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Forest Fire Laboratory at Riverside and Fire Research in California: Past, Present, and Future

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INTRODUCTION

The Incident Commander and Operations Section Chief stopped to catch a breath of fresh air in the middle of the timber fuelbreak. The Incident Commander looked back at the smoke-covered watershed that they had just flown over in their helicopter. The FLIR (forward-looking infrared) equipment had allowed them to see some hotspots through the smoke, but there seemed to be a line around the perimeter of the fire.

An airtanker had just dropped a load of red fire retardant on the spotfire in Mud Creek, and a helitack crew had been dispatched to follow the air tanker drop and build fireline.

"More good news," the Incident Commander told his Section Chief. "I just received a radio report from the Fire Behavior Team at the command center that the dry, east winds are expected to diminish by evening. Things are looking better. With these new computer models, we are finally able to plan the suppression job that is needed."

"I agree," said the Operations Chief, "but the fuel modification work we did last year kept the spread rate down on the whole north flank and that helped a lot. Now if our red flag alert program works as well as it has in the past, maybe I can get home to see my husband for a change!"

The Incident Commander smiled with satisfaction and ordered the helicopter to fly them back to the command center. Thanks to modern fire tools another fire had been stopped the same day it started.

Accomplishments of Forest Fire Research

The Incident Commander and Section Chief probably took their organization, tools, and equipment for granted. If asked, they would have said that most had evolved over time within various fire protection agencies—maybe a few such as retardants [sic] had come from the chemical or aircraft supply industries. Yet, all of the equipment and techniques described in this fire scene, including the incident command organization, was based on research over the past three decades—much of it from the Forest Fire Laboratory in Riverside, California—a field facility of the Pacific Southwest Forest and Range Experiment Station (fig. 1).

These "research products" were produced in close collaboration with the user, fire agencies, or relevant industries. In fact, the Incident Commander would have been a "Fire Boss" prior to the FIREScope (Firefighting Resources of Southern California Organized for Potential Emergencies)

Research, Development, and Application program, which was launched after the destructive 1970 fire season in California, to coordinate activities among agencies and help fire managers make decisions.

The Fuel-Break Executive Committee had its first formal meeting on November 20, 1957, and the *timber fuel-break* concept was effectively demonstrated on the Stanislaus National Forest in the early 1960's.

The Night Helicopter Project, which eventually resulted in the development of the *FLIR* concept for wildland firefighting was started as a light guidance system by the Fire Laboratory in the late 1960's. It expanded in the 1970's in cooperation with State and Federal agencies as well as the Los Angeles County Fire Department when more advanced electronic equipment became available.

Air tanker feasibility was demonstrated on the Mendocino National Forest in the mid-1950's and was expanded Statewide in California in 1956. During the 1950's and 1960's, field tests held at Willows, Redding, Ramona, and elsewhere throughout California determined the operating specifications, such as the best flying height and speed for the various types of aircraft then being rapidly put into service.

The *fire retardant* concept was developed and tested during Operation FIRESTOP in 1954, and sodium calcium borate retardant was first carried in a seven-plane fleet of World War II surplus trainers in 1956. During the next 20 years, retardants were improved and refined at the Pacific Southwest Forest and Range Experiment Station and elsewhere until they became the highly effective chemical systems used today (fig. 2).

The term *helitack* was coined in 1956, and the helitack crew program was implemented Statewide by the early 1960's. During the 1960's and 1970's, helicopter accessories such as retardant-mixing equipment, cargo nets, and a series of training manuals were developed by fire researchers at Riverside, working in close cooperation with users.

The concept of the *Fire Behavior Team* was developed after a disastrous fire on the Cleveland National Forest in 1956 and was tested in the late 1950's and 1960's. The concept involved an experienced fire behavior officer, a professional meteorologist, and a team of meteorological observers who worked with a mobile Weather Service Fire Weather Specialist. The team allowed on-the-fire weather observations as well as the use of specialized tools such as weather balloons.

Light burning for *fuel modification*—not considered a practical substitute for suppression at the time—was marked as a "research need" by a joint meeting of scientists and administrators in San Francisco in 1923. When the California (now Pacific Southwest) Forest and Range Experiment Station was established in 1926, the new research was to be a balanced program that included "fire use as well as fire



Figure 1--The Forest Fire Laboratory at Riverside, California, is a field facility of the Pacific Southwest Forest and Range Experiment Station



Figure 2--Forest Fire Laboratory researchers attempting to ignite "weatherproof" fire retardant. The objective was to find a retardant that could be used to fire proof roadsides and around campgrounds for the duration of the fire season.

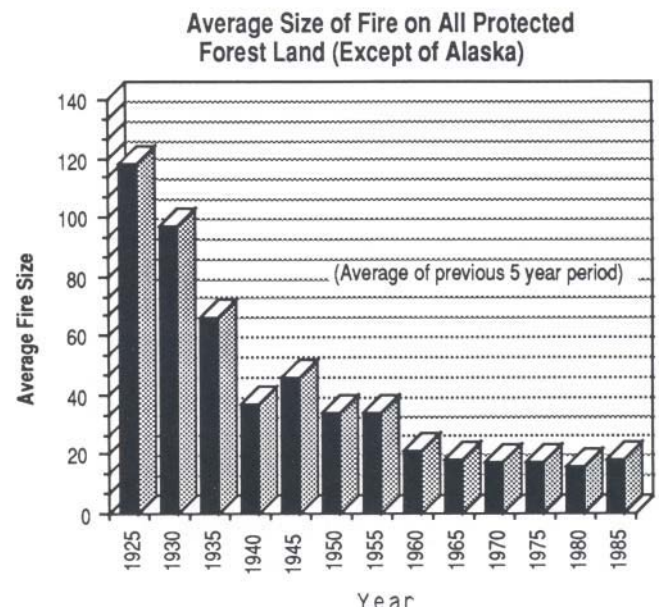


Figure 3--While the number of fires per million acres protected has remained about the same since 1925, the average fire size on protected land has been reduced from 120 acres to about 20 acres.

suppression." It still is--two of the Forest Fire Laboratory's six current programs are investigating the use or effects of prescribed fire.

The same balanced program at the California Forest and Range Experiment Station also included fire prevention. Since then, the Station has conducted fire prevention research, though the level of the program has varied considerably over time. One of the most effective efforts has been the joint work of scientists, fire prevention officers, and the public on a system in which red flags are displayed during high fire hazard days--the *red flag alert*.

Beginning with a series of contracts with the University of California Operations Research Center in 1962, through in-house projects such as FOCUS (Fire Operational Characteristics Using Simulation) and FEES (Fire Economics Evaluation System), the Pacific Southwest Forest and Range Experiment Station has sought to bring economics and management science to bear on fire problems. The fire planning *computer models* now in operational use by the Forest Service and many States have some of their roots in the economic and operations research conducted by the Station.

Success Story

Each year, on the average, 250,000 wildfires burn almost 5 million acres of forest, brush, and grass-covered lands in the United States. Protection services cost more than \$1/2 billion annually. Losses approach \$2 billion. The costs do not include the services of thousands of volunteer fire departments, nor do they include the expenses of the many city fire departments that fight fires on undeveloped lands within or near their jurisdictions.

Yet few activities, public or private, have had such a high degree of success as fire prevention and management. Use of the tools and techniques described have had a profound effect on reducing fire damage and cost.

While the number of fires per million acres protected throughout the nation has remained about the same since 1925, the average fire size on protected land has been reduced from 120 acres in 1925 to about 20 acres in 1985 (*Fig. 3*). The number of fire starts per million acres protected has not increased significantly in spite of the fact that the risk of fires starting, as determined by various types of land use, has increased more than 10 times (Davis and others 1977).

This has been accomplished in the Forest Service's Pacific Southwest Region (R-5) by controlling at small sizes what in the past would have been medium or large fires (*fig. 4*). Fire research at the Station and the Forest Fire Laboratory has played an important part in this damage and cost reduction.

ROOTS OF THE FOREST FIRE LABORATORY

Fire research at the Pacific Southwest Forest and Range Experiment Station did not begin with the dedication and

opening of the new Forest Fire Laboratory at Riverside in 1963--it really started in the last century (*fig. 5*).

Early Fire History in California

The need for protection from uncontrolled fires in California was identified by Abbott Kinney, Chairman of the State Board of Forestry, more than 100 years ago. Congress responded to the concerns of the public in 1891 by giving President Benjamin Harrison authority to set aside "Public Reservations." A year later in 1892, the San Gabriel Forest Reserve, later to become the Angeles National Forest, was created. The proclamation said, in part: "The future prosperity of southern California depends upon protecting the water supply of the numerous streams which have their source in the mountains embraced by the reservation." Thus, the beginnings of the National Forest System were based partly on protection of chaparral watersheds from uncontrolled fires! It was easy to show the close association between wildfires and floods in the steep watersheds in southern California.

