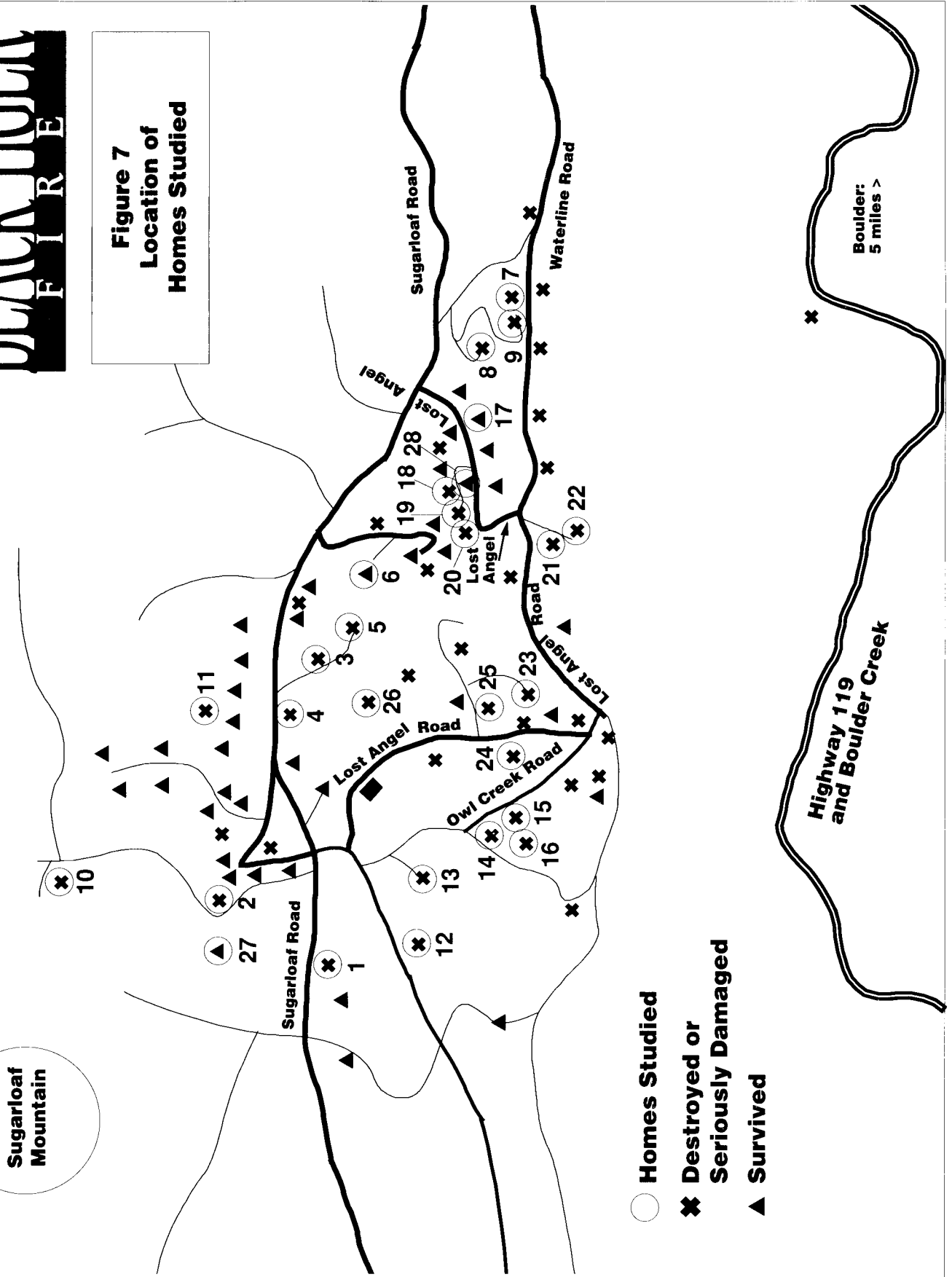
"Our foothills and canyons are a beautiful and often perilous place to live. Many people who choose to do so take prudent steps to protect their property. Others, as officials working the Sugarloaf fire pointed out, have not done so, making efforts to save their homes futile.

"As we have stated here before, the City of Boulder has devoted countless hours and resources to preparing for a flood that may come this year or in a century from now. A similar effort has not been made to anticipate and mitigate the results of the fires that flare up in the hills every year."

