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LIGHTNING FIRES IN SOUTHWESTERN FORESTS

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LIGHTNING FIRES IN SOUTHWESTERN FORESTS (1)

by

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Final Report

May 1978

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LIGHTNING FIRES IN SOUTHWESTERN FORESTS

I. INTRODUCTION

Lightning is the leading cause of fires in southwestern forests. On all protected private, state and federal lands in Arizona and New Mexico, nearly 80 percent of the forest, brush and range fires are ignited by lightning. The Southwestern region leads all other regions of the United States both in total number of lightning fires and in the area burned by these fires.

Lightning fires are an important factor in the management of wildland resources in all of the western United States and especially on the 139 million acres under organized fire management in Arizona and New Mexico. On these lands in the Southwest an annual average of nearly 2400 lightning fires occur. These fires are a natural element in wildland ecosystems and under precisely specified conditions some lightning fires may be used beneficially in natural resource management. Lightning fires also adversely impact society causing losses of needed natural resources, human life and property.

This report presents a summary of research aimed at gaining an in-depth understanding of the nature and magnitude of Southwestern lightning fires. The research focuses on lightning fire factors related to the development of policies and programs for overall management of forest and range resources. Information is presented for evaluation of both ecological and societal aspects of lightning fires. The main data base is some 28,000 individual fire reports from national forests and general fire summaries of more than 48,000 fires in Arizona and New Mexico The research also analyzes lightning fires in national forest wilderness and primative areas and wilderness study areas.

I-1. Lightning and Man-Caused Fires

A first step in the development of this research involves an overview of both lightning and man-caused fires. While the objective is clearly to concentrate on lightning fires, it is necessary to understand the relative role of both lightning and man-caused fires in resource protection and management.

Forest fire statistics show the importance of both lightning and man-caused fires in Arizona and New Mexico (U.S. Forest Service, 1960-1975). As shown in Table I-1, a total of 37,934 lightning fires and 10,138 man-caused fires were reported on protected state, private and federal lands in the two states during the 16-year period 1960-1975. Lightning accounted for 78.26 percent of the fires in Arizona and 80.14 percent in New Mexico. The largest number of both causes of fires was in Arizona.

Analysis of fires on all protected lands in the various western regions shows that the Southwestern region accounts for 26.95 percent of the lightning fires but only 5.88 percent of the man-caused fires. The Southwestern region leads all other western regions both in total number of lightning fires and in percent of fires caused by lightning (78.91%). The Northern Rocky Mountain region (Idaho and Montana) ranks second to the Southwest in percent of fires caused by lightning (65.07%). The Pacific Northwest region (Oregon and Washington) ranks slightly higher than the Northern Rockies in total number of lighting fires (Table I-1).

As shown in Table I-2, Arizona leads all western states in number of lightning fires per million acres and ranks sixth in man-caused fires. New Mexico ranks fifth in lightning fire density and tenth in man-caused fires. Only Nevada has a lower density of man-caused fires than New Mexico.

Further insight into the general scope of lightning and man-caused fires is gained by examining the fire records of the six western regions of the U.S. Forest Service. Region Three (Southwest Region, USFS) leads all other western regions both in total number of lightning fires and in area burned by these fires. As shown in Table I-3, during the 16-year period 1960-1975 lightning fires in Region Three national forests accounted for 80 percent of the fires and 65 percent of the area burned in the region. Only Region One (Northern Rockies) recorded a higher percentage of area burned by lightning fires.

This overview emphasizes the dominant role played by lightning fires in the Southwest and especially in the Region Three national forests. However, this does not suggest an unimportant impact by man-caused fires. As shown in Table I-3 the average annual area burned by man-caused fires in Region Three is second only to Region Five (California).

Table I-1. Number and Percent of Lightning and Man-Caused Fires on all Protected Private State and Federal Lands in Twelve Western States, 1960-1975

State and Region	Lightning Fires No.	Lightning Fires %	Man-Caused Fires No.	Man-Caused Fires %	Total No.
Arizona	24,528	78.26	6,815	21.74	31,343
New Mexico	13,406	80.14	3,323	19.86	16,729
Total Southwest	37,934	78.91	10,138	21.09	48,072
Colorado	5,921	34.41	11,287	65.59	17,208
Wyoming	3,375	46.11	3,944	53.89	7,319
Total Central Rockies	9,296	37.90	15,231	62.10	24,527
Idaho	17,423	65.98	8,985	34.02	26,408
Montana	11,377	63.73	6,474	36.27	17,851
Total Northern Rockies	28,800	65.07	15,459	34.93	44,259
Nevada	3,041	46.63	3,481	53.37	6,522
Utah	4,677	45.25	5,660	54.75	10,337
Total Intermountain	7,718	45.78	9,141	54.22	16,859
California	25,903	25.69	74,942	74.31	100,845
Oregon	21,372	50.09	21,291	49.91	42,663
Washington	7,733	25.30	22,836	74.70	30,569
Total Pacific Northwest	29,105	39.74	44,127	60.26	73,232
Alaska	2,005	38.33	3,226	61.67	5,231
Total West	140,761	44.97	172,264	55.03	313,025

Table I-2. Fire Occurrence Density on Protected State, Private and Federal Lands in Western States, 1960-1975.

State	Lightning Fires		Man-Caused Fires	
	Average Annual No. of Fires Per Million Acres	Ranking	Average Annual No. of Fires Per Million Acres	Ranking
Arizona[1]	45.72	1	12.70	6
New Mexico	20.65	5	5.13	10
Colorado	11.16	8	21.27	4
Wyoming	5.84	10	6.81	9
Idaho	24.89	4	12.85	5
Montana	17.37	7	9.89	7
Nevada	3.32	11	3.81	11
Utah	6.52	9	7.90	8
California	28.29	3	81.83	1
Oregon	29.57	2	29.46	3
Washington	18.73	6	55.35	2
Total Western States	138.756 8,672 18.93		10,564 23.06	

[1] Arizona figures will change in the future because of recent addition of protection to large areas of arid lands where fire occurrence is low.

Table I-3. Summary of Occurrence and Area Burned for Lightning and Man-Caused Fires in Western Forest Service Regions, 1960-1975

	Region						
	R-1	R-2	R-3	R-4	R-5	R-6	TOTAL
Lightning Fires							
Total No.	15,934	5,641	29,973	11,380	19,275	17,840	100,043
Annual Ave.	996	353	1,873	711	1,205	1,115	6,253
% of Regional Total	74	59	80	60	53	56	
% of Western Total	16	6	30	11	19	18	
Acres Burned	225,835	69,088	383,006	141,355	115,381	288,821	1,223,486
Annual Ave.	14,115	4,318	23,937	8,835	7,211	18,051	76,468
% of Region Total	71	49.8	65	54	9	65	
% of Western Total	18	6	31	12	9	24	
Man-Caused Fires							
Total No.	5,463	3,986	7,555	7,609	16,787	13,900	55,300
Annual Ave.	341	249	472	476	1,049	869	3,546
% of Regional Total	26	41	20	40	47	44	
% of Western Total	10	7	14	14	30	25	
Acres Burned	92,566	69,607	204,084	120,133	1,140,878	155,348	1,782,616
Annual Ave.	5,785	4,350	12,755	7,508	71,304	9,709	111,413
% of Region Total	29	50.2	35	46	91	35	
% of Western Total	5	4	11	7	64	9	
Total All Fires							
No. Fires	21,397	9,627	37,528	18,989	36,062	31,740	155,343
Annual Ave.	1,337	602	2,346	1,187	2,253	1,984	9,708
% of Western Total	14	6	24	12	23	21	
Acres Burned	318,401	138,695	587,090	261,488	1,256,259	444,169	3,006,102
Annual Ave.	19,900	8,668	36,693	16,343	78,516	27,761	187,881
% of Western Total	11	5	20	9	41	14	

I-2. Background For The Research

This research of lightning fires in Southwestern Forests is motivated by several factors including:

(1) The significance of lightning fires to fire management and overall planning and management of multiple resource programs.

(2) The major advances in knowledge of lightning phenomena (especially the results of Project Skyfire research at the Northern Forest Fire Laboratory).

(3) The need for development of an in-depth understanding of lightning fires to aid in application of Skyfire and other research results to specific features of the Southwestern environment.

When the Forest Service organized Project Skyfire in 1953 in cooperation with several other agencies the research objectives were: (a) to gain basic information on the occurrence, behavior and control of lightning-caused forest fires and the characteristics of storms that produce these fires; and (b) to develop methods for suppression of lightning fires, including study of cloud modification as a possible means of preventing or reducing the severity of lightning fires (Barrows et al., 1957).

Early in the Skyfire program, Region Three of the Forest Service became one of the focal areas for the Research. In 1956, a Skyfire research team including members from the Weather Bureau, Munitalp Foundation, Meteorology Research, Inc., and the Forest Service established studies on the Coconino National Forest. Working from headquarters at the Fort Valley Experimental Forest, studies were initiated of lightning storm characteristics in the San Francisco Peaks area and at other locations on the Coconino and Sitgreaves National Forests. These sites were chosen because of the unique opportunities for study of convective cloud phenomena in a region known to have a high occurrence of lightning fires. Mt. Elden on the Coconino and other forest fire lookouts were used as key observation points.

The Arizona studies pioneered several important methods for lightning fire research. Cloud and lightning observation methods developed earlier in the Northern Rockies were tested in the Southwest (MacCready, Schaefer, Dieterich and Barrows, 1955). The first Skyfire mobile radar unit was employed in monitoring cloud development and movement. Both ground based and

airborne silver iodide generators were used to explore cloud seeding effects on lightning storm systems. Two aircraft were used to observe and record special features of clouds and fires (Barrows et al., 1957). Following the pioneering Skyfire experiments in the San Francisco Peaks area, many other meteorological research groups found the advantages of this site for cloud, lightning and weather modification studies.

Many years of Skyfire research both in Arizona and the Northern Rockies have produced results of great potential significance to fire and natural resources management. These include:

(1) Lightning characteristics. The special features of some lightning strikes that are most likely to ignite forest fires have been discovered and documented in the Northern Rocky Mountains (Fuquay, Taylor, Hawe and Schmid, 1972). These fire igniting strikes are characterized by a long continuing current phase and are now commonly known as LCC strikes. It may be postulated that very large numbers of LCC strikes occur in the Southwest and are directly related to the very high lightning fire occurrence in the region.