Six years later in 1898, Gifford Pinchot, in his first year as Chief of the new Federal Division of Forestry, ordered a study of the nature and effects of southern California fires. By 1904, a detailed report on forest fires and chaparral in southern California was prepared by the Forest Service recommending improved protection.

Nevertheless, during its first 4 years the Forest Service found the going fairly easy, and the fire problem seemed unimportant. Then 1910 came. It was the most disastrous fire year in the West since the creation of the National Forests. A fresh look at the fire problem was essential.

Fire Research in California, 1921-1945

The 1910 disasters led Coert DuBois, then Associate District Forester for District (now Region) 5, to conduct fire studies on the Stanislaus National Forest. These later set the pattern for similar studies on all forests in the District. In the early days research was likely to be practical and pragmatic, and "researchers" frequently came from the ranks of administrators (*fig. 6*). Some of the pioneers of Forest Service research such as H. T. Gisborne, who set the stage for fire control in the Rocky Mountains, had been National Forest supervisors.

It is not surprising then, that E. I. Kotok, supervisor of the Eldorado National Forest, was drafted for a research assignment by the Regional Forester. This brought S. B. Show, representing research, and Kotok of administration together as a team at the same location. From this close association fire protection in California was enhanced. They produced the landmark publication, "Forest Fires in California, 1911-1920, An Analytical Study" (Show and Kotok 1923).

In 1921, in recognition of the worsening fire situation throughout the West, Forest Service Chief Greeley called a national fire conference at Mather Field, California. The

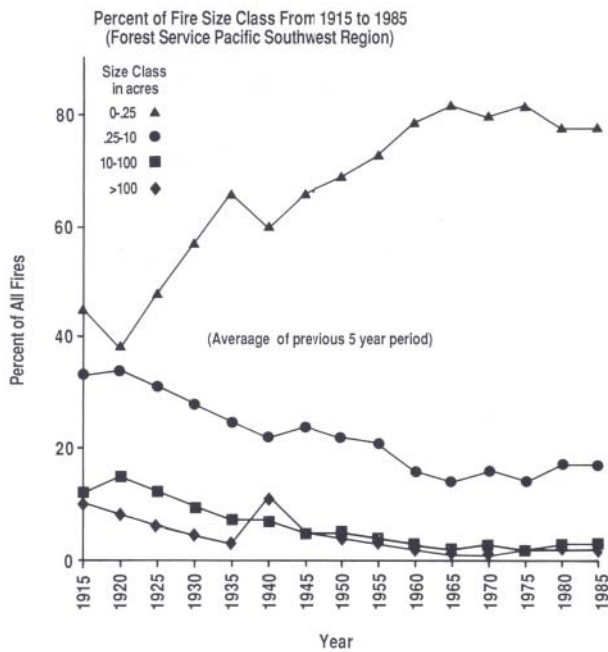


Figure 4--During the past 70 years in the Pacific Southwest Region (Region 5) the percent of small (Class A) fires has increased from 45 to 80 percent. During the same time Class B fires (0.25-10 acres) have decreased from more than 30 percent to less than 20 percent.

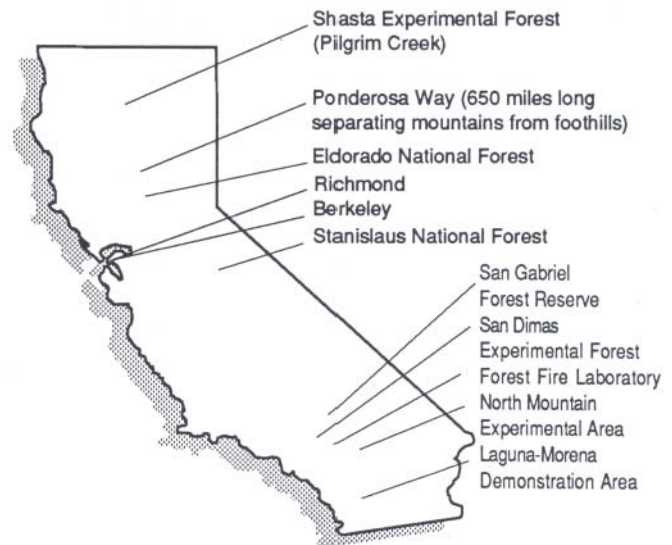


Figure 5--Places shown are key locations in the fire research history of California.



Figure 6--How field research was done in the 1910's. Knowing how to throw a diamond hitch was as important as a knowledge of statistical methods.

session's summary report strongly endorsed a program of fire research "as an essential tool in developing an adequate fire control organization."

The first "official" joint meeting of researchers and administrators of Region 5 was held in San Francisco in 1923--3 years before there was an experiment station. The "Investigative Committee," as it became known, focused special attention on the following fire research needs:

- Light burning
- Fire damage appraisal
- Analysis of fire reports
- Tracking of lightning storms
- Fire-danger rating
- Initial attack speed-up

Even at this early meeting there was already a deep concern about "application of results from research."

The disastrous 1924 fire season in California again dramatized the need for improved wildfire protection. Just 2 years later in 1926, a national program of forest fire research was developed and with it came the establishment of the California Forest and Range Experiment Station. The new research program contained plans for a balanced program of fire research including (a) laws of combustion, (b) fire prevention and hazard reduction, (c) fire suppression, (d) fire as an agent, and (e) protection standards and organization. Yet no funds were appropriated; so, Kotok and Show continued to conduct fire studies in their spare time.

Two years later the first Forest Service funds were authorized for fire research. Forest Supervisor George Gowen became the first fire research Project Leader. He and his two assistants were located in 1929 at the newly created Shasta Experimental Forest at Pilgrim Creek near McCloud, California.

Meanwhile Show and Kotok continued their respective studies, and in 1930 they published their important paper "The Determination of Hour Control for Adequate Fire Protection for Major Cover Types of the California Pine Region." This publication had a major impact on fire planning nationwide (Show and Kotok 1930). Although their work on fire behavior and fuel types was based on analysis of individual wildfire reports, Show and Kotok recognized the need for testing their findings on experimental fires.

The research-administration partnership continued in 1935 when Charles C. Buck (Fire Research) and George Gowen (Administration) developed a fire-danger rating system to meet the unique needs of the California Region. They set up a grid of weather observation stations in the State--many of which are still in use.

Help From the Civilian Conservation Corps

The emergency programs during the Great Depression were of much assistance to the Forest Service in improving fire control and speeding up fire research. The Civilian Conservation Corps (CCC), launched in April 1939, was particularly important because the helping hands of the CCC enrollees enabled the newly hired research technicians to move ahead with studies that had been at a standstill. Special

emphasis was placed on:

- Integrated detection systems
- Communications
- Firebreak systems--the forerunner to fuelbreaks
- Fire road systems
- Initial attack.

The CCC accelerated research in another way. There was a real need to know how to use the large crews effectively and efficiently on fires, so emphasis was increased on studies such as on fireline production rates, fire behavior, and fire planning. CCC crews built extensive road and fire break systems including the Ponderosa Way, portions of which can still be seen today.

Cooperation with Fire Management

Fire research results and practical experience were put to good use in 1937 when a Fire Control Handbook was developed by Region 5 (USDA Forest Service 1937). This working tool for fire control people helped to cement a close working relationship at the Station with fire specialists in the Region.

A second landmark publication was "A Planning Basis for Adequate Fire Control on the Southern California National Forests" (USDA Forest Service 1938). This important report emphasized that person-caused fires in flash-fuels and brush zones presented the dominant southern California fire problem--not much has changed in half a century.

The Impact of World War II On Fire Research

During World War II, fire research at the Station nearly came to a halt. Most of the limited staff was assigned to projects of interest to the military. However, the war produced a terrible specter that would influence the Station's fire program for the next 35 years: What would be the consequences of a nuclear attack on both people and the environment?

Post-War Years

Post-war budgets were small. For example, only \$81,000 was budgeted for fire research nationwide--enough for about 13 full-time technical personnel. The California Station's share was \$17,000. This kept three scientists working, concentrating on ignition and combustion, chemical control of vegetation, and fire damage.

Even with tight budgets, there were major accomplishments. One of the most important was the completion in 1949 of a joint project between the fire and watershed research groups that produced the "Fire Damage Appraisal Guides" (Buck and others 1948). This set of six publications displayed the damage expected from fires of various sizes on most of the southern California watersheds. Probably no single research effort has been used more often or relied on so heavily in southern California.

Effects of Weapons Studies

At the end of World War II, the United States found itself with a weapon whose capability was unknown. As part of a series of atomic weapon tests, the military contracted with the Forest Service to conduct the classified Armed Forces Special Weapons Project (AFSWP). This project dealt with the effect of nuclear weapons on forests, primarily from ignition and blowdown. Eventually, the Station's research for the Defense Department was expanded to include studies of survival of persons trapped in basements and fallout shelters (Broido 1960).

