FIRE MANAGEMENT NOTES

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Fire Management Notes

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Smokechaser's emergency ration in Montana (K.D. Swan, 1928), 228450

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Fire Control Notes first reproduced this Smokey Bear poster on the back cover of its January 1963 issue.

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Special Feature

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Fire Research—What's the Forest Service Doing?

Gay L. Almquist

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Forest Fire and Atmospheric Sciences Research, Washington, DC

The year 1989 was another record-breaking fire season. In the midst of the season and in its aftermath, such fire events sparked a basic question: What's the USDA Forest Service doing in fire research? It seems appropriate to stop and take a look at Forest Service fire research—where we are and where we are going.

Fire Research in the Forest Service

When the fire research community looks at the needs of wildland fire managers, it must take a wide view. The objective of fire research is to support the wildland fire community as a whole; our clients include State and other Federal agencies with fire management responsibilities as well as the National Forest System and State and Private Forestry. The Forest Service, primarily a natural-resource management agency, has the unique opportunity to see firsthand what's involved in dealing with the complex array of needs, viewpoints, and interrelationships in resource and wildland fire management.

Basic or Applied Research? To support and respond to the array of issues in the short- and long-term, the Forest Service pursues both basic and applied research. The appropriateness of Forest Service fire research in basic research areas such as fire physics, combustion processes, and fire chemistry is sometimes questioned. On the surface, it may seem that there are more suitable places than the Forest Service for this type of work, such as colleges, universities, or private research facilities. Much research, in fact, is undertaken by these other entities. The Forest Service, however, has some advantages over other institutions in its ability to provide continuity, longevity of study, and geographic diversity to research efforts.

The benefits of applied research are more readily perceived because research results are immediately useful. These results are easily recognized when you look at products of applied research, such as the Incident Command System, National Fire-Danger Rating System, Administrative and Forest Fire Information Retrieval and Management System, aerial retardants, and telemetered infrared fire imagery. The Forest Service is recognized both nationally and internationally as a vital source of fundamental research and information and technology useful in fire management.

The goal is to maintain an overall research program that is stable yet flexible enough to respond to emerging needs of our use-community at large.

Focusing Research Priorities. Keeping research relevant and timely continues to be a challenge to researchers and managers alike. The timelag between the identification of a problem needing study and finding the answer or developing a product ameliorating the problem frustrates the fire community. Forest Service fire research programs, as all Forest Service research programs, are periodically evaluated to keep them focused on high-priority issues, while providing an orderly termination to low-priority work or subjects on which research has already provided sufficient insight. This redirection toward the highest priority issues is accomplished through internal and interagency communications as well as review, evaluation, revision, or termination of research work projects every 5 years. The goal is to maintain an overall research program that is stable yet flexible enough to respond to emerging needs of our use-community at large.

Current Fire Research Projects—Who's Doing What, Where?

Currently there are 13 Forest Service fire or fire-related research projects underway. This work is being done at locations throughout the United States (fig. 1) and much of the work is done in conjunction with colleges, universities, and other research facilities. The 13 projects in progress are highlighted here.

Fire Behavior: Fundamental and Systems Development, Richard Rothermel, Project Leader, Intermountain Fire Sciences Laboratory, Intermountain Forest and Range Experiment Station, Missoula, MT. This project team is conducting fundamental and applied research on forest and rangeland fire behavior as needed by fire and land managers for systematic planning, prescribed burning, and control of wildfires. The goal is to further develop our understanding of fire behavior under many different conditions and be able to quantitatively model that behavior. This research will lead to the development of an integrated fire danger and fire behavior system.

Fire Suppression Research, Charles George, Project Leader, Intermountain Fire Sciences Laboratory, Intermountain Forest and Range Experiment Station, Missoula, MT. Using both fundamental and applied research, the project team is working to develop the knowledge base and application systems needed to improve fire control capabilities at reduced costs. The primary focus has been on chemical retardants and delivery systems and on improving the effectiveness and efficiency of fire suppression techniques and tactics. Research is starting on special suppression needs in the wildland-urban interface.

Prescribed Fire and Fire Effects, James Brown, Project Leader, Intermountain Fire Sciences Laboratory, Intermountain Forest and Range Experiment Station, Missoula, MT. The project team is working to determine the effects of fire on forest, range, and wilderness ecosystems. They are modeling fundamental fire effects relationships and developing guides and information systems for applying fire effects knowledge to the planning and execution of prescribed fires. Much of their work is focused on meeting silvicultural, range management, and natural area objectives in the interior west. Work is also being done to develop knowledge and technology for supporting the special needs of application of prescribed fire in wilderness and natural area ecosystems. The team recently developed the automated Fire Effects Information System and is currently working on the technology transfer phase.

Combustion Processes: Fire and Emission Characterization, Darold Ward, Project Leader, Intermountain Fire Sciences Laboratory, Intermountain Forest and Range Experiment Station, Missoula, MT. Research is being done to characterize combustion processes and emissions from burning forest and rangeland fuels. Not enough is known about the relationships among fire behavior variables and resulting emissions or about wildland smoke characteristics for incorporation into current emission inventories and smoke management guidelines. There are also concerns about combustion products from chemically treated forest fuels and wood products. The results of these and other studies are being used by scientists from the occupational health fields to better understand the health effects of wildfire smoke on firefighters.

Interactions Between Wildland Fire and the Atmosphere, Moist Temperate Forests, and Society, Linda Donoghue,[1] Project Leader, Michigan State University, East Lansing, MI. This project team focuses on how atmospheric and socioeconomic environments influence wildland fire activity and how wildland fire, in turn, affects moist temperate forests and society. Project scientists will be simulating the formation and development of horizontal roll vortices in crown fires, developing a national information system to predict wildland fire severity, and identifying and classifying wildland-urban interface areas in the Northeast using remote sensing data and geographic information system (GIS) technology. This research will assist wildland managers with fire management planning and decisionmaking.

Silviculture of Interior Pacific Northwest Forests, Johanna Landsberg, Project Leader, Silviculture Laboratory, Pacific Northwest Forest and Range Experiment Station, Bend, OR. This project team is conducting research on the silviculture and regeneration of interior Pacific Northwest, mixed conifer forests. Fire is an integral part of the ponderosa pine ecosystem. Along with other emphases, the team will look at the use of prescribed fire as a silvicultural tool in ponderosa pine systems and the effect of reintroducing fire (after 70 years of suppression) on tree growth, physiology, and soil nutrients.

Fire and Air Resource Management, David Sandberg, Project Leader, Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station, Seattle, WA. With the continuing and growing concerns about air quality and the potential implications to the use of prescribed fire, research is being done to provide answers for more effective use of prescribed fire to achieve resource management objectives while continuing to reduce resulting pollutants. Studies are focusing on methods to predict and describe the immediate effects of fire use in various situations, characterization of emissions from prescribed fire in different burning conditions, and evaluation of techniques and strategies to reduce air pollutant emissions from prescribed fire. Through a cooperative effort with the Alaska Bioenergy Program, the project has produced a videotape

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[1] North Central Forest Experiment Station research forester.

focusing on the research and emission reduction accomplishments by forest managers. In addition, a cooperative effort with the Environmental Protection Agency has recently led to revised emission characteristics of wildland fuels.

Chaparral Ecology and Fire Effects in Mediterranean Ecosystems, Susan Conard, Project Leader, Forest Fire Laboratory, Pacific Southwest Forest and Range Experiment Station, Riverside, CA. Ongoing research is being done to increase our understanding of the factors that influence dynamic processes such as erosion and vegetation development in chaparral and associated woodland ecosystems, with particular emphasis on responses to fire. Since fire is such an integral part of the chaparral ecosystem, the products of these studies are essential for improving management of these areas. Emphasis is being placed on understanding the impact of prescribed and wildfire on erosion, sedimentation, and streamflow; response of long-term productivity of chaparral ecosystems to fire; the relationships between physical site characteristics and the growth characteristics of individual species; and the impact of fire and air pollutants on nutrient cycling in chaparral ecosystems.

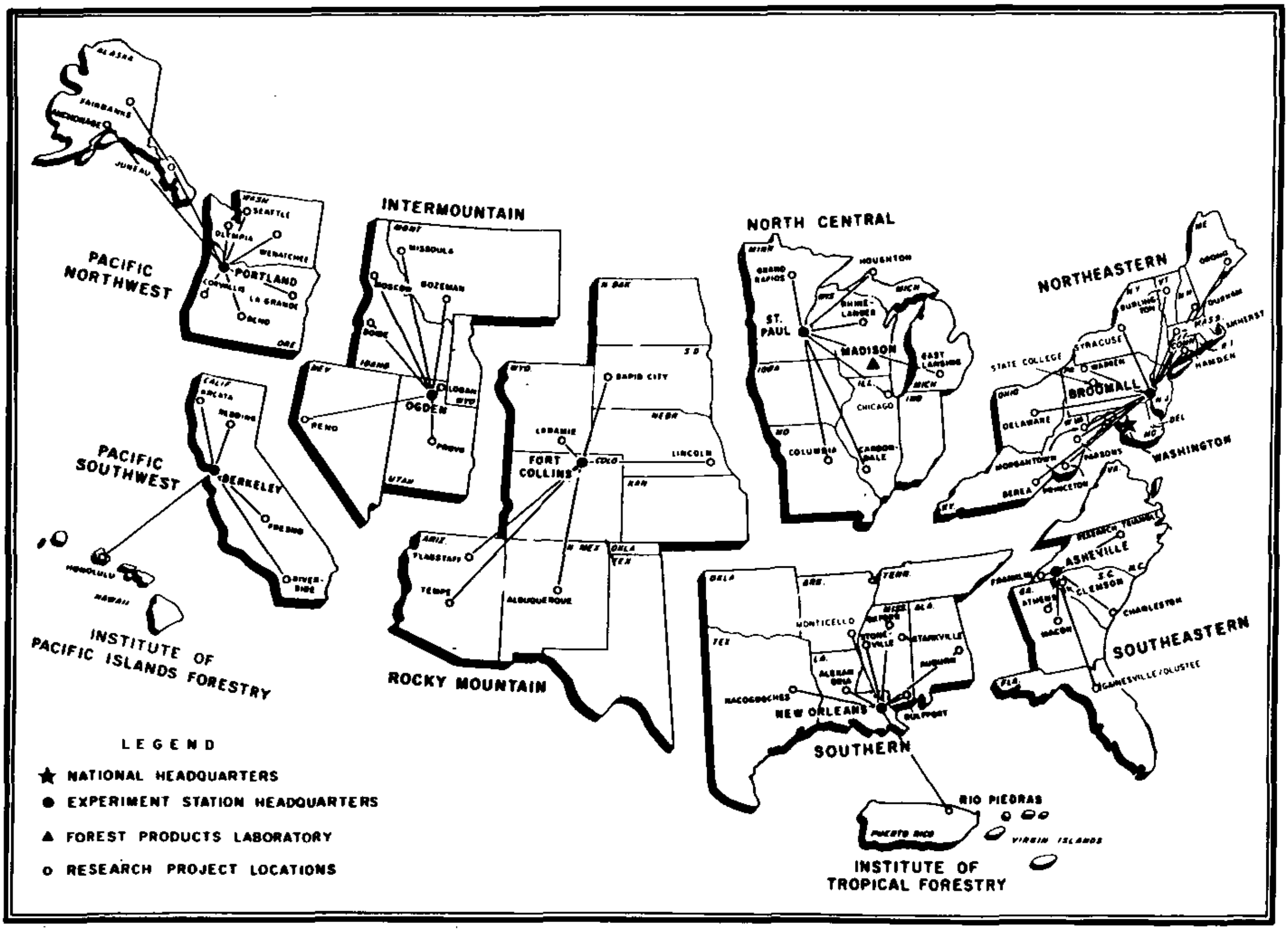

Figure 1—*Map of forest and range experiment stations, the Forest Products Laboratory, and research project locations.*

Meteorology for Fire Severity Forecasting, Francis Fujioka, Project Leader, Forest Fire Laboratory, Pacific Southwest Forest and Range Experiment Station, Riverside, CA. Work is being done to create tools for medium- and extended-range (10- to 30-day) weather predictions for fire management applications on a local, regional, and national scale. We need a better understanding of the magnitude, duration, and the spatial variations of fire severity in certain weather conditions for effective presuppression management and deployment of fire suppression resources. This information needs to be accessible to fire managers in a context that will allow them to evaluate the forecast reliability, relative to the risks involved with the decision at hand.

Prescribed Fire Research, Andrea Koonce, Project Leader, Forest Fire Laboratory, Pacific Southwest Forest and Range Experiment Station, Riverside, CA. This project team is researching the use of prescribed fire to help meet resource management objectives. Emphasis will be on developing prescriptions to restore disturbed or degraded habitats and to maintain ecological structure and function in wildland ecosystems; using prescribed fire to enhance resource values such as ecosystem productivity, biodiversity, and individual species vitality and to reduce losses from wildfire; and evaluating the fire behavior characteristics to be included in fire prediction and resource allocation models used in fire suppression. The project scientists are also cooperating with international scientists, doing research on fire effects, vegetation management, and sustained yield.

Fire Management and Economics, Richard Chase, Project Leader, Forest Fire Laboratory, Pacific Southwest Forest and Range Experiment Station, Riverside, CA. Recognizing that the wildland-urban interface is basically a "people problem," this project team is exploring the political, economic, sociological, and demographic dimensions of wildfire in the interface, in addition to the physical attributes, in order to better understand the overall dynamics of the issue. A focus will be to determine what educational, regulatory, or other approaches would be acceptable and effective in mitigating potential fire-related problems. This project is also initiating research studies in the use of GIS for fire management planning and operational decision support and the development of systems for more efficient allocation and management of fire resources.

Forest Meteorology and Eastern Fire Management, James Paul, Project Leader, Southern Forest Fire Laboratory, Southeastern Forest Experiment Station, Macon, GA. Research is being done to better understand weather and forest ecosystem relationships in southern and eastern environments and provide forest managers with the tools for managing fires and resulting smoke. Basic weather and smoke relationships and guidelines are needed to manage the serious problem of smoke on the highways that results from burning. Also, work is underway to make the National Fire-Danger Rating System (NFDRS) more effective for the moist eastern forests.

Fire Safety of Wood Products, Susan LeVan, Project Leader, Forest Products Laboratory, Madison, WI. This project team is working to generate technology for improving fire safety of wood-using structures. The project goals include development of database and design methodologies to define the effects of new technologies in wood construction on fire safety and the fundamental fire and thermal performance characteristics of wood products. Work is also underway on a conceptual model that could be used in the field to assess fire hazard for structures in the wildland-urban interface.

Where Are We Going From Here?

Forest Service research needs to maintain momentum in ongoing research efforts but recognize new issues as they emerge. To be able to "stay ahead of the issues" requires critical thinking, strategic planning, and interaction with a wide variety of leaders, managers, scientists, and practitioners. In a world where technology and "management challenges" are evolving at an ever-increasing rate, staying ahead requires anticipation and awareness of change.

Catastrophic Fire. One such change in the forest resource is resulting from the combination of many environmental conditions, to set the stage for catastrophic fires. The recent events of the 1985, 1987, and 1988 fire seasons are sobering indicators of this fact. Some of these factors contributing to this fire threat are persistent drought situations; fuel buildups (particularly in wilderness areas); the effect of insects, disease, and pollutants on wildland vegetation; and the ever-increasing infiltration of human activity and development in wildland areas.

A catastrophic fire is not defined just by the total number of acres that are burned. Considered also is its impact on the environment and society as a whole—physical, biological, social, or economic. Catastrophic fires can be categorized into two broad groups: those that are particularly damaging from a natural-resource standpoint and those that are particularly destructive to life and property. The solution to catastrophic fires, if there is one, however, goes beyond the specific tools and technologies of fire suppression to the social, economic, political, and environmental arenas. Additional thinking and research are going to be needed to assess what can really be done to minimize the occurrence and the effects of catastrophic fires. Much of the research currently underway will undoubtedly play an important role, but we have to make sure we understand all the questions before we can define solutions.

Global Climate Change. Global climate change, an emerging concern, will have an indirect but important effect on wildland fire. Awareness, nationally and internationally, is increasing regarding this phenomenon and Forest Service research has an important role to play. Predicted global climate change would significantly affect the health, productivity, and diversity of forest ecosystems worldwide.

Increase in pollutants and gases such as carbon monoxide and carbon dioxide (one source of which is fire) in the atmosphere accelerates change in atmospheric chemistry and can eventually contribute to change in fuel characteristics such as species composition and biomass. This in turn may lead to change in fire frequency and severity.

Some of the major questions that the Forest Service must address in global change research are:

- What processes in wildland ecosystems are sensitive to physical and chemical changes in the atmosphere?
- How will future physical and chemical climate changes influence these ecosystems?
- What are the implications for forest management and how must forest management activities be altered to sustain forest health and productivity and reduce the risk of wildfire?

Air Pollution. As already alluded to, a third concern is air pollution and the corresponding response of forest ecosystems. Research is already underway to evaluate the effects of acid deposition and its associated pollutants on forest health. There are currently a number of "research cooperatives," multi-institutional and multi-disciplinary teams of investigators, studying the effects of atmospheric deposition. The Forest Service must determine how these factors will affect forest management activities.

Changing Research Approach. The manner in which we approach these and other issues is changing also. Just as the national forest land management planning process has increased our awareness of the value of integrated resource management, so fire research is moving more to integrated or ecosystem-based interdisciplinary research. While it is still very important to study individual elements of fire science, it is increasingly important to understand the larger picture of the complex interactions and interrelationships occurring between fire characteristics, atmospheric changes, vegetative responses, and societal influences.

Public Information and Education. We will also need to put more emphasis on public information and education. In the past, this was not really viewed as part of the research role but as our public becomes more environmentally sophisticated and involved in many aspects of resource management activities, there is an opportunity to educate them regarding the full spectrum of Forest Service roles and an obligation to do what we can to make accurate information available on processes at work in wildland ecosystems. Forest Service researchers need to be sensitive to the importance of packaging information and products in a manner that is not only understandable to the managers in the field but also for an informed public. As issues such as global climate change, acid rain, ecosystem recovery from the Yellowstone fires, and wildland-urban interface continue to make headlines, it is to our collective benefit for the public to know that the Forest Service is taking a part in working toward solutions. ■

ONLY YOU!