(2) Lightning sensing. Technology has been developed for measuring and recording lightning features and tracking lightning storms from both ground based stations and aircraft (Fuquay and Baughman, 1969; Fuquay, 1975). This technology has a high potential for beneficial use in fire management.

(3) Prevention of lightning fires. Intensive research has demonstrated that lightning fires may be prevented through proper application of weather modification technology (Baughman, Fuquay and Mielke, 1976; Fuquay, 1975; Fuquay and Baughman, 1969; Barrows, 1966). The results of these studies have undergone rigorous examination by the scientific community and by agencies responsible for management of natural resources (Interdepartmental Committee for Atmospheric Sciences, 1971).

(4) Fire danger rating. The National Fire Danger Rating System includes a subjective estimate for lightning risk (Deeming, Burgan, and Cohen, 1978). Currently the results of Skyfire lightning and other research are being applied in the development of a much more complete and definitive model for rating and predicting lightning fire potential.

In 1974 Dr. Donald M. Fuquay of the Northern Forest Fire Laboratory suggested that future research on lightning and applications of existing technology in fire management would benefit from an in-depth analysis of lightning fires in various forest regions. The initial approach would be to up-date

previous analyses of forest fires in the Northern Rocky Mountains (Barrows, 1951). As a result of these suggestions the Forest Fire Science Program at Colorado State University initiated research of lightning fires in Region One under terms of a Forest Service grant. The primary data base for these studies was the individual fire reports from Region One, national forests for a 28-year period. CSU developed a series of special computer programs to facilitate the analyses. A final report on this research was prepared in 1976 (Barrows, Sandberg and Hart, 1976).

During the course of the research on lightning fires in the Northern Rockies, it was suggested that similar studies should be made for Southwestern Forests. It was recognized that the intense lightning fire zones in Forest Service Region Three should be prime targets for an in-depth analysis. The results of such studies could aid in further linkage to Skyfire and other fire research and could foster applications to fire and natural resource management in the Southwest. Many of the lightning fire analytical methods and computer programs developed for the Region One studies could also be adapted for use in Region Three. Accordingly in 1975, Colorado State University initiated research of lightning fires in the Southwest again under terms of a Forest Service grant arranged by the Northern Forest Fire Laboratory and the Intermountain and Rocky Mountain Forest and Range Experiment Stations.

Several other factors provide motivation for research of lightning fires in Forest Service Region Three. Fire management policies and programs are undergoing changes. Increasing recognition is being given to the natural role that lightning fires play in ecosystems. Fire management is seeking appropriate methods to facilitate this role. In many situations, there will be critical fire management decisions affecting both ecosystems and society. Special considerations are needed for wilderness fires and possible impacts of these fires on adjacent non-wilderness resources. Criteria are needed for <u>unwanted</u> and <u>wanted</u> fires (Barrows, 1974). Fire management costs are increasing at an accelerated rate. Fire impacts on needed resources are of continuing importance. All of these factors suggest the need for an enlarged understanding of lightning fires.

I-3. Research Objectives and Methods

Purpose

The main purpose of the research is to provide detailed knowledge of the lightning fire situation in Southwestern National Forests. The knowledge will provide input for fire management decisions such as fire intelligence needs, presuppression and suppression activities and prediction of resource impact in various forest areas; and to research activities in fire occurrence simulation fire management systems analysis, and identifying research directions. A valuable data base will be established for future research and resource management.

Objectives

Specifically, the research will:

1. Describe the distribution of lightning fire occurrence in Region Three. The variation in the temporal and spatial density of fires will be related to years, short time periods, topography, forest types, and fuel types for each National Forest, zone, and the Region as a whole.

2. Describe statistically the influence of fuel, topography, and fire ignition on the severity of lightning fire problems. Define the critical fire problem in terms of the fire environment features associated with large outbreaks of fires, area burned, and fire management operations. Analyze the feature of lightning fire situations having various degrees of severity.

3. Describe the historical occurrence of ciritcal and non-critical lightning fire situations. Identify any non-random features in the location, time or frequency of problem situations.

4. Locate and define critical fire areas, if they exist, i.e., areas with a non-random, recurrent lightning fire load.

5. Describe the recent historical occurrence of fires within existing and proposed Wilderness Areas. Analyze the potential fire load in Wilderness Areas. Propose a model for utilizing historic wilderness fire data in analyzing probably long-term effect, of lightning fires in wilderness.

Data Base

The primary data for this research comes from the individual reports of more than 28,000 lightning fires occurring in Region Three national forests during the 15-year period 1960-1974. Other data used in selected parts of the analyses stem from annual National Forests Fire Reports (U.S. Forest Service, Washington, D.C.), annual Wildfire Statistics (Division of Cooperative Fire Protection, U.S. Forest Service, Washington, D.C.), and various publications describing the forests, climate and environment of the region. Supplemental data were obtained from U.S. Forest Service reports and maps.

The individual fire report data were obtained on magnetic tape. An enormous amount of work was required to clean up the data and develop it in a proper format for computer aided analysis. Errors and omissions had to be corrected on several hundred fires. A special computer program was used to identify some of the errors. The data clean-up program included searches of fire reports on file at GSA Federal Record Centers and many contacts with the Forest Service Regional Office, Washington Office and National Forest Supervisors Offices. As a result of this work the individual fire data are in reasonably accurate form. In some cases changes in coding instructions or omissions that could not be filled in prevented continuity or fully complete data on certain phases of the studies. For example, the wilderness fire studies could be made for only seven years and it was necessary to totally eliminate fire danger rating analyses. However, for most of the studies, the data base provides a wealth of significant information.

Following clean up of the data, new magnetic tapes were prepared. On these tapes, all data for both the 1960 and 1970 decades were recorded in a common coding format developed at CSU. The fire data in this format will be provided to the Forest Service and will also become a part of the CSU fire science data bank system.

Research Methods

This entire research effort involves the use of data gathered by others. Some additional observations stem from the experience of the authors. The basic methodology for the research required the development or adaptation of computer programs, data processing formats and analytical and statistical procedures.

We adopted a procedure of examining the fire data in two major dimensions:

(1) Temporal -- years, months, periods of days and individual days.

(2) Spatial -- region, states, zones, groups of national forests, individual areas (including wilderness, primitive, wilderness study and non-wilderness areas).

In parts of the fire analyses the Region Three National Forests were subdivided into four zones as follows:

Southwestern Zone

- Coronado National Forest
- Tonto " "

Northwestern Zone

- Coconino National Forest
- Kaibab " "
- Prescott " "

Central Zone

- Apache-Sitgreaves National Forest
- Gila " "

Eastern Zone

- Carson National Forest
- Cibola " "
- Lincoln " "
- Santa Fe " "

Several special computer programs were prepared for this research. All programs were written in CDC Extended Fortran.

Program	Purpose
BUF2CSU	Converts a USFS buffered tape containing individual fire reports, to a formated tape compatible with CSU Fire Science programs, while standardizing all data codes to one base set.
CRITLD	Scans the data for days which a specified number of ignitions, previously determined to be a critical fire load, in either the region as a whole, all wilderness areas, or both and outputs the appropriate table.
TABLES3D	Provides a three way stratification of any two user-specified variables.
REGANAL FORANAL ZONANAL	Produce a tabular output of the fire load and fire size class distribution for each day, ten-day period, month, and year for each forest, zone, and the region as a whole.

The data from these computer outputs are presented as follows:

(1) Summarized in tables, figures or narrative material in the text.

(2) Supplementary information summaries in the Appendix.

(3) A data bank furnished in a series of magnetic tapes for computer use.

The narrative descriptions and conclusions on lightning fires are those of the authors prepared following appropriate analytical and statistical procedures.

II. THE LIGHTNING FIRE LOAD ON THE NATIONAL FORESTS

In fire management fire load has often been a term describing the volume, difficulty and overall magnitude of forest fire operations. The definition of fire load as applied to this research is "the total impact of fire occurrence and fire growth on the requirements of management organizations to meet natural resource protection and utilization objectives." The studies of fire load concentrate first on the basic features of fire occurrence, size class of fires and area burned. Later in this report, attention is given to other factors including fire environment, fire control and critical lightning fire situations.

Lightning fires in Forest Service Region Three have several distinctive features that characterize the dimensions of the fire load. These include:

(1) A long fire season.

(2) Great variations in fuel flammability during the fire season.

(3) Large numbers of lightning fires during most fire seasons.

(4) Occasional simultaneous occurrence of fire ignitions and weather conditions favoring development of large fires.

(5) Distinctive areas of maximum fire occurrence.

(6) Distinctive areas having a high potential for large lightning fires.

II-1. Lightning Fire Occurrence

Regional Fire Occurrence

High annual occurrence of lightning fires is a constant event in Region Three. During the 36-year period 1940-1975, a total of 59,518 lightning fires occurred in Region Three national forests. This is an annual average of 1653 fires. As shown in Table II-1, fewer than 1000 fires occurred during only two fire seasons -- 1941 and 1955. More than 2000 lightning fires have occurred during ten fire seasons. The peak occurrence during the 36-year period was 2841 lightning fires in 1961.

The reported number of lightning fires is increasing. As shown in Table II-1, the average annual lightning fire occurrence has increased in each decade since 1940-1949. The average annual occurrence of 1386 fires in the decade of the 1940's has increased to 2098 fires in the 1970-1975 period. The reasons for this substantial increase are not clear. A combination of factors may be involved including better surveilance of lightning storms, improved fire detection, increased fuel flammability and changing methods in fire cause identification. However, the data does clearly show that Region Three has a continuing lightning fire load of great magnitude.

Average annual lightning fire occurrence in Region Three is 86 fires per million acres. This figure for fire density was determined from detailed computer analysis of all Region Three lightning fires during the 1960-1974 period (Table II-6). The lightning fire density per unit area is greater in Region Three than in any other major forest region in the United States. Other studies have shown that a greater number of lightning fires in a single year have occurred in Forest Service Region One, but not the long term occurrence density found in Region Three.