Although these studies were terminated in 1959, the Station was asked by the Office of Civil Defense and Defense Atomic Support Agency (both of the Defense Department) to activate Project Flambeau (*fig. 7*). It studied mass fire spread, critical weather patterns, and prediction of fire spread following a nuclear attack on the United States. Some of the results of these studies are still classified and have not been made available to the public.

Cooperation on FIRESTOP

Operation FIRESTOP was an effort by a giant task force involving fire control agencies, fire research, Federal civil defense, and private industry. The central idea was to explore the application of new technology to fire control problems and how to expand the boundaries of fire behavior (Arnold 1955).

The 1-year project, held mostly on the Camp Pendleton Marine Corps Base in San Diego County, concentrated on fire retardants, fuel studies, seasonal chaparral moisture, aerial firefighting including both fixed-wing aircraft and helicopters, light-weight pipe for extended hose lays, wind machines for fire suppression, and backfiring chemicals (*Fig. 8*).

FIRESTOP became the launching pad for innovative and revolutionary cooperative research in California. The project demonstrated that a task force effort in fire research could pay huge dividends. Not only were results readily available for application and further testing, but the fire control members of the team were enthusiastic about applying the information that they personally had helped discover. Operation FIRESTOP showed that cascading liquids from aircraft was feasible and that liquid fire retardants could be effective in stopping wildland fires. FIRESTOP also showed that there were many potential roles for helicopters, ranging from personnel transport to small air tankers.

As a result, 1954 to 1955 became a crucial period in forest fire research. Informal reports and publications of FIRESTOP findings served as the basis for many important future research efforts including helitack, air attack, and the use of chemical fire retardants. FIRESTOP not only stimulated prompt acceptance of research results, but also encouraged interest in expanding research budgets through both Federal appropriations and cooperative funds.

Air Attack and Use of Retardants

The use of aircraft to attack a forest fire with water or firefighting chemicals had long been a dream of many fire

managers, and from time to time studies had been conducted on the problem without much success. Now, surplus military aircraft including helicopters were becoming available that had the capability to carry heavy payloads in mountainous terrain.

The Pacific Southwest Forest and Range Experiment Station in cooperation with other agencies, chemical companies, and aircraft operators launched a series of laboratory and field studies that resulted in the prototype firefighting chemicals, retardant mixing systems, tank and gate designs, and the initial operating guides for fixed-wing aircraft and helicopters used today (*fig. 9*).

Air attack resulted in a revolution in fire control. It also made firefighting so expensive that it forced a rethinking of fire suppression policy that led to the fertile field of fire economics research.

Not in an Ivory Tower

During the post war period, fire research was not in an ivory tower. Technology transfer policy and emphasis on applied versus basic research may have changed from year to year and with changes in Station Directors, but strong ties to both the user and the research community always existed.

Besides its research activities, the Station staff helped to conduct National Forest Fire Behavior Training Courses beginning in 1958 at Missoula, Montana. This landmark school, where fire researchers were instructors, helped set a high standard for future behavior training courses which are still held every year at the National Advanced Resource Technology Center (NARTC) at Marana, Arizona. In 1962, the Station assumed full responsibility for conducting the Department of Interior Interbureau Fire Behavior Training Course held at Asilomar and Riverside, California. At some of these courses tuition was charged, starting a trend that later carried to NARTC where "appropriate tuition charges" are made for most courses.

In response to the serious timber fires in northern California during 1960 and 1961, the Station activated in 1962 a new project known as "Conflagration Control." The main purpose was to develop a multifunctional, interdisciplinary concept of fuel modification in the timber zone to reduce the potential for disastrous fires.

Another example of technology transfer has been the construction and maintenance of fuelbreaks. Fuelbreaks are strips of land, strategically located for fire control, on which hazardous woody vegetation has been converted to less hazardous ground cover—usually herbaceous vegetation (*fig. 10*).

Starting in 1957, the Fuelbreak Research and Demonstration Project, organized by the Los Angeles County Fire Department, California Department of Forestry, and the USDA Forest Service, worked together to develop the necessary vegetation management techniques. These included clearing the brush or excess conifers by hand, machine, or by prescribed fire. Studies also included the use of herbicides to control plant regrowth and the establishment and maintenance of a ground cover to complete the conversion.



Figure 7--Smoke from a Flambeau "burn." The fire represents a block of homes in a residential neighborhood ignited by an atomic explosion.



Figure 8--Measuring chaparral volume and density during operation FIRESTOP.



Figure 9--B-17 airtanker dropping retardant on a wildland fire.



Figure 10--Fuelbreak in chaparral. Fuelbreaks are strips of land, strategically located for fire control, on which hazardous woody vegetation has been converted to less hazardous ground cover--usually herbaceous vegetation.

By the early 1970's there were about 1,850 miles of fuelbreaks wider than 100 feet in California brush fields and forests. Additional timbered fuelbreaks were constructed in the Pacific Northwest. However, since the 1970's, the amount of land in fuelbreaks has declined; budget limitations and restrictions on herbicide use have thwarted much planned fuelbreak construction and maintenance of existing fuelbreaks.

Over the years, user involvement has been a two-way street fire research has received as much help as it has given. Typical is the California Department of Forestry and Fire Protection which, beginning with FIRESTOP in 1954, has actively supported the Statewide fire research program by providing manpower, specialized equipment, and funds. For example, during the early days of the air tanker and helicopter programs in 1956 and 1957, the Department made manpower and money available for several air tanker calibration tests and the Western Air Attack Review. Also, the Department designed and built the prototype tank and gates for the first Forest Service TBM air tanker.

Similar support and cooperation has been received from the Los Angeles County Fire Department, several Department of Interior agencies, other States, several National Forests, and the Forest Service's Washington Office Staff for Fire and Aviation Management.

Over the years user involvement has been expressed in several other ways, including assigning State personnel to Forest Service research under the Intergovernmental Personnel Act, by detailing National Forest System staff to work as liaison officers and in some cases, such as FIRESCOPE--having the program manager assigned from one of the user agencies, particularly during the implementation phase.

NEED FOR A FIRE LABORATORY

1953 and 1955 Fire Seasons

The 1953 fire season was a disaster for southern California forests and watersheds and a major turning point for fire research; however, after the fires the worst was still to come. Flood waters running from denuded slopes during heavy January rains resulted in major damage to several southern California cities. In response, concerned citizens met in Arcadia during the floods to consider how the current and future threats to life and property could be met. In addition to funds for burn rehabilitation and additional protection forces, one of the more important results was the organization of the Southern California Watershed Fire Council. Over the years, this group has had an important impact on generating Federal Congressional support for fire protection and research budgets.

In 1955, an 18-day period of critical fire weather in late August and early September dramatized the need for

strengthening fire research and development in California. More than 307,000 acres were blackened during this period. Firefighting costs and damage exceeded \$7.6 million--a lot of money in those days! Later in October 1955, key representatives of the California Division of Forestry (now the Department of Forestry and Fire Protection), Forest Service, University of California, and private industry organized the California-Nevada Forest Fire Research Council (now the California-Nevada-Hawaii Fire Council). Then, as today, one purpose of the council was to advise and stimulate State, Federal, and other research groups on matters of fire research, equipment development, and promote new and improved methods of fire prevention and control.

Inaja Fire and the Engle Report

On the night of November 25, 1958, 11 firefighters were cut off from escape and killed on the Inaja Fire on the Cleveland National Forest in San Diego County.

The task force created by the Chief of the Forest Service after the disaster identified the need for improved knowledge of fire behavior and more powerful methods for attacking mass fires. The Inaja Fire also stressed the urgent need for better fire behavior training and handy guides for alerting firefighters to potentially hazardous fuel and weather conditions.

Equally important were the political ramifications of the disaster. Congressman Engle, Chairman of the House Committee on Interior and Insular Affairs, conducted a congressional hearing on the disaster. The document titled "Forest Fire Control in Southern California" paved the way for strong political and financial support for both forest fire research and control in the State. The Engle Report not only emphasized the complexity of fire control in southern California, but it also provided official justification for increases in fire research funds for the next decade.

Meanwhile, the Station was doing its best with limited laboratory facilities for fire research. It used a small fire table in a basement room in Giannini Hall on the University of California campus in Berkeley, and conducted combustion studies and fire retardant research in a surplus boiler room at the University's Engineering Field Station in Richmond.

For field studies, there were the "Eiffel Tower" wind tunnels at Tanbark Flats in the San Dimas Experimental Forest in southern California and the Shasta Experimental Forest in the northern part of the State (*fig. 11*). Both were a long way from Berkeley and maintenance costs of the Shasta facilities were "eating up" the Station's limited maintenance budget. A laboratory designed specifically for fire research studies was obviously needed.