Old Soldiers

James B. Davis and Clinton B. Phillips

Research forester, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Riverside, CA; and forestry consultant, Fire Safe Consultants, Cameron Park, CA[1]

"Old soldiers never die; they just fade away," is supposed to be a military truism. Perhaps the same thing could be said for old air tankers. However, at least one type of air tanker is having a happy, productive retirement.

Did you ever wonder what happens to an old air tanker after it has served its usefulness—provided it could still fly? Take, for example, the F7F Tigercat that saw extensive fire experience in California from 1959 through 1976 (fig.1). Not only did the F7F provide its share of firefighting, but it also served as a test bed for fire scientists and engineers who first studied such things as drop patterns and the effect of retardant viscosity and identified corrosion problems (Davis and Phillips 1965).

The F7F Tigercat

Grumman Aircraft built 363 Tigercats between 1944 and 1946. Most were built as a single-seat, midwing fighter, although there was also a two-seat night-fighter version (F7F–3N). Operated by the U.S. Navy and Marine Corps, they flew from bases in the Philippines, Okinawa, and Tsingtao and Tientsin, China, during and after World War II. Armed with four .50 caliber machine guns and two 20-millimeter cannon, the F7F was an excellent air superiority fighter and also performed well in ground attack. Power came from two Pratt and Whitney R–2800–34W radial engines with 2,100 horsepower each—enough to make the Tigercat one of the most highly powered fighters in the sky at the time (Linkewich 1972).

As for many old soldiers—even foresters and their firefighting aircraft—retirement from work does not mean the end of a useful life.

While they still flew night missions during the Korean War, they and other propeller-driven fighter aircraft were largely replaced by newer jets. By the mid-1950's, the Tigercats were phased out of service and were sent to the Naval Air Station at Litchfield Park, AZ, to be scrapped.

About this time, the forest fire air attack program was getting under way, and potential air tanker operators were looking for aircraft that could carry a large payload, operate with reasonable safety in rugged, steep terrain, yet were not too expensive to own and operate. Operators in the Western United States turned to surplus military aircraft.

The F7F as an Air Tanker

In 1958—more than 30 years ago—two men starting out in the air tanker business, George Kreitzberg of Salem, OR, and Robert Stevenson of Grass Valley, CA, purchased most of today's 10 surviving Tigercats for about $1,200 each. Late that year they experimented with one of the F7F's at Salem, OR, mounting a 500-gallon (1,892.7 l) tank under each wing (Larkins 1964). Satisfied with the results of the experiment, they converted 6 of the 10 F7F's to air tankers through the winter months, for use during the summer fire season of 1959. The final version, however, utilized a partially internally mounted tank, some carrying 800 gallons (3,028.2 l) while others carried 900 gallons or 3,406.8 liters (about 7,400 lb or 3,357 kg) of retardant in a divided belly tank (fig. 2). For example, Air Tanker 64, now undergoing military restoration at Chino, CA, carried 900 gallons (3,406.8 l) of retardant in two 450-gallon (1,703.4 l) compartments. The compartments could be discharged separately or in salvo. However, if the retardant in only one compartment was dropped, an opening between the compartments allowed the remaining retardant to flow into the empty compartment, dividing the load, and balancing the aircraft (George, Blakely, Johnson, and Hightower 1982).

At their 210 knot speed, they could deliver up to 30 percent more retardant to a fire than slower aircraft, such as the TBM Avenger or PBY Catalina (Reinecker and Phillips 1959). At times the pilot of a slower, lumbering air tanker would give a noncomplimentary hand salute to an F7F pilot as the latter sped by on his way to a fire.

The F7F became the aircraft of choice for some pilots. Ralph Ponte of Grass Valley, CA, a retired veteran of 24 consecutive years of piloting air tankers,[2] describes the F7F as his favorite (Davis 1978): "I believe the F7F is best as far as flying the airplane. We've got airplanes like the S–2 that really do

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[1] Mr. Phillips, now retired, formerly held the position of Assistant Deputy State Forester of the California Department of Forestry and Fire Protection.

[2] Ralph Ponte believes his 24 years as an air tanker pilot is the unofficial record.

well. But the ''7'' was so easy to fly. I can tell you...it was a very good airplane.''

Ironically, the high performance of the aircraft led to its undoing as an air tanker. Because flight stability and maneuverability required a high flying speed, the plane often got into difficulty where the fire and topography required terrain-hugging and tight turns. The relatively short runways at air tanker bases were also a problem for the Tigercat, which was not able to reach the 126 knot speed it needed for single-engine flight stability. Engine failures—two of them during takeoffs—resulted in three fatal crashes.[3] In addition, the F7F was subject to pitch-up when it dropped its retardant load—a phenomenon more severe with short aircraft than with longer coupled planes such as the PBY or B–17 Flying Fortress. These problems led to an engineering study by the San Dimas Equipment Development Center and ultimately to phasing out of the Tigercats.

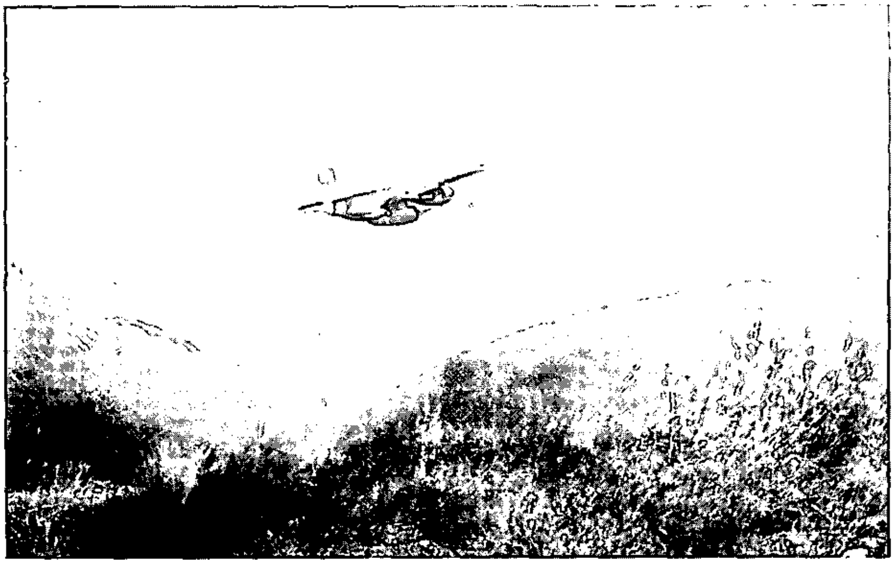

Figure 1—*F7F air tanker enroute to a fire on the Angeles National Forest in southern California.*

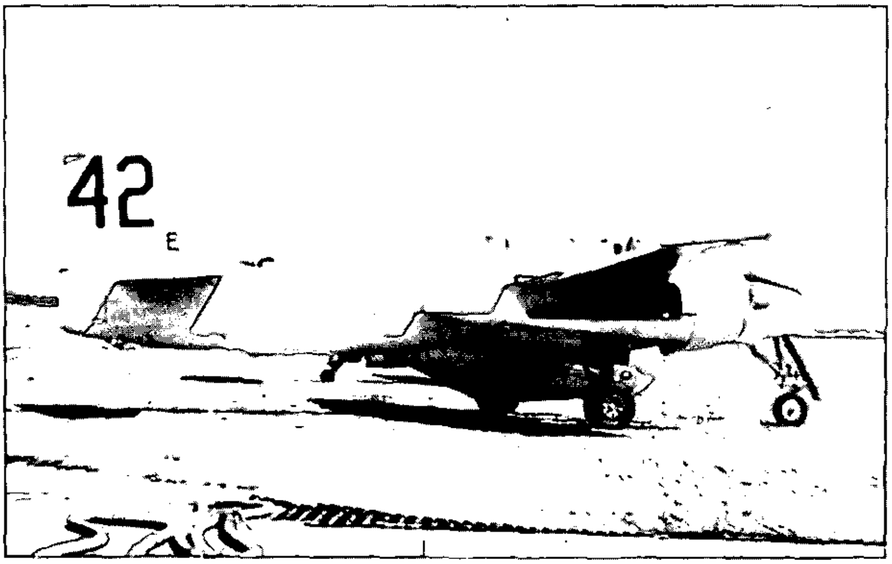

Figure 2—*Air Tanker 42 shows F7F midwing configuration and belly tank. This air tanker is in flyable condition at the Weeks Air Museum, Miami, FL. It now has a U.S. Navy paint scheme.*

The F7F in Retirement

As for many old soldiers—even foresters and their firefighting aircraft—retirement from work does not mean the end of a useful life. Of the 10 remaining Tigercats, 6 former air tankers have been fully restored and some are flying (table 1). Four other tigercats that had not been converted to air tankers range from ''better than mint condition'' to ''basket cases.'' Most, however, are undergoing restoration (fig. 3).

The Tigercats, while not fighting for their country or dropping retardant on fires, will be around for a long time to come. Some are having an outstanding retirement it seems. Air Tanker 62, fully restored and

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[3] Personal communication from Fred Fuchs, Assistant Director for Aviation Management, USDA Forest Service, Washington, DC.

flown regularly, won the prestigious Experimental Aircraft Association (EAA) Grand Champion Warbird trophy in 1986. This former air tanker is located at the Kalamazoo, MI, Air Zoo, where it displays the colors of Marine Photographic Squadron VMD–254.

However, the most impressive of all F7F's is Air Tanker 43. Still in its air tanker markings, but with its retardant belly tank replaced with both internal and external fuel drop tanks, Air Tanker 43 flew to England via the Azores during the week of November 5, 1988. The aircraft was purchased from the Weeks Air Museum of Miami, FL, by Paul Wilson, a Harrier pilot and RAF squadron commander. It was prepared for its journey by Macavia Aviation (formerly Sis–Q Flying Service) whose mechanics maintained the F7F when it was an air tanker. According to *In Flight Aviation News Monthly*, the 40-plus-year-old aircraft had no trouble during its check flight. At the time of this writing, the aircraft is receiving a U.S. Marine Corps paint scheme in England and will be flown in air shows in England and on the Continent (Veronico 1988).

While old soldiers may fade away, the F7F air tankers are coming out of retirement, continuing to fly, and giving fun and thrills to their owners and aviation enthusiasts throughout the United States and Europe. ■

Table 1—*F7F Tigercat retirees*

Air tanker number	Flyable	Current location
41	No	U.S. Marine Air-Ground Museum, Quantico, VA
42	Yes	Weeks Air Museum, Miami, FL
43	Yes	Paul Wilson, England[1]
62	Yes	Kalamazoo Aviation History Museum, Kalamazoo, MI[2]
63	No	U.S. Naval Aviation Museum, Pensacola, FL
64	Yes	Military Aircraft Restoration Corp., Chino, CA

[1] This Tigercat with its retardant tank removed and outfitted with extra fuel tanks flew to England via the Azores during the week of November 5, 1988.

[2] Restored to military configuration, this aircraft won the Grand Champion Warbird trophy at Oshkosh, WI, in 1986.

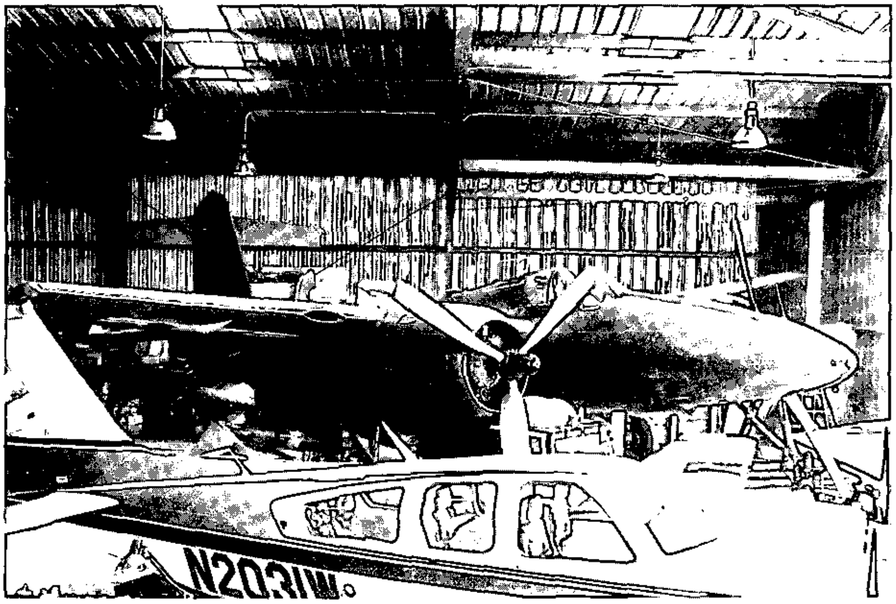

Figure 3—*Air Tanker 64 is undergoing refurbishing at the Military Aircraft Restoration Corporation, Chino, CA. Flyable, it bears the markings of Marine Squadron VMFN–513.*

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Handling Stress in Emergency Situations

Dan Casey

Area forest supervisor, Minnesota Department of Natural Resources, Division of Forestry, Blackduck, MN

Most of us can relate to stress. In fact, many of us have taken classes in how to manage it. But how does one handle the feelings that result after witnessing an accident or fire where someone is killed, after finding the body of an apparent suicide victim, after comforting someone who has just experienced a rape? The answer is—*Critical Incident Stress Debriefing*.

The Need and Approach

A critical incident is defined as a situation where emergency service personnel experience unusually strong emotional reactions that can interfere with their ability to function either at the scene of the incident or later. Consider, for instance, the volunteers of a rural fire department in a village of 300 who were called to a blaze in which 11 people died. How can feelings be kept in check during the emergency and later dealt with, when all who died are friends, neighbors, and acquaintances?

Critical Incident Stress Debriefing is an organized approach to managing the type of stress-related incident faced by people working in emergency services. Those who have witnessed or assisted with a critical incident meet with a debriefing team. This team encourages the people to talk about their feelings and reactions to the incident. The firefighters of that small rural village described above were unable to save 11 people. They needed to discuss their feelings and vent their frustrations at having to carry out the bodies of children and adults they had known and seen nearly every day.

The Debriefing Team

The debriefing team consists of one mental health professional (a doctor, psychologist, or counselor) and several support members. The debriefers are trained in extracting information from the affected individual, providing support, and assessing the amount of stress that that person is experiencing. Support members help develop trust between the debriefing team and the affected individual. They ensure that the meeting moves forward in a controlled manner and maintain continuity for the duration of the meeting.

How can feelings be kept in check during the emergency and later dealt with when all who died are friends, neighbors, and acquaintances?

The Debriefing

Critical Incident Stress Debriefing can be divided into three parts. First, the affected individual vents his or her feelings, and then the team members assess the intensity of these feelings. They discuss in detail what these intense feelings mean. The mental health professional and team support members provide support and reassurance. Finally, there is a time for questions, and a plan of action on how to best handle the stress-related emotions is developed. At this point, referrals for additional help are made, if considered necessary.

Program Beginnings

The Minnesota Department of Natural Resources (DNR) began its Critical Incident Stress Debriefing program in 1987. Starting with two trained debriefers, the program now relies on 19 individuals. DNR foresters, conservation officers, or parks people are the support members of the team. Trained counselors from the employee assistance program provide professional mental health expertise. Support team personnel are the key to the debriefing process, however. A firefighter, after all, can best understand what another firefighter is going through. When a debriefing team is needed, one professional and two or three support people respond.

The DNR's debriefing team members received their initial training from Dr. Jeffrey Mitchell, a well-known disaster psychologist from the University of Maryland. Team members are available to handle those emergencies that involve DNR personnel and their families. They also respond to calls from fire and county sheriff departments and any other organization that has agreements with DNR such as the five-State Great Lakes Forest Fire Compact. A debriefing team is available to answer any call that comes from a State or Federal agency through DNR's Northern Fire Center in Grand Rapids, MN. Debriefings have occurred in the following emergency situations:

- Multiple deaths in a single-dwelling fire
- Death on the fire line
- Death in the line of duty

- Death at the workplace
- Suicide of fellow worker
- Rape of fellow worker
- Return of fire crews as they return from western fire duty

A debriefing team should be called upon to help alleviate the stress that develops during a critical incident. To do the best job, the team should be on hand within 72 hours of the incident.

The DNR's debriefing team is one of few available for wildland fire duty at this time. However, as the need for immediately handling the stress that occurs in emergency situations is more widely recognized and understood, additional teams from other agencies and organizations will be formed. ■

Critical Incident Stress Debriefing Conference

On June 3-6, 1990, the Minnesota CISD Interagency Council held the first Mid-America CISD conference, "Build a Network" at Cragun's Conference Center in Brainerd, MN. Dr. Jeffrey T. Mitchell, assistant professor of Emergency Health Services at the University of Maryland and developer of CISD, conducted training sessions for beginners. For others who wanted to continue their CISD training, panels of experts and speakers focused on issues and systems. There was something for everyone.

The Schedule

June 3, 1990—Sunday
Dinner, welcome, and caucus of State delegates
June 4, 1990—Monday
Morning: General session—Pre-CISD Stress Mechanics; panel discussions on "Voluntary vs. Mandatory Debriefing" and "The Professional Perspective on CISD"
Afternoon: CISD Training (John Mitchell); "Basic MN CISD Protocol," "Spouse/Significant Other Support Systems," and "United 232 Crash in Iowa"
June 5, 1990—Tuesday
Morning: CISD Training (John Mitchell); "Debriefing the Debriefer and Point System for Burnout"; panel discussion on "Team Member Selection"; General Session on State and Province exchange and discussion regarding CISD application
Afternoon: CISD Training (John Mitchell); panel discussions on "Peer Support Systems" and "Shooting Incidents"
June 6, 1990—Wednesday
Morning: CISD Training (John Mitchell); panel discussions on "Systems Development," "Nurses, ER, and CISD," "Call-Up Procedures," and "Rural Fire Departments"
Afternoon: "Critical Incident Management"

Information

For more information about the conference, contact Dan Casey, conference coordinator, Department of Natural Resources, Box L, Blackduck, MN 56630; telephone 218-835-6684.

"Vortices in Wildland Fire"

"Vortices in Wildland Fire," a 14-minute videotape, produced by the USDA Forest Service, documents and describes seven types of vortices that form during wildland fires. It shows the duplication of some vortices in the laboratory and specifies conditions under which they most often occur. This tape can be used to train firefighters before they encounter vortices in the field.