-Boulder *Daily Camera*,
July 11, 1989

BLACK TIGER FIRE

Figure 7
Location of
Homes Studied



- Homes Studied
- ✕ Destroyed or Seriously Damaged
- ▲ Survived

Table 2
Home Features and Loss Factors Matrix, part 1

Map Reference	Roof Material	Eaves Open/Closed	Deck/Porch /Balcony	Exterior Construction	Dead End Distance	Slope %	Vegetation Type	Clearance from Veg.
1	asphalt	closed	y	wood	150	5	p.pine	10
2	asphalt	closed	n	wood	1100	15	p.pine	10
3	asphalt	closed	n	concr./wood	1000	10	mix. conif.	75
4	asphalt	open	y	wood	150	15	dry mead.	5
5	metal	none	y	wood	1200	5	dry mead.	5
6	metal	none	y	metal	2000	0	p.pine	5
7	asphalt	open	n	wood	1800	20	p.pine	5
8	wood	closed	y	wood	2000	5	p.pine	5
9	wood	closed	y	wood	1200	20	p.pine	10
10	wood	open	y	wood	4200	15	mix. conif.	10
11	asphalt	closed	y	wood	1200	10	p.pine	15
12	asphalt	closed	y	wood	900	10	p.pine	10
13	asphalt	closed	y	metal	1200	10	p.pine	20
14	asphalt	open	y	wood	100	10	p.pine	10
15	asphalt	closed	y	wood	600	25	p.pine	15
16	asphalt	closed	y	wood	850	15	p.pine	20
17	wood	closed	n	stucco	250	15	riparian	5
18	wood	closed	y	wood	500	20	p.pine	20
19	asphalt	closed	y	wood	800	20	p.pine	15
20	asphalt	closed	y	wood	200	35	p.pine	20
21	metal	none	n	wood logs	400	10	dry mead.	5
22	asphalt	open	y	wood	900	10	mix. conif.	5
23	wood	closed	y	wood	600	15	p.pine	5
24	asphalt	closed	n	wood	300	0-5	p.pine	10
25	asphalt	closed	y	wood	300	0-5	p.pine	20
26	asphalt	open	y	wood	200	15	mix. conif.	5
27	asphalt	open	y	wood logs	900	15	mix. conif.	10
28	wood	closed	y	wood	200	20	p.pine	10

Table 2
Home Features and Loss Factors Matrix, part 2

Map Ref.	Fire Type	Flame Length (ft)	Rate of Spread (ft/min)	Fireline Intensity (Btu/ft/sec)	Notes on Loss
1	heading surface	6-8	25	40	total -limited defensible space, open wood deck
2	heading crown	9-11	45	800	total -high intensity fire, limited def. space
3	heading crown	11	45	1500	saved -hvy. damage, large def. space, owner wet roof
4	flanking surface	4	80	140	total -rap. spread thru grassy slope, open wood porch
5	heading surface	4	60	120	total -limited def. space, open pier foundation
6	heading crown	8	30	600	total -high intensity fire, limited def. space, deck
7	flanking crown	2-4	3	60	total -steep slope, limited def. space, long driveway
8	heading crown	4-6	15	300	total -wood roof, limited def. space, gone in 15 min.
9	heading crown	4-6	15	300	total-wood roof, slope, little def. space, poor access
10	heading crown	11	45	1500	total-intense fire, wood roof & deck, poor access
11	flanking surface	4	15	250	total-fire spotting, limited def. space, open wood deck
12	heading surface	68	25	450	total-limited defensible space, heavy veg., open deck
13	heading surface	68	25	450	total-owner action too late, limited space, balcony
14	heading crown	10	45	900	total-intense fire, limited space, open wood deck
15	heading crown	8	45	800	total-3 bldgs, limited def. space, open deck
16	flanking surface	68	25	450	total-garage only, more def. space saved home
17	heading surface	2	10	100	saved, wood roof damage-FD exting., access good
18	flanking surface	4	10	180	total-fire spotting to wood roof, open deck
19	flanking surface	4	10	180	total-spotting, open deck, long dead-end driveway
20	heading crown	10	3	540	total-spotting, steep slope, open deck, wood exterior
21	heading surface	10	70	140	total-wood foundation, limited def. space, grassy slope
22	heading crown	10	60	1000	total-intense fire, limited def. space, comb. constr.
23	heading crown	10	47	875	total-limited def. space, open wood decks, intense fire
24	heading crown	10	47	875	total-heavy surr. vegetation, intense fire, wood constr.
25	heading crown	10	47	875	total-intense fire, limited def. space, open wood deck
26	heading crown	11	45	1500	total-fire line unsucc., intense fire, limited def. space
27	flanking surface	4	25	450	saved-successful owner & FD dozer line intervention
28	flanking surface	4	10	180	saved-garage damage only, FD used hot tub water

Map reference 28 denotes a home saved with damage to the garage only. Lost Angel Road helped slow the fire in this area, which had an intensity of only 180. However, total loss would have resulted without fire department intervention, due to the close proximity of combustible vegetation and the wood roof and exterior. Combustible materials were also stored adjacent to the garage. Although fire department personnel were available here, water tankers were not, so fire fighters extinguished the garage fire with water from the owner's hot tub.

■ **Command and control.** The rapid growth of the fire required a multijurisdictional fire attack that complicated the command structure and strained communications capabilities.

After the fire made its first rapid run across a broad front where fire intensities were especially devastating, fire fighting forces were still not available in sufficient time and number to simultaneously protect all remaining homes and continue the broad attempt to stop the wildfire. Mutual aid fire departments can provide critical assistance when a major fire threatens a single jurisdiction. In this case several fire departments had trained together to handle a major fire, but the unprecedented size of this fire caused unexpected problems.