Support for a Southern California Laboratory

In addition to Forest Service concerns, others had been pointing out the need of having a fire research facility. Following the Engle Report, grass roots and local political sup-

port for an increased fire research program continued to grow in southern California and elsewhere:

- As early as 1947, the Pacific Coast Intermountain Association of Fire Chiefs asked for a major fire research facility in southern California.
- In 1956, the California Wildland Research Planning Committee under the guidance of the Chairman of the State Board of Forestry began developing an "innovative sound and comprehensive research plan for all forest lands in the State." The committee surveyed the state-of-knowledge and determined for each major field where research was deficient. The survey was published by the State of California as "Wildland Research in California--the Key to Better Resource Management." The new plan called for a major fire research facility and an additional annual expenditure of \$500,000 by the Federal Government.
- In January 1959, the FIRESTOP Executive Committee composed of representatives of the major fire control agencies of the State, prepared a plan for a fire research facility in the West and presented that plan to the Governor's Fire Conference. It unanimously resolved that such a program be activated at the earliest possible moment.
- A site and funds were made available for a fire laboratory in Macon, Georgia, followed a year later with the construction of the Northern Forest Fire Laboratory in Missoula, Montana. Yet, that portion of the nation with the worst fire problem--southern California--still did not have a fire laboratory!

The groundswell of support for a fire research facility in southern California continued to grow. In May 1959, Paul Anderson, Chairman of the Riverside County Board of Supervisors, went to Washington to testify on behalf of the proposed Forest Fire Laboratory. In his presentation before the Senate Interior Appropriation Subcommittee, he stressed the need for the \$350,000 appropriation recommended by the Engle Report. He asked that this amount be "made immediately available to develop and staff a cooperative Forest Fire Research Center and to provide \$2 million for construction."

A meeting was held on November 23, 1959, in Riverside, sponsored by the Southern Empire Association of County Supervisors with the topic-The Fire Behavior Research Program of the USDA Forest Service. Chief Richard McArdle and other top Forest Service administrators were on the program. The goal of the supervisors was to "stress the need for a fire and watershed research center."

A site near the University of California campus in Riverside was chosen because it would be at the center of the southern California fire problem, near other cooperating agencies, and would benefit from scientific and technical research, and association with the University.

In many respects this meeting was the kickoff for the public relations and political campaign that followed in 1960 and 1961. An editorial in the local newspaper pointed out that "during the past two weeks, the 1960 fire season provided more than its share of tragic evidence of the desperate needs for more scientific information on the prevention and control of forest and brush fires."

FOREST FIRE LABORATORY AT RIVERSIDE

A bill that included authorization of \$900,000 for a "Regional Forest Fire Research Laboratory, Riverside, California," was passed by the U.S. Senate on March 29, 1960. However, the Senate-House Conferees did not include the laboratory in the Forest Service budget. In early March 1961, the Station Director was informed that the "Western Forest Fire Laboratory" was *positively* in the 1962 budget.

Design and Construction

In the meantime, the fire research staff of the Pacific Southwest Forest and Range Experiment Station had developed specifications for a facility at Riverside that included an instrument shop, electronics laboratory, staging area, forest meteorology facility, humidity chambers, forest fuels laboratory, communications room, fire behavior training laboratory, fallout shelter, mobile meteorological laboratory, and chemistry laboratory. The total area was to be about 31,000 square feet, in three buildings: administrative, technical, and laboratory. The total estimated cost was \$1 million.

One of the major tasks during fall and winter 1961 was to prepare the specifications for laboratory equipment. Chief among these was the fire environment chamber (*fig. 12*). It was to be a one-of-a-kind system that would simulate the conditions of temperature, humidity, and windspeed to which forest fuels are subjected under natural conditions. The chamber would provide the predetermined hourly and daily environmental conditions that may exist for a fuel complex at a specific location.

Another interesting innovation were the LARP's. The two LARP's (Low Altitude Retrievable Probes) were radio controlled, instrumented, drone airplanes with about a 6 foot wingspread (*fig. 13*).

They were designed to fly in and around the smoke column of a fire and measure temperature, humidity, and barometric pressure. The LARP's performed as designed, but qualified pilots were hard to find.

In late 1961, the North Mountain Experimental Forest--about 25 miles southeast of the laboratory site--was obtained from the Bureau of Land Management. This 10,000-acre site is probably the largest set aside in this country for fire research including prescribed fire, equipment development, and fire training. In addition, the area already had a prototype fuelbreak system that could be developed and expanded.

With money finally in hand, the design contract was given to the Riverside architectural firm of Herman Ruhnau, and blueprints were to be ready by spring 1962.¹ The building contractor was Byerly Construction Company of Banning, California, which was awarded a contract for \$694,020.



Figure 11--Eiffel Tower Wind Tunnel at Pilgrim Creek in 1939. The wind tunnel was later moved to Tanbark Flat.

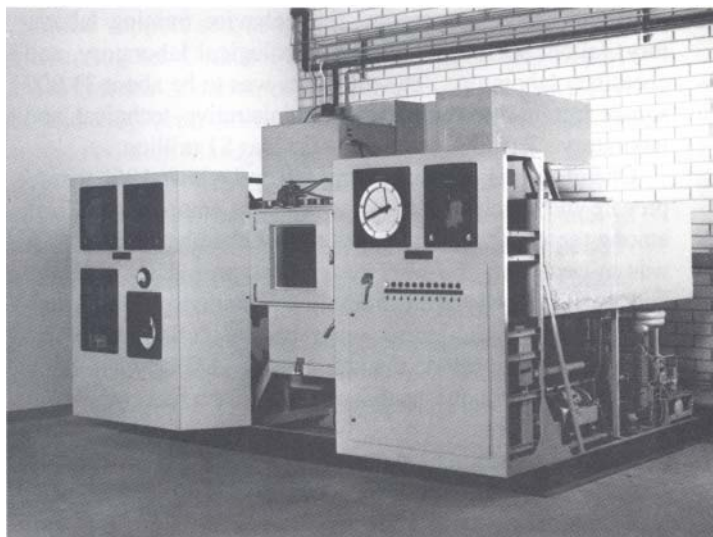


Figure 12--Environment Chamber. The chamber could simulate a predetermined daily weather cycle.



Figure 13--The low altitude retrievable probe (LARP), a radio controlled drone airplane. The LARP was designed to fly in and around the smoke column of a fire gathering weather information.

Dedication

The dedication of the Forest Fire Laboratory on September 11, 1963, was attended by several hundred visitors and guests. The weather was clear and hot, and most seemed to enjoy the exhibits, the tour of the facilities, the catered lunch, and the dedication speeches by local, State, and national dignitaries, including Forest Service Chief Edwin Cliff (*fig. 14*). (A possible exception was the individual who upon viewing the emergency eye wash stated, "I don't see how two people can drink at the same time from the same fountain; the contractor has failed to hook up a drain; and this is a perfect example of government waste.")

RESEARCH AT THE FOREST FIRE LABORATORY

1964 to 1969

Much of the fire research of the Station was moved to Riverside just before the dedication, and the Station began to make giant strides in its fire research program. Station Director John R. McGuire (who later became Forest Service Chief) not only encouraged the staff to meet the needs of California clients, but also encouraged Westwide and even nationwide programs including fire meteorology for Region 4 (Intermountain Region) and Region 6 (Pacific Northwest Region) and efforts aimed at minimizing the impact of slash burning on atmospheric pollution (Green 1968).

The Station was asked by Region 6 to examine the slash disposal problems on the Siuslaw and other National Forests and a cooperative program was established with both Oregon State University and the Region.

This period, however, was not without its trials. Funding for the 10-year-old Flambeau Program came to a close in 1969, and the Station was forced to reduce staffing at the Laboratory from 72 to 50 full-time permanent employees. At about the same time, the research studies in Region 4 and 6 were closed out, and the Conflagration Control Project and the Helitack R&D studies were terminated.

1970--A "Watershed" Year For Fire Research

The 1970 fire season was another major turning point for forest fire research in California. Governor Ronald Reagan appointed a Task Force on California's Wildland Fire Problems. One of us (Wilson) served on it for 2 years and later chaired the follow-on Fuel Management and Hazard Reduction Action Committee. Two important byproducts of this Committee's efforts were creation of the Laguna Morena

¹Commercial enterprises and products are mentioned for information only. No endorsement by the U.S. Department of Agriculture is implied.

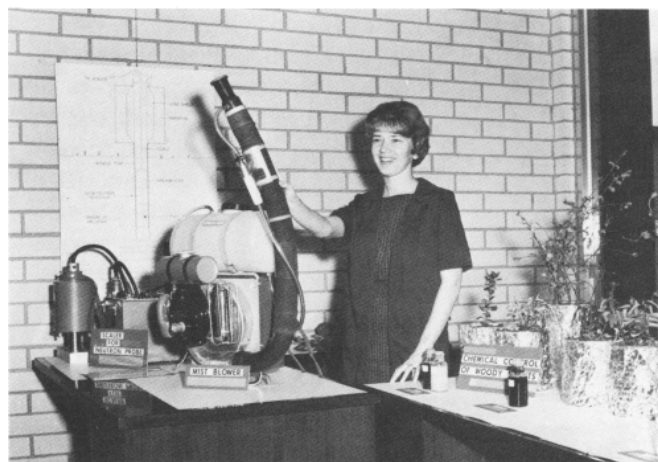


Figure 14--Dedication ceremonies at the new Forest Fire Laboratory included demonstrations of research projects including equipment used to control woody vegetation.