Tapes are distributed through Real Productions, 1821 University Avenue, Suite N-153, St. Paul, MN 55104. Send a check or U.S. Government purchase order (payable to Real Productions) with order. The cost is $15 for VHS ½ inch or $23 for VHS ¾ inch. Price includes postage and handling. ■

Infrared Fire Mapping: The Untold Story

R.L. Bjornsen[1]

President, FMA International, Inc., Gardnerville, NV[1]

It was 26 years ago (1964) that infrared (IR) fire mapping was first used operationally on wildfires. But its initial use where current perimeter intelligence was delivered to the fire boss occurred the year before when a fire on the Union Ranger District, Wallowa-Whitman Forest, OR, was flown to test the primitive scanner installed in a "Twin Beachcraft" of ancient vintage.

From that humble beginning, fire managers now enjoy a sophisticated mapping system that is a "must" on any large fire occurring nationwide. Yet in the beginning there were many skeptics who derided the early "newfangled" device that would never replace conventional aerial reconnaissance and ground scouting.

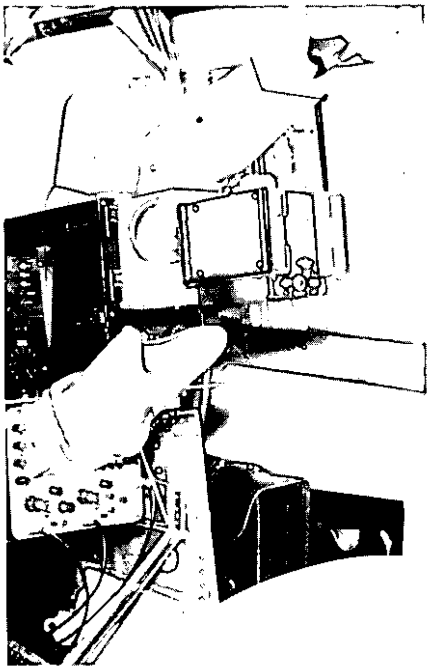
The IR-mapping project was initiated in the early 1960's as Project FIRESCAN at the Forest Service Northern Forest Fire Laboratory, Missoula, MT, under the direction of the late Jack Barrows. Stanley Hirsch was principal project scientist and electronic engineer, and I headed an operational team of Bob Cook, fire management officer and technician, and Eldon Down, pilot of the mapping aircraft.

Military Cooperation and Security

At the time, only the military possessed IR scanners that could be adapted to the fire-mapping mission. Much modification was required to accommodate the high thermal signal of a forest fire yet provide sufficient topographic detail to identify the fire perimeter. Using innovative technology, scientists at the laboratory were able to modify a military AAS–18 scanner to perform a wildfire mapping mission.

...Project FIRESCAN stands as a shining example of teamwork between Forest Service scientists and operational personnel in bringing applied research results to efficient, effective wildfire suppression.

Meanwhile, in the fall of 1963, a U.S. Army Mohawk aircraft equipped with a different scanner was employed to map prescribed logging slash fires in western Montana. These tests were done to determine if a state-of-the-art military scanner could be used for fire mapping. The result showed it to be too sensitive for this application by producing imagery in which the high heat source obscured all terrain and perimeter features.



State-of-the-art fire mapping equipment in 1965.

All personnel working on the project had security clearances because the scanner components were classified for military use only. This classification complicated the use of the modified scanner also, because it necessitated the removal of the detector from the aircraft and storage in a safe when not in use. The first operational team working in the field had to take the detector to their off-duty facility for safe storage, a bothersome task considering the remote locations of field missions.

The security situation carried over to imagery interpreter training. At the time, no civilian instruction was available to train interpreters, and I was granted special permission in the fall of 1963 to attend a military IR imagery interpretation course at Fort Holabird, MD, so that I could later develop a Forest Service course. Subsequently, a much "sanitized" version of the military course was developed and the first IR imagery interpreter's course was given at the fire laboratory in the winter of 1964. Another session was conducted at the Redding Fire Center in California the following spring.

One of the memorable IR fire-mapping missions carrying overtones of top security precautions was the 1965 Watts Riot in Los Angeles. To this day, few people are aware the Forest Service IR-mapping aircraft

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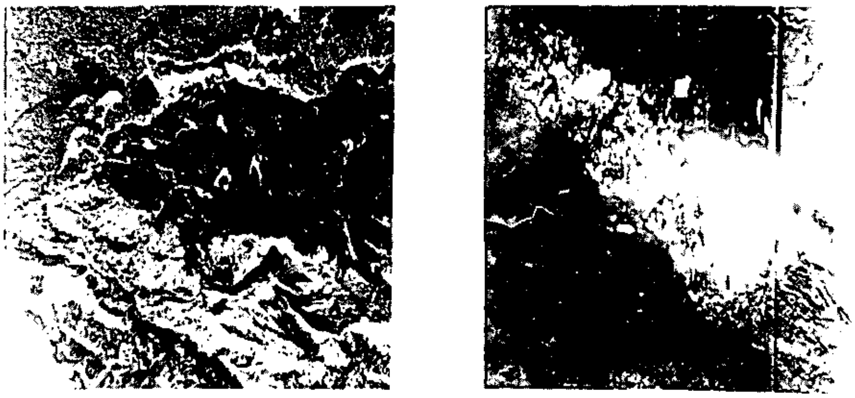
[1] Mr. Bjornsen, now retired, formerly served as Assistant Director of Fire and Aviation Management, USDA Forest Service. FMA International, Inc., is made up of a group of foresters specializing in fire management.

provided vital intelligence to the city's firefighters who were denied access to fires raging in the riot area. Operating under tight security from the air tanker base at Burbank Airport, the unit flew low-level night sorties, coming under fire from snipers on the ground. A local TV station knew something was afoot but was unable to obtain coverage because officials were concerned the rioters would learn more about the surveillance of their activities.

Interpretation and Delivery of Imagery

It was a challenge to interpret the crude imagery displayed on 3- by 5-inch (7.6- by 12.7-cm) Polaroid prints. Identifying the barely discernible terrain or man-made features tested all the skills of the interpreter. One had to essentially forget conventional photo interpretation knowledge and substitute imagery interpretation based on a thermal signal equivalent to temperature emission characteristic of the terrain and cultural features. (See photograph of Gravel Creek Fire IR imagery.)

Concurrently, further modifications to produce better imagery from the mapping scanner were proceeding. An Aero Commander, Model 500–B, was purchased and equipped with a scanner and drop tube ports. This aircraft, N142Z, pioneered many of the early mapping missions through the 1960's. The team of Cook and Down flew many missions in the Western United States, including Alaska. Much is owed them for making IR fire mapping the success story we know today.



Early IR imagery (right) of 1963 Gravel Creek Fire on the Bridger-Teton National Forest showing high thermal emissions, which make it difficult to interpret fire perimeter location.

The Area Commander 500–B aircraft carried experimental fire mapping equipment in 1964.

The drop tube was a vital component for getting Polaroid imagery quickly from the aircraft to fire camp before the perimeter intelligence became too old. This primitive delivery device consisted of placing the imagery into a clear plastic tube about 18 inches (0.46 m) in length, equipped with a bicycle horn and strobe light that were activated by flashlight batteries when the tube was dropped. After much experimenting, the technique was perfected and became a reliable delivery system even for nighttime drops.

All told, 23 wildfires were flown in 1963–64, 17 of which IR perimeter intelligence was provided to the fire boss. The fires ranged in size from 10 acres (4 ha) to the 215,000 acre (87,010.5 ha) Coyote Fire, Los Padres National Forest, near Santa Barbara, CA.

Operational Success, Leading the Way

With this modest accomplishment, even the skeptics were convinced IR mapping had potential to provide vital perimeter, intensity, and mop-up intelligence through smoke, day or night, that conventional methods could not match. Twenty-six years ago IR mapping was in the crawling stage compared with today's up and running technology and the mind-boggling systems envisioned by John Warren for 2038.

Although IR fire-mapping history may have now become something of a trivia-pursuit, Project FIRESCAN stands as a shining example of teamwork between Forest Service scientists and operational personnel in bringing applied research results to efficient, effective wildfire suppression. □

Literature Cited

Hirsch, S.N. et al. 1965. The use and system requirements of infrared scanners in mapping wildfires. [Unpublished paper.] Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 90 p.

Warren, J.R. 1989. A look at the next 50 years. Fire Management Notes. 50(1) 9–12.

Thanks, Smokey

Surplus Motors Power Pumps for Water Tenders

Grant County Fire District No. 5, Moses Lake, WA, identified a need to supply water for structural and wildland fire protection in their fire district of 450 square miles (1,166 km^2). A 5-year plan was designed to develop water supply point and tenders. It was decided to build six needed water tenders at the district shop. District personnel obtained chassis and tanks from suppliers and by working with the Washington State Property Agency, six Federal surplus Detroit 3–53 diesel motors[1] were obtained and a 1,000 gallon (3,785 l) per minute transfer pump was mounted to them.

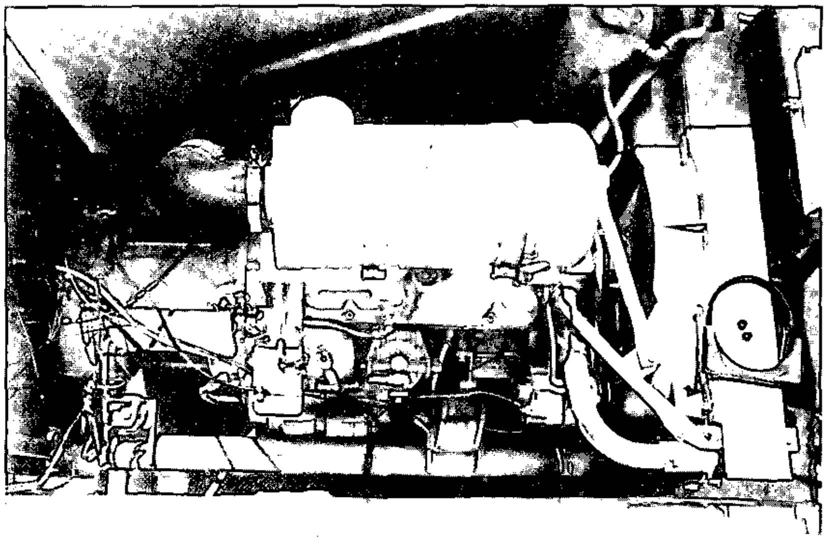
The tenders carry 3,000 gallons (11,356 l) of water each and can be loaded or unloaded in less than 5 minutes.

When equipped with a remote control front nozzle, the tenders can do double duty as wildland fire engines. District No. 5 contracts fire equipment on a regular basis to the Washington Department of Natural Resources, the USDA Forest Service, and the USDI Bureau of Indian Affairs.

Many State and local fire departments improved their firefighting capabilities at minimal cost through the use of Federal excess and Federal surplus property. ■

Bruce Holloway, *fire chief, Grant County Fire District No. 5, Moses Lake, WA*

Pump mounted on top of surplus Detroit 3–53 engine.



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[1] *Three-cylinder, 53-inch motor.*

Fire Managers' Risk Perceptions

Hanna J. Cortner, Jonathan G. Taylor, Edwin H. Carpenter, and David A. Cleaves

Professor, School of Renewable Natural Resources, University of Arizona; research social scientist, National Ecology Center, U.S. Fish and Wildlife Service; professor, Department of Agricultural Economics, University of Arizona; and professor, Oregon State University[1]

Purpose

The purpose of this paper is to present data that discuss the risk-taking attitudes of Forest Service fire managers and the relationship that those data could have to urban-wildland fire interface situations. Data are drawn from a survey study contracted for by the Pacific Southwest Station and completed in 1987 (Taylor et al. 1987).

The study surveyed five western regions of the agency: Northern (R–1), Southwest (R–3), Intermountain (R–4), Pacific Southwest (R–5), and Pacific Northwest (R–6) Regions. The regional offices provided names of personnel who are in positions of decisionmaking regarding Escaped Wildfire (EWF), Prescribed Burning (RxB), and Long-Range Fire Budget Planning (LRP). Eighty-four percent of the 994 Forest Service personnel contacted replied with completed questionnaires.

Results

Base Scenarios. The first part of the survey presented base-scenario choices for each of the three fire decisionmaking situations: Escaped Wildfire, Prescribed Burning, and Long-Range Fire Budget Planning. (For an example of the choices given the decisionmakers, see EWF scenario at the end of this article.) Each scenario consisted of a short, four-to-five paragraph description of a fire situation that involved tradeoffs between risk and cost. For EWF and RxB, respondents were given either/or decisions:

- EWF—whether or not to order more equipment to fight an escaped fire
- RxB—whether to proceed with a planned burn or to postpone it

For LRP, the respondent was asked to rank a series of budget or risk combinations.

In the EWF base scenario, 63 percent of the respondents selected the more risk-averse choice. For RxB, 73 percent chose the more risk-taking selection. For the LRP scenario, 48 percent of the respondents selected the center position as their first choice. The remaining 52 percent were spread fairly evenly over the four other choices, ranging from 9 to 17 percent.

Regional differences among the respondents could be discerned. Overall, across the three base scenarios, Pacific Southwest Region fire managers avoided risk taking in fire decisions more than did those from the Northern, Southwest, Intermountain, or Pacific Northwest Regions. Pacific Southwest respondents consistently showed the highest risk avoidance across the three base scenarios. Fire managers in the Southwest and Intermountain Regions showed greater willingness to take risks in EWF and LRP situations than the other respondents. Northern Region respondents were more willing to take risks in RxB situations, but not in EWF or LRP. In the latter case, these Northern Region personnel were substantially more middle-of-the-road than the others. Pacific Northwest fire managers were somewhat less willing to take risks, or more willing to spend money, in LRP than the others, except for the Pacific Southwest personnel.

Alternative Base Scenarios. The second part of the survey was designed to see what, if anything, would make respondents change their original risk postures. This was accomplished by the use of two sets of alternative scenario questions (see example). If the response to the initial scenario was risk-averse, the next six alternative questions asked the respondent were designed to move the respondent toward a more risk-taking position. If the response to the initial scenario question was risk taking, then the next six alternative scenario questions asked were designed to move the respondent toward a position of risk avoidance. Recognizing that risk is multidimensional and can be perceived from several perspectives, each of the alternative scenario questions altered the base scenario by changing an assumption or adding a new piece of information for the respondent to consider. The information in each alternative scenario reflected one of the following six risk factors:

- *Safety*
- *Resources at risk*
- *Policy directives*
- *Public opinion*
- *Information reliability*
- *Personal considerations*

As expected, *safety* and *resources-at-risk* considerations had the greatest influence on fire managers' decisions. Three-quarters of the overall EWF and nearly 70 percent of the RxB respondents changed from their initial fire-risk positions when a *safety* factor—some increased danger

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[1] The University of Arizona is located at Tucson, AZ; the National Ecology Center at Slidell, LA, and Oregon State University at Corvallis, OR.

to fire crews—was introduced. One-third of the LRP respondents shifted their fire-risk position toward avoiding risk when a fire crew safety factor was added. Nearly 75 percent of the fire managers' answers to the EWF modules and 45 percent of the answers to the RxB questions shifted when a change was introduced vis-a-vis *resources at risk*. Forty-four percent changed their LRP base scenario decisions in response to a change in *resources at risk*. EWF attack decisions were most susceptible to change in *safety* and *resources-at-risk considerations*.

The data show a tendency for fire managers to be susceptible to pressures to avoid risk in the fire decisionmaking process.

Safety risk factors strongly directed fire managers' responses toward risk avoidance. Fire managers can be substantially swayed from their original course of action when they discover a potential threat to human safety or a new safety risk countervailing their original safety concerns. This shows strong support for the longstanding policy that the first item of importance in firefighting is safety.

For *resources at risk*, strong shifts occur toward both risk taking and risk avoidance. When told that an adjacent stand contained valuable post and pole timber, 67 percent of the original risk-takers in EWF and 38 percent in RxB shifted to avoid risk to that resource. However, having an adjacent mature area that had been recently prescribed-burned shifted 64 percent of the original risk-averse in the RxB group toward conducting the prescribed burn. In the LRP *resources-at-risk* scenario, when summer residences and recreational facilities were introduced into the forest under consideration, risk avoidance increased substantially.

That the urban-wildland fire interface influences risk-taking fire-risk behavior is strongly supported by the LRP results. These results show the greatest shift toward risk avoidance took place when respondents were informed residences and recreational facilities were located in the forest for which LRP was being worked out. Since most long-range fire budget choices involve explicit trade-offs between efficiency and risk, the increased pace of interface development could act as a force propelling agency personnel to pay closer attention to structural values in determining fire-efficient budgeting.

The fire managers' decisionmaking responses to changes in *public opinion* depicted in the scenarios ranked third in importance. These responses were generally toward avoiding risks.

The *information reliability* factor ranked fourth in influence on fire managers' decisions. Having a computer model or in the case of RxB a weather station forecast contradict the fire managers' experience or observations caused between 20 to 40 percent of the respondents to change their minds.

Local or regional *policy* changes were fifth in level of influence on fire managers' decisions. For example, when informed of a regional office policy statement in direct contradiction to their initial EWF attack choice, 24 to 37 percent of the fire managers altered their decisions. Interestingly, a LRP *policy* scenario that suggested a regional office announcement of restricted presuppression money sent some LRP planners to ask for more money rather than less, possibly as a means of establishing a trade-off position closer to the desired budget.

Of all the decision factors introduced in these scenarios, *personal considerations* had the least influence. They almost had negligible impact on fire decision behavior with one exception: 27 percent of the fire managers who decided initially to conduct the prescribed burn were swayed by a new Forest Supervisor who was "only lukewarm about prescribed burning."