Region Three has a long lightning fire season. Normally the lightning fire season begins in April and extends into October. During the 1960-1974 period, more than 99 percent of the lightning fires in the region occurred during the seven months April through October (Table II-2). A total of only 44 fires (less than 1 percent) occurred in the late fall and winter months. As explained later in this report the character of the April to early July lightning fire season is vastly different from the late summer season. The earlier months are normally characterized by dry and often windy weather.

June and July are the peak months for occurrence of lightning fires. As shown in Table II-2, two-thirds of the lightning fires occur in these two

months. During two years (1970 and 1971) more than 1000 fires have occurred in July. The peak monthly occurrence during the 1960-1974 period was 1194 in July 1971. In May 1961, the occurrence of 1039 lightning fires was the third highest single month total during the 15-year study period (Table II-3).

Average lightning fire occurrence exceeds 200 fires in some ten-day periods. As shown in Table II-4 the ten-day periods with the highest average lightning fire occurrence were as follows:

	Period Average	Daily Average
June 21-30	230	23.0
July 1-10	304	30.4
July 11-20	274	27.4
July 21-31	207	18.8

During the years 1960-1974, lightning fire occurrence rates of 200 or more fires in a ten-day period were recorded three times in May, thirteen in June, twenty-seven times in July and five times in August.

Average lightning fire occurrence is above 100 fires in nine consecutive monthly decades. As shown in Figure II-1 an average of more than 100 fires occur in each monthly decade from May 21-31 through August 11-20. The average occurrence is more than 200 fires for the last decade in June and each decade in July with the peak of 304 fires being reached July 1-10.

Peak lightning fire occurrence exceeds 500 fires in a ten-day period. This peak fire occurrence rate was reported on five separate ten-day periods as follows:

	Total Fires	Daily Average
May 21-31, 1961	582	52.9
June 21-30, 1960	619	61.9
July 1-10, 1973	511	51.1
July 11-20, 1970	629	52.9
July 11-20, 1971	617	61.7

The only known lightning fire occurrence rates exceeding the above were recorded in Forest Service Region One as follows (Barrows, Sandberg and Hart, 1976):

	Total Fires	Daily Average
July 1-10, 1940	1488	148.8
August 21-31, 1939	760	69.0
August 21-31, 1961	799	72.6

Table II-1. Lightning Fire Occurrence by Years in Region Three, 1940-1975.

Year	No. of Fires	Year	No. of Fires	Year	No. of Fires	Year	No. of Fires
1940	2,283	1950	1,390	1960	2,546	1970	2,200
1941	841	1951	1,700	1961	2,841	1971	2,351
1942	1,645	1952	1,063	1962	2,210	1972	2,462
1943	1,393	1953	1,483	1963	1,432	1973	1,647
1944	1,236	1954	1,751	1964	1,661	1974	2,342
1945	1,211	1955	782	1965	1,448	1975	1,586
1946	1,231	1956	2,396	1966	1,490		
1947	1,318	1957	1,389	1967	1,184		
1948	1,210	1959	1,678	1968	1,246		
1949	1,490	1959	2,077	1969	1,305		
Total	13,858		15,709		17,363		12,588
Average Annual Occurrence	1,386		1,571		1,736		2,098

Table II-2. Number and Percent of Lightning Fires by Months in Region Three, 1960-1974.

	Average Annual No. of Lightning Fires	Percent of Total Lightning Fires
April	14	0.75%
May	213	11.24
June	460	24.29
July	785	41.48
August	298	15.76
Sept.	106	5.61
Oct.	14	0.71
Other Months	3	0.16
Total Region Three	1,893	

Table II-3. Lightning Fire Occurrence by Years During Peak Occurrence Months in Region Three, 1960-1974

	May	June	July	August
1960	572	902	778	213
61	1,039	937	560	214
62	12	434	649	713
63	56	144	766	394
64	219	320	872	152
65	88	196	834	266
66	184	518	502	165
67	164	243	697	61
68	57	330	641	83
69	195	199	505	322
1970	100	700	1,119	201
71	58	552	1,194	432
72	214	686	903	474
73	125	177	780	496
74	111	559	971	288
Total	3,194	6,897	11,771	4,475

Table II-4. Lightning Fire Occurrence by Ten Day Periods in Region Three National Forests, 1960-1974

Year	1-10	11-20	21-31 (1)	1-10	11-20	21-30	1-10	11-20	21-31 (1)	1-10	11-20	21-3 (1)
1960	420	105	47	93	190	619	386	316	76	110	72	3
1961	13	444	582	284	285	368	229	138	193	128	52	3
1962	4	2	6	71	19	344	107	117	425	83	494	13
1963	4	22	30	65	66	13	200	219	347	238	102	5
1964	2	60	157	28	10	282	230	368	274	72	36	4
1965	2	58	28	58	25	113	368	379	87	90	133	4
1966	29	37	118	54	310	154	114	256	132	76	66	2
1967	2	44	118	58	121	64	472	166	59	25	14	2
1968	40	10	7	126	159	45	245	188	208	33	20	3
1969	10	98	87	146	45	8	159	230	116	183	79	6
1970	2	4	94	245	43	406	471	529	119	90	66	4
1971	2	40	16	16	214	322	171	617	406	313	89	3
1972	26	23	165	323	198	165	424	275	204	295	127	5
1973	2	88	35	37	36	104	511	115	154	90	287	11
1974	70	10	31	17	88	444	470	200	301	164	45	7
Total	628	1045	1521	1621	1809	3451	4557	4113	3101	1990	1682	80

(1) Eleven days in period

Fifty or more lightning fires frequently occur in a single day. During the 1960-1974 period there were a total of 133 days when this rate of lightning fire occurrence was reported (Table II-5). The occurrence summary is as follows:

Year	No. of Days with 50 or More Fires
1960	16
1961	14
1962	10
1963	4
1964	6
1965	5
1966	5
1967	6
1968	7
1969	1
1970	15
1971	14
1972	12
1973	6
1974	12
Total	133
Annual Average	8.87

Peak lightning fire occurrence is in the afternoon hours. More than 67 percent of the lightning fires occur from 1201 to 1800 hours (Figure II-2). The hours of 1801 to 2400 account for 19 percent of the fires. Less than five percent of the fires occur from 0001 to 0900 hours.

Table II-5. Dates When 50 or More Lightning Fires Occurred in Region Three, 1960-1974.

Year	Date	No. of Fires	Year	Date	No. of Fires	Year	Date	No. of Fires
1960	5/5	95	1964	5/26	52		7/17	56
	5/6	60		6/25	54		7/18	103
	6/20	51		6/27	53		7/19	119
	6/22	67		6/28	79		7/20	55
	6/23	78		7/14	64			
	6/27	68		7/21	52	1971	6/16	63
	6/28	143					6/17	58
	6/29	62	1965	7/7	63		6/23	72
	6/30	68		7/10	67		6/24	98
	7/6	51		7/11	72		7/13	76
	7/8	58		7/12	64		7/14	68
	7/9	63		7/13	54		7/15	55
	7/10	56					7/16	112
	7/13	56	1966	5/31	51		7/17	87
	7/14	66		6/14	53		7/18	83
	7/15	55		6/15	74		7/19	59
				6/16	68		7/30	68
1961	5/11	51		7/17	53		7/31	56
	5/16	103					8/1	72
	5/17	93	1967	7/3	78			
	5/18	52		7/4	86	1972	5/30	65
	5/23	87		7/5	86		6/1	52
	5/24	116		7/6	50		6/3	106
	5/25	91		7/10	56		6/11	61
	5/26	80		7/12	55		6/21	54
	5/27	62					7/5	75
	6/1	58	1968	6/3	53		7/6	70
	6/14	64		6/19	59		7/7	83
	6/22	53		7/3	89		7/9	54
	6/30	54		7/4	54		7/16	57
	7/10	50		7/19	63		8/4	66
				7/20	65		8/5	74
1962	6/27	60		7/21	63	1973	7/3	57
	6/28	83					7/4	50
	6/29	112	1969	7/4	50		7/7	95
	7/23	77					7/8	101
	8/14	63	1970	6/4	85		8/13	50
	8/15	66		6/5	62		8/14	50
	8/16	125		6/6	52			
	8/17	60		6/23	93	1974	6/24	60
	9/20	85		6/26	87		6/25	71
	9/21	54		6/28	58		6/27	58
				7/7	104		6/28	59
1963	7/19	63		7/8	89		6/29	74
	7/20	62		7/9	57		7/1	89
	7/31	50		7/15	52		7/2	91
	8/3	52		7/16	96		7/3	54
							7/5	74
							7/28	51
							9/3	50
							9/4	61