Demonstration Area in San Diego County and establishment of the Chaparral Management Program. Other important spinoffs from the 1970 "near disaster" were the Night Helicopter project and the FIREScope Program, both of which were given strong support by Keith Arnold (then Deputy Chief for Forest Service Research) and Station Director Harry Camp.

1971 to 1985

Flying Helicopters at Night

The Night Helicopter Project was a cooperative effort of the Forest Service, U.S. Army Night Vision Laboratory, Los Angeles County Fire Department, California Department of Forestry, Oregon Division of Forestry, Bureau of Land Management, and private industry. The main goal of the special project was to utilize military technology in developing a helicopter system for detecting and fighting forest fires at night. Among the items tested were the night vision goggles and the FLIR navigational system. This special fire detection and suppression equipment has become operational in southern California.

FIREScope Research Development and Application Program

The FIREScope RD&A program was one of the most ambitious studies undertaken at the Forest Fire Laboratory. It was aimed at developing a computer-driven management information system that would provide fire managers at all levels with the information needed to make prompt decisions. Much of the research and development work was done by contractors who had a background in the nation's aerospace program.

Another important objective of the system was to coordinate the efforts of southern California fire protection agencies which had to work together on major wildland fires--rather than just protecting their own areas. FIREScope essentially developed the methods and the vocabulary for interagency

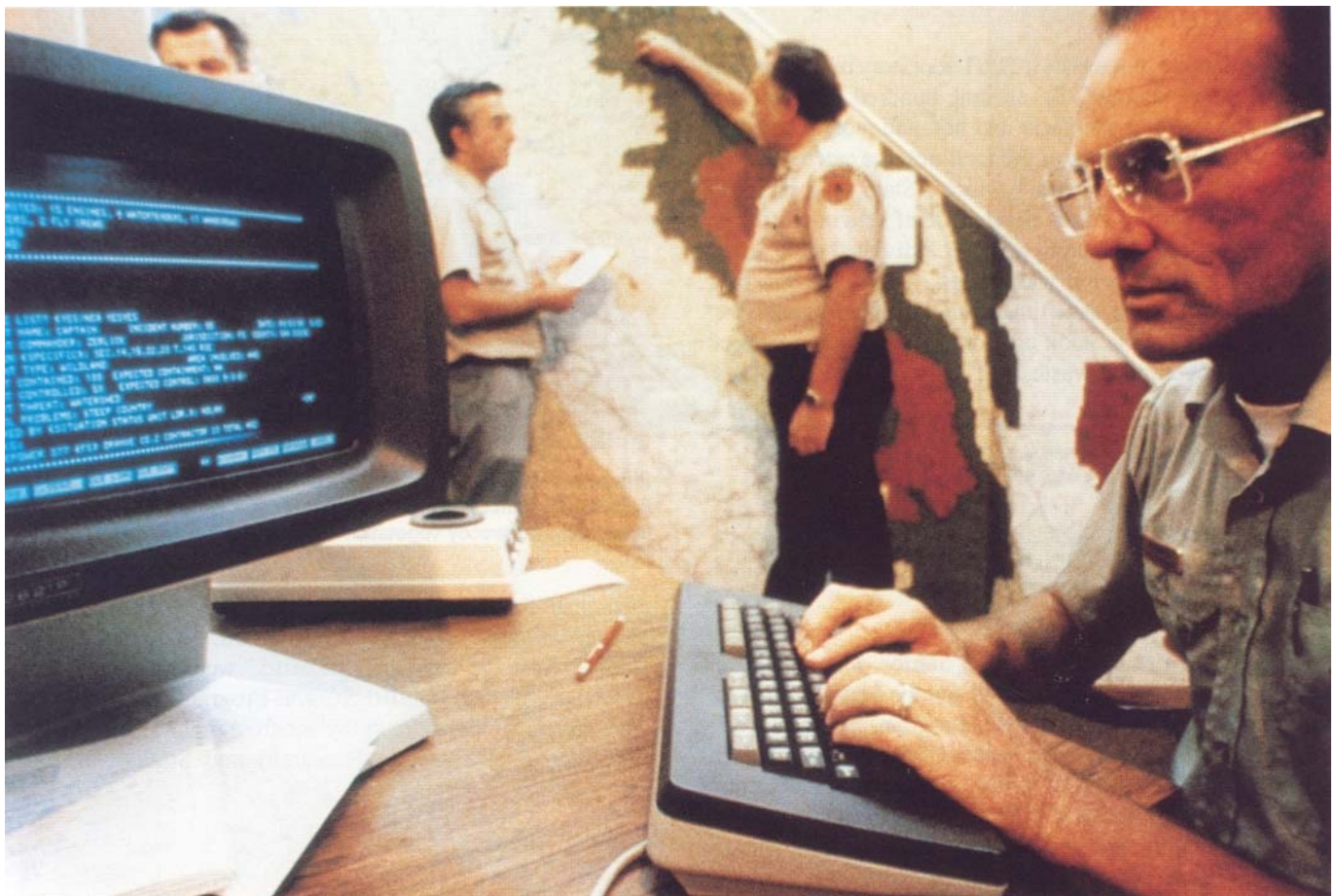


Figure 15--FIREScope has led to computerized dispatch centers such as this facility in Riverside, California, shared by the California Department of Forestry and Fire Protection and the USDA Forest Service.

cooperation. FIREScope met these objectives so well that the resulting Incident Command System (ICS) is being used worldwide to manage a wide range of activities where multiple groups of people need to work together in complex situations (fig. 15).

FOCUS and FEES

The Forest Service maintains what is generally recognized as the world's largest and most efficient fire control organization. It is also the world's most expensive one. Anything to increase fire management and organizational efficiency potentially could save millions of dollars in public funds.

FOCUS was one of the Forest Service's first efforts to develop a computer simulation model to evaluate alternative fire management organizations. The initial FOCUS design was ambitious (Bratten and others 1980). It was designed to model all possible fire agency configurations--nationwide. Although the model was used on several National Forests, its large data requirements and complexity made it intractable for many users.

In a sense, FEES--a fire economic planning model--profited from the problems of FOCUS in that instead of being a "hands on" simulation model to be run by the user it was to be a series of guide books in which the needed information could be looked up (Mills 1986). FEES was also based on the

economic principle of finding the least *cost plus net value change* solution to alternative fire organizations and strategies, that is, minimizing the combination of costs and losses (Althaus and Mills 1982). Although a prototype was developed for the northern Rocky Mountain Region, FEES has not been adapted for use in planning. Yet, many of its economic concepts proved valuable. While neither system is currently used, they were important in getting fire managers to think about modeling their organizations and using economic principles. Both systems had a role in the development and refinement of the National Fire Management Analysis System (NFMAS), now in wide use.

Chaparral Research and Development Program

Early Spanish diaries describe European explorers' first contact with chaparral. However, after more than 300 years of contact, there is still much to know about this complex ecosystem comprised largely of xerophytic shrubs. The Research and Development program consisted of 11 separate studies including development of an inventory and classification system for the chaparral ecosystem, investigation of the nutrient budgets of chaparral, and development of techniques for predicting the long term erosion and nutrient loss in soils that become water-repellent following a fire.

The Program was successful in meeting many of its objectives including development of the chaparral inventory system, an evaluation of post-fire erosion rates, and information on the photosynthetic rate and water needs of several important chaparral species. Equally important, it helped set the stage for some of the current research projects (Green 1981).

1986 to 1988--On-Going Research

The current research effort, with considerable aid from cooperators, is strong. Six research work units are involved in fire, watershed, environmental quality, and recreation studies.

Ecology and Fire Effects in Mediterranean Ecosystems

Chaparral and associated woodland and forest vegetation cover approximately 20 percent of California (20 million acres). Because ecosystems characterized by these plant communities dominate low and middle elevations adjacent to the State's interior and southern valleys, much of this vegetation is near major population centers. These ecosystems are extremely important for watershed protection, recreation potential and wildlife values. California's Mediterranean ecosystems have evolved with fire as a recurring phenomenon. Many characteristics of these ecosystems have been influenced both by the long summer drought period and by these intermittent wildfires--which can change vegetation patterns, accelerate erosion, cause downstream flooding and siltation (Wells 1986), and alter the distribution and cycling of nutrients. The chronic regional air pollution, typical near major metropolitan areas, also significantly impacts these ecosystems.