Implications

Because there is no a priori or fixed-scale means of determining just how risk-averse a fire manager might be for any of these fire decisionmaking contexts, the data reported in this study should be considered a baseline measure. What the data show is a tendency for fire managers to be susceptible to pressures to avoid risk in the fire decisionmaking process. Fire managers tend toward risk-aversion when safety may be endangered or risk to high-value resources is present. The conclusion that safety is important to fire personnel is not surprising. However, as urban-wildland fire interface situations spread through the country and become more severe in impact, decisionmaking both on-the-ground and within budget-planning processes could easily move toward greater risk-aversion. Such a change could have budgetary implications for both fire protection and suppression functions. Many of the fire policy innovations over the past two decades have been explicitly tailored to make fire management decisions more sensitive to considerations of cost. The pressures toward risk-aversion that could be prompted by urban-wildland fire situations might well work to undo many of these innovations. ■

Examples of Escaped Wildfire Scenarios: Base and Two Alternatives

Escaped Wildfire—Base Scenario

You are a district fire management officer (FMO) on the Summit National Forest. You are responsible for making the attack dispatch decisions for a wildfire in your district.

It is the middle of a moderate fire season, and a fire was spotted last night on the east side in the lower third of a major north-south canyon. By 0700 hours the fire has grown to 20 acres (8.1 ha). Two 20-person crews and 2 air tankers are ready.

The fire is burning in light fuels in a primary grazing area consisting of grassland area with scattered ponderosa pine, which is not accessible by road. However, over the top of the ridge is a forested area of heavy fuels that is managed for timber. Up the canyon is a popular improved recreational area with 25 campsites that are currently vacant.

It is 75 °F, the humidity is at 42 percent, and the wind is steady at 5 miles per hour (8 km/h) from the southwest. However, the weather forecast gives a 40 percent chance that gusty winds will occur some time this afternoon or evening.

You have been the fire management officer on this district for 5 years. You have driven the forest and hiked the canyon area extensively.

Under these circumstances, which of the following actions will you choose? (***Circle one choice from below and go to page indicated.***)

Choice A. Send in crews and air tankers, with a 90-percent chance that the fire will be put out at a cost and net resource loss of $50,000. If the fire escapes initial attack and requires more crews and tankers, it will cost an additional $100,000. (***Please go to page EWF-4.***)

Choice B. Send in crews with only a 75-percent chance of putting out the fire at a cost plus loss of $20,000 and a 25-percent chance that the fire will escape and require more crews and tankers for an additional $150,000. (***Please skip to page EWF-2.***)

Alternative Scenario A

Reconsider the base scenario and suppose regional office policy has said that you should maintain aggressiveness in wildfire suppression. What choice would you make?

Choice A. Crews and air tankers ($50,000 or $150,000, depending on escape).

Choice B. Crews only ($20,000 or $170,000, depending on escape).

Alternative Scenario B

Add to the base scenario and suppose that last summer in another district in your forest a similar situation occurred. The fire got away, destroyed some campgrounds, and the local news media provided coverage. The Forest Service came in for heavy criticism for the way it handled the fire. As a result, there is a likelihood there would be public anger and criticism if it happened again. What choice would you make?

Choice A. Crews and air tankers ($50,000 or $150,000, depending on escape).

Choice B. Crews only ($20,000 or $170,000, depending on escape). ■

The More Things Change, the More They Remain the Same

Computerized infrared analyzers, bullseye targeting of water drops, remote fire detection and weather sensing, danger-rating predictive systems, interactive video fire training, satellite communication systems, computer-based information and data systems at the fire incident—no one doubts that the tools of the firefighter have changed in a major way. Yet, the similarities between the tools in the fire cache required to carry out the labor-intensive work on the fire line 50 years ago and now are still strong. Experienced firefighters of today just as their earlier counterparts know the staples of the fireline well: the McLeod, the Pulaski, the shovel, the axe. The fire equipment specialist in Region 5, writing in a 1937 *Fire Control Notes* article about "the loose axe handle," speaks a common language: "Much has been written on the subject of tightening loose handles in axes....After all the years, however, loose handles are still a problem."

Photographs:
Courtesy of National Agricultural Library, Forest Service Photo Collection

Firefighters with their firefighting equipment, pails and sprinkling cans, used for putting out ground fires in Oklahoma (1918). 12751A

Firefighter beating out brush blaze with wet blankets on the Wallowa National Forest in Oregon. 77982

Redding crew members move on up on Mitchell Creek Fire on Wenatchee National Fire in Washington (Jim Hughes 1970). 520885

Kerosene torch used to test flammability of pasture firebreak at the Tidewater Research Center in North Carolina (W.O. Shepperd, 1950). 465050

Forest Service Reserve members using tools to build a practice fire line around a small slash fire in Oregon (George E. Griffith, 1943). 426090

Portable pump used on brush fire on Medicine Bow National Forest in Wyoming (1927). 222251

Portable kerosene backfiring torch used by forest officer C. G. Herrick on the Francis Marion National Forest in South Carolina (Dan O. Todd, 1950). 465050

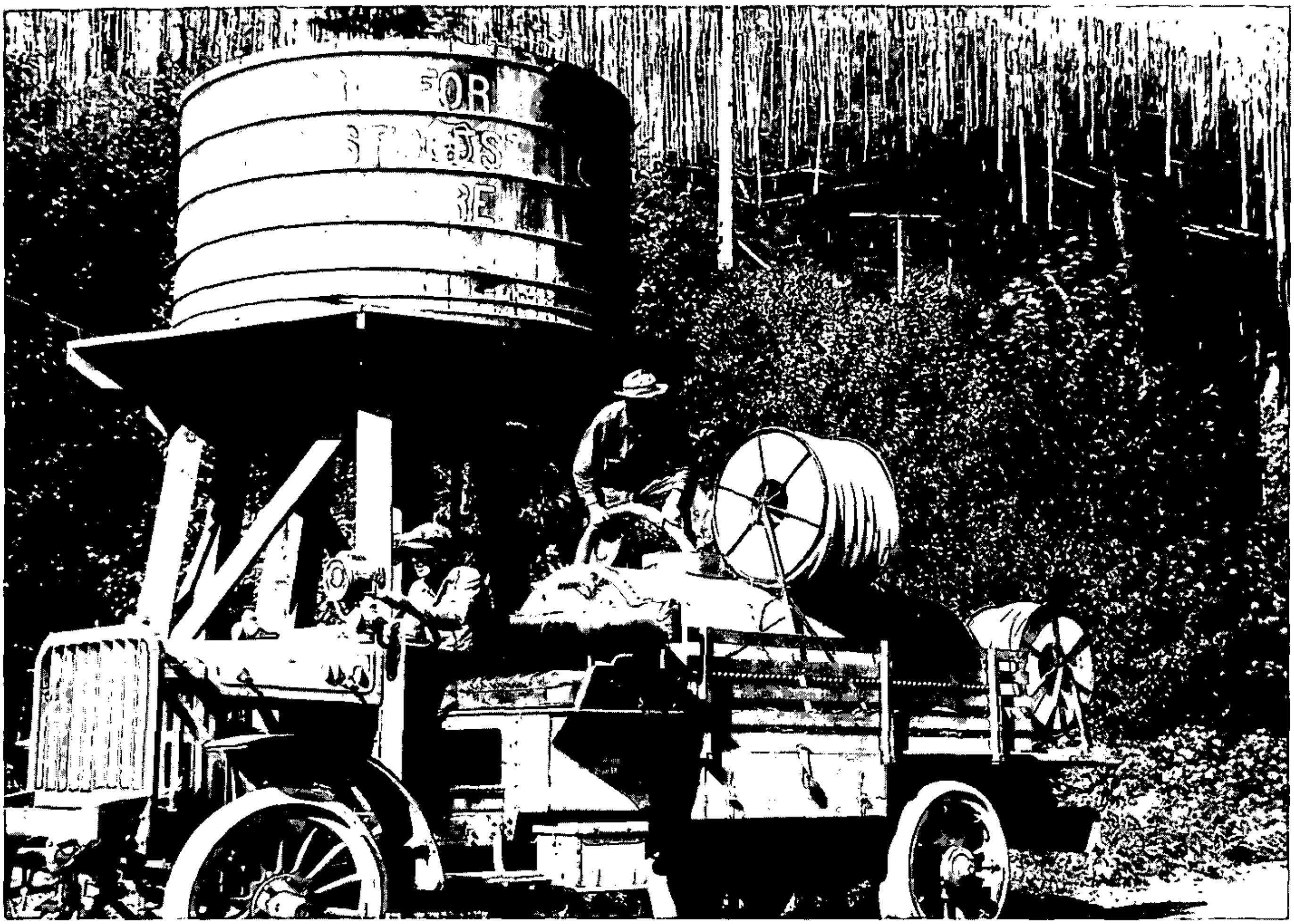
Firefighter with protective see-through shield spraying water from a packer pump. 96634

Foreman Raymond Fletcher reading fire danger meter at Camp S-52, Rhode Island (Lentz and Hoar, 1940). 399155

Firefighters with axes, saws, and shovels on the Wasatch National Forest in Utah (W.S. Clime, 1914). 21580A

Yolande Hensen from Mississippi wears protective clothing and carries a McLeod brush rake used in firefighting training on the Targhee National Forest (A.P. Matejko, 1980). 531292

Firefighters drinking water from bags on the Ranier National Forest in Washington (July 1919). 444482A



Forest Service truck used on Olympic blowdown on the Olympic National Forest in Washington (Tom Gill, 1924). 191364

Pack string to supply fire camps inaccessible by road on the Sleeping Child Fire on the Bitterroot National Forest in Montana (Arnold Hanson, 1961). 507314

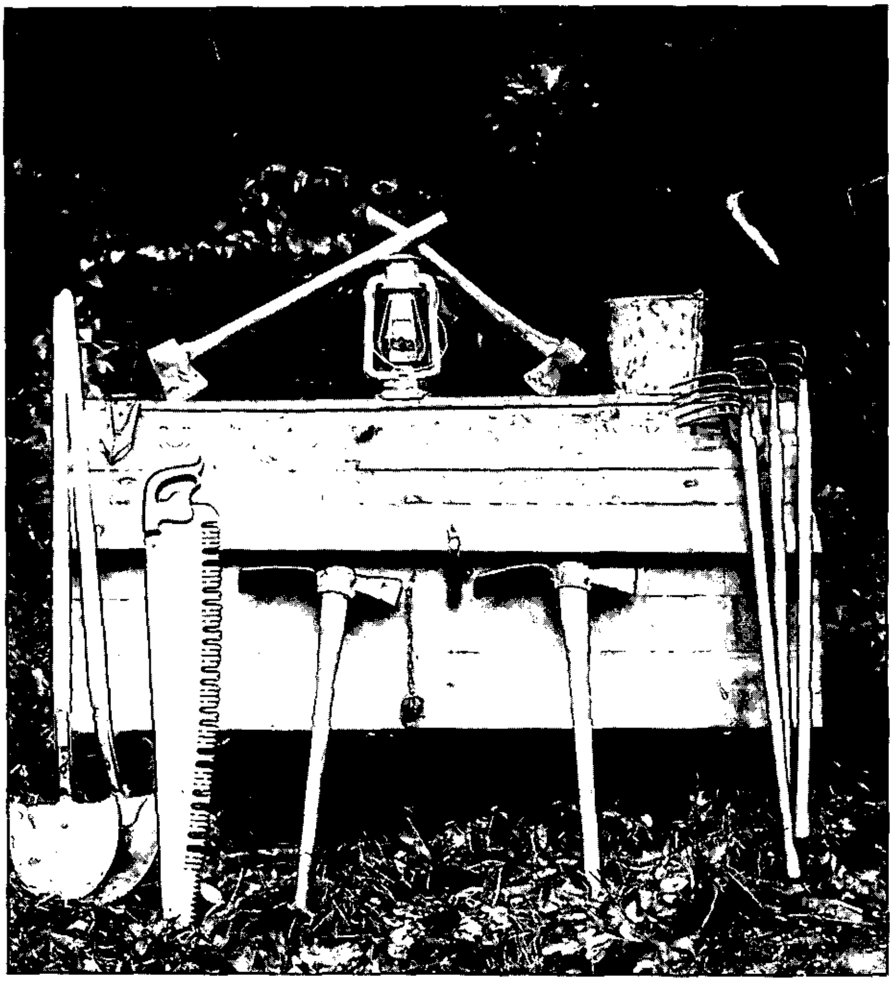
Farmer plowing fire break around privately owned field (longleaf pine belt) within the Osceola National Forest purchase boundary (George A. Duthie, 1939). 379409


A closeup of Pulaski used on a fireline in Massachusetts. (B.W. Muir 1939). 383092


Zuni fire crew from Cibola National Forest in New Mexico ready to fly in DC-3 to Ranshorn Fire in R-5 (1959). 494820


Fire Box No. 1 with equipment stacked in foreground on the Monongehela National Forest in West Virginia (1936). 325801


Helicopter use was tested intensively by the Forest Service and the U.S. Army in the summer of 1946 on two of the national forests of southern California (W.I. Hutchinson, 1946). 442413


Fire tool box and contents, located along Southern Railroad in North Carolina (E.S. Shipp, 1913). 15483A

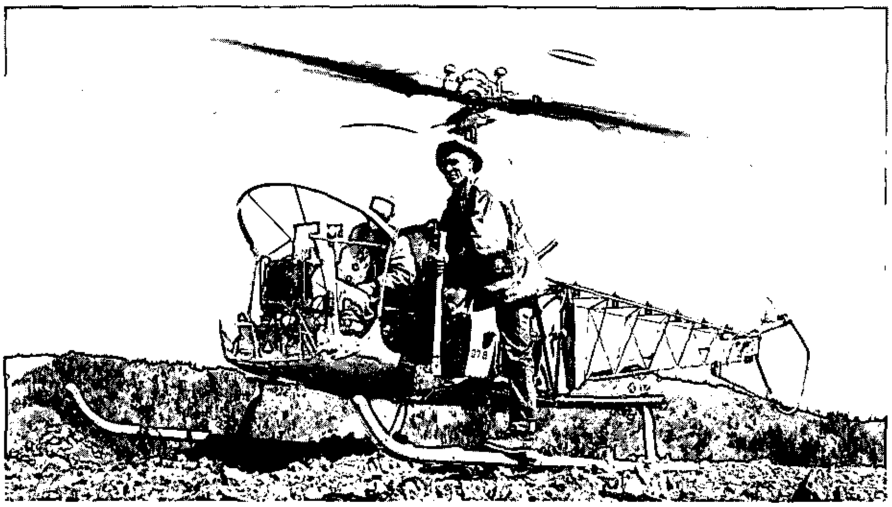
Fire guard in the fire observatory on Mount Hale reporting fire to headquarters by means of telephone on White Mountain National Forest in New Hampshire (B.W. Muir, 1939). 379800

Telephone line construction through Flathead National Forest in Montana (1908). 80574

Grey Butte Radio Relay Station on Shasta National Forest in California (Fred Funke, 1941). 414468

Ranger about to release carrier pigeon with fire message on Deschutes National Forest on Oregon (1920). 47459A

Leatrice Evinger with radiophone at the Buck Rock Lookout on Sequoia National Forest in California (Norman L. Norris, 1944). 436288



Checking fire line in Backbone Ridge area on the Trinity National Forest in California (Jack Rottier, 1953). 474366

Portable hot table in truck, feeding firefighters of the Los Angeles County Forestry Department on the Angeles National Forest in California (Howard Ballew, 1947). 447561

Bedroll used by firefighter after all-night duty on the fire line of the Outlaw Fire on the Coronada National Forest in Arizona (W.L. Hansen, 1956). 482540

R.B. Adams sends first wireless telephone message in the national forests on Lolo National Forest in Montana (1919). 45520A

Sector boss and fire crew boss use radio to obtain information on hot spot on Salmon National Forest in Idaho (B.W. Muir, 1961). 501008

Bed rolls being loaded at Poverty Flat Fire camp on the Payette National Forest in Idaho (Bluford W. Muir, 1961). 499985

FLIR: A Promising Tool for Air-Attack Supervisors

Charles W. George, Gerald F. Ewart,[1] and Walter C. Friauf[1]

Project leader, USDA Forest Service, Intermountain Forest and Range Experiment Station, Missoula, MT; fire management consultant, Chandler, AZ; and fire management consultant, Safford, AZ

The ORE Project

In 1983, an operational retardant evaluation (ORE) was initiated to evaluate fire retardant and aerial retardant delivery system effectiveness (George 1985) on actual wildfires. The objective of the program was to ascertain retardant coverage requirements in various fuel types and fire behavior situations. This knowledge would provide the basis for developing guidelines for applying retardant and for tailoring both chemical retardants and delivery systems to characteristics of specific fires.

The first season (1983) of the ORE study was devoted to evaluating proposed techniques and methods and exploring the feasibility of conducting such a study under operational conditions. The ORE evaluation team was composed of personnel knowledgeable in aerial fire suppression, fire retardant characteristics and delivery systems, fuels and fire behavior, research methods, and the use of instrumentation to be utilized in the study.

The FLIR System

One of the tools selected for evaluation and use in the study was forward-looking infrared (FLIR) imagery. The FLIR system provides an image by sensing the amount of heat (temperature) radiating from objects or areas within its field of view. In the process of the evaluation, each incident was documented from an observer aircraft, using a conventional high-quality color video camera system and the infrared FLIR system. FLIR Inframetrics (Model 525), Panasonic video camera (Model D5000), and SVHS recorders (Model AG7400) make up the FLIR and video systems presently being used in the ORE study. The imaging systems were installed in a Cessna 337 aircraft provided by the California Department of Forestry and Fire Protection and used in the ORE study (fig. 1).