AVERAGE NUMBER OF LIGHTNING FIRES

BY MONTHLY DECADES IN REGION

THREE NATIONAL FORESTS, 1960 - 74

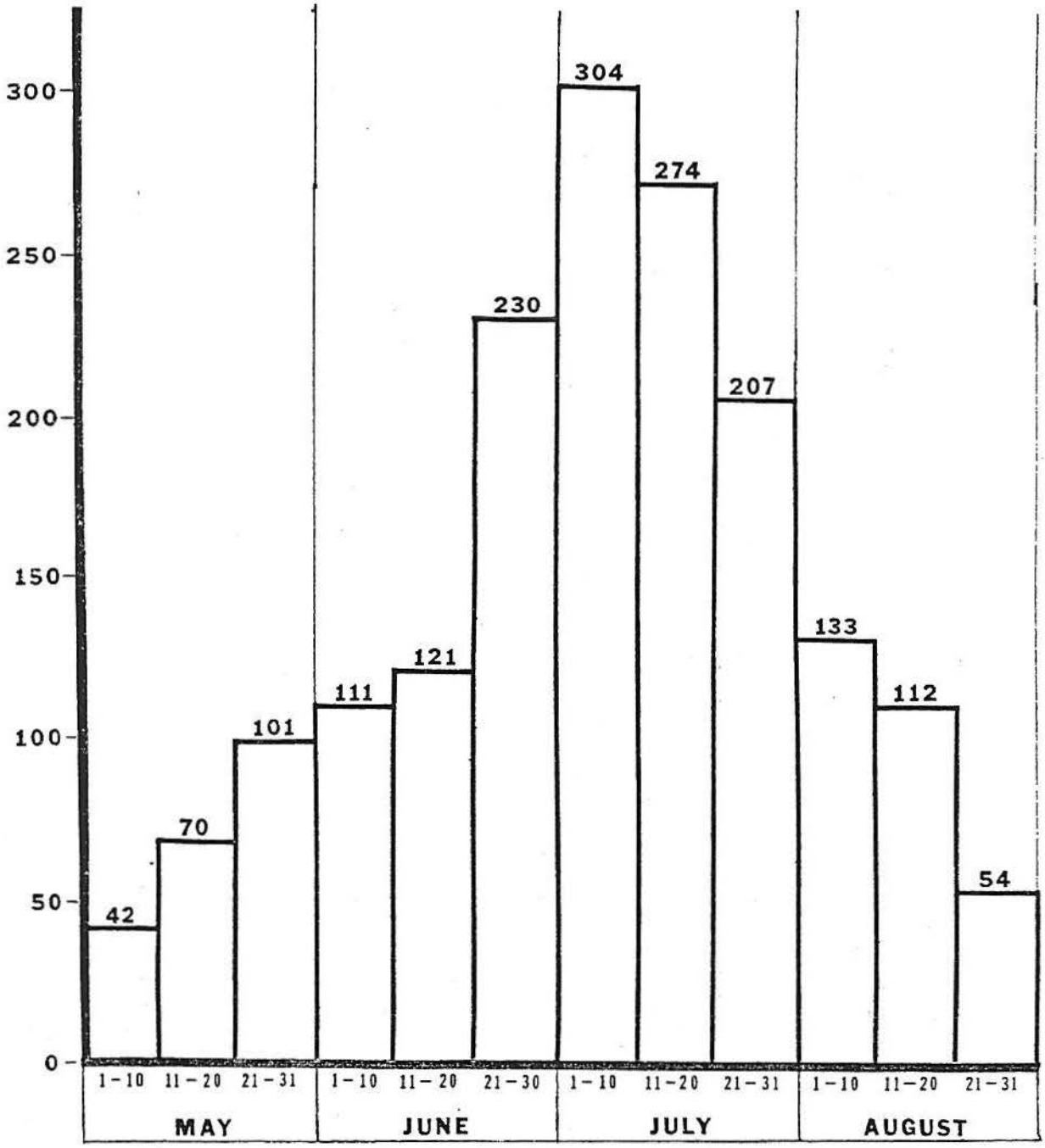

Figure II-1.

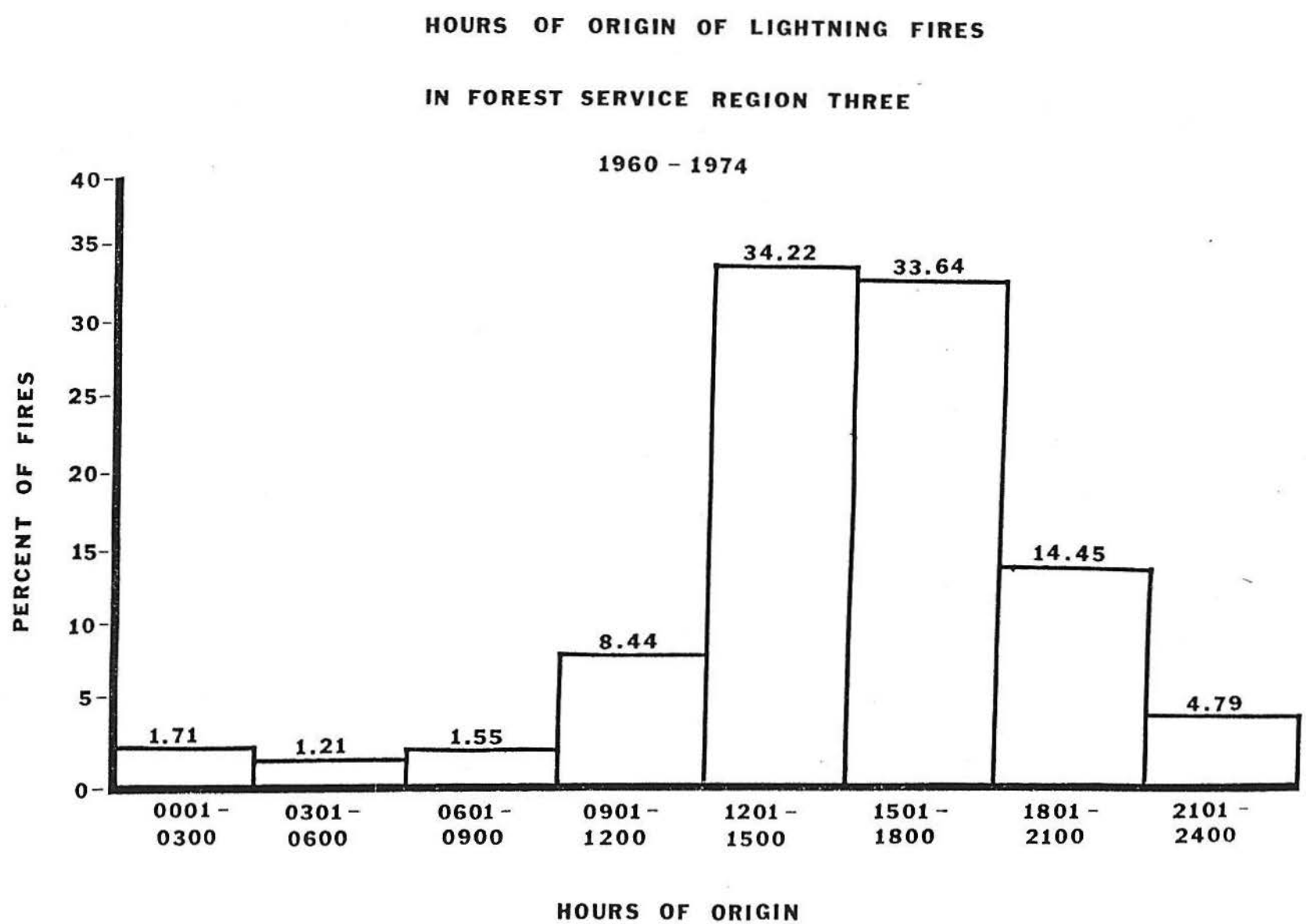
HOURS OF ORIGIN OF LIGHTNING FIRES
IN FOREST SERVICE REGION THREE
1960 - 1974
PERCENT OF FIRES
40
35
30
25
20
15
10
5
0
1.71
1.21
1.55
8.44
34.22
33.64
14.45
4.79
0001 - 0300
0301 - 0600
0601 - 0900
0901 - 1200
1201 - 1500
1501 - 1800
1801 - 2100
2101 - 2400
HOURS OF ORIGIN

Figure II-2.

Lightning Fire Occurrence by Zones and National Forests

The Central Zone leads Region Three in lightning fire occurrence. As shown in Table II-6, the average annual occurrence of 691 fires and 124 fires per million acres in the Central Zone are the top lightning fire ignition rates in the region. For individual national forests, the Gila and Apache-Sitgreaves rank second and third respectively in lightning fire occurrence density.

The Coconino leads all individual national forests in lightning fire occurrence density. During the 1960-1974 period, the Coconino National Forest recorded an annual average of 162.63 fires per million acres (Table II-6). These occurrence density rates on the Coconino varied from a high of 301.39 in 1960 to a low of 79.57 in 1968.

Lightning fire occurrence in a single year often exceeds 700 fires in the Northwestern and Central Zones. During the 1960-1974 period these high single-year outbreaks of lightning fires have occurred 11 times in the two zones (Tables II-7 and II-8). The years with more than 700 lightning fires in each zone were as follows:

Year	Zone	No. of Fires
1960	Northwestern	921
	Central	934
1961	Northwestern	808
	Central	1254
1962	Northwestern	782
	Central	770
1970	Central	813
1971	Central	977
1972	Northwestern	870
	Central	802
1974	Central	835

Single year occurrence rates seldom exceed 400 fires in the Southwestern and Eastern Zones. These single-year rates of lightning fire occurrence have been recorded only five times in the 15-year study period (Tables II-7 and II-8). The years with more than 400 lightning fires in each zone were as follows:

Year	Zone	No. of Fires
1961	Southwestern	510
1962	Southwestern	409
1970	Southwestern	419
1971	Eastern	428
1972	Eastern	407

Table II-6. Average Annual Lightning Fire Occurrence by National Forests and Zones in Region Three, 1960-1974.

	Area Within Unit Boundaries	Average Annual No. of Fires	Average Annual No. of Fires Per Million Acres	Fire Occurrence Ranking Forests	Fire Occurrence Ranking Zones
Kaibab	1,600,712	158	98.71	4	
Coconino	2,010,733	327	162.63	1	
Prescott	1,407,602	74	52.57	9	
N. W. Zone	5,019,047	559	111.38		2
Coronado	1,855,825	142	76.52	5	
Tonto	2,969,602	184	61.96	6	
S. W. Zone	4,825,427	326	67.56		3
Apache-Sitgreaves	2,763,017	342	123.78	3	
Gila	2,797,617	349	124.75	2	
Central Zone	5,560,634	691	124.27		1
Carson	1,491,423	46	30.84	11	
Santa Fe	1,719,414	97	56.41	7	
Cibola	2,110,844	105	49.74	10	
Lincoln	1,271,069	67	52.71	8	
Eastern Zone	6,592,750	315	47.78		4
Total Region Three	21,997,585	1891	85.96		

Table II-7. Lightning Fire Occurrence In Each National Forest in the Northwest and Southwest Zones, 1960-1974.

Year	Kaibab	Coconino	Prescott	N.W. Zone	Coronado	Tonto	S.W. Zone
1960	220	606	95	921	124	262	386
61	193	511	104	808	214	296	510
62	225	448	109	782	109	300	409
63	99	226	50	375	111	111	222
64	118	258	74	450	108	157	265
65	112	251	53	416	154	152	306
66	87	273	56	416	135	136	270
67	86	167	21	274	82	90	172
68	121	160	62	343	80	131	211
69	95	210	41	346	138	135	273
70	182	346	102	630	195	224	419
71	221	346	74	641	157	148	305
72	283	464	123	870	174	209	383
73	140	269	57	466	167	203	370
74	187	368	90	645	185	213	398
Total	2369	4903	1111	8383	2132	2767	4899

Table II-8. Lightning Fire Occurrence In Each National Forest in the Central and Eastern Zones, 1960-1974.