A basic understanding of ecosystem processes and how they are altered by perturbation is critical to management of these highly dynamic--and heavily disturbed--ecosystems. Based on earlier research, generalization of ecosystem responses to disturbance is extremely difficult due to the great physical, climatic, and interspecific variability typical of these systems. Because of the resulting complexity of interactions in chaparral ecosystems, we need to focus on understanding basic processes and on studies of regional scope to have any hope of developing site-specific models that will be useful for management of these ecosystems.

Research on this project is directed at increasing our understanding of the factors that influence dynamic processes--such as erosion, vegetation dynamics, biomass development, and nutrient fluxes in chaparral and associated woodland ecosystems, with particular emphasis on responses to fire and fire/air pollution interactions.

Recent major accomplishments include these:

- Observation of two to three orders of magnitude increases in both wet and dry erosion during and shortly after fire. Dry erosion processes can contribute up to 30 percent of this early sediment production.
- Hillslope erosion research suggests that rapid development of rill networks may be the key to debris flow propa-

gation. A university cooperator has obtained some of the first measurements of debris flow density (flows contained up to 60 percent suspended sediments by weight) and tracked their movement through reservoirs using a network of pressure sensors.

- The importance of pore pressure buildup in causing soil slips and shallow landslides was evaluated on artificially induced soil slips in cooperation with U.S. Geological Survey scientists. A sharp drop in pore pressure was always observed immediately prior to slope failure.

- A recently completed study showed that surface sediment movement on unburned slopes was lower under grass than under chaparral. We have just begun a major multi-year study of the effects of fire and pre- and post-fire vegetation on erosion processes and vegetation dynamics in the chaparral ecosystem.

- The intensity and duration of soil heating during fire are critical factors affecting post-fire regeneration of chaparral shrubs. Studies of heat-induced seed mortality have shown that seeds of obligate-seeding *Ceanothus* species are more heat tolerant than seeds of sprouting species.

- Research shows that streamwater nitrate concentrations in parts of the San Gabriel Mountains with heavy air pollution are elevated by as much as three orders of magnitude compared with areas of reduced pollution. Recent studies show that severe fire may mobilize large amounts of accumulated nitrogen in streamwater.

- Initial data from cooperative research on two recent fires show greatly elevated levels of sulfur and nitrogen compounds in smoke, probably as a result of remobilization of deposited air pollutants.

- Biomass in chaparral stands increases rapidly in the first 20 years after fire. Data from several sites showed that biomass was strongly correlated with stem basal areas, but generally unrelated to initial stand density.

- Project research has illustrated the profound effect that site differences and species composition can have on fuel structure in chaparral stands.

- Research on silviculture and management of evergreen oaks showed that stump-sprouting was markedly more vigorous in clearcuts than in thinned stands (*fig. 16*).

Meteorology for Fire Severity Forecasting

Anyone who has faced a wildland fire knows how critical weather is to fire behavior. Rushing air currents in mountainous terrain, for example, cause winds to reverse directions in a few minutes or within a few miles (*fig. 17*), creating serious fire threats. Many years of research at the Forest Fire Laboratory have been devoted to the problems of the imminent fire weather threat.

In the early years, landmark studies identified the critical large-scale weather patterns that produced high fire threats in different regions of the country. The project's research next focused on local weather phenomena, particularly the behavior of winds in complex terrain. The nature of the problems, and the depth of the research, placed project scientists at the forefront of mountain meteorology. New tools were devel-



Figure 16--Scientists study the response of evergreen oaks to thinning, clearcutting, and prescribed fire.



Figure 17--Scientists installing weather instruments on a tower.

oped for the practitioner in the early 1970's: the prototype remote automatic weather station network, and the AF-FIRMS computerized fire weather system, which has endured to the present.

Recently, the project was asked to provide fire managers with the means to anticipate weather conditions a week to a month in advance. These tools were needed by the Forest Service as it implemented prescribed fires (which are planned up to 2 weeks in advance), and as its firefighting force acquired greater mobility. Project scientists are currently doing research which would have been considered implausible just a few years ago—developing methods to prepare medium (6- to 10-day) and extended-range (30-day) forecasts of fire weather conditions on national and regional scales. This information will be used in presuppression planning for mobilization and deployment of firefighting resources. Laboratory meteorologists will develop the interface to National Weather Service forecasts that are necessary to translate its global weather information to national and regional fire potential. In more ways than one, the scope of the project's research has greatly expanded from its early beginnings.

Recent major accomplishments include these:

- A computerized wind model that depicts winds in three dimensions. The model was used to describe fire potential in southern California, the dispersion of air pollutants, and the airborne transport of gypsy moth larvae in the Santa Cruz Mountains of California.
- A method for choosing locations of weather stations for optimum meteorological support of fire management (Fujioka 1986). With this tool, fire managers can utilize the full capability of remote automatic weather stations to operate without conventional power, communications, and manual assistance. Moreover, the procedure can be used to design a network of sensors to analyze air quality efficiently.
- A fire climatology atlas for California. Given present fire weather conditions, fire managers can use the information in this atlas to anticipate future fire weather, extrapolating historical trends.
- Statistical tools to integrate weather information concisely in fire planning. Statistical modeling techniques were tested to estimate wind, temperature, and humidity in hilly terrain.

Fire Management and Economics

Wildland fire protection is expensive—it costs more than half a billion dollars each year. Many fires cost more than \$1 million to put out. The total cost to the nation in resources damaged from fire is estimated at \$2 billion annually. A single major fire may call on a complex supply system that taps sources of crews, transportation, equipment, food, and other resources from every state in the nation. To make the most effective use of resources, fire managers need reliable economics information to plan fire management strategies and to make tactical decisions.

In some ways fire management decisions have become more demanding since the late 1970's when the USDA Forest

Service, and State and other Federal fire protection agencies reversed a long-standing policy that required trying to control every fire regardless of the cost. Under the more recent policy, potential fire impact is evaluated from both an economic and an ecological standpoint. These factors are then considered with land management objectives in deciding on a fire management strategy. A variety of strategies is now available to fire managers, making their decisions even more complex. More information and systems are needed to help them make intelligent choices.

Along with economic and ecological considerations, cost-effective fire prevention requires that managers understand social factors such as population trends. Over the past 10 to 15 years a growing number of people have been leaving cities and moving into woodland areas. Here, they and their property are at a much greater risk from wildfires (*fig. 18*). We need to take a closer look at wildland-urban interfaces and the population changes that are taking place.

Information and methods are needed that integrate the temporal and spatial variability of fire occurrence and severity with costs and values-at-risk for use in allocating suppression resources shared between National Forests or with other regions or agencies.

The Fire Management and Economics Research Work Unit uses economic principles, operations research, sociology, and computer science in developing techniques to predict and measure the economic consequences of fire management decisions.

Important research accomplishments include these:

- Fire Laboratory scientists have shown how computers using Geographic Information Systems software can integrate land forms, vegetation patterns, and weather information to produce maps of fire behavior estimates over large areas (*fig. 19*).
- Researchers developed methods of integrating fire management activities and resource management goals with cost analysis procedures to evaluate economic efficiency of program alternatives.
- The economics of fuel treatment activities, as part of the prescribed use of wildfire in resource management, have been examined. The variability of fuel treatment costs is tied, at least in part, to specific site characteristics, program objectives, and (perhaps most important) institutional constraints.
- Scientists have helped develop a systematic approach to fire prevention planning that is based on the risks of fire occurrence, potential fire behavior, and the values being protected. The system facilitates subsequent evaluation of prevention activities (no small feat since we cannot count prevented wildfires).
- The potential of computer based expert systems for fire management has been explored with development of a tutorial for the newly developed prevention planning process.
- Statistical examination of the rare occurrence of large and damaging wildfires has given new understanding of the frequency and distribution of multiple wildfire events

(more than one fire at once) that place severe demands on protection forces.

- Statistical analysis of 15 years of data has begun to identify the beginning and ending dates of typical fire seasons.
- Researchers have analyzed the consequences of not incorporating wildfire safety standards into community planning and development, especially where the development is potentially threatened by wildfires.
- Research with fire managers has shown that tendencies to take more or fewer risks in fire management decisions vary with geographic regions (with differing fire behavior patterns) and the nature of the fire situation.

Site-Specific Fire Prescriptions For California Chaparral and Associated Ecosystems

Wildfire in chaparral can be a terrifying event. Flame lengths of 50 feet and spread rates of 10 miles per hour are common (*fig. 20*). However, for a variety of reasons, Californians have chosen to live close to this potentially explosive vegetation. Chaparral can be compatible with humans but only if it is properly managed. One way of keeping it under control is the prescribed use of fire. However, chaparral may not burn--or may burn explosively--depending upon a variety of fuel and atmospheric conditions.