The radio command channel was occasionally overwhelmed due to the quantity of messages attempted. On several occasions the communications center tried to remind personnel to reserve the command channel for critical communications and to use other channels for local coordination. One of the recommendations from local critiques of the fire suppression activities was to acquire a repeater radio channel for better penetration and coverage in mountainous areas.

With radio communications strained, many mutual-aid departments were left to operate independently after being assigned a general area. Local coordination of ground and aerial water tankers, evacuation, and awareness of the fire's overall progress were hampered. Mutual-aid departments were not as familiar with the area as the home department. Another recommendation from the local critique of the fire suppression activities was in the future for each fire district to prepare maps of their own area to present to arriving mutual-aid departments.

So that mutual-aid personnel could be tracked better, it was suggested that a check-in sheet listing all responding personnel be carried on each apparatus for collection at the staging area.

Some requested mutual-aid departments could provide only limited assistance to this fire area because of a concern that the fire would extend into their own areas.

■ **Emergency access.**

Roadways and restricted driveways to homes limited response and operational choices of fire fighters. The mountainous terrain featured roads that twisted to follow the hillsides and ridges. Old mining activity influenced the location of many roads, which in some cases followed the same paths used by horse-drawn wagons. Although paved, these roads typically were not widened sufficiently for easy use by large emergency vehicles.

Fire command officials reported making some decisions to defend or sacrifice individual homes based on their accessibility. If there was a danger of fire crews or apparatus becoming trapped from rapid fire blowup - or the structure was prone to especially easy and rapid ignition, such as with wood shingle roofs - then the structure would more likely be abandoned,

Mountain Residents Must Take Care

"The recent fire on Sugarloaf Mountain and the continuing concern for the residents who lost homes or who had severe fire damage has bothered me.

"While I feel deeply for those who lost their homes, there does not seem to be any assignment of blame on those who build in a wooded area and take no precautions to protect their investment.

"Gov. Romer is proposing small business loans and other relief for those people who had no insurance or were underinsured. I believe this type of concern dilutes the responsibility homeowners must take to protect their property..

"People who choose to build in flood plains, at or near the end of runways, or in wooded areas must assume the consequences of the risks they take."

*-Dave Haughey
July 20, Fort Collins*

Letter to the Editor The Denver Post, July 26, 1989

Statistical Analysis of Factors in Damaged Homes

Table 2 provided a two-part matrix overview of home features and loss factors for the 28 houses that were badly damaged or destroyed and for which detailed information was available. It may be seen from the fireline intensity column that these homes include some where the fire was so severe that no combination of home features and fire department response could be expected to prevent destruction. The other homes, where the fire was less severe, are likely to have suffered losses that were more sensitive to their home features and fire department response, because the lesser fire severity left the outcome more in doubt.

The deciding line for these two groups may be drawn at 500 Btu/feet/second, because, according to Richard Rothermel of the U.S. Forest Service, fires of this severity are usually beyond control by any manual means. Tables 3 and 4 therefore divide the 28 homes into a group of 17 that encountered fireline intensities of at least 500 Btu/feet/second and 11 that encountered lesser intensities.

To further support an explanatory statistical analysis, the major factors also have been divided into "good" and "bad" groups. For roof materials and exterior construction, wood is bad and anything else is good. For eaves, open is bad and closed or none is good. For decks, porches and balconies, having one is bad and not having one is good. All of these reflect significant differences in the vulnerability of exposed exterior features to ignition by an established hostile fire.

The lead investigator determined 200 feet is the maximum dead-end road access distance that could be called good under these severe burning conditions. A slope of 20% or more was categorized as bad, and a good rating on clearance from vegetation required at least 30 feet distance.

With this scheme, it may be seen that the 17 homes facing the more severe fire averaged 3.1 good ratings out of seven possible, while the 11 homes facing the less severe fire averaged 2.5 good ratings out of seven. This is consistent with the hypothesis that a very severe fire will overpower even a "good" home, while a less severe fire will be more likely to need some flaws in the home design and/or maintenance to support spread to the home.

Because only 28 homes were in the study

A less severe
fire will be
more likely to
need some
flaws in the
home design
and/or maintenance to support spread to
the home.

and some of the factors do not divide sharply into "good" and "bad" categories, a statistical analysis has to be considered tentative, exploratory and illustrative. Nevertheless, the results of this exercise are plausible and should provide food for thought. Some factors (e.g., dead-end distance, clearance from vegetation) can be seen as potentially important because they were rated as bad in nearly all cases. Other factors (e.g., wood roofs, slope) often were not bad in homes when the fireline intensity made severe or total damage a nearly foregone conclusion but often were bad in homes where the fire intensity left the outcome more in doubt. Specific findings and comments on each factor are as follows:

Roof Material

For more severe fires, 15 of 17 homes (88%) had good roofs, while for less severe fires, only 6 of 11 homes (55%) had good roofs. This 33 percentage point spread was the largest spread for any factors (although slope showed the same spread).