	Apache-Sitgreaves	Gila	Central Zone	Carson	Santa Fe	Cibola	Lincoln	Easte Zon
1960	495	439	934	52	108	86	59	305
61	596	658	1254	44	71	86	68	269
62	418	352	770	27	89	86	47	249
63	256	288	544	60	92	103	36	291
64	252	315	567	44	118	129	88	379
65	223	244	467	33	56	107	63	259
66	267	207	474	44	99	127	60	330
67	190	245	435	42	114	87	60	303
68	233	233	466	26	75	76	49	226
69	180	259	439	34	69	76	68	247
1970	421	392	813	37	67	134	100	338
71	554	418	977	76	151	123	78	428
72	415	387	802	57	132	148	70	407
73	322	261	583	48	58	83	39	228
74	304	531	835	64	155	120	125	464
Total	5131	5229	10360	688	1454	1571	1010	4723

Single-year occurrence of 300 or more fires has been recorded on four national forests. As shown in Tables II-7 and II-8, this single-year lightning fire ignition rate has occurred eight times on both the Apache-Sitgreaves and Gila, seven times on the Coconino and once on the Tonto. The peak single-year ignitions were 658 fires on the Gila in 1961 and 606 fires on the Coconino in 1960. On the other extreme the peak single-year occurrence on the Carson was 64 fires in 1974.

Average annual lightning fire occurrence is highest in July in all zones. A monthly summary of lightning fire occurrence by years in each zone is presented in Tables II-9 through II-12. The peak July occurrence was 437 fires in the Northwestern Zone in 1971. During July 1971 and 1975, the Central Zone recorded 405 fires. The percent of lightning fires occurring during July in each zone is as follows:

Northwestern Zone	39.82%
Southwestern Zone	47.78
Central Zone	42.30
Eastern Zone	36.08

The Central and Eastern Zones have a high proportion of lightning fires in May and June. As shown in Tables II-11 and II-12, the percent of lightning fires in these early season months was 42.92 in the Central Zone and 46.26 in the Eastern Zone. The largest number of lightning fires in any month was 459 recorded in the Central Zone in 1961.

The Northwestern Zone has a high proportion of late season lightning fires. During the 1960-1974 period nearly 34 percent of the lightning fires in the zone occurred in August and September. The peak occurrence during these months was 485 fires in the Northwestern Zone in 1962.

On four national forests in the Northwestern and Central Zones, 25 or more lightning fires have occurred in a single day. As shown in Table II-13, there were 57 occasions with this rate of single-day fire occurrence in the Kaibab, Coconino, Apache-Sitgreaves and Gila National Forests. The peak single-day occurrence was 57 lightning fires in the Coconino on June 28, 1960. The number of days with 25 or more fires in each of the national forests and zones was as follows:

	No. of days
Kaibab National Forest	4
Coconino National Forest	16
Northwestern Zone Total	20

Apache-Sitgreaves National Forest	14
Gila National Forest	23
Central Zone Total	37

Table II-9. Number of Lightning Fires by Months, Northwestern Zone, 1960-1974

Year	April	May	June	July	Aug.	Sept.	Oct.	Other Months	Total
1960	19	133	411	196	51	4	2	5	921
1961	2	217	145	245	171	21	2	5	808
62	2	5	75	205	261	224	9	0	781
63	0	3	31	128	169	31	13	0	375
64	2	7	114	202	67	50	8	0	450
65		8	65	167	156	17	3		416
66	13	40	104	143	67	35	10	4	416
67		32	26	180	28	8	1	0	275
68	5	24	12	218	43	36	5	0	343
69	1	27	38	107	129	41	3	0	346
70		11	95	387	102	20	11	4	630
71	1	12	4	437	172	14		1	641
72		68	216	213	237	135	1		870
73		35	24	179	218	7	3		466
74	1	13	31	231	124	205	40	0	645
Total	46	635	1391	3338	1995	848	111	19	8383
Percent	0.55	7.62	17.18	39.82	23.80	10.11	0.74	0.18	

Table II-10. Number of Lightning Fires by Months, Southwestern Zone, 1960-1974

Year	April	May	June	July	Aug.	Sept.	Oct.	Other	Total
1960	3	83	145	123	29	7			390
61	1	184	240	82	2	4			513
62	2		93	124	141	46	3		409
63	1	1	2	142	70	5	2		222
64	1	2	73	166	14	8	2		266
65	2	5	20	221	50	5	1	1	308
66	6	3	74	125	53	7		1	269
67		28	22	110	9	3		1	173
68	3	4	13	148	20	20	3		211
69	1	26	10	111	108	18			274
70		6	59	302	47	5	1		420
71	1	4	39	175	63	25			307
72		21	122	154	66	19		1	383
73		14	34	198	113	9	2		370
74	1	13	91	166	50	76	4		397
Total	21	394	1037	2347	835	257	18	4	4912
Percent	0.43	8.02	21.17	47.78	17.00	5.23	0.29	0.08	

Table II-11. Number of Lightning Fires by Months, Central Zone. 1960-1974

Year	April	May	June	July	Aug.	Sept.	Oct.	Other	Total
1960	8	266	273	284	98	4			933
61	8	541	459	201	37	7		1	1254
62	2	1	199	245	239	80	3	1	770
63	1	12	43	389	88	7	4		544
64	2	124	79	329	27	3	3		567
65	6	33	57	324	35	8	4		467
66	16	68	208	155	17	7	2	1	474
67		49	99	283	3	1	1		436
68	1	15	223	177	6	28	17		467
69	6	90	76	195	64	7	1		439
70	4	38	429	295	26	21	2	1	814
71	14	17	328	405	163	50		3	980
72		67	214	389	107	24	1		802
73		61	75	305	109	26	7		583
74	1	36	267	405	60	62	6		842
Total	69	1418	3029	4386	1079	335	51	7	10372
Percent	0.66	13.68	29.24	42.30	10.41	3.23	0.49	0.07	

Table II-12. Number of Lightning Fires By Months, Eastern Zone, 1960-1974

Year	April	May	June	July	Aug.	Sept.	Oct.	Other	Total
1960	13	90	73	75	36	12	1	5	305
61	35	97	93	32	4	4		3	268
62	4	6	67	75	72	23	2		249
63	1	40	68	107	67	8	2		293
64	3	86	54	175	44	15	1	1	379
65	3	42	51	122	25	14	3		260
66	4	73	132	79	28	11	2	1	330
67	1	55	96	124	21	5		1	303
68		14	82	98	14	10	8		226
69		52	75	92	21	7			247
70		45	117	136	26	12	2		338
71		25	182	177	34	6		2	428
72		58	134	147	64	4	1		408
73	1	15	44	98	56	10	4		228
74	11	49	170	169	54	12	3	1	466
Total	78	747	1438	1706	566	153	26	14	4728
Percent	1.65	15.80	30.46	36.08	11.97	3.23	0.51	0.30	

Table II-13. Dates of Occurrence of 25 or More Lightning Fires in Individual National Forests, 1960-1974.

Year	Date	National Forest	No. of Fires	Year	Date	National Forest	No. of Fires
1960	5-5	Gila	29	1971	6-17	Apache-Sitgreaves	32
	6-27	Coconino	28		6-23	Gila	37
	6-28	Apache-Sitgreaves	27		6-24	Gila	38
	6-28	Coconino	57		6-24	Apache-Sitgreaves	31
	6-28	Kaibab	30		7-13	Apache Sitgreaves	26
	6-29	Coconino	32		7-14	Coconino	34
	7-9	Coconino	28		7-16	Coconino	25
	7-14	Coconino	26		7-16	Apache-Sitgreaves	31
1961	5-11	Gila	26		7-17	Kaibab	26
	5-16	Gila	40				
	5-17	Gila	27	1972	6-21	Coconino	25
	5-17	Coconino	30		7-16	Gila	26
	5-24	Coconino	30		8-4	Coconino	35
	5-24	Apache-Sitgreaves	28				
	5-26	Apache-Sitgreaves	30	1973	7-7	Apache-Sitgreaves	30
	5-27	Apache-Sitgreaves	26				
	6-1	Gila	32	1974	6-27	Gila	3
	6-22	Apache-Sitgreaves	25		6-28	Gila	36
1962	6-29	Gila	39		7-1	Gila	2
	8-15	Kaibab	25		7-2	Gila	55
	8-16	Coconino	33		7-3	Gila	3
	9-21	Coconino	25		9-3	Coconino	26
1964	5-26	Gila	33		9-4	Coconino	2[illegible]
1965	7-13	Gila	26				
1966	6-14	Apache-Sitgreaves	27				
1967	7-4	Gila	26				
1968	6-19	Gila	29				
1970	6-4	Gila	27				
	6-21	Gila	25				
	6-23	Apache-Sitgreaves	46				
	6-26	Apache-Sitgreaves	36				
	6-26	Gila	33				
	6-27	Gila	28				
	7-7	Coconino	30				
	7-16	Kaibab	26				
	7-18	Apache-Sitgreaves	36				
	7-19	Gila	30				

II-2. Size Class of Fires and Area Burned

Size Class

More than three-fourths of the lightning fires in Region Three are less than one-fourth acre in size. During the 36-year period 1940-1975, a total of 46,389 Class A lightning fires occurred in Region Three national forests (Table II-14). This was 77.94 percent of the total lightning fires. These fires, while small, are a definite factor in the overall fire load. While specific data is lacking on personnel requirements for Class A fires, experience indicates that an average of 2 to 3 personnel and 1 to 2 days are required per fire (including travel, suppression and mop up). With an annual average of 1289 class A fires during the 1940-1975 period, this amounts to 2578 to 7734 personnel days per fire season. These estimates may be higher for recent years because the annual average number of class A lightning fires increased to 1626 during the 1970-1975 period.