Chaparral is closely associated with woodlands, riparian zones, conifer forests, and other plant communities. When fires start in chaparral areas they threaten these other ecosystems, including important watersheds and recreation areas. Under carefully controlled conditions, prescribed fires can reduce these hazards. And when used in certain coniferous forest stands, such burns not only reduce fuel hazards, but also act as a silvicultural tool to provide better growing conditions for the trees. By the judicious use of prescribed fire to create a combination of browse, cover, and "edge," big game populations can be increased dramatically (*fig. 21*).

This Research Work Unit at the Fire Laboratory is developing the knowledge needed to predict prescribed fire behavior, soil heating, and other fire effects for California chaparral lands (*fig. 22*). The scientists in this Unit are directing efforts toward producing guides so that managers can use information on weather, site, and firing techniques to conduct prescribed burns for specific chaparral sites to achieve designated goals.

The Unit is organizing the information collected and developed for both fire behavior and fire effects so that it can be related to selected components of the southern California vegetation classification system. The result will be a more comprehensive knowledge of prescribed burning.

Recent accomplishments include these:

- Scientists at the laboratory have produced a preliminary model of how heat transfers through the soil when moisture is present. Laboratory experiments are under way to further evaluate the model.
- Studies of ground surface heating have found that the most important heat transfer mechanisms are conduction of heat into the soil and surroundings and the exchange

of heat between the soil, ground surface, and smoldering embers left behind by the fire.

- Laboratory scientists are identifying site specific factors important to conducting prescribed burns safely.
- Headway is being made in understanding the effect of heat on soil nutrients and subsurface microorganisms.
- Scientists have found that older stands of chamise do not necessarily contain a greater percentage of dead, combustible material than younger aged stands. Live chamise can also burn readily.

Atmospheric Deposition Effects on Montane Forest in the Western United States

Air pollution in the Western United States has increased dramatically since the late 1940's, when populations and industry expanded. Emissions from automobiles, power plants, and other sources that burn fossil fuels produce pollutants that are transported downwind (*fig. 23*). These atmospheric chemicals are then deposited on plants, soils, and water systems within an ecosystem. Important and unique ecological communities may be damaged by this pollution.

In forests, this spread of pollution may mean that sensitive tree species are damaged, and that their growth and reproduction are seriously reduced. Ponderosa pine, a major forest tree, is one of the species most sensitive to air pollution. It makes up 26.6 million acres or 25 percent of the total commercial timberlands in the Western United States. Studies during the sixties, seventies, and eighties at the Fire Laboratory have documented the damage to forests in the San Bernardino Mountains and now to forests in the Southern and Central Sierra Nevada. We need to know to what extent pollution is harmful to this and other sensitive tree species, and whether it is causing widespread damage to forests in the West. In addition, air pollution adversely affects recreational and other amenities in forest environments.

Although Southern California remains one of the most polluted areas in the world, similar effects have been observed throughout the Western States in mountainous basins and valleys where pollutants are transported from urban centers. The problem of air pollution is worldwide. Data from Switzerland, Germany, and Mexico suggest that forests have declined where these pollutants occur.

Recent important research accomplishments include these:

- Height and diameter measurements are one indication of growth reduction. In a recent study in the central of samples taken at both affected and unaffected sites, showed that Jeffrey pine suffered a decrease of 11 percent in mean annual growth since 1965. A similar study in ponderosa pine showed no diameter growth reduction in spite of leaf symptoms of pollution damage.
- Tree foliage reflects injury from air pollution--generally from ozone or sulfur dioxide. Research at the Forest Fire Laboratory has shown that a certain type of leaf mottling is a symptom of ozone damage. The amount of the chlorosis-a mottled yellowing or blanching of the leaves--indicates the extent of damage. However, in



Figure 18--Homes at risk! The Coyote Fire (1964) approaches the city of Santa Barbara. Many homes were lost that night. Photo: Santa Barbara News-Press.

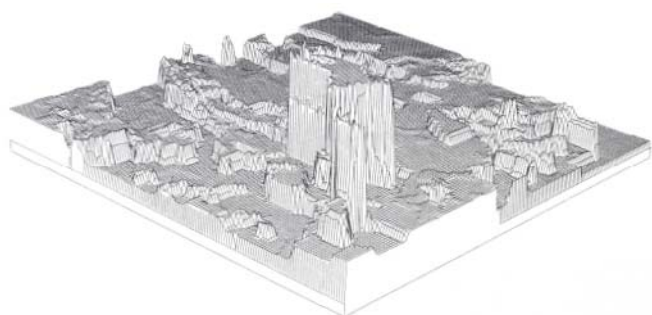


Figure 19--Computer generated Geographical Information System (GIS) map of fire spread rate on a forested area in the San Jacinto Mountains in Southern California. The higher the "spikes," the faster the spread rate.



Figure 20--Flame lengths of 50 feet and spread rates of 10 miles per hour are common in chaparral fires.



Figure 21--Helitorch igniting chaparral during a prescribed burn.



Figure 22--Measuring sprout growth to determine the effect of a recent fire.



Figure 23--Automotive traffic is a major source of pollution that adversely affects forest vegetation.



Figure 24--Almost any "swimming hole" gets intensive use in the wildland-urban interface.

some cases, pollution stress is not always readily visible and other biochemical changes need to be identified.

- Many western montane forests are found on shallow, granitic soils that are vulnerable to the effects of pollution. Research has shown these soils have little or no ability to neutralize acidic pollutants such as sulfate and nitrate. While nitrogen is an essential element for plant growth, in high dosages, it becomes harmful by polluting groundwater and causing changes in plant physiology. In such situations, important nutrients (possibly magnesium) are leached from the soil, causing deficiencies in plant growth and development.
- Researchers at the Laboratory have shown that air pollution damage is reducing the genetic diversity of the forest. Individual trees within a species are more resistant to pollution injury than others. In southern California, sensitive individuals have died out, leaving the more resistant trees. This trend is expanding north and eastward through western forests, with significant implications. Managers are forced to rely on the remaining resistant trees as their nursery stock. This nursery stock has lost some of its genetic base and we can expect it to have less ability to adapt to environmental changes in the future.
- Scientists have shown that the microorganism *Nitrosomonas europaea* which creates a form of the nitrogen pollutant found in water can also volatilize the nitrogen pollutant into the air in a harmless form. This occurs in stream bottoms when they are moist and slightly anaerobic. This discovery may provide one tool for management to control the nitrogen pollutants in water coming from forests.

Wildland Recreation and the Urban Culture

"Wildland-urban interface" is not the favorite term of many foresters. It conjures up visions of fire control problems and limited timber harvesting options. On the other hand, it offers the Forest Service the opportunity to meet the outdoor recreation needs of a growing population (fig. 24).

The Wildland Recreation and Urban Culture Research Unit was headquartered at Riverside in 1987, and is charged with developing guidelines for managing recreation in wildlands near large urban areas. The objective is to meet the needs of the public while conserving natural resources.

Outdoor recreation problems abound on most State and Federally managed wildlands in California, and they are not unique to the State. Problems include vandalism, littering, and conflicts of use between recreation groups. For example, backpackers and off-road vehicle (motorcycle and mountain bicycle) users are usually not compatible.

We need to understand the cultural and recreational differences between various populations using wildlands. We must devise methods to predict emerging recreation uses, such as shorter, more frequent visits, closer to home, and the growing demand for more conveniences and services. We need to develop methods of interactive communication between recreation groups and resource managers. We must manage vandalism on developed recreation sites and areas of dis-

persed recreational use, which costs the Forest Service--the taxpayer--an estimated \$3 million per year nationally.

While not forests in the conventional sense, "urban forests"--city parks and plantings along sidewalks--are expensive to manage. Procedures are needed to reduce costs and manage the vegetation more effectively on developed recreation sites in both wildland and urbanized areas.

Progress is being made in the following areas:

- Determining if trees with columnar root systems produce the least root mass in the upper one foot of soil, and evaluating the inheritance characteristics of root structure. The goal is to produce trees with root systems least likely to damage sidewalks.
- Studies of fabrics, planters, and wells for controlling tree roots show promise for physical barriers to control root damage to sidewalks.
- Two urban forestry data base management systems have been developed for use in cities to computerize urban tree inventories and maintenance records.
- Identifying seasonal defoliation patterns and developing clones of trees that support energy conservation--provide shade in the summer yet permit solar heating in the winter when they lose their leaves--has been one goal of the work unit (Wagar 1985).
- A study to test photo and dot-count procedures for measuring summer shade provided by trees has been developed. The study will help determine the "shade producing potential" of various tree species and their ultimate energy conservation potential.
- A study is under way to improve analytical abilities of resource managers to assess environmental changes through the use of before-and-after photography. Color slides ranging in age from 17 to 25 years that depict various landscape components throughout California are being compared to new photography. The objective is to provide a guide to increase manager's ability to evaluate changes.
- Research is under way to determine the recreation needs of our newest citizens, many who come to the United States with wildland recreational needs and expectations that may differ from that experienced by recreation managers in the past. Gaining understanding of the perceptions, preferences, and concerns of various ethnic groups toward wildland recreation is a new challenge to wildland managers.
- Research is being conducted to identify the interests, interactions, perceptions, and concerns of special interest groups including off-road vehicles, recreational shooting, hang gliding, and mountain bicycling.
- A study is being conducted to develop strategies that permit effective communication between diverse visitors and recreation managers.
- A survey has been completed that identified recreation problems associated with the urban population in southern California including illegal off-road vehicle use, vandalism, litter, illegal shooting, overuse of the recreation resource, and noise and partying.