Put simply, in a very severe fire area, homes didn't need to have untreated wood shingle roofs to succumb to fire. In a less severe fire area, it was much more likely that an untreated wood shingle roof was there to facilitate the entry of the fire into the house. The 33 percentage point spread is evidence that this was one of the most important factors in the damage to those homes where the outcome was most sensitive to home features.

Important as it was, there is reason to believe that the potential hazard created by untreated wood shingle roofs did not more fully emerge in this fire, as it has in previous fires, because of the happenstance of prevailing wind velocity. In the most serious wildfires of recent decades where untreated wood shingle roofs were a major spread factor, wind velocity had been much higher than the roughly 10 to 15 mile per hour rate in the Black Tiger fire. For example, the \$50 million Anaheim, California, fire in 1982 featured gusts up to 60 miles per hour. In such conditions, not only the flammability of untreated wood shingles but also their suitability as a source of flying brands create a role as vector of extensive fire spread that can be even clearer and more unmistakable than was the case in the Black Tiger fire.

NFPA maintains records of a distressing number of large-loss multiple structure fires where untreated wood shingle and shake roofing was a contributing factor. More recent examples include fires at Davis, California, March

Table 3
Home Features Rated (Fireline Intensity At Least 500Btu/feet/second)

Map Ref.	Degree of Loss	Roof Material	Eaves Open/Closed	Deck/Porch /Balcony	Exterior Construction	Dead End Distance	Slope %	Clearance from Veg.
1	Total	Good (Asphalt)	Good (Closed)	Bad (Yes)	Bad (Wood)	Good (150')	Good (5%)	Bad (10')
2	Total	Good (Asphalt)	Good (Closed)	Good (No)	Bad (Wood)	Bad (1100')	Good (15%)	Bad (10')
3	Saved	Good (Asphalt)	Good (Closed)	Good (No)	Good (Con/Wd)	Bad (1000')	Good (10%)	Good (75')
6	Total	Good (Metal)	Good (None)	Bad (Yes)	Good (Metal)	Bad (2000')	Good (0%)	Bad (5')
10	Total	Bad (Wood)	Bad (Open)	Bad (Yes)	Bad (Wood)	Bad (4200')	Good (15%)	Bad (10')
12	Total	Good (Asphalt)	Good (Closed)	Bad (Yes)	Bad (Wood)	Bad (900')	Good (10%)	Bad (10')
13	Total	Good (Asphalt)	Good (Closed)	Bad (Yes)	Good (Metal)	Bad (1200')	Good (10%)	Bad (20')
14	Total	Good (Asphalt)	Bad (Open)	Bad (Yes)	Bad (Wood)	Good (100')	Good (10%)	Bad (10')
15	Total	Good (Asphalt)	Good (Closed)	Bad (Yes)	Bad (Wood)	Bad (600')	Bad (25%)	Bad (15%)
16	Total	Good (Asphalt)	Good (Closed)	Bad (Yes)	Bad (Wood)	Bad (850')	Good (15%)	Bad (20')
20	Total	Good (Asphalt)	Good (Closed)	Bad (Yes)	Bad (Wood)	Good (200')	Bad (35%)	Bad (20')
21	Total	Good (Asphalt)	Bad (Open)	Bad (Yes)	Bad (Wood)	Bad (900')	Good (10%)	Bad (5')
23	Total	Bad (Wood)	Good (Closed)	Bad (Yes)	Bad (Wood)	Bad (600')	Good (15%)	Bad (5')
24	Total	Good (Asphalt)	Good (Closed)	Good (No)	Bad (Wood)	Bad (300')	Good (0-5%)	Bad (10')
25	Total	Good (Asphalt)	Good (Closed)	Bad (Yes)	Bad (Wood)	Bad (300')	Good (0-5%)	Bad (20')
26	Total	Good (Asphalt)	Bad (Open)	Bad (Yes)	Bad (Wood)	Good (200')	Good (15%)	Bad (5')
27	Saved	Good (Asphalt)	Bad (Open)	Bad (Yes)	Bad (Wd logs)	Bad (900')	Good(15%)	Bad(10')

Table 4
Home Features Rated (Fireline intensity Less Than 500Btu/feet/second)

Map Reference	Degree of Loss	Roof Material	Eaves Open/Closed	Deck/Porch /Balcony	Exterior Construction	Dead End Distance	Slope %	Clearance from Veg.
4	Total	Good (Asphalt)	Bad (Open)	Bad (Yes)	Bad (Wood)	Good (150')	Good (15%)	Bad (5')
5	Total	Good (Metal)	Good (None)	Bad (Yes)	Bad (Wood)	Bad (1200')	Good (5%)	Bad (5')
7	Total	Good (Asphalt)	Bad (Open)	Good (No)	Bad (Wood)	Bad (1800')	Bad (20%)	Bad (5')
8	Total	Bad (Wood)	Good (Closed)	Bad (Yes)	Bad (Wood)	Bad (2000')	Good (5%)	Bad (5')
9	Total	Bad (Wood)	Good (Closed)	Bad (Yes)	Bad (Wood)	Bad(1200')	Bad (20%)	Bad (10')
11	Total	Good (Asphalt)	Good (Closed)	Bad (Yes)	Bad (Wood)	Bad(1200')	Good (10%)	Bad(15')
17	Saved	Bad (Wood)	Good (Closed)	Good (No)	Good (Stucco)	Bad (250')	Good (15%)	Bad (5')
18	Total	Bad (Wood)	Good (Closed)	Bad (Yes)	Bad (Wood)	Bad (800')	Bad (20%)	Bad (20')
19	Total	Good (Asphalt)	Good (Closed)	Bad (Yes)	Bad (Wood)	Bad (800')	Bad (20%)	Bad (15')
21	Total	Good (Metal)	Good (None)	Good (No)	Bad (Wd logs)	Bad (400')	Good (10%;	Bad (5')
28	Saved	Bad (Wood)	Good (Closed)	Bad (Yes)	Bad (Wood)	Good (200')	Bad (20%)	Bad (10')