Nearly one-fourth of the lightning fires exhibit growth potential. During the 36-year study period, an annual average of 365 fires reached sizes of one-fourth acre or more (22.06 percent of total). It is recognized that many Class A fires also have growth potential, but are prevented from significant growth by efficient control action. The Class B and larger fires clearly demonstrate some potential for growth. The average annual number and percent of Class B or larger lightning fires in each decade was recorded as follows:

Years	Average Annual Number	Percent of Total Fires
1940-1949	357	25.78
1950-1959	364	23.17
1960-1969	309	17.79
1970-1975	471	22.47

Slightly less than three percent of the lightning fires in Region Three reach Class C or larger size. As shown in Table II-14, the percent of Class C or larger fires varied from a low of 2.59 percent in the sixties decade to a high of 3.36 percent in the seventies. The 36-year average is 2.97 percent. This is a remarkable record of fire control efficiency. During three years (1941, 1958, 1963) not more than 20 fires reached Class C or larger size. The greatest number in a single year was 149 fires in 1974.

An average of 10 fires per year reach Class D or larger size. As explained later in this report, these fires have a great impact on the total fire load. During the 1940-1975 period, a total of 372 Class D or larger fires occurred.

More than 42 percent of these big fires occurred in just seven years (1943, 1956, 1960, 1961, 1969, 1971 and 1974) with the peak of 32 fires being recorded in 1974 (Table II-14). The average annual number and percent of fires reaching Class D or larger size in each decade was as follows:

Years	Average Annual Number	Percent of Total Fires
1940-1949	8	0.56
1950-1959	9	0.55
1960-1969	12	0.70
1970-1975	14	0.69

Lightning fires reaching 100 acres in size have a high potential for continued growth. This potential is vividly illustrated by the large fires in Region Three during the 1960-1974 periods (Table II-5):

(1) Of the fires reaching Class D size, 51.78 percent continued on to Class E or larger size.

(2) Of the fires reaching Class E size, 47.06 percent continued on to Class F or larger size.

(3) Of the fires reaching Class F size, 35.42 percent continued on to Class G size.

Expressed as betting odds, these data show:

(1) When a fire becomes 100 acres in size, the odds are better than 1 to 1 that it will burn more than 300 acres.

(2) When a fire becomes 300 acres in size, the odds are about 5 to 6 that it will burn more than 1000 acres.

(3) When a fire becomes 1000 acres in size, the odds are about 1 to 2 that it will burn more than 5000 acres.

The importance of holding fires to less than 10 acres in size should also be noted. During the 1960-1974 period, 24 percent of the fires reaching Class C size continued on to Class D or larger size (odds of 1 to 4).

The Southwestern Zone has the greatest number and percent of Class C or larger lightning fires. During the 1960-1974 period, 408 class C or larger fires occurred. This was 8.33 percent of the lightning fires in the zone (Tables II-15 and II-16). The Southwestern Zone also had the largest number of Class D, E, F and G fires. The Coronado and Tonto national forests rank first and second respectively in Region Three in total number and percent of lightning fires in size classes C through F. Both national forests recorded four class G fires to lead the region in this category (Table II-15).

The Northwestern Zone has the smallest number and percent of Class C or larger lightning fires. Exhibiting a remarkable difference from other zones the Northwestern Zone recorded only 57 class C or larger fires during the 15-year period 1960-1974 (Table II-16). This is only 0.68 percent of the total lightning fires in the zone. Only the Carson National Forest in the Eastern Zone recorded a smaller number of class C or larger fires than the Kaibab, Coconino or Prescott national forests in the Northwestern Zone. Both the Central and Eastern Zones exceed the Northwestern Zone in number and percent of Class D or larger fires.

Table II-14. Lightning Fires by Size Class in Region Three, 1940-1975

	No. of Fires by Size Class							
Year	A	B	C	D	E+(1)	Total	% Class C or larger	No. of Class D or larger
1940	1877	382	21	2	1	2283		3
41	723	114	4	0	0	841		0
42	1263	350	27	3	2	1645		5
43	942	384	48	11	8	1393		18
44	898	291	39	3	5	1236		8
45	882	289	34	2	4	1211		6
46	856	317	44	5	9	1231		14
47	896	364	49	4	5	1318		9
48	827	344	32	4	3	1210		7
49	1122	320	42	5	1	1490		6
Total	10286	3155	340	39	38	13858	3.02	77
1950	985	344	49	9	3	1320		12
51	1299	357	39	1	4	1700		5
52	792	241	27	3	0	1063		3
53	1111	310	51	7	4	1483		11
54	1280	401	63	4	3	1751		7
55	597	157	23	3	2	782		5
56	1704	588	73	13	18	2396		31
57	1085	273	25	2	4	1389		6
58	1447	211	18	0	2	1678		2
59	1770	279	24	0	4	2077		4
Total	12070	3261	392	42	44	15709	3.02	86
1960	2133	356	40	3	14	2546		17
61	2388	395	42	10	6	2841		16
62	1921	259	22	5	3	2210		8
63	1286	134	8	2	2	1432		4
64	1414	212	24	9	2	1661		11
65	1183	211	43	3	8	1448		11
66	1120	318	41	5	6	1490		11
67	959	198	19	2	6	1184		8
68	948	254	31	7	6	1246		13
69	922	302	58	14	9	1305		23
Total	14274	2639	328	60	62	17363	2.59	122
1970	1646	483	56	4	11	2200		15
71	1721	551	59	8	12	2351		20
72	2096	339	24	2	1	2462		3
73	1293	309	40	4	1	1647		5
74	1747	466	117	17	15	2362		32
75	1276	257	41	5	7	1586		12
Total	9759	2405	337	40	47	12608	3.36	87
Grand Total	46389	11460	1397	181	191	59539	2.97	372

(1) Class E or larger

Table II-15. Distribution of Lightning Fires By Size Class in Each National Forest and Zone, 1960-1974

	A	B	C	D	E	F	G	Total
Northwest Zone								
Kaibab	2078	277	10	1	1	0	2	2369
Coconino	4361	523	12	5	1	1	0	4903
Prescott	962	125	19	4	1	0	0	1111
Zone Total	7401	925	41	10	3	1	2	8383
Zone %								
Southwest Zone								
Coronado	1424	455	175	30	30	14	4	2132
Tonto	2086	526	117	22	8	4	4	2767
Zone Total	3510	981	292	52	38	18	8	4899
Zone %								
Central Zone								
Apache-Sitgreaves	4063	958	91	10	2	4	3	5131
Gila	4014	1093	106	8	5	1	2	5229
Zone Total	8077	2051	197	18	7	5	5	10360
Zone %								
Eastern Zone								
Carson	544	138	6	0	0	0	0	688
Santa Fe	1180	239	30	1	1	3	1	1455
Cibola	1203	311	41	9	3	3	0	1570
Lincoln	842	142	17	5	2	1	1	1010
Zone Total	3769	830	94	15	6	7	2	4723
Zone %								
Region Three No. of Fires	22757	4787	624	95	54	31	17	28365
%	80.23	16.88	2.20	0.33	0.o9	0.11	0.06	

Average Size Per Fire

Lightning fires in Region Three have an average size of nearly 13 acres. Great variation in fire size exists between zones and individual national forests. The smallest average size per fire (2.87 acres) is in the Northwestern Zone and the largest (32.12 acres) is in the Southwestern Zone (Table II-16). Average fire size exceeds 20 acres in the Coronado, Tonto and Lincoln National Forests, while the average is less than two acres in the Carson, Coconino and Prescott. The extremes are 0.42 acres in the Carson and 44.41 acres in the Coronado.

The average size per lightning fire is increasing. As shown in Table II-17 the average size per lightning fire has increased in every decade of the study period. The average fire size to date during the seventies decade is more than double that of the forties decade. The reasons for the steady increase in fire size is not clearly understood although very large fires in 1971 and 1974 strongly influence the average for the seventies decade. This is countered by an increase in number of lightning fires. The summary data for each decade are as follows:

Years	No. of Fires	Acres Burned	Acres Per Fire
1940-1949	13,858	101,266	7.31
1950-1959	15,709	131,846	8.39
1960-1969	17,363	167,733	9.66
1970-1975	12,588	215,890	17.15

Table II-16. Average Size and Percent of Lightning Fires Reaching Class C or Larger Size in Each National Forest and Zone. 1960-1974.

Forest and Zone	Average Size Per Fire (Acres)	No. of Class C or Larger Fires	Percent of Fires Reaching Class C or Larger Size
Kaibab	7.83	14	0.59%
Coconino	0.72	19	0.39
Prescott	1.80	24	2.16
N. W. Zone	2.87	57	0.68
Coronado	44.41	253	11.87
Tonto	22.66	155	5.60
S. W. Zone	32.12	408	8.33
Apache-Sitgreaves	16.90	110	2.14
Gila	8.48	122	2.33
Central Zone	12.65	232	2.24
Carson	0.42	6	0.87
Santa Fe	13.74	36	2.47
Cibola	6.03	56	3.57
Lincoln	21.92	26	2.57
Eastern Zone	10.99	124	2.63
Total Region Three	12.85	821	2.89

Area Burned

Lightning fires burned more than 616,000 acres in Region Three in 36 years. As shown in Table II-17, the area burned has been steadily increasing. More than 30,000 acres were burned in seven of the years studied (1946, 1951, 1956, 1959, 1960, 1971, and 1974). Less than 2000 acres were burned in three years (1941, 1953 and 1958). The average annual area burned in the region was 17,131 acres during the 1940-1975 period. The peak area burned in a single year was 96,661 acres in 1971.

The area burned by lightning fires has increased in each decade. During the forties decade the average annual area burned by lightning fires in Region Three was 10,127 acres (Table II-17). The area burned has increased in each decade since the forties culminating in an annual average of 35,982 acres durting the 1970-1975 period. Gaining an understanding of this steady increase in area burned requires analyses of several factors including fuel flammability, fire control methods and the magnitude of the total fire load in the region. These factors are summarized in later sections of the report.

The largest area burned by lightning fires is in the Southwestern Zone. As shown in Table II-18 more than 157,000 acres were burned in the Southwestern Zone during the 1960-1974 period. This is 43 percent of the area burned by lightning fires in Region Three and is more than double the area burned in the combined Northwestern and Eastern zones. The Central Zone ranks second in area burned with more than 131,000 acres during the 1960-1974 period. The Central Zone had the greatest burn in a single year with 76,937 acres in 1971.