Publication Record

Over the years the annual production of publications--the Station's most visible product--has varied greatly (fig. 25). The reduction of research during World War II is reflected in the paucity of fire publications during and for a few years after the war.

The Station issued 218 publications from 1923 to 1961. The 1962 to 1964 period was productive for fire research. The Station issued 99 publications, including:

- Landmark summary reports for Project Civil (Broido 1960, 1961)
- Critical Fire Weather Patterns (Schroeder 1964)
- Predictions of Fire Spread Following Nuclear Explosion (Chandler and others 1963).

As part of the effort to develop "bridges" with the user, several efforts at popularized publication were tried including a leaflet called "What's Happening in Forest Fire Research." It was written in an informal, semi-humorous vein and was easy to read. It was a "hit"--so much so that it became the prototype for the Western Forest Experiment Stations' *What's New in Forestry Research*, now called *Forestry Research West*.

The years between 1971 and 1988 saw wide fluctuations in fire research at Riverside. The number of scientist years budgeted to fire research ranged from a high of 21 in 1980 to 12 in 1987 (fig. 26). This reduction has been offset somewhat by personnel funded from other functions including watershed, recreation research, and other outside sources.

Publication production has not declined with a decreasing permanent staff. This is partly because of an increasing staff

of very productive temporary employees (Davis and others 1987). While they are usually not the principal authors of major publications, they are important contributors to the Forest Fire Laboratory's accomplishments. An examination of the publication record--both in total numbers and rate per scientist year for both intramural research and station scientists--shows a considerable increase from 1982 to 1987 (Aitro 1977, Brannon 1973, Hostetter 1966, Shaw and Davis 1978, Wilson and Nilsson 1962).

Another reason for the recent increase in publication is that during the 1970's and early 1980's many of our cooperators and contractors produced engineering and administrative reports that were not counted as publications--many FIREScope reports are examples. During the past 5 or 6 years, on the other hand, intermural research has tended to produce more publishable information.

FUTURE OF FIRE RESEARCH

By concentrating efforts on anticipated high priority needs, fire research should continue to make important contributions in the future as it has in the past. We expect that the Forest Fire Laboratory will play an important role in achieving these contributions. In addition, new research in recreation, air pollution and other areas will continue to keep the Laboratory a major research center for the Forest Service. The Forest Fire Laboratory, in the best tradition of the Forest Service, is producing well. Gifford Pinchot would be proud.

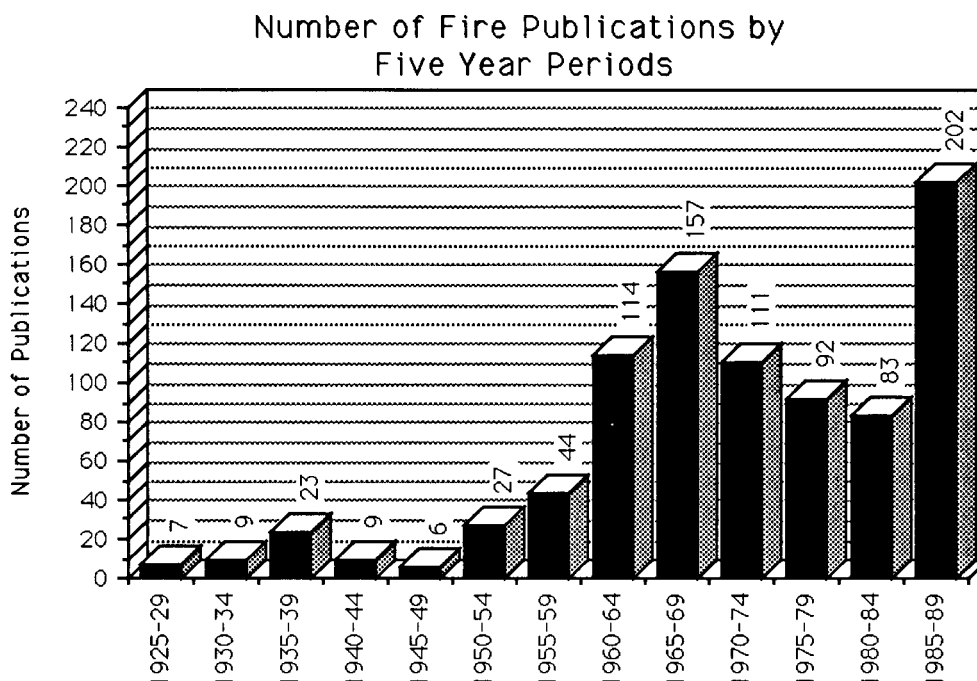


Figure 25--Number of publications by 5-year periods. The projection for the period 1985 to 1989 is based on the average of the years 1985, 1986, and 1987.

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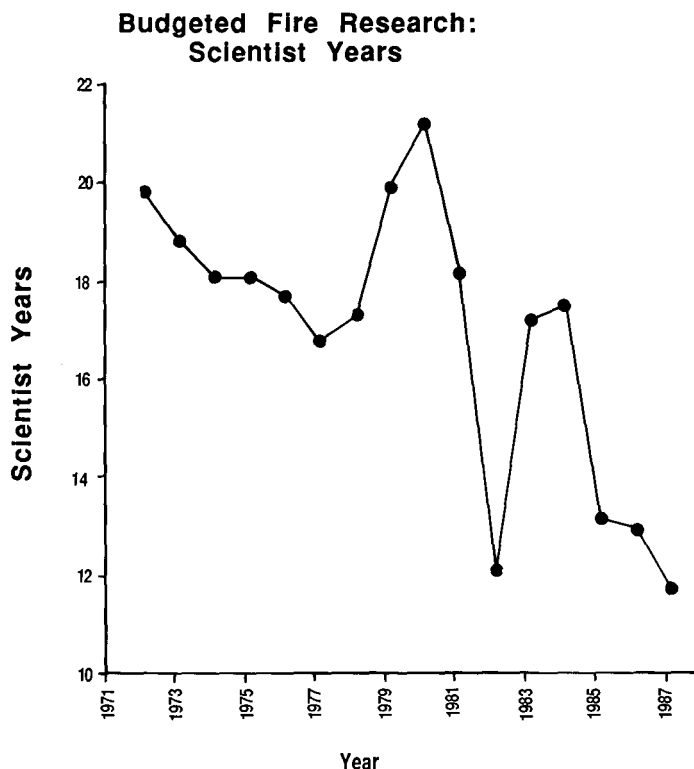


Figure 26--Budgeted fire research scientists from 1971 to 1987. These represent permanent professional scientists with the grade of

GS-11 or higher that are funded within the Forest Fire and Atmospheric Sciences budget.

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The Forest Service, U.S. Department of Agriculture, is responsible for Federal leadership in forestry. It carries out this role through four main activities:

- Protection and management of resources on 191 million acres of National Forest System lands.
- Cooperation with State and local governments, forest industries, and private landowners to help protect and manage non-Federal forest and associated range and watershed lands.
- Participation with other agencies in human resource and community assistance programs to improve living conditions in rural areas.
- Research on all aspects of forestry, rangeland management, and forest resources utilization.

The Pacific Southwest Forest and Range Experiment Station

- Represents the research branch of the Forest Service in California, Hawaii, and the western Pacific.
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The need for protection from uncontrolled fire in California was identified by Abbott Kinney, Chairman of the State Board of Forestry, more than 75 years before the construction of the Riverside Forest Fire Laboratory.

With the organization of the USDA Forest Service the need for an effective fire protection organization became apparent. In response, a somewhat fragmented research program got under way in the 19 10's. Although the research was successful in reducing fire damage undermost conditions, severe fire years still made it clear that a strong cohesive fire research effort, headquartered at an adequate laboratory was necessary. However, the Fire Laboratory did not "just happen." It was the result of considerable organized public and private support.

During the 50 years prior to the dedication of the Laboratory, and the 25 years since, there has been an effort to balance a pragmatic approach toward dealing directly with the fire manager, and also maintaining scientific excellence. There are currently six research projects at the Laboratory with emphases on fire management and the beneficial use of fire, forest recreation, effects of air pollution on forest ecosystem, and watershed management.

Retrieval Terms: fire management, fire research, fire laboratory, forest history