The FLIR and video cameras, recorders, rear-seat monitor, and audio equipment were mounted in a special fixed rack in the aircraft. The video and FLIR cameras were positioned side by side on a fluid-head pedestal constructed by the San Dimas Technology and Development Center (SDTDC). The pedestal was fixed to the floor of the aircraft where the cameras could be aimed out the cargo door opening (door removed). A radio scanner was used to pick up air-to-ground radio communication, which was recorded on channel 2 of both video recorders. Air-to-air communication was monitored through aircraft avionics (two Wolfsburg 9600 radio/transmitters); selected transmissions and intercom communications were recorded on channel 1 of the video recorders. The FLIR image enabled observers to evaluate placement of retardant drops and their effective-

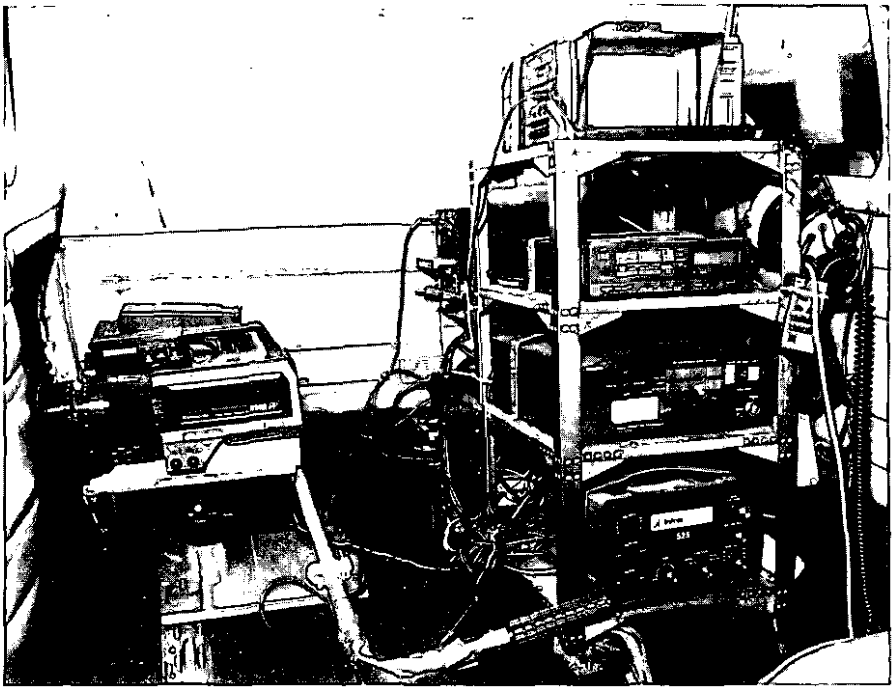


Figure 1—*Observer/evaluator Cessna 337 aircraft fitted with video and FLIR cameras and recording instrumentation.*

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[1] Gerald F. Ewart was formerly the assistant fire management officer on the Tonto National Forest and Walter Friauf was a district fire management officer on the Coronado National Forest. Both are now retired from the USDA Forest Service.

ness when smoke obscured both video and visual observation. The video and FLIR imagery were correlated with data collected from selectively instrumented air tankers, on-the-ground observations, and retardant coverage level/fuel sampling information from the drop zone.

Operational Problems That Can Be Overcome With FLIR

The following problems commonly occur and often are not seen by air attack and lead-plane personnel because of smoke:

- Inability to see the location and distribution of retardant due to the lack of sufficient retardant color fuel contrast, smoke, or a combination of the two. Placement and effectiveness of water or foam from helicopters can similarly be difficult to evaluate, because visible wetness is frequently short-lived and is to some extent dependent on near constant replenishment by aerial attack.
- Failure to recognize gaps in retardant placement due to either excessive tank door opening delay or inadequate overlap of two separate drops (fig. 2).
- Misjudgment of the fire's rate of spread and intensity relative to the retardant being placed. Will the fire burn through or under the retardant line or outflank the last retardant drop before the next one arrives?
- Lack of recognition and use of natural barriers to anchor or enhance the retardant line, such as bare or sparsely covered ridgetops, open area, streams, and lakes (fig. 3).
- Failure to recognize and make known how long the retardant line will hold until ground support can be provided.
- Inefficient aerial fire suppression due to lack of accurate information on the fire situation.

Introducing FLIR into the Air-Attack Supervision Program will not solve all the problems associated with retardant delivery and application, but will result in significant improvements.

The use of FLIR eliminates most of these chronic problems. FLIR allows for unobstructed monitoring of each retardant release from the time it leaves the aircraft until it has evaporated or reached the ambient temperature of the fuel or terrain treated by it. FLIR can typically display the retardant distribution for 15 to 30 minutes, depending on the drop-coverage level, weather conditions, and fire activity. From the FLIR imagery, the observer can plainly see where the retardant has fallen, its relative level of concentration, its proximity to the fire, the progress of the fire into, through, or around the retardant drop, and whether the fire has been extinguished or is rekindling. The observer can assess subsequent drops, drop placement and accuracy, need for uniformity of the retardant coverage, gaps caused by mistimed sequential drops, the extent of drop displacement caused by wind or fire convection activity, inadequate anchoring of the retardant line, and so on. In addition, spot fires ignited across a fire or retardant line can be identified at the earliest possible moment. Most importantly, this appraisal is possible even when smoke masks the zone of operations.

FLIR allows lead-plane or air-

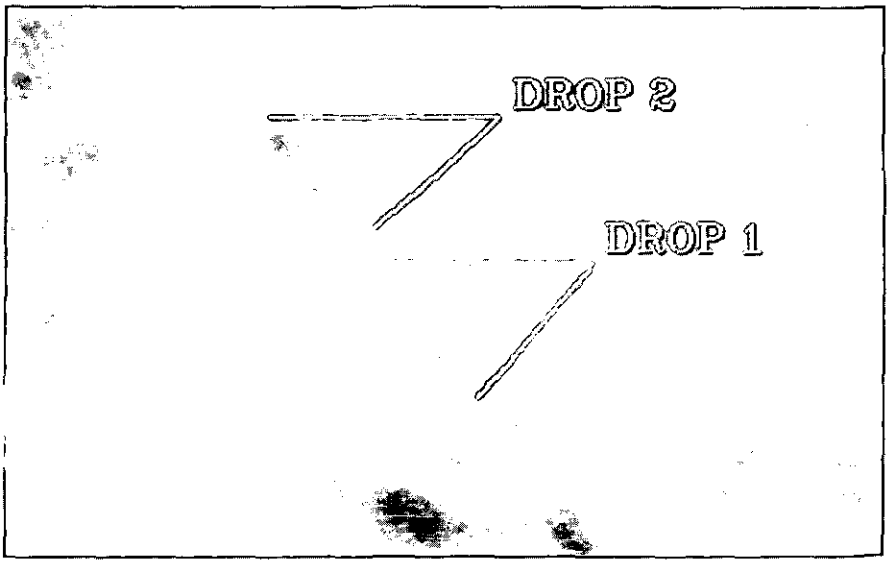

Figure 2—*FLIR imagery showing a gap in a retardant line due to use of an excessive door delay interval.*

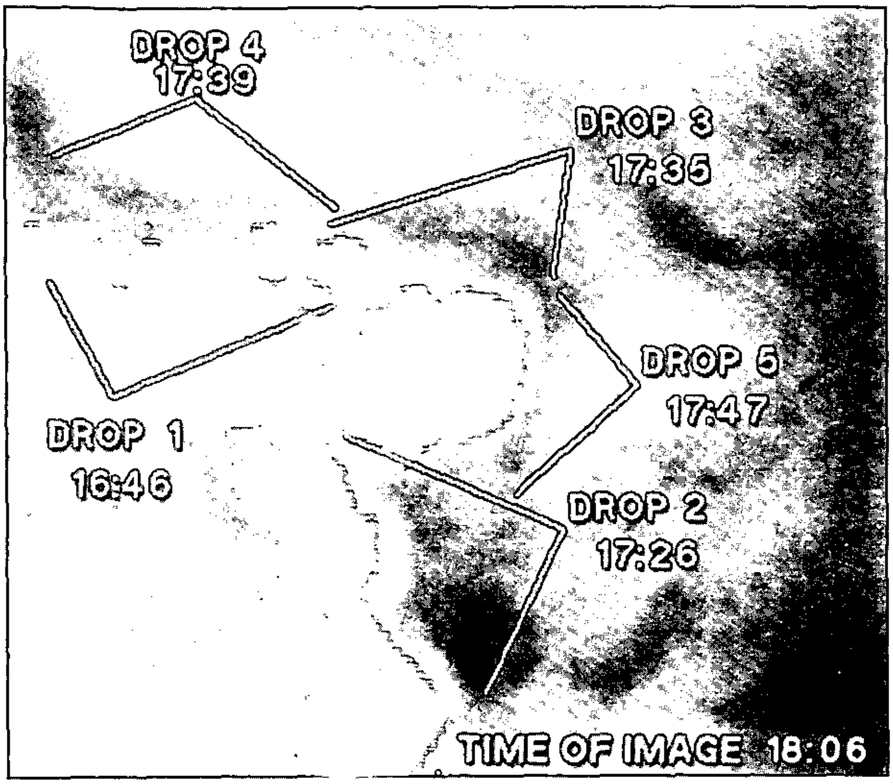

Figure 3—*FLIR imagery of an improperly anchored retardant line that is being out-flanked by the fire.*

attack personnel an opportunity to reinforce lines before they burn through and to modify an application that is too heavy or too concentrated. It can also enhance target identification, description, and communication between air-attack supervisors, lead-plane pilots, and air-tanker pilots.

Immediate feedback to the air-tanker pilot or air-attack supervisor regarding true performance can often enhance effectiveness. FLIR can remove much of the guesswork and hence hesitancy on the part of supervisors to offer advice and direction to air-tanker and lead-plane pilots. Accurate assessment of effectiveness facilitates concise communication. Inability to see through smoke and assess fire behavior, direction of spread, and retardant placement and concentration can lead to erroneous assessment and inappropriate tactics and strategy at all pilot levels (ground, air attack, lead plane, and air tanker).

ORE experiences indicate that observers typically select retardant coverage levels more accurately in light fuels when the fire edge and retardant color are plainly visible than in heavy fuels, where the retardant distribution and sometimes fire behavior is not as discernible. In heavier fuels, there is a tendency to use much more retardant than necessary and to continue ineffective applications. FLIR provides the observer with a clear view of the fire edge and applied retardant in all fuels, and thus facilitates assessment of retardant needs in most wildland fuels.

The lofting of live embers across retardant lines is a common problem.

Ten Principles of Retardant Application

1. **Determine tactics, direct or indirect, based on fire size-up and resources available.**
2. **Establish an anchor point and work from it.**
3. **Use the proper drop height.**
4. **Apply proper coverage level.**
5. **Drop downhill and down-sun when feasible.**
6. **Drop into the wind for best accuracy.**
7. **Maintain honest evaluation and effective communication between the ground and air.**
8. **Use direct attack only when ground support is available or extinguishment is feasible.**
9. **Plan drops so that they can be extended or intersected effectively.**
10. **Monitor retardant effectiveness and adjust its use accordingly.**

Figure 4—*Principles of retardant application.*

Rapid detection and location of spot fires along with appropriate suppression action, namely, a helicopter with a bucket, an air tanker, or ground suppression forces, can have a major impact on overall suppression effectiveness and cost. Detection of spot fires and rapid relay of this information to the air-attack supervisor has demonstrated numerous times the impact FLIR can have on suppression efficiency. FLIR imagery can similarly provide valuable information on the location, activities, and effectiveness of other suppression equipment, such as dozers and fire trucks.

Operational use of FLIR to aid direction of retardant application appears to offer significant payoff in both safety and costs. To emphasize this point, the 10 principles of retardant application are presented in figure 4. The principles were developed for the National Advanced Resource Technology Center course, ''Aerial Retardant Application and Use.'' It is readily apparent that FLIR can enhance implementation of the principles of retardant application.

Summary and Recommendations

As suppression costs increase in the face of constrained budgets, fire management specialists struggle to find ways to improve efficiency. Fire management practices are changing rapidly in order to get the job done at less cost but with reasonable safety. With the cost of long-term fire retardant and aerial delivery often pushing $2 per gallon, we should implement programs and technology that improve effectiveness while reducing cost. Implementation of the ORE FLIR and development of a handheld FLIR for the air-attack supervisor should receive high priority in future research and development efforts. The study should attempt to describe the technical, physical, and general operational requirements for an ''air-attack FLIR system.'' The initial evaluation should use the onboard ORE or similar FLIR and video recording equipment, because it will provide not only the needed imagery but document the effectiveness and application of information in ''operational use.''

Introducing FLIR into the Air-Attack Supervision Program will not solve all the problems associated with retardant delivery and application, but will result in significant improvements. The cost of equipment appears to be more than justified by projected savings. During the ORE program, numerous situations were documented where FLIR could have paid for itself on a single incident. ■

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"Watch Out!" Situations

1. Fire not scouted and sized up.
2. In country not seen in daylight.
3. Safety zones and escape routes not identified.
4. Unfamiliar with weather and local factors influencing fire behavior.
5. Uninformed on strategy, tactics, and hazards.
6. Instructions and assignments not clear.
7. No communication link with crew members/supervisors.
8. Constructing lines without safe anchor point.
9. Building fireline downhill with fire below.
10. Attempting frontal assault on fire.
11. Unburned fuel between you and the fire.
12. Cannot see main fire—not in contact with anyone who can.
13. On a hillside where rolling material can ignite fuel below.
14. Weather is getting hotter and drier.
15. Wind increases and/or changes direction.
16. Getting frequent spot fires across line.
17. Terrain and fuels make escape to safety zones difficult.
18. Taking a nap near the fireline. ■

The Keetch/Byram Drought Index: A Guide to Fire Conditions and Suppression Problems

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The 1988 version of the National Fire Danger Rating System (NFDRS) has been completed and should be operational by the first part of 1991. The NFDRS has an important new addition: The Keetch/Byram (K/B) Drought Index calculations have been added to the system. As a part of the NFDRS, the K/B index will be the most widely used drought index for fire danger rating. Fire personnel will need to know specifically the effect of drought on both wildfire and prescribed fire and the significance of the index and its relationship to the fire environment. This means fire managers must understand the K/B index system, be able to interpret the data from the system, and apply that knowledge to the local fire situation.

The K/B Index

John Keetch and George Byram developed the K/B index at the Southern Forest Fire Laboratory to evaluate the effects of long-term drying on litter and duff and subsequently, on fire activity (1968). The index is based on a measurement of 8 inches (0.2 m), of available moisture in the upper soil layers that can be used by vegetation for evapotranspiration. The index measure is in hundredths (0.01) of an inch of water and has a range of 0 through 800, with 0 being saturated and 800 representing the worst drought condition. The index indicates deficit inches of available water in the soil. A K/B reading of 250 means there is a deficit of 2.5 inches (6.4 cm) of ground water available to the vegetation. As drought progresses, there is more available fuel that can contribute to fire intensity.

Fire Behavior at Selected K/B Levels

The following information is a compilation of data and observations fire managers and I have made from field observations of both wild and prescribed fire at numerous locations. It is an attempt to qualify and quantify in common terms the effect of continued drought on forest fuels and the problems arising from drought conditions during the course of wildfire and prescribed burns. This information should help fire practitioners to more fully understand the relationship between the K/B index readings—which indicate the extent of drought—and the fire environment.

As a part of the NFDRS, the K/B index will be the most widely used drought index for fire danger rating.

The effect of drought on fire behavior will vary between fuel types and topographic regions. Mountainous hardwood fuels will react differently than the Southern pine fuels to drought and consequently fire effects will also differ. Rain or relative humidity and wind may also require an adjustment to K/B level interpretation. For instance, even if the K/B level is extremely high, a brief rain will temporarily render fuels incapable of burning. Yet on the other hand, the K/B index can be low (<100) and high wind and low relative humidities can create an extreme situation in some fuel types. The following descriptions of conditions at various K/B levels is primarily related to the Southern Coastal Plain and Piedmont regions, but these can be considered applicable in many areas of the country. Fire personnel should remember that specific situations may be different than those described and should use this information to complement his or her experiences at a particular location.

K/B Levels 0–150. During this stage of drought, the fuels and ground are quite moist. Fine fuels exhibit daily drying, burning readily at times but also recovering to a high moisture content at night. This level is ideal for winter or spring prescribed burns. Most fires are easily suppressed with normal practices and generally are not a problem. The lower litter and humus layers are moist and not affected by fire. Most fires die out at night due to humidity recovery and its dampening effect on the fine fuels. Some fuel types (grasses) burn actively, but seldom create much problem with control efforts. Generally, extensive mop-up is not required, since most heavy fuels (100 and 1000 h) are too wet to ignite. Ignition of snags is not normally a problem on wild or prescribed fires. The spring fire season can still generate some extremes in behavior on wildfires due to the nature of fine fuels, especially in fuel types with a heavy loading of grasses. Drying is generally limited to the fine surface fuels and the organic layers still retain sufficient moisture to resist burning. This could be considered the business-as-usual period.

K/B Levels 150–300. Within this range, scattered patches of surface litter remain in low-lying or damp areas following a fire, and the organic layer remains basically undisturbed. Both pine and hardwood stumps may ignite but seldom burn below ground. Most will go out. Hardwood snags less than 10 inches or 0.3 meter in diameter at breast height may ignite and burn while larger snags (>14 in or 0.4 m) still resist deep burning due to high interior moisture levels. Generally snags are not a serious threat to control efforts, and most will go out during the night. However, snags within falling distance of the lines should be considered a major threat for potential fire escape. Normally, escaped fires pose little problem to standard suppression tactics. Fire behavior is predictable. Spotting is usually minimal.

When the K/B level exceeds 200 and approaches 300, a more intense and active fire situation develops, requiring closer attention by fire personnel. Usually at this level, minimum mop-up is required. Normal fire personnel and equipment levels are adequate, especially for most forest type fuel models. Wildfires can generally be suppressed with direct attack. Humidity recovery at night will aid in the control of fires during the night hours making suppression simple. Fire personnel should keep in mind that the 300 level represents the upper range that can be considered acceptable for normal winter or spring burning. Large acreages (500 acres or 202.4 ha) ignited at this level can create intense conditions that are difficult to control during the peak burning period and can do unnecessary damage to timber stands (scorch and bole damage). Fire personnel should be especially careful with helicopter operations that ignite large areas of fuels simultaneously. Larger downed fuels will ignite, sometimes creating hazardous smoke conditions at night along nearby highways. Topographic features and drainages normally used for control lines can be expected to hold both wild and prescribed fires.

A backing prescribed fire carried out when K/B index was below 100. Note absence of smoke following the fire. This indicates only fine surface fuels are being consumed and no deep burning of litter or soil organic layer.

K/B Levels 300–500. At the K/B 300 to 500 level, fire consumes most surface litter along with a significant loss in organic soil material. Site preparation burns expose mineral soil, producing areas causing erosion problems. The heavier fuel complexes (100 and 1000 h) ignite readily, contributing to fire intensity. For instance, stumps are ignited readily and burn underground. Pine "lighter" stumps are totally consumed, but most hardwood stumps still resist deep burning, especially underground. Both pine and hardwood snags ignite at this level, although larger snags (20 in or 0.5 m and over) still resist deep burning. Hardwood snags ignite readily and pose control problems when located near lines.