The Coronado and Apache-Sitgreaves National Forests lead Region Three in total area burned by lightning fires. During the 1960-1974 period the Coronado burn was 94,686 acres and the Apache-Sitgreaves 86,736 acres to rank these forests first and second respectively in area burned by lightning fires. This amounts to 49.78 percent of the total area burned by lightning fires in Region Three during the 15 year study period. It should be noted that 87 percent of the area burned in the Apache-Sitgreaves National Forest occurred in a single year - 1971. On the other hand, the Coronado had burns of more than 10,000 acres during five years and less than 500 acres in only one year. A summary of area burned by years in each national forest in Region Three is presented in Tables II-19 and II-20.

Table II-17. Acres Burned by Lightning Fires by Years in Region Three, 1940-1975.

Year	Acres Burned	Year	Acres Burned	Year	Acres Burned	Year	Acres Burned
1940	2220	1950	5310	1960	31490	1970	21776
41	383	51	34117	61	16421	71	96661
42	3068	52	2077	62	13848	72	3799
43	11314	53	1483	63	3928	73	2110
44	9741	54	4548	64	9512	74	72334
45	3961	55	3366	65	17127	75	19210
46	35447	56	41743	66	27525		
47	18004	57	5554	67	7774		
48	13905	58	1522	68	28836		
49	3223	59	32126	69	11272		
Total	101266		131846		167733		215890
Annual Average	10127		13185		16773		35982
Ave. Size Per Fire	7.31		8.39		9.66		17.15

Table II-18. Acres Burned by Lightning Fires in Region Three and in Each Zone, 1960-1974.

Year	N. W. Zone	S. W. Zone	Central Zone	Eastern Zone	Total R-3
1960	9637	15095	5370	1388	31490
61	611	13641	1002	1167	16421
62	8817	2435	784	1812	13848
63	50	317	267	3294	3928
64	772	6691	1012	1037	9512
65	95	15539	455	1038	17127
66	779	24745	1090	911	27525
67	1954	1031	4264	525	7774
68	262	24925	3322	327	28836
69	240	7872	2559	601	11272
1970	77	18209	3235	255	21776
71	273	3996	76937	15455	96661
72	116	684	98	2901	3799
73	36	1720	120	234	2110
74	359	20474	30555	20946	72334
Total	24078	157374	131070	51891	364413

Table II-19. Acres Burned by Lightning Fires in the National Forests of the Northwest and Southwest Zones, 1960-1974.

Year	Kaibab	Coconino	Prescott	N. W. Zone	Coronado	Tonto	S. W. Zone
1960	8760	51	826	9637	14671	424	15095
61	302	199	110	611	12729	912	13641
62	8716	15	86	8817	1798	637	2435
63	20	28	2	50	247	70	317
64	61	303	408	772	1143	5548	6691
65	23	40	32	95	12434	3105	15539
66	517	53	209	779	3498	21247	24745
67	22	1908	24	1954	769	262	1031
68	14	239	9	262	24825	100	24925
69	44	57	139	240	5129	2743	7872
1970	0	65	12	77	2609	15600	18209
71	0	253	20	273	3507	489	3996
72	20	50	46	116	634	50	684
73	16	0	20	36	500	1220	1720
74	32	270	57	359	10193	10281	20474
Total	18547	3531	2000	24078	94686	62688	157374
An Ave.	1236	235	133	1605	6312	4179	10492

Table II-20. Acres Burned by Lightning Fires in the National Forests of the Central and Eastern Zones, 1960-1974.

Year	Apache-Sitgreaves	Gila	Central Zone	Carson	Santa Fe	Cibola	Lincoln	Eastern Zone
1960	182	5188	5370	20	418	19	931	1388
61	657	345	1002	5	22	1132	8	1167
62	548	236	784	5	1607	154	46	1812
63	143	124	267	103	1954	1224	13	3294
64	577	435	1012	33	545	79	380	1037
65	260	195	455	11	53	21	953	1038
66	597	493	1090	24	201	540	146	911
67	3136	1128	4264	35	55	419	16	525
68	2953	369	3322	11	12	233	71	327
69	536	2023	2559	12	48	470	71	601
1970	583	2652	3235	0	32	150	73	255
71	75783	1154	76937	0	13115	187	2153	15455
72	72	26	98	30	128	2743	0	2901
73	60	60	120	0	44	190	0	234
74	649	29906	30555	0	1761	1911	17274	20946
Total	86736	44334	131070	289	19995	9472	22135	51891
An Ave	5782	2956	8738	19	1333	631	1476	3454

The average annual area burned by lightning fires per million acres protected in Region Three is more than 1100 acres. The annual amount of burned area per million acres varies from a high of 3401 acres in the Coronado National Forest to a low of only 13 acres on the Carson (Table II-21). In addition to the Coronado, four other national forests (Apache-Sitgreaves, Gila, Lincoln and Tonto) recorded annual average burns of more than 1000 acres per million.

Nearly sixty percent of the area burned by lightning fires in Region Three results from fires starting in June. During the 1960-1974 period the distribution of area burned by month of fire start was as follows (Table II-22):

April	0.8	percent
May	17.7	"
June	59.2	"
July	18.1	"
August	2.5	"
September	1.4	"
October	0.2	"
Other Months	0.1	"

Table II-21. Average Annual Area Burned by Lightning Fires by National Forests and Zones in Region Three, 1960-1974.

Forest and Zone	Average Annual Area Burned	Average Annual Area Burned Per Million Acres Protected	Area Burned Ranking Forests	Area Burned Ranking Zones
Kaibab	1236	772	7	
Coconino	235	117	9	
Prescott	133	94	10	
N. W. Zone	1605	320		4
Coronado	6312	3401	1	
Tonto	4179	1407	3	
S.W. Zone	10492	2174		1
Apache-Sitgreaves	5782	2093	2	
Gila	2956	1057	5	
Central Zone	8738	1571		2
Carson	19	13	11	
Santa Fe	1333	775	6	
Cibola	631	299	8	
Lincoln	1476	1161	4	
Eastern Zone	3459	525		3
Total Region Three	24294	1104		

Table II-22. Acres Burned by Lightning Fires in Region Three and in Each Zone, 1960-1974.

	Northwestern Zone	Southwestern Zone	Central Zone	Eastern Zone	Total R-3
April	46	1089	1316	323	2774
May	10098	39842	7390	7031	64361
June	2403	66785	109209	37482	215879
July	10748	41261	7562	6303	65874
August	543	5589	2564	352	9048
Sept.	200	2086	2577	367	5230
October	29	156	452	19	656
Other Months	11	525	0	14	55
Total	24078	157374	131070	51891	364413

Fires starting in June cause the greatest area burned in the Southwestern, Central and Eastern Zones. In these three zones the percent of the area burned by lightning fires starting in June is as follows:

Southwestern Zone	42.44 percent
Central Zone	83.32 "
Eastern Zone	72.22 "

In the Northwestern Zone only 9.98 percent of the burn results from June fires. The leading months for area burned in the Northwestern Zone are July with 44.64 percent and May with 41.94 percent. The area burned by months and years in all zones is shown in Tables II-23 through II-26.

Table II-23. Area Burned by Lightning Fires by Months, Northwestern Zone, 1960-1974.

Year	April	May	June	July	Aug.	Sept.	Oct.	Other Months	Total
1960	1	8676	199	752	6	0	0	3	9637
61	0	271	90	230	16	2	2	0	611
62	2	0	3	8720	59	32	1	0	8817
63	0	17	4	9	12	8	0	0	50
64	9	0	400	341	16	3	3	0	772
65	0	0	19	22	51	1	0	0	95
66	29	29	579	70	29	22	13	8	779
67	0	876	1012	56	0	10	0	0	1954
68	1	25	1	201	22	7	5	0	262
69	4	137	10	27	37	20	5	0	240
70	0	65	0	12	0	0	0	0	77
71	0	0	0	178	95	0	0	0	273
72	0	0	20	46	0	50	0	0	116
73	0	0	16	20	0	0	0	0	36
74	0	0	50	64	200	45	0	0	359
Total	46	10098	2403	10748	543	299	29	11	24078
Percent	0.19	41.94	9.98	44.64	2.25	0.83	0.12	0.05	

Table II-24. Area Burned by Lightning Fires by Months, Southwestern Zone, 1960-1974.

Year	April	May	June	July	Aug.	Sept.	Oct.	Other Months	Total
1960	0	13925	1001	167	2	0	0	0	15095
61	0	12590	908	143	0	0	0	0	13641
62	282	0	1410	197	231	310	5	0	2435
63	0	9	0	189	81	1	0	0	317
64	4	23	5860	774	19	6	5	0	669
65	742	4	454	14137	101	11	0	90	15539
66	13	12734	10866	981	128	20	0	3	24745
67	0	285	20	277	13	4	0	432	1031
68	48	5	23567	283	30	859	133	0	24925
69	0	180	663	3979	2817	233	0	0	7872
70	0	65	1677	16010	457	0	0	0	18209
71	0	0	1937	1999	0	60	0	0	3996
72	0	0	75	609	0	0	0	0	684
73	0	26	82	410	1137	65	0	0	1720
74	0	0	18265	1106	573	517	13	0	20474
Total	1089	39842	66785	41261	5589	2086	156	525	157374
Percent									

Table II-25. Area Burned by Lightning Fires by Months. Central Zone, 1960-1974.