14, 1988; Dallas, Texas, March 21, 1983; Anaheim, California, April 21, 1982; Tulsa, Oklahoma, April 5, 1980; Los Angeles, California, November 16, 1980. Each large loss fire in the record has reported damages of \$500,000 or higher. Brush fires involving wood-shingle roofing in San Bernardino, California, destroyed 290 homes in 1980 and destroyed 239 homes in Santa Barbara, California, in 1977.

Other Exterior Features

The presence of decks, porches or balconies, and the use of wood in exterior construction were problems for the overwhelming majority of homes, regardless of fire severity, so the differences between more-severe and less-severe fires were modest and not always in the expected direction. Open eaves were rare in both cases. A statistical analysis alone would find little evidence to focus attention on any one of these features, not because they were not important in fire development, but because they tend to vary together. Among the less-severe fire intensity cases, for example, seven of 11 had used exterior wood construction; a deck, porch, or balcony; and open or no eaves. Seven of the 17 more-severe fire cases had the same combination. This fairly standard construction approach was sufficiently popular and the alternatives to it were sufficiently varied that it proved too difficult to get a clear statistical reading on differences in importance of these three features. Their collective importance in fires of this type is not an issue, of course, and is apparent in the descriptions of fire development in the individual homes.

Access Road Dead End Distance

Little emerged statistically on this factor because nearly all the homes were at a distance

where fire department access was likely to be impaired. Only four of the 17 more-severe fires (24%) and two of the less-severe fires (18%) showed acceptable distances, and half of these had distances right at the assumed upper limit of 200 feet.

Slope

With wood roofs, slope was the other factor that clearly discriminated between more-severe and less-severe fire intensities. In more-severe fire intensity areas, 15 of 17 homes (88%) had good slopes of 15% or less, while only six of 11 homes (55%) in less-severe fire intensity areas had these lower slopes. A large percentage point difference (17 percentage points) also exists if slopes of 15% and higher are regarded as bad. Therefore, it appears that more-severe fire intensity areas were able to overpower homes even when slopes were mild, while less-severe fire intensity areas were more likely to need, or at least to benefit from, the steeper slopes to involved homes.

Clearance from Vegetation

Nothing could be said statistically about this factor because only one home in 18 had an acceptable clearance factor. It is worth noting that the one home, which also was the only home to rate good on all four exterior features, was also one of only two homes to be saved from serious or total destruction in the face of a more-

severe fire. In fact, the fireline intensity for that fire was the highest recorded; only three homes were faced with that severe a fire intensity. This case - Figure 7, map reference 3 - can be counted as a partial success story, illustrating the potential impact of good fire protection design and practices to help defend homes in an urban/wildland interface.

Your Chance to Become Involved in the Process

NFPA 299, Protection of Life and Property from Wildland Fire, when completed and when adopted by a local jurisdiction will be an important foundation for a majority of the factors discussed above and for the recommendations listed on the following pages. Its stated purpose is to 'provide criteria for fire agencies, land use planners, architects, developers, and local government for fire safe development in areas which may be threatened by wildfire. "Its continuing development mirrors the first recommendation from this section: namely, that the best way to solve a complex problem is to apply the combined efforts of representatives from all affected groups. Indeed, the particulars of NFPA 299 are still being considered prior to final issuance in 1991, and the NFPA standards-making system is designed to facilitate input from all the interested parties listed.

To learn more about the current status of NFPA 299 or about how you could provide input to the proposed standard, contact the Public Fire Protection Division of NFPA at 1 Batteymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

RECOMMENDATIONS

Tragic losses of homes in the wildlands are preventable. However, **combined** efforts of the community organizations; fire services; federal, state and local governments; and individual homeowners are necessary to minimize losses.

The Black Tiger Fire has resulted in a greater local and statewide awareness of the problems associated with the wildland/urban interface. Nevertheless, a continuing and expanded effort must be undertaken to inform the public nationwide of the potential hazards involved in interface areas, to inform them of how they can assess the hazards in their area, and to assist them in alleviating the hazards. Clearly, this effort cannot be accomplished by just the individual efforts of one of the listed groups.