Fire intensity increases dramatically in this range due to the increased burning of heavier fuel classes. Spotting begins to be a major problem and in some fuel types could be considered the rule. Escaped fire is difficult to control because heavier fuels are contributing to intensity, especially during the peak burning period. Fire behavior is still predictable but situations may require additional personnel and equipment to control a fire. Escaped fire in both prescribed and wildfire situations holds over during the night and burns again the next day. Humidity recovery is generally insufficient to extinguish heavier fuels, resulting in a large number of hold-over fires. Increased mop-up and patrol activities are required. All normally planned winter or spring understory fire should be canceled when the K/B index exceeds 350. Direct attack on wildfires is difficult due to intensity. Topographic features used for lines in prescribed fire and wildfire suppression will hold, but smaller drains begin to dry up, and drifted debris is dry enough to allow fires to creep across drains. Swamps begin to show reduced water levels.

K/B Levels 500–700. Generally, all surface litter and most of the organic layer is consumed by fire. Site preparation operations consisting of broadcast chemical application followed by fire ("brown and burn") result in almost complete removal of organic material from the site. At this level, 1000 hour fuels contribute readily to fire intensity.

When the K/B index is above 600, expect the following:

- Stumps burn to the end of the roots and all large downed fuels (logs and so on are totally consumed over a period of 48–72 hours. This will result in a massive amount of smoldering fire in the burned area.
- Dead snags ignite. Large dead snags will create a safety hazard due to the potential for falling.
- Dead limbs on trees ignite from sparks, sometimes at considerable height above the ground (50 ft or 15 m and over).
- Spotting is difficult to control.
- Escaped fire continues to burn through the night and into the next day.
- Burns leave excessive site damage.

Above the 600 K/B level, fire suppression is a major problem. Direct attack is generally not effective due to increased intensity and spotting. Extreme intensities add to the control efforts. When winds approach 10 miles per hour (16 km), spotting is the rule. Some nighttime activity can be extreme, dependent on fuels available. Fire personnel should expect and prepare for the previous day's fire to escape the next day during the peak burning period. Summer site preparation burns should be canceled when the K/B index reaches the mid-500's. Fire behavior is still predictable but tends to be underpredicted, since extreme intensity levels caused by the heavier fuel complexes might be overlooked. Extensive mop-up is critical to fire suppression. Increased need for fire suppression personnel and equipment can be expected.

As the K/B level approaches 700, understory vegetation wilts and is consumed by fire. All ephemeral drains and intermittent drains are dry. Only larger river drainages contain enough water to be useful in fire

A summer site preparation burn area, 1 year after an intense fire consumed basically all the organic layer, penetrating the mineral soil. The K/B index was over 600 at the time of the burn. Note almost total exposure of soil with no ground cover remaining and only one sprout showing.

control, and these are easily compromised by spotting. Most larger swamps will show significant water loss and intense fires can be expected if they occur in these areas.

As the K/B index goes into the upper 500 range, fire personnel can expect to encounter more urban interface type fire starts. Experience has shown that the general public is not aware of the volatile situation and more wildfire starts will tend to originate from "normal" burning by the public. At this point, only a major rainfall will reduce the fire hazard.

K/B Level 700 Plus. Expect more of the same, only worse! At the 700-plus level, many understory species with shallow root systems continue to exhibit extensive wilting and contribute to fire activity by acting as ladder fuels and increasing the chance of extreme fire behavior. All burning should be banned until the K/B index falls below 500, the minimum. Only rapid response time to wildfires along with intense suppression efforts will keep a major fire situation from developing. Most fire agencies and State organizations will issue burning bands on all outside burning, especially if wildfires have developed. At this K/B level, urban-interface fires become a major problem. Increasing numbers of wildfires originate from the vicinity of homes and residences since the general public does not adequately understand the care that must be taken in this kind of drought situation.

Additional Observations

There are two other conditions worth mentioning here that may affect the danger level as indicated in the K/B index. These are days-since-rain and humidity recovery. During the normal fire year, there will be a rise and fall of the drought conditions. The index is usually low in the spring and rises as summer progresses on into fall and then begins a slow decline as winter rains return.

Days-Since-Rain. During the early spring when the K/B index would normally show a level below 200, the days-since-rain number represents valuable information to the fire manager. If focusing on the drought index as a chief indicator for danger of wildfire occurrence, it is easy to forget that fine fuels readily burn and can create relatively intense conditions even at low K/B levels. At low K/B levels, days-since-rain is a better indicator of actual burning potential than the drought index. As the index rises into the 300 range and above, days-since-rain is of less importance because of the deep drying occurring in the lower fuel layers and in larger fuels with resulting increase in fire intensity. Very intense fires can occur in only 2 or 3 days following rain, if the drying of fuels is deep and requires significant moisture to saturate to near the moisture of extinction point. Consequently, the more advanced the drought, days-since-rain becomes less important. At this point, more emphasis should be placed on the K/B level.

Humidity Recovery. Humidity recovery normally happens to some extent each night. In the South, normal night humidities can average over 90 percent, while in the West 40 percent might be considered high. Regardless of the location, this increase in humidity has an effect on the availability of fuels to be consumed by fire. During the early stages of drought (below the 300 level), humidity recovery can actually control fires at night by raising the fuel moisture of fine fuels near or above the extinction level. Moisture is transferred from the atmosphere to the fuels and also from the lower fuel layers and soil which are very moist. As the drought increases, there is less moisture available from the lower fuel layers and soil and consequently fires can continue to burn through these deeper fuel layers at night. The resulting increase in fire intensity can effectively counter any increase in night humidity. Generally, as the K/B index approaches and exceeds the 500 level, humidity recovery alone will not stop the combustion process.

Summary

In review, and this is particularly true in the Southern States, normal spring or winter prescribed fires should be curtailed when the K/B index exceeds 350, and summer site preparation fire should be reduced when the K/B index exceeds 500. Wild and prescribed fires that occur when the K/B index approaches and exceeds 300 will cause increasing difficulty of control as the index goes higher. Wildfires that occur below the 300 level in fine fuel types or in steep topography can still be extremely difficult to control even though the soil and lower fuel layers are moist.

Fire personnel need to be especially cautious in using prescribed fire if the K/B index has been high and is falling into the upper 200-to-300 range. The heavier fuel classes will still be sufficiently dry inside to burn for extended periods and can result in smoldering fuels and subsequent smoke problems if near any smoke sensitive locations. Hazardous nighttime smoke conditions can reoccur for several nights. These heavier fuels will continue to smolder and burn until the next rain or until they are essentially consumed.

Fire personnel should be alert for K/B levels that depart from the normal precipitation yearly patterns, especially during spring or fall fire seasons. Figure 1 illustrates the typical K/B index readings for a year of normal precipitation. Figure 2 shows how the K/B readings in one period of the year can be used to predict fire danger later in the year. Spring fire seasons that coincide with increasing K/B levels of 300 and above can lead to increasingly hazardous fire conditions. Since most of the smaller fuel classes are cured at this time, they readily burn with increasing intensity as deep-drying continues. Likewise, fall fire seasons that coincide with K/B levels of 400 and above through October and November are usually busy seasons for fire personnel. Fall fires that occur during this situation will be extremely difficult to control and require extensive mop-up, since all of the fuel classes and soil were abnormally dry from the summer's heat, and fires will basically consume every class of fuel that can be ignited. For example, the fall fire season of 1987 had K/B level readings in excess of 700 through November, falling into the 600 level in December. Consequently, the spring season of 1988 was basically a carryover from the previous season with K/B readings in the 600 level common until mid-June in many parts of the South. ◻

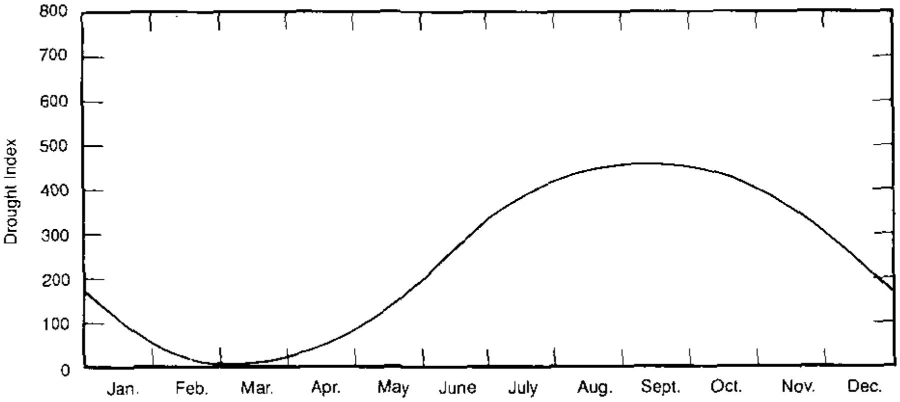

Figure 1—*A typical annual Keetch/Byram curve that can be expected with normal precipitation levels. (Actual levels may be different, depending on the locale, but the curve shape will be similar.)*

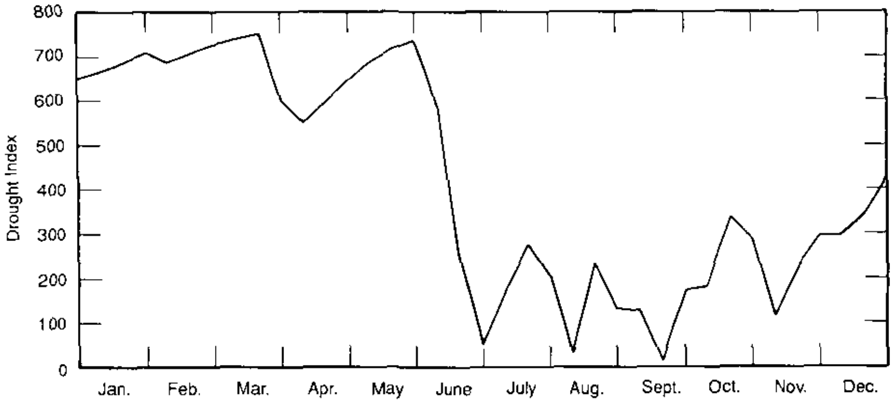

Figure 2—*A Keetch/Byram curve showing abnormally high spring readings. Situations such as this can result in extreme fire seasons in the spring. The reverse of this curve indicates the potential for a heavy fall fire season such as was experienced in 1987.*

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Wildland Fire Occurrence and Behavior Analysis in the Year 2000 and Beyond

Forestry Canada Forêts Canada

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Introduction

The purpose of the Symposium on Wildland Fire 2000 was to examine the "possible, preferred, and probable status of wildland fire management and research in the year 2000 and beyond" (Davis and Martin 1987). A half-day "futuring" session was an integral component of the program. Attendees were divided into nine topic-oriented task groups. This paper is adapted from the report submitted by futuring group 8 (fire occurrence and behavior analysis) which eventually appeared in the symposium proceedings following preparation during the working session and presentation to the entire conference delegation on the final day of the program (Davis and Martin 1987).

In addition to the authors, the other members of the group included: Tim Lynham and Charlie Van Wagner, Forestry Canada (then the Canadian Forestry Service); Dick Rothermel, USDA Forest Service; Kathy Davis, USDI National Park Service; and Orvil Robinson, USDC National Weather Service. Martin Alexander served as spokesperson and both authors compiled the report. The group facilitators were Gary Brittner, Chris Scrowe, and Don Escher, all with the California Department of Forestry and Fire Protection.

Definitions

For purposes of clarification, some simple definitions of terms, as taken from Merrill and Alexander (1987), are deemed in order:

- *Fire occurrence:* The number of fires started in a given area over a given period of time
- *Fire behavior:* The manner in which fuel ignites, flame develops, and fire spreads and exhibits other related phenomena as determined by the interaction of fuels, weather, and topography

It's worth noting that the term "fire danger rating" is used to describe fire management systems that systematically evaluate various factors influencing fire potential, chiefly for the purpose of determining fire protection needs.

The fire occurrence and behavior analysis futuring group identified 15 key trends and formulated 5 key visions with their associated strategies.

Futuring Concepts and Procedures

Futuring "is a participative process that brings together several individual ideas into a collective group perspective of a preferred future" (Albright 1987). By working in small groups, with the assistance of trained facilitators, people with different ideas and backgrounds can use futuring to develop a "vision" of a desired or preferred future.

The 4-hour futuring process used at the Wildland Fire 2000 conference involved the following:

- Identifying trends
- Focusing on key trends and their implications
- Developing visions
- Identifying actions or strategies in order to realize those visions.

The facilitators directed the administrative aspects of the futuring process but did not interfere with the technical content of the group's deliberations.

A *trend* was defined as the direction current political, economic, social, and technological factors affecting wildland fire management and research were taking. A *vision* was considered an image of a preferred future that is attainable and serves as a guide to interim strategies, behaviors, and decisions. A *strategy* was viewed as a broad, general approach to attaining a vision or part of a vision.

Identified Trends

The group identified 15 key trends:

- Continuing need to improve "fire intelligence systems" (Barrows 1969) in fire control and use programs
- Adoption and increasing use of geographic information systems in fire management (e.g., Kessell et al. 1984)
- Steadily increasing demand for three-dimensional fire growth modeling (e.g., Kourtz 1984) for use in presuppression planning, including training, and daily operations
- More and greater expectations of fire managers due to external and internal pressures (e.g., cost-effectiveness, urban-wildland interface problems)

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[1] On long-term training from the Northern Forestry Center, Martin Alexander is currently a visiting fire researcher with Commonwealth Scientific and Industrial Research Organization, National Bushfire Research Unit in Australia; Patricia Andrews is stationed at the Intermountain Fire Sciences Laboratory.

- Increased weather data gathering activity (e.g., remote automatic weather station (RAWS) networks, lightning locator systems, precipitation radar, and satellite imagery)
- Greater demands on the existing systems used to evaluate fire danger and predict fire occurrence or behavior (i.e., they are being applied to fire problems and opportunities that exceed their original purpose or capability or both)
- Significant improvement in electronic communications
- Gradual acceptance of centralized fire control centers
- Skill level of some fire management personnel being surpassed by the state-of-knowledge and new technology
- Widespread misunderstanding of the proper application of the present analytical systems available for fire occurrence and behavior
- Growing interest in more robust schemes for predicting human-caused and lightning-ignited fire loads
- Tendency toward greater international cooperation in fire research (e.g., Albini and Stocks 1986)
- Necessity for designing systems to address all levels of fire management activities (Rothermel 1987)
- Continuing demand for "longer range" weather forecasts
- Increased interest by fire-prone countries in the use of the various other national systems of fire danger rating developed in Canada, Australia, and the United States (e.g., Valentine 1978; Peet 1980; Van Wilgen 1984)

Key Visions and Associated Strategies

The group formulated five key visions outlined below along with their associated strategies:

Basic Models of Physical Fire Phenomena. *Vision:* Comprehensive fire occurrence and behavior models would take into account nonuniformities in fuels, topography, and weather. *Strategies:*

- Conduct problem analyses to identify knowledge gaps
- Fund basic fire research and model development to address the needs identified above

Practical Application of Models in Fire Management. *Vision:* An internationally accepted family of fire occurrence and behavior systems would be available to serve the needs of fire management at all levels within the organization, from planning to operations, for both wildfire and prescribed fire. *Strategies:*

- Form an international working group to coordinate system development
- Determine the needs of fire management with respect to wildfire and prescribed fire applications
- Design a family of systems
- Build and test these systems

Centralized Fire Control Operations. *Vision:* Centralized fire command centers would use data from satellite transmissions, advanced weather-gathering systems, and other state-of-the-art technology. Integrated systems would display last-known fire perimeter and intensity as well as predicted fire growth on a near real-time basis. *Strategies:*

- Conduct an in-depth feasibility study in engineering and development requirements, options and alternatives, and so on
- Follow the course of action recommended above

Role of Geographic Information Systems (GIS). *Vision:* A computerized data base on fuels, terrain, etc., would be available for use with weather models (e.g., wind flow over complex terrain) and weather forecasts for predicting the occurrence and behavior of potential or going fire situations. The predictions would include not only the probabilistic (rather than deterministic) outcomes of conventional parameters (e.g., probability of ignition, rate of spread, intensity, crowning potential, spotting distances) but other important considerations (e.g., likely location and timing of fire whirl development, "blowup" potential, and smoke column configuration). Predictions from fire growth models can be updated using near real-time surveillance of actual fire perimeter. *Strategies:*

- Survey the construction, content, and use of GIS
- Explore the feasibility of using GIS in a fire intelligence system
- Supply fire research input to GIS plans
- Incorporate GIS's into fire intelligence systems

Training of Fire Management Personnel. *Vision:* Fire managers would understand and use the appropriate analytical systems for predicting fire occurrence and behavior through training courses and field application, interpretation, and evaluation of results. *Strategies:*

- Determine the specific training needs of fire managers
- Develop and conduct a series of

modularized training courses

- Ensure that quality control for monitoring user's performance in using the systems takes place and is maintained

Concluding Thoughts

Many participants at the Symposium on Wildland Fire 2000 considered the individual futuring sessions to be a highlight of the conference. Our group certainly concurred with this observation. The futuring process can be a very useful tool in strategic planning.