Fire Protection Agencies

Fire protection agencies are the groups with the greatest knowledge of and experience with the current wildland/urban interface fire problem. Actions need to be taken by these agencies to further prepare themselves, as well as the people they protect, from the identified fire hazards associated with the wildland/urban interface. The public and lawmakers also rely on the fire service of the community to inform them of fire protection risk and mitigation strategies.

✓ Fire protection agencies need to conduct an assessment of the particular risks present in their jurisdictions and prepare a strategic plan to reduce those risks. The plan should answer these questions: Are there measures currently within their jurisdiction to prevent construction of easily ignitable homes or that provide adequate access to them for fire suppression purposes? Which homes can be defended during a wildland fire without jeopardizing the safety of fire crews? Also, as part of this assessment, a baseline study to determine the level of awareness of the public concerning these issues should be accomplished.

✓ Once the prospects for local wildland/urban interface fire disaster is known, specific training should be conducted to prepare fire suppression agencies for the fires that can be expected,

✓ *"Fire protection agencies need to conduct an assessment of the risks present in their jurisdictions and prepare a strategic plan to attack those risks."*

✓ If wildland fire agencies may be called upon to fight structure fires within wildland areas, they should arrange for the necessary cross-training and equipment (including communication equipment) to deal effectively with that type of fire fighting.

✓ Conversely, if structural fire agencies maybe called upon to fight wildland fires that threaten structures, they should arrange for the necessary cross-training and equipment to deal effectively with wildland fire fighting.

✓ As the fire fighters discovered in the early minutes of the Black Tiger Fire, conditions may be present that make it virtually impossible for available forces to quickly control a wildfire. Therefore, fire agencies should concurrently train the public to prevent fires and to react properly when a fire occurs.

✓ A fire prevention and public education effort should combine direct-contact training with the distribution of additional informational materials to those individuals who may not initially respond to the offer of direct training. Libraries are also willing to retain or distribute provided materials. The details of this public education effort will depend on the results of the local assessment of the wildland/urban interface risks present.

✓ Fire agencies should determine what interagency cooperative agreements are

needed to improve multijurisdictional coordination in both fire prevention efforts and fire suppression. Major fires will require this combined attack, and when the fire occurs it is too late to begin the preparations for different organizations to work together effectively.

✓ Fire agency personnel should become better aware of the political process that influences items varying from agency funding to fire safety and building code regulations. Agencies should seek out information from other organizations on how best to work with lawmakers to prepare and justify proper regulations to help prevent unsafe development and lack of maintenance of fire safety features in the wildlands.

The Public/Homeowners

The people who choose to live in the scenic wildlands have the basic responsibility to take necessary precautions when facing predictable hazards. Informed homeowners would be better prepared for surviving a wildfire, but some homeowners in the area of the Black Tiger Fire admitted to a lack of knowledge about the wildfire risks where they lived.

✓ Potential homeowners should determine the wildfire hazard potential of the immediate area before buying or moving into any home. This information can be obtained from the local fire department. NFPA 299 will provide guidelines for rating the wildfire potential of an area,

✓ Homeowners should contact federal, state and local fire and forestry agencies for educational programs and materials to address the fire hazard in general. Information should also be shared with children. Information and publications covering numerous wildland home fire safety details are available free from many sources, but until individual apathy is overcome the homeowner may not be motivated to take proper precautions. (Here, the fire services can function as fire protection resource centers for the public.)

✓ It is the responsibility of the individual property owner to provide a defensible space around structures to help protect them. Extra measures to provide additional space are re-

quired for structures built on steep slopes, above canyons, combustible materials and exposures.

✓ When homeowners become aware of the wildfire risk of their own areas, they should join forces with other interested individuals and groups to urge lawmakers to respond with legislative assistance to require appropriate fire safety measures by all of those who live in the affected areas.

Community Planners and Officials

A community's planning and building officials are often the first individuals who communicate local practices and standards to those who want to buy or build in the wildlands. Their understanding of the potential hazards of building in these areas is therefore vitally important.

✓ A wildland fire behavior potential map should be created for existing and planned structures. The features specified for the map would include several topography-related factors: elevation, slope percent, drainages, prevailing wind direction, worst-case wind direction (toward structures), and broken topography features.

✓ The wildland fire behavior potential map should also include fuel types. Zones of possible high-intensity fire must be identified and communicated to property owners. Fuel modification—the removal, spacing or volume reduction of fuel types to accomplish a reduction in fuel loading—is a primary mitigation measure.

✓ Areas with abnormal accumulations of forest litter should be identified, and a review made of past fire history in each area fuel bed.

✓ The Authority Having Jurisdiction (determined locally) should evaluate all existing or planned housing developments to determine relative wildland fire protection ratings. In doing this, jurisdictions must review fire danger weather records to determine patterns of rain, heat, humidity and fuel moisture. Then property owners must be advised of conditions and their responsibilities.

✓ *“It is the responsibility of the individual property owner to provide a defensible space around structures to help protect them.”*

Developers

This event has also focused on the need to have construction standards for homes in the wildlands. The published version of NFPA 299 will provide important guidance in this area, but it becomes fully effective only when adopted by local lawmakers.