A sequel to the Wildland Fire 2000 conference has been tentatively scheduled for the spring of 2001 (Davis and Martin 1987). It will be interesting to see then how many of our visions have become realities. ■

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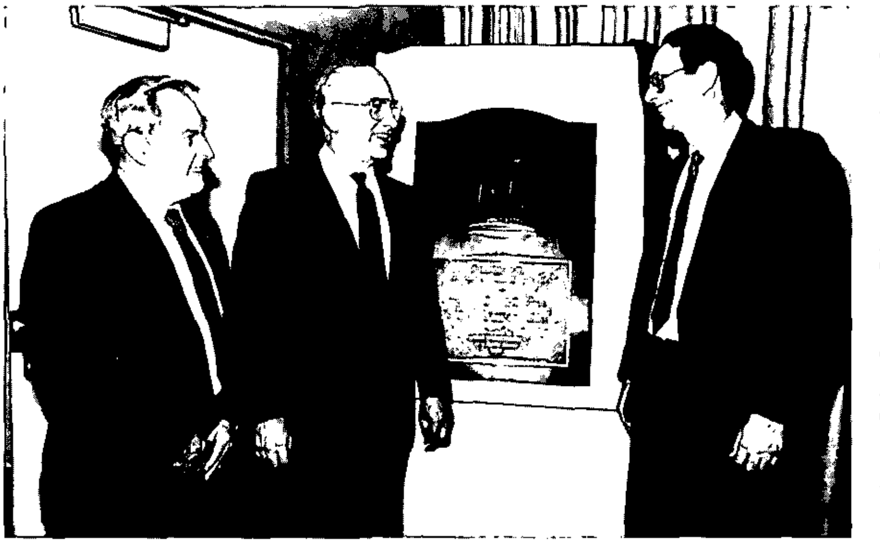
Forest Firefighters Honored

A statue honoring the men and women who fight forest fires was presented to the Forest Service by Steven Spielberg's film company, Amblin Entertainment, at a special Washington, DC, viewing for the Forest Service of its recently released film, "Always." Filming on location on the Kootenai National Forest, Region 1, Amblin Entertainment produced "Always" with considerable assistance from the Forest Service.

The statue, sculpted by retiree Rudy Wendelin, is inscribed with these words: "In honor of the courageous men and women who risk their lives to fight wildfires on the ground and from the air in defense of this country's precious lands and homes." ■



(Left to right) Deputy Chief Allan J. West, Secretary of Agriculture Clayton Yeutter, and Chief F. Dale Robertson with statue.

Prescribed Fire in Southern California: Managing Conflicts of Public Safety and Air Quality

Scott E. Franklin and Philip J. Riggan

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The Fire Management Setting

Chaparral and woodland ecosystems of southern California are subject to conflicting pressures from natural processes and human needs. Native ecosystems are subject to recurring wildfire, and some actually require periodic burning to remain viable and survive. Yet free-ranging burning is completely unacceptable in today's mix of wildlands and urban development. Vegetation management is a response to these conflicts.

The premise of vegetation management is to provide the ecosystem requirements for fire while diminishing the potential for catastrophic loss of life and property. This controlled application of fire is made under predetermined conditions of fuel moisture and weather, hence the term "prescribed fire."

Historically, fire suppression programs implemented by Federal, State, and local agencies have sought to exclude fire from wildlands. Both natural ignitions from lightning and man-caused ignitions from such sources as arson or arcing powerlines have been suppressed as quickly as possible. Whether because of a resultant accumulation of fuel or simple inability to extinguish fires under extreme weather, the result of following this policy alone has been a succession of large, high-intensity fires.

In support of this claim, one needs merely to examine the period from 1970 to the present. In 1970, 1 million acres (400,000 ha) of California wildlands burned including 90,000 acres (36,000 ha) in Ventura and Los Angeles Counties. In 1975, 50,000 acres (20,000 ha) burned in the San Gabriel Mountains north of the San Fernando Valley. In 1978, the Kanan Fire burned 25,000 acres (10,000 ha), traveling 11 miles (18 km) from U.S. Route 101 to the Pacific Ocean in 2.5 hours. The largest fire of record in the Santa Monica Mountains burned 42,000 acres (17,000 ha), in 1982. The Wheeler fire in Ventura County consumed 120,000 acres (49,000 ha) in 1985; fires in the Santa Monicas that year consumed another 20,000 acres (8,000 ha).

Each of these fires burned under the influence of high air temperatures, low humidity, and critically dry live biomass. Many were fanned by extremely high winds. Beyond the immediate losses of life and property are the subsequent flooding and debris production that can exact an even higher toll. While it may be politically expedient to place the blame upon the arsonist, to rely on fire suppression alone is to assure the continuance of catastrophic fires.

Scientists and fire managers in southern California are cooperating to show that prescribed fire can meet the needs of public safety with a minimal disturbance of air quality.

Major wildfires are also a strong source of particulates, hydrocarbons, nitrogen oxides, and other compounds. With an assumed emission rate of 4 percent, particulate emissions from a 100,000 acre (40,000 ha) wildfire would be equivalent to one-quarter those produced annually from the South Coast Air Basin. (Estimation assumes 50 Mg/ha of fuel and 60 percent fuel consumption; air basin emissions specified in the 1979 baseline inventory are 2.0×10^5 Mg/y). Although a large fraction of these emissions would be vented from the basin, the potential for short-term but spectacular air-quality impacts is clear.

Since the 1950's, California has experienced an accelerating population growth into suburbia and onto chaparral-covered hillsides (fig. 1). Residents are drawn to the ambiance of the wildlands, but they are often unaware of and largely unprepared for fast-moving wildfires. This situation continues despite public education efforts by the fire agencies. Residents may even contribute to the destruction of their own homes by planting flammable ornamental plants such as junipers, pines, or eucalyptus. Ornamentals can provide a continuous fuel bed from the native vegetation to the dwelling. Even fire-resistant construction and clearance of native vegetation around dwellings can prove ineffective. This was apparent during the 1988 Sesnon Fire in the Granada Hills community of Los Angeles. There numerous homes were burned when fire brands blown by high winds ignited planted vegetation around residences.

Fire hazards have been further worsened by a recent dieback of chaparral, especially in wildlands bordering areas of urban development in the San Gabriel and Santa Monica Mountains. The dieback was associ-

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[1] First presented at the 82d annual meeting of the Air and Waste Management Association, June 25–30, 1989, in Anaheim, CA.

ated with extreme drought during 1983 and 1984. The increased loading of deadwood has created an explosive situation in large areas that were previously difficult to burn under all but the most extreme weather conditions.

Responding to the Problem

But how may the extant pattern of recurring high-intensity fires be broken? A comprehensive approach demands at least three steps: construction or replacement of structures using fire-resistant methods (e.g., use of approved roofing materials and boxing of exposed eaves); maintenance of adequate clearance between structures and vegetative fuels, both native and ornamental; and the periodic application of prescribed fire to reduce accumulations of biomass, especially deadwood, on larger parcels of natural vegetation. Prescribed fire attempts to introduce younger age classes into a vegetation mosaic, reducing the heaviest fuel loads and resistance to control of wildfires under adverse weather. Prescribed burning may also provide a means of mitigating the infrequent but potentially heavy impacts on air quality from major wildfires. No other environmentally acceptable alternative to prescribed burning is possible in areas of mixed development and native vegetation such as the Santa Monica Mountains, if the ecosystem is to survive, and the public demands that all prudent action be taken to assure public safety.

Cooperative Studies

Stone Canyon Research and Development Project. A research and demonstration project developed at Stone Canyon in the City of Los Angeles provides an example of the potential for this approach. This cooperative effort involves the City of Los Angeles Fire Department and Department of Water and Power; the County of Los Angeles Fire Department; and the USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. Stone Canyon is situated between Mulholland Drive and the community of Bel Air, site of the disastrous Bel Air Fire of 1961, which burned 484 structures. Chaparral management was begun there at the request of local residents

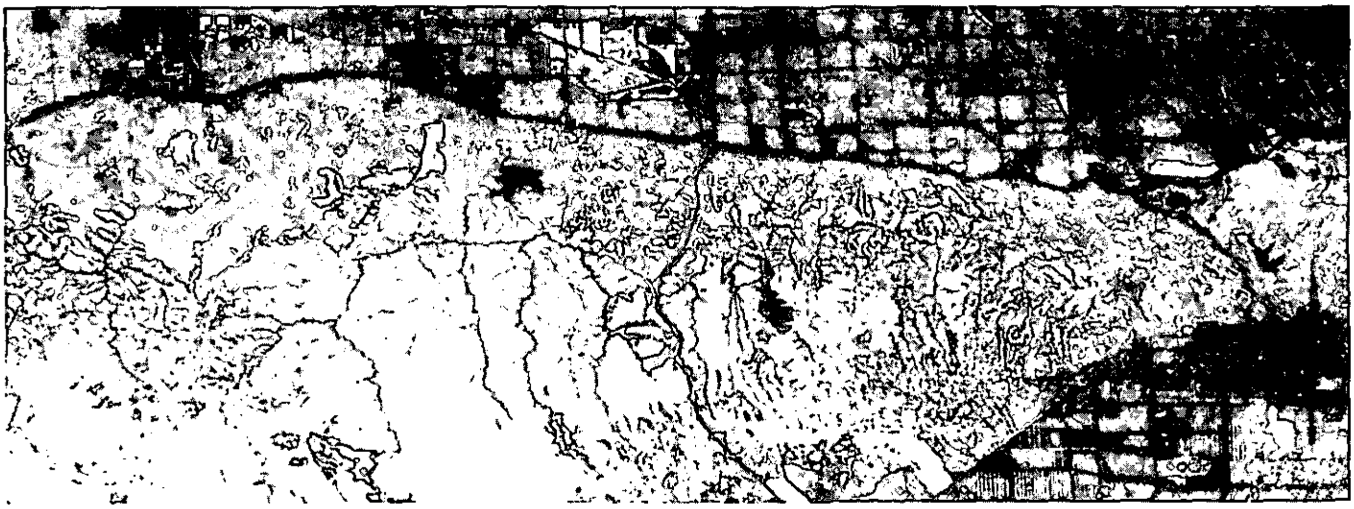

Figure 1—*Near infrared reflectance of the Santa Monica Mountains and portions of Los Angeles, CA. In this digital image the incursion of urban development into the eastern Santa Monica Mountains is apparent. Heaviest chaparral is shown by very bright tones. Portions of Beverly Hills and Hollywood are at the bottom right; the San Fernando Valley is at the top; Interstate 405 dissects the mountains at the center. Stone Canyon contains the reservoir to the right of Interstate 405. Areas of chaparral east of Stone Canyon have no recorded fire history and are extremely flammable. Under high winds, large fires in such a setting have the potential to burn several city blocks into residential neighborhoods. (Image courtesy of J.A. Brass, NASA Ames Research Center.)*

who recognized the increasing potential for a repeat of this disaster. Portions of the 600 acres (240 ha) of native chaparral are being burned under prescription in small increments during a 4-year period.

Reducing air-quality impacts. Certainly the use of fire in this situation has the potential for adverse air-quality impacts. But the application is being made in close coordination with the South Coast Air Quality Management District and the following measures have been taken:

- The size of individual burn units has been restricted to less than 100 acres (40 ha) to minimize total smoke production.
- Standing fuels on moderate terrain are being crushed by bulldozer before burning to aid in fire control, assure more complete venting of smoke above the surrounding ridges, assist regrowth of the native *Ceanothus* vegetation, and assure more complete combustion than would be possible in live wood and foliage.
- Ignitions are made in conformance with a variance from the Air Quality Management District (AQMD), which requires extensive public notification and sets standards for ambient air quality at the time of ignition.
- Vertical wind profiles are measured at the project site to provide local data to assist forecasts provided by the AQMD.

Ecological response to burning. Ecological research at Stone Canyon has been assessing the recovery of vegetation after a series of different fuel treatments (Riggan, Franklin, and Brass 1986). These include prescribed burning of standing chaparral, burning crushed chaparral, manual clearing with burning of piled brush, and felling with reduction into a more compact fuel bed before burning. The most dense regeneration of native shrubs has been with the burning of crushed chaparral. Pile burning apparently produces prolonged temperatures that kill seed buried in the soil. Virtually no seedling regeneration occurs when fire is excluded from the site. In such a case, a degraded plant community of buckwheat, sage, nonnative grasses, or black mustard will develop. Such vegetation may burn under a much wider range of moderate weather than will the taller chaparral species.

Lodi Canyon Experiments. Cooperative studies developed in part by the USDA Forest Service, California Department of Forestry and Fire Protection, and Los Angeles County Fire Department have also been undertaken to make the first measurements of emissions from large chaparral fires. Set in Lodi Canyon at the San Dimas Experimental Forest, these experiments involved some of the most elaborate measurements yet made of emissions from large fires. The most important results to date have shown the following:

- Emissions of hydrogen, methane, and hydrocarbons that were one-half to one-third those observed in logging slash fires (Cofer III et al. 1988)
- Emissions of nitrogen oxides and sulfur dioxide that were orders of magnitude greater than previously measured above slash fires, presumably due to mobilization of accumulated pollutants from the South Coast Air Basin (Hegg et al. 1987)
- Increased particle emission factors and light extinction coefficients in smoke from the most intense, flaming combustion (Radke 1988)
- High rates of ammonia emissions during moderate-intensity burning (Hegg et al. 1988)
- Record levels of biogenic nitric and nitrous oxide production from postfire soils (Anderson et al. 1988)
- Exceptionally high levels of reduced gases associated with oxygen depletion at the soil surface beneath flaming combustion (Levine 1988)

Although the Lodi project was a first attempt to characterize emissions from chaparral fires, the results do indicate that greater emissions per acre may be expected from intense wildfires than are produced from more moderate conditions typically found in prescribed burning. They also indicate that a substantial fraction of nitrogen and sulfur oxide emissions during burning originate from our inability to control emissions within the urban basin.

Conclusion

With a commitment to minimizing the impact of burning on air quality, both through research and operational techniques, and an intelligent approach to selection of prescribed fire opportunities, we feel that both the needs for public safety and minimum disturbance of air quality can be met. We think that continued cooperation between the fire services and AQMD is the approach to meet those goals. ■

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Every 2 Years: FEPP Inventory Required

The USDA Forest Service is authorized by Congress to lend to State forestry agencies for rural fire protection, property that is excess to Federal agencies. This has been a valuable source of assistance to State fire programs for over 30 years. This Federal Excess Personal Property (FEPP) comes in the form of aircraft, trucks, sedans, office machinery, handtools, pumps, generators, compressors, and a host of other useful equipment and supplies.

There is no direct cost for these materials. The only expense is in screening and transportation costs, modification and repair (if necessary), and accountability.

Accountability

The cost of accountability comes in the form of identifying FEPP as Federal property, maintaining records, and taking inventory. Once every 2 years, it is necessary for the State forestry agency borrowing the property to inventory it and reconcile their findings with the USDA Forest Service inventory. This very important responsibility is stated in the FEPP Cooperative Agreement between the Forest Service and the State Forester and in the Property Acquisition Assistance Handbook, FSH 3109.12.

In order to facilitate this job every other year, it is vital that the Forest Service and State Forester are making identical entries in their records. It is important that a State provide the Forest Service with the following:

- An accurate description of FEPP and the quantity received. (This should include make, model, serial number, and State property number.)
- A report when accountable FEPP is ready for disposal or return. FEPP is to be returned through the same channel it was received—to the Forest Service and then to the General Services Administration.
- The proper paperwork when FEPP is lost, stolen, or damaged. The Forest Service should be notified of any adjustments in the State's quantity of FEPP.
- Properly record adjustments when property descriptions are changed due to use modification, cannibalizations, or other actions.

Although there is no direct cost for FEPP, there is a cost involved in keeping records according to Federal standard. Most States have found this a very small price to pay for participation in this very popular program. ■

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An Analysis of Fire Planning in Alaska

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Introduction

In the early 1980's, land managers in Alaska—Federal, State, Tribal, and local—substantially changed the way fire was managed there. From the impetus of these land managers, a fire-working group was established to develop interagency "protection goals and objectives, categories of protection, and complementary suppression strategies" (Erskine 1987). Eventually, 13 fire management planning areas and planning teams made up of a cross-section of land managers were created. By 1984, the fire-prone areas of Alaska were almost all under fire plans, and plans for areas scheduling planning were completed by 1988. The purpose of this paper is twofold: To discuss a method of partially evaluating the results of the planning effort and to evaluate the results of the interagency fire plans in Alaska from the data collected for years 1984 to 1988.

The fire plans call for four separate suppression options:

- *Critical protection* is provided for areas of human habitation or development. These areas receive immediate initial attack and continuing suppression action until the fire is out.
- *Full protection* is provided to areas of high-resource values. Fires receive immediate initial attack and aggressive suppression to minimize acreages burned.
- *Modified action* provides for initial attack on new fires during the severe part of the fire season. Escaped fires are evaluated by the land manager and suppression agency for appropriate suppression strategies. On specified dates, the modified action areas convert to limited action.
- *Limited action* is provided to areas of low-resource values or where fire may actually serve to further land management objectives. Suppression response is the monitoring of fire behavior and those actions necessary to ensure it does not move onto areas of higher values.

A fifth category of area exists—the unplanned areas. A few land managers declined participation in the planning process. Generally, these unplanned lands receive the equivalent of full protection.

This study focuses on two questions: How much suppression funding was actually saved by implementing the *limited action* option and how many more acres burned under *limited action* than if the fires had received initial and continuing suppression action?

One of the primary objectives of the interagency planning effort was an effort to reduce suppression costs by not fighting fires where resource values did not warrant suppression expenditures or where land managers believed wildfires could help achieve resource objectives. This was to be accomplished by use of *limited action* over large areas in Alaska. As with all plans, the evaluation of the results is, or should be, an integral part of the planning process.

Problems with Evaluation

In evaluating fire program results, the process is always confounded by variations between fire seasons. As with everywhere else, Alaska experiences episodes of numerous fires with large acreages burned, among years when "normal" conditions occur. Historic records indicate that numbers of fires varied from a low of 102 in 1962 to a high of 869 in 1974, while acreage burned ranged from a low of 5,100 acres (2,064 ha) in 1961 to a high of 5,050,000 acres (2,043,735 ha) in 1957. Costs too have the same variability as the other statistics. The very slow 1961 fire year also had low suppression costs with only $155,231 being expended while in the active 1988 fire season $29,000,000 was spent on firefighting by the USDI Bureau of Land Management alone.

Another question that probably should be asked is whether land managers, who wanted wildland fire for management purposes, actually achieved their objectives. These objectives related to resource benefits that would derive from conversion of vegetation from later to early successional stages.

Objectives of the Study

After some lengthy examination, it was decided that the study would focus on two questions:

- How much suppression funding was actually saved by implementing *limited action* through the plans?
- How many more acres burned under *limited action* than if the fires had received initial and continuing suppression action?

The answer to the first question requires direct evaluation of the plan objective of saving suppression dollars. It must be recognized that, although *limited action* calls for monitoring initially, costs can still be incurred. A long period of monitoring can ultimately be more expensive than a successful, small-scale initial attack. Further, there was never any question that some *limited action* fires would either threaten higher resource value lands or even human developments, and suppression actions would be necessary.