In the absence of clear and meaningful regulations for the common good, the practices of uninformed developers may create potential hazards. Fire protection features, or their costs, may not be appreciated by uninformed buyers. However, decisions made at the early stages of a development will affect a home's fire safety for many years in the future.

✓ All developments should have more than one ingress-egress route and employ looped road networks. Roads should be wide enough for simultaneous access for emergency vehicles and the evacuation of residents. In consideration of the lane, wheelbase of tankers and other emergency vehicles, roads should be constructed with an adequate curve radius. Homes along dead-end roads and long driveways provide extra privacy for residents but also provide the potential for fire apparatus to become trapped by spreading fire. These roads and driveways should not prevent easy access by large emergency vehicles.

✓ Developers should reconsider their frequent use of combustible exterior building materials, or at least offer options for more fire-safe materials for potential buyers who may not yet understand the differences.

✓ Developers should also consider the long-range implications of siting unprotected homes on slopes or where water supplies for fire fighting are weak or non-existent.

✓ Developers can provide a valuable service to new buyers, who may initially be distracted by other moving details, by creating appropriate fuel breaks or greenbelt areas.

Lawmakers

Although the public determines acceptable levels of risk from fire in wildland areas, lawmakers react to the perceived needs of constituents and enact the regulations controlling that level of risk. Therefore, it is generally up to homeowners and fire protection agencies to articulate and justify acceptable and unacceptable levels of risk. When tragic losses occur, they usually focus attention on the risks, but preventive actions are preferable.

✓ Lawmakers should take the initiative to examine existing laws, regulations and standards from other jurisdictions that are available for local use in mitigating fire hazards associated with wildland fires.

✓ Lawmakers are encouraged to adopt NFPA 299, when it becomes available, as one part of the protection provided for new construction in the wildlands.

✓ Authorities should provide other strong building regulations to restrict non-treated wood shingle roofs and other practices known to decrease the fire-safety of a structure in the wildlands. In the past, untreated wood shingle roofs have repeatedly been shown to be a major contributing factor in the loss of structures to wildfires, yet some residential subdivisions in Colorado and elsewhere still encourage and even require wood shingle roofs for aesthetic reasons.

✓ *“Decisions made at the early stages of a development will affect a home's fire safety for many years in the future.”*

APPENDIX

Methodology of the Study of the Black Tiger Fire

Soon after the Black Tiger Fire, representatives from the National Fire Protection Association, U.S. Forest Service, Boulder County Sheriffs Office, Colorado State Forest Service, and Sugarloaf Volunteer Fire Department met to discuss a study of the fire to be conducted by the NFPA's Fire Investigations Division. A one-day meeting of the participants was held, resulting in the discussion of various approaches to the analysis. Participants identified the available data and how it might be collected and discussed. In general terms, the wildland/urban interface fire problem was also discussed and how those factors may or may not be applicable to the Black Tiger Fire.

(Participants included: *U.S. Forest Service*: Bob Swinford, Michelle Nolde, Bob Willmot, Chad DeVore, Dick Chase, Dick Rothermel, Al Roberts; *Boulder County Sheriffs' Office*: Ernst Little, Al Staehle, Larry Stern; *Colorado State Forest Service*: Dave Farmer, Ron Zeleny; *Sugarloaf Fire Protection District*: Ruth Ravenel; *NFPA*: Tom Klem, Bill Baden, Jim Smalley, Heather Hintz.)

In addition to the meeting, an on-site survey of the fire area was arranged through the Boulder Sheriff's Office so that participants could examine the factors that might have led to the destruction of homes and how to mitigate other severe fires from causing such extensive damage. A thorough one-day survey of the burn site including examination of those homes destroyed/survived was undertaken.

A complete drive/walk through the fire area was conducted by the representatives. During the tour, the representatives spoke to several residents to supplement previous observations and determinations. Researchers from the U.S. Forest Service and other wildland fire experts relayed their observations/determinations with other representatives. Details of the rapid development and spread of the fire were provided and physical evidence shown to corroborate determinations. Further, the effects that such rapid growth and spread might

The survey team began to understand the full impact of the effects of fuels, temperature, slope, and wind that existed on the day of the fire.

have had on the ignition/survival of the homes was discussed. Again, these technical observations were corroborated with physical evidence.

The survey began at the base of the Black Tiger Gulch where the origin of the fire was pinpointed by local authorities. Coupled with observations of the available videotapes of the fire, interviews conducted with local fire authorities and other eyewitnesses, and upon examination of the physical evidence, the group began to piece together a scenario of how the fire developed and spread. These determinations were then coupled with the fire spread scenario that was documented during the fire suppression effort by the incident commanders. These fire spread observations plotted the "head" of the fire as it varied over time,

The survey team also examined the fuels in the immediate area of origin and found that they were typical of many grass-type fires. However, beyond several acres an extreme uphill slope began to affect the terrain and this area was the beginning of forest fuels consisting of ponderosa pine and mixed conifer. From this vantage point, the survey team observed evidence of a "crowning" fire that began within sight of the area of origin. The survey team began to understand the full impact of the effects of fuels, temperature, slope, and the up-slope wind that existed on the day of the fire.

The survey team moved to Waterline Road to view conditions of fire growth. The survey team was able to view several of the homes destroyed in the initial run of the fire. The team observed that the homes were located near the rim of the extreme uphill slope and that combustible vegetation was in close proximity to their foundations. The remains of the homes were examined to attempt to identify other variables that might also have resulted in the ignition of the homes. However, these other suspected variables, i.e. combustibility of construction, roof, etc., were more difficult to identify from the remains because of their destruction

Other factors also began to emerge, such as what role fire department access to the homes might have played. The long, narrow-approach driveways were assessed by the team as dangerous for fire department use, and considering the intensity and speed of the fire, these homes likely had no fire department intervention.

Summary comments regarding the homes at the rim of the canyon along Waterline Road were that the position of the homes, the intensity of the fire, the proximity of combustible vegetation, the lack of access for fire fighting, and the short interval of time between the awareness and the threat of the property were extremely important variables in determining why these homes were destroyed. Variables, such as combustibility of the home, that may have been important variables could not be confirmed. Similar analytic methods were used by the survey team the remainder of the day as they moved through the burn area. The significance of the variables, it was felt, varied from location to location.

Several members of the survey team, including Tom Klem, NFPA, and Al Roberts, U.S. Forest Service, Denver, continued an in-depth survey of the burn area for two additional days. This in-depth survey also included detailed interviews with numerous occupants in an attempt to corroborate the technical determinations being made of the fire spread and intervention by the homeowner, if any.

This survey team conducted an on-site analysis of every home that burned or survived in Black Tiger Gulch. The team began to hypothesize that the homes that did not burn: probably survived due to fire department intervention; had noncombustible vegetation around the homes or had combustible vegetation cleared from the proximity of the homes; were constructed of noncombustible construction materials; and/or were more distant from the main intensity of the fire. It was felt that some of the homes that survived could well have burned had it not been for fortunate circumstances. One such home observed had hay stored under its wooden porch, yet it was not ignited despite enough heat near the combustible hay pile to scorch the paint on a window frame. The survey team also decided to conduct a survey of unaffected home sites within the same general area with similar topography, home construction and other factors. This thorough survey of homes lead to a number of additional variables, if representative of the homes in the Black Tiger Gulch, that

The 28 homes studied were selected on the basis of the best available data and the location of the homes relative to four identified fire intensity areas.

would have contributed to the ignition of the homes. They were: 1) inaccessibility for fire fighting during a severewildland fire; 2) lack of water supply; 3) close proximity of combustible vegetation to the home; 4) combustibility of roof and structure; and 5) storage of combustible materials beneath wooden porches.

Based on the assessment of the similar area, the survey team then decided to examine local records of the homes in the fire area to determine the construction and arrangement of the homes. As a result, the team visited the City of Boulder Assessor's Office and determined that information was available from the assessor's records that include photos of the homes from the affected area. Records were examined and it was determined that they contained information regarding construction arrangements of the homes and adjacent combustible vegetation as depicted by a photograph attached to each record. It was felt that the vital information regarding the construction of a home, proximity to combustible vegetation, and other factors could be overlaid with the other variables to gain insight into the behavior of the home under assault.

The team decided that a more thorough analysis of the assessor's records, coupled with an overview of the location of a home and its proximity to the intensity of the fire, might yield important data regarding the variables that contributed to the loss or survival of the homes of the Black Tiger Fire.

As a result, NFPA contracted with Aspen Engineering, Inc., to conduct this thorough analysis of the assessor's records. The Aspen Engineering representative met with the representative of the U.S. Forest Service Denver Office for input regarding the intensity of the fire and background information. The contractor also visited the Boulder Tax Assessor's Office to acquire the necessary data for such a rigorous analysis. The tasks also included a thorough survey of the burn site by the contractor and the U.S. Forest Service representative

Provided with the fire intensity map and having been briefed on the factors that may have affected the burning or survival of the homes, the contractor began the in-depth analysis. The findings from this analysis are contained in the Black Tiger Fire report and in the contractor's submittal to the NFPA.

In addition to this task, a statistical analysis of the data from affected homes was conducted by Dr. John Hall, NFPA Fire Analysis and Research Division, to further verify the implications of the study.

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 - Utah Department of Natural Resources: *Protect Your Summer Home*.
 - Wisconsin Department of Natural Resources: *Forest Fires Burn More Than Trees*.

Source List of Organizations

For additional information, contact your local fire department or forestry agency, or contact the following organizations:

National Fire Protection Association

Public Fire Protection Division
1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269-9101
617-770-3000

United States Department of Agriculture Forest Service

Fire & Aviation Management
P.O. Box 96090
Washington, DC 20090-6090
703-235-3220

National Association of State Foresters

444 N. Capitol Street, NW
Washington, DC 20001
202-624-5415

Boise Interagency Fire Center

Publications Management System
3905 Vista Avenue
Boise, ID 83705
208-389-2512