The second question attempts, in an indirect manner, to address the benefits to the resource of *limited action*. There are difficulties, however, in evaluating resource benefits:

- Resource benefits were not a specific objective of the plan and only spelled out in very general terms.
- No quantification of these benefits has been made, either in the plans or in subsequent reviews of the results. Thus, while it is possible to say that the *limited action* fires have burned some 2,700,000 acres (1,092,690 ha) of vegetation over 5 years, no one can say how many moose this equates to, what forest products were lost, or anything else, other than there was a vegetation conversion of 2,700,000 acres (1,092,690 ha). At any rate, knowing the number of acres burned should provide some starting point for an estimation of fire effects.

Methodology

The calculation of these two determinations—suppression dollars saved or spent as a result of the use of *limited action* and the number of additional acres burned under *limited action* is possible because the Bureau of Land Management's Fire Reporting System produces a report providing the number of fires, acres burned, and cost of suppression by the suppression options (unplanned, limited, full, and so on). These statistics are shown in table 1 for 1,560 fires between the years 1984–88, inclusively.

In order to evaluate the cost savings or additional expenditures from *limited action*, the following formula was developed:

$$\frac{CU+CC+CF+CM}{IU+IC+IF+IM} \times IL - CL = \text{dollars saved}$$

where:

CU = cost of fires in unplanned area
CC = cost of critical fires
CF = cost of full action fires
CM = cost of modified fires
CL = cost of limited fires
IU = number of fires in unplanned area
IC = number of fires in critical area
IF = number of fires in full area
IM = number of fires in modified area
IL = number of fires in limited area

Readers will quickly recognize that, in spite of the apparent complexity of the formula, all that is being done is to calculate an average cost for the fires in areas where they receive initial attack and subsequent suppression actions. This average cost is then multiplied by the number of *limited action* fires. This number then presumably represents the cost of *limited action* fires if they had been fought like the other fires. The actual cost (CL) is then deducted from the calculated cost of *limited action* fires, and the difference is the dollars saved, expressed as a positive number. Note that it is possible for the final value to be a negative number, indicating that it has cost more for fires for *limited action* than if they had been aggressively suppressed. This actually happened for 1 year and will be discussed later.

A similar evaluation was conducted to determine the difference in acreage burned between those fires receiving initial attack and the *limited action* fires whose initial response is monitoring only. The formula is as follows:

$$AL - \frac{AU+AC+AM+AF}{IU+IC+IM+IF} \times IL = \text{additional acres burned}$$

where:

AL = acres burned in limited area
AU = acres burned in unplanned area
AC = acres burned in critical area
AM = acres burned in modified area
AF = acres burned in full area
IU = number of fires in unplanned area
IC = number of fires in critical area
IM = number of fires in modified area
IF = number of fires in full area
IL = number of fires in limited area

Table 1—*Fire plan statistics for 1984 through 1988*

	Occurrence		Area			Nominal dollars			Adjusted (to 1988) dollars		
Management option	Number of ignitions	Total ignitions (percent)	Acres burned	Total burned (percent)	Average size per ignition	Suppression cost	Total dollars (percent)	Average cost per ignition	Suppression cost	Total dollars (percent)	Average cost per ignition
Unplanned	61	3.9	26,732	0.9	438.2	$ 4,635,209	7.1	$75,987	$ 4,851,836	7.1	$79,538
Critical	72	4.6	452	0.0	6.3	462,208	0.7	6,420	493,215	0.7	6,850
Full	465	29.8	70,452	2.3	151.5	14,337,006	21.8	30,832	15,391,026	22.5	33,099
Modified	411	26.3	228,798	7.4	556.7	25,932,536	39.5	63,096	26,969,093	39.4	65,618
Limited*	551	35.3	2,753,945	89.4	4,998.1	20,347,420	31.0	36,928	20,784,248	30.3	37,721
Total	1,560	100.0	3,080,379	100.0	1,974.6	$65,714,379	100.0	$42,125	$68,489,418	100.0	$43,903

*Cost savings from limited action: $4,426,806 in nominal dollars; $5,266,841 in adjusted dollars.
Additional acres burned under limited fires: 2,575,684 acres.

Again, this formula simply calculates an average acreage burned for those fires receiving initial attack, multiplies that acreage by the number of *limited action* fires and deducts this from the actual acreage burned under *limited action*. The difference is the additional acreage burned under *limited action*. As with the cost figures, this number could be negative, that is, fewer acres are burned under *limited action* than the other suppression options, but it has not happened in 5 years.

One final step in the analytical process was to convert the expenditures to constant year dollars. Because of inflation, current dollars are worth less than past dollars. This, if left uncorrected, tends to distort the analysis. The Consumer Price Index for the years 1984–88 was used to convert all suppression expenditures to 1988 dollars. Actual expenditures are shown on table 1 as "nominal dollars" while the adjusted are shown as "adjusted" or "inflated dollars."

Table 1 is a combined summary for 5 years. In actual practice, each year from 1984–88 is kept as an individual record. Originally done by hand each year, this data is now held as Lotus 1-2-3 files on a computer. All that is necessary each year is to enter the number of ignitions, acres burned, and dollars spent for each management option. The formulas are built into the worksheets and the calculations are electronically made. Once created, the data files have been easy to maintain and update.

Results

In reviewing the data in table 1, there are some items of significance. First in terms of number of ignitions, 35 percent of the fires occur in the *limited action* areas, with the remainder in the *unplanned, critical protection, full protection,* and *modified action* areas. However, Erskine states that land managers put 60 percent of the total acreage into the *limited action* category. By way of explaining the difference in percentages, nearly the entire Arctic area of Alaska north of 68° N. latitude is designated to receive *limited action.* While large fires are not unknown in this region, their frequency would be on the order of about one lightning fire per 1 million acres (404,700 ha) per 100 years (Gabriel 1983). The numbers of ignitions in the *full protection* and *modified action* option areas were very similar, a reflection of similar acreages and fuel types included in these categories. Similarly, the *unplanned area* and *critical protection* options also had like numbers of ignitions in their respective areas.

It is in the area-burned category that the most dramatic differences are observed. The 2,753,945 acres (1,114,522 ha) burned in the *limited action* areas represent 89 percent of all of the acreage burned in the 5-year period. This figure would have been even larger had not suppression actions been taken on some of the *limited action* fires. The *modified action* category, with somewhat fewer ignitions than the full protection areas, had substantially more acreage burned than was found in the *full protection* areas. The *unplanned areas*, representing a very small proportion of the total acreage under plans, had a fairly substantial acreage burned. On the other hand, the critical management option, representing primarily specific sites, had a very small acreage burned, which was consistent with the objectives of the plans.

The average size per ignition per management option appears consistent with the intent of the plans, except for the *unplanned area* category. While these fires were generally treated as *full protection* areas, acreages burned were substantially larger than under the full protection category. A partial explanation for this difference can be found in the fact that much of the acreage in the *unplanned* category was land withdrawn for military use, and even more important, military ordinance impact areas. In such areas, initial attack and subsequent suppression actions are usually impossible or conducted under very tightly controlled conditions.

Finally, under the cost of suppression, there seem to be some unexpected results. For instance, in spite of the expectations of aggressive and continuing suppression action, the *critical protection* fires have the lowest cost per ignition. Of course, most of the fires in this category are occurring close to human habitation, with a resulting short discovery time and rapid initial attack. Similarly, *limited action* would seem certain to cost less than *full protection* fires. In reality it appears that limited action fires cost some $6,000 more per fire than those in the *full protection* category.

Table 2 gives the 5-year results of a combined analysis of those fires in initial attack categories, that is, the *unplanned, critical protection, full protection,* and *modified action,* compared with those in the *limited action* category.

Table 2—*Five-year results of a combined analysis of fires in initial-attack categories*

Management option	Number of ignitions	Average acres burned per fire	Average cost per fire
All fires except limited action	1,009	324	$44,962.00
Limited action fires	551	4,998	$36,928.00

In this analysis, the cost reduction by use of the *limited action* is clearer than in dealing with the individual management options. Cost of *limited action* fires are about $8,000 less per fire than those areas where a commitment of suppression resources is planned. Equally obvious is the substantial increase in the size of *limited action* fires over the other management options.

Conclusions

There are a number of conclusions that can be drawn from this 5-year study of fire costs and acreages burned under fire plans. First, when the study was initiated, it was felt that an appropriate study period should be about 10 years. This period was chosen since it had been observed that episodes of large acreages burned in Alaska occur about once every decade. The current 5-year study period includes 1 active fire year (1988) that may be producing results out of proportion to its relative importance over a longer period of time. Based on the results of the first 5 years, it is recommended that the study be continued for 10 years. As long as the USDI Bureau of Land Management continues to report its fires as it currently does, it appears that the results of the fire plans could be evaluated indefinitely on an annual basis.

One of the facts that is inescapable is the effectiveness of the Alaska suppression organizations in reducing acreages burned. The impact of initial attack and subsequent suppression actions is dramatic. Over the 5-year period, fires initially receiving monitoring action only were 15 times larger, on average, than those receiving active suppression responses. The implication of this fact is that the firefighting organizations have the ability to alter the natural fire regime of an ecosystem substantially. This should not be construed as meaning fire will be excluded from an area by suppression activities; rather, over a period of time, acreages burned will be substantially reduced under *critical protection, full protection,* and *modified action* protection standards.

For those land and resource managers who want fire for management purposes, the acreage figures should be encouraging. On the negative side, other than from purely counting acres, there is no real way of estimating resource benefits, either from increased animal or fiber production or from a dollar value standpoint. It will not be possible to evaluate the resource benefits of the Alaska fire plans until some quantifiable measures have been established.

The *limited action* management option has the potential for creating additional expenditures, as well as saving suppression dollars. In 4 out of the 5 years from 1984–88, the *limited action* fires saved money over those fires receiving initial and sustained suppression responses. However, in 1988, the calculated cost of *limited action* fires was $6,780,959 more than if those fires had received a more conventional suppression response. The principal problems were heavy expenditures on fires that required suppression actions after burning for 2 weeks with monitoring as the only suppression response.

The statistics and analysis that have been developed for this evaluation are specific to Alaska fuel types, fire regimes, and patterns of expenditures. Whether they have wider applications is unknown and would be beyond the scope of this paper. ◘

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A New Goat for Fire Protection!

The Department of Defense (DOD) will be phasing the Gamma Goat out of their inventory during fiscal years 1990 and 1991. Over 2,000 of these articulated 6-wheel drive vehicles will be available. Some will pass through the Forest Service's Federal Excess Personal Property (FEPP) program to qualifying State forestry agencies and their cooperators.

The Gamma Goat is made with both truck or cargo (M–561, 1¼ t, 6 × 6) and ambulance (M–792, 1¼ t, 6 × 6) bodies. They have proved quite useful in getting through steep and rough terrain. Several State forestry agencies and their cooperating fire departments are now operating the Gamma Goat.

General Services Administration (GSA), the agency that approves transfers of FEPP, requires representatives of agencies receiving a Gamma Goat to sign a statement that they are aware of the unique handling characteristics of this vehicle and they will use the vehicle off-road only and return the vehicles to DOD disposal officers, through the Forest Service, when they no longer have use for it.

Agencies operating the Gamma Goat are cautioned to be sure they are insured, carrying balanced loads that are within safe limits, and their operators are properly trained. Some type of rollover protection should be used on the vehicle. The vehicles are to be operated primarily off paved surfaces and must be operated at safe speeds.

Caution: Only qualified drivers may operate FEPP vehicles, including the Gamma Goat, on loan from the Federal Government to State Foresters and their cooperators!

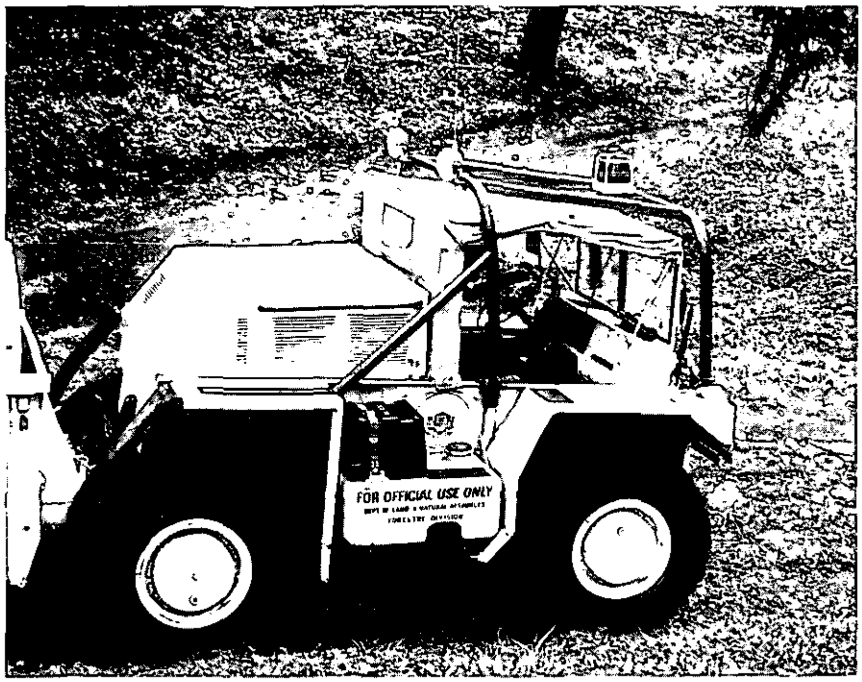
The Roscommon Equipment Center (REC) program, located at the Michigan Department of Natural Resources Forest Fire Experiment Station in Roscommon, MI, has evaluated this vehicle and found it to be very useful for wildfire protection. As with most major military vehicles, REC has documented their findings and provided suggested payload, tank design, and other valuable data. Project 53–A, "An analysis of the M–561 'Gamma Goat' Vehicle for Wildfire Use," and other REC project reports explaining how to safely modify military vehicles for fire protection are available by contacting the following:

Bob Adams
Cooperative Fire Protection
Northeastern Area
State and Private Forestry
USDA Forest Service
5 Radnor Corporate Center,
Suite 200
100 Matsonford Road
Radnor, PA 19087
Telephone: 215-975-4152;
FTS 8-975-4152

Brian Hutchins
REC Program
℅ Forest Fire Experiment Station
Michigan Department of Natural Resources
P.O. Box 68
Roscommon, MI 48653
Telephone: (517) 275-5211;

Other project reports that cover the safe conversion of FEPP military vehicles to fire suppression engines include:

Project No.	*Title*
4	Jeep Tanker Handbook ¼ Ton 4×4
22	1000 Gallon 6×6 Tanker Handbook 2½ Ton 6×6



Gamma Goat, Model M–561, modified for fire protection by Hawaii Division of Forestry. Note rollover protection.

33	Tanker Handbook Military 1¼ Ton 4 × 4 Cargo Truck
34	Tanker Handbook Military ¾ Ton 4 × 4 Cargo Truck
39	Tanker Handbook Military 5 Ton 6 × 6 1500 Low Profile Tanker
40	Tanker Handbook Military 880 Series 1¼ Ton 4 × 4 Cargo Truck (Dodge W-200)

Projects at the REC are jointly funded by the State Foresters of the 20 Northeastern Area States and the USDA Forest Service. ■

Robert G. Adams, Jr., fire suppression specialist, Northeastern Area State and Private Forestry, Radnor, PA

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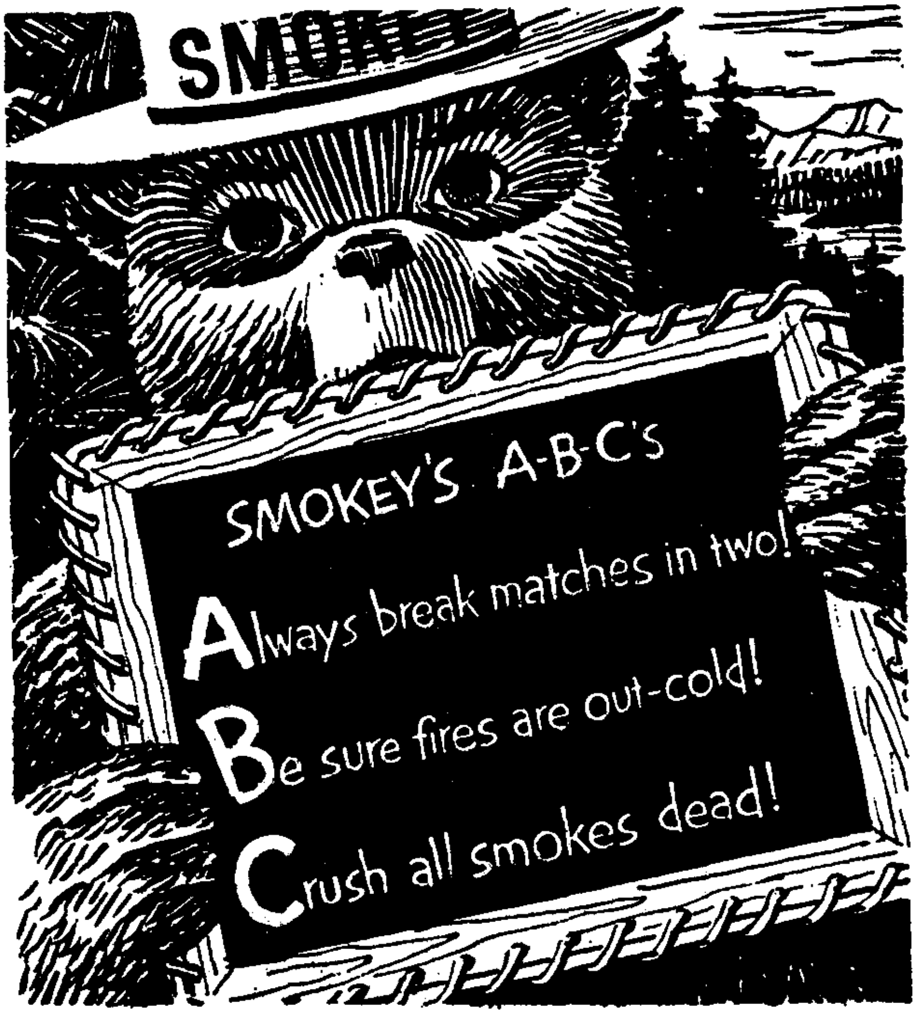

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