Year	April	May	June	July	Aug.	Sept.	Oct.	Other	Total
1960	3	157	115	5062	33	0	0	0	5370
61	31	660	153	101	11	46	0	0	1002
62	1	0	433	63	137	87	63	0	784
63	50	2	32	104	29	46	4		267
64	0	216	165	169	181	0	281		1012
65	4	30	31	258	88	14	30		455
66	279	116	563	109	88	10	5	0	1090
67	0	3341	43	874	6	0	0		4264
68	0	22	2894	58	5	274	69		3322
69	40	1749	90	181	481	18	0		2559
70	0	332	355	0	1111	1437	0		3235
71	908	0	75659	107	28	235	0	0	76937
72	0	0	0	72	26	0	0	0	98
73	0	0	35	0	85	0	0		120
74	0	765	28641	404	335	410	0		30555
Total	1316	7390	109209	7562	2564	2577	452		131070
Percent									

Table II-26. Area Burned by Lightning Fires by Months, Eastern Zone, 1960-1974

Year	April	May	June	July	Aug.	Sept.	Oct.	Other Months	Total
1960	2	1349	11	6	11	7	0	0	1388
61	2	33	1114	7	0	0		11	1167
62	27	11	1609	12	148	5	0		1812
63	270	41	1674	1233	14	62	0		3294
64	2	256	74	701	3	1	0	0	1037
65	0	991	20	14	8	2	3		1038
66	9	354	385	138	19	3	3	0	911
67	1	52	70	387	10	4		1	525
68		4	202	83	7	18	13		327
69		62	71	442	22	4			601
70		12	118	73	0	52			255
71	0	1575	13664	136	0	80		0	15455
72		70	63	2690	78	0	0		2901
73	10	0	16	164	32	12	0		234
74	0	2221	18391	217	0	117		0	20946
Total	323	7031	37482	6303	352	367	19	19	51891
Percent	0.62	13.55	72.22	12.14	0.68	0.72	0.04	0.03	

II-3. Summary of Fire Load

The foregoing analyses show the characteristics of the lightning fire load in Region Three National Forests. Results of these studies dramatically illustrate that lightning fires are important phenomena to be considered in the development of policies and programs for management of national forest resources. Fire management, especially in relation to overall natural resources management, is entering a dynamic era of new policies. These include provision for "prescription fire using either planned or unplanned ignitions to protect, maintain and enhance production of National Forest resources" (U.S. Forest Service, 1978). The knowledge now available on the lightning fire load provides an increased basis for regional development and implementation of these national policies. Other phases of this report on lightning fire environment, wilderness and critical fire situations include additional information for application in future fire management programs.

In evaluations of the total fire load it is necessary to consider both lightning and man-caused fires. A detailed study of the man-caused fire load was beyond the scope of this research. However a summary of the combined lightning and man-caused fire load was prepared (Table II-27).

Summary of the total fire load, 1960-1974, showed:

(1) A total of 35,081 lightning and man-caused fires in 15 years.

(2) 81 percent lightning caused fires.

(3) More than 3000 lightning and man-caused fires in three separate years (1961, 1972, 1974).

(4) A major increase in man-caused fires 1970 thru 1974.

(5) Peak single year lightning occurrence more than three times greater than peak man-caused fire year.

(6) A total of 372 class D or larger lightning and man-caused fires.

(7) 53 percent of class D or larger fires are lightning caused.

(8) In 10 of 15 years most class D or larger fires are lightning-caused.

(9) A total of 562,428 acres burned by lightning and man-caused fires.

(10) 65 percent of area burned by lightning fires.

(11) In 10 of 15 years largest area burned is by lightning fires.

(12) More than 100,000 acres burned by lightning and man-caused fires in two separate years (1971, 1974).

Table II-27. Summary of Fireload by Years for Lightning and Man-Caused Fires in Region Three, 1960-1974

Year	Lightning Fires			Man-Caused Fires		
	No. of Fires	No. of Class D or Larger Fires	Acres Burned	No. of Fires	No. of Class D or Larger Fires	Acres Burned
1960	2546	17	31490	362	5	3839
61	2841	16	16421	267	5	4229
62	2210	8	13848	356	5	2701
63	1432	4	3928	339	13	4853
64	1661	11	9512	323	9	4475
65	1448	11	17127	340	7	7336
66	1490	11	27525	338	9	6045
67	1184	8	7774	347	20	32019
68	1246	13	28836	360	14	10036
69	1305	23	11272	365	17	15254
70	2200	15	21776	495	14	6659
71	2351	20	96661	563	21	18593
72	2462	3	3799	715	6	32616
73	1647	5	2110	775	8	17289
74	2342	32	72334	771	22	32071
Total	28365	197	364413	6716	175	198015

III. LIGHTNING FIRE ENVIRONMENT

In the Southwest many features of the climate, local weather, topography and vegetative cover combine to provide a unique environment for lightning fires. At first glance it might be postulated that the arid Southwest has neither the frequency of atmospheric moisture situations for generation of substantial numbers of thunderstorms or the expanses of flammable wildland fuels to create a severe lightning fire environment. The long history of wildland fires shows that the overall natural environment of the Southwest operates in a fashion that produces a massive amount of lightning and fuel complexes conducive to fire ignition and spread.

This research of lightning fire environment concentrates on selected factors of lightning storm meteorology, climatology, topography, vegetative cover and fuel types. The main thrust of the studies is to determine the relationship of these environmental factors to the ignition and spread of lightning fires. The main data base is provided by climatological summaries for Arizona and New Mexico and individual fire reports showing the dates, location, size, topography, cover types and fuels for some 28,000 lightning fires.

III-1. Fire Climate

In the Southwest there are two distinctly different fire seasons. During the principal months for lightning fire occurrence there is a spring dry season from April through June and a summer wet season (relatively speaking) from July through September. As shown in Table III-1 these dry and wet seasons occur in each national forest zone of the region. During both the dry and wet seasons the Eastern Zone has the largest amount of precipitation. The Southwest Zone has the least precipitation during both seasons.

The largest number of thunderstorm days occur during the wet fire season months. Table III-2 shows the average number of thunderstorm days, relative humidity and precipitation at selected cities in Arizona and New Mexico. Unfortunately similar long term climatic data are not available for higher elevations more representative of the national forest sites for most lightning fires. The fire records show a much larger number of thunderstorm days than indicated by the climatic data for the lower elevations. However, the general differences between the spring and summer periods shown in Table III-3 hold true throughout the region although the figures may be different. During the dry season the humidity is very low, precipitation is light and relatively few thunderstorm days are recorded. During the wet season all of these factors are increased. During July and August the average number of thunderstorm days is 7 to 14 times greater than the average for the spring months.

Synoptic weather patterns indicate lightning storm characteristics. During the dry spring season a high pressure system to the north of the region and moisture in a shallow layer aloft may produce dry thunderstorms. Moisture flow may be either from the southwest or southeast in this shallow layer. Normally as summer weather develops the Bermuda High moves westward in the Gulf of Mexico and produces a deep layer of moisture flow over the region. The resulting thunderstorms have large amounts of lightning and rainfall reaching the ground (Schroeder and Buck, 1970).

Lightning fires are most severe during the dry spring season. The combination of small amounts of precipitation and enough dry lightning storms to ignite significant numbers of fires results in a severe and sometimes critical fire situation (Table III-3). In each national forest zone of the region the spring season produces the largest area burned and average size per fire.

The largest number of fires and area burned during the spring season occurs in the Central Zone. As shown in Table III-3 the Central Zone averages 301 lightning fires and 7861 acres burned annually during the April-June period.

It is notable that the number of spring lightning fires is almost as great as the summer occurrence in Central Zone. Only the Northwest Zone has a larger number of lightning fires during the summer months.

The Southwest Zone has a persistently severe lightning fire problem during both the spring and summer periods. This zone has less precipitation than any other zone in the region during both the spring and summer. While average annual occurrence is only 96 lightning fires during the spring months the average size of these fires is 74.8 acres. During the summer months the average size per lightning fire of 14.24 acres is also the largest of any zone. For the combined dry and wet seasons the Southwest Zone has the greatest area burned by lightning fires (Table III-3).

Table III-1. Approximate Average Annual Inches of Precipitation at Lower Elevations in Each Zone of Region Three, April - September. (1)

Month	Northwest Coconino, Kaibab, Prescott	Southwest Tonto Coronado	Central Apache-Sitgreaves Gila	Eastern Carson Santa Fe	Eastern Cibola Lincoln
April	.65	.39	.54	1.12	.79
May	.23	.14	.50	1.65	1.10
June	.17	.14	.75	1.24	1.25
July	.97	1.06	2.27	2.34	2.94
Aug	1.63	1.56	2.71	2.76	2.95
Sept.	1.10	.83	1.61	1.64	1.86

(1) Estimates from data in Climates of the States (Arizona and New Mexico) Vol. II, NOAA, U.S. Dept. of Commerce, 1974.

Table III-2. Average Thunderstorm Days, Relative Humidity and Precipitation During Fire Season Months at Selected Stations in the Southwest.(1)

Station	Weather Factor (2)	Month April	May	June	July	Aug.	Sept.
Flagstaff	T.S.	2	2	4	16	16	6
	R.H.	34%	24%	19%	37%	42%	41%
	Precip.	1.18	.51	.69	2.28	2.84	1.58
Phoenix	T.S.	1	1	1	6	7	3
	R.H.	18%	13%	13%	20%	26%	25%
	Precip.	.32	.13	.09	.77	1.12	.73
Tucson	T.S.	1	1	2	14	14	5
	R.H.	11%	12%	13%	28%	34%	26%
	Precip.	.27	.13	.29	2.06	2.88	1.00
Winslow	T.S.	2	2	3	11	11	5
	R.H.	19%	14%	12%	26%	32%	31%
	Precip.	.45	.32	.26	1.02	1.43	.91
Albuquerque	T.S.	2	4	5	12	12	5
	R.H.	18%	16%	17%	28%	31%	31%
	Precip.	.47	.75	.57	1.20	1.33	.95

(1) Data from Climates of the States (Arizona and New Mexico) Vol II, NOAA, U.S. Dept of Commerce, 1974.

(2) T.S. = No. of thunderstorm days
R.H. = Relative Humidity
Precip. = Inches of precipitation

Table III-3. Comparison Between Precipitation and Lightning Fire Occurrence, Acres Burned and Average Size Per Fire During Dry and Wet Fire Season Months in Each Zone. (1)

	Northwest Coconino, Kaibab, Prescott	Southwest Tonto, Coronado	Central Apache-Sitgreaves Gila	Eastern Carson, Cibola Santa Fe, Lincoln
Dry Months (April-June)				
Average inches of Precipitation	1.05	.67	1.79	3.57
Average Annual No of Lightning Fires	138	96	301	151
Average Annual Acres Burned	836	7181	7861	2984
Average Size Per Fire (Acres)	6.06	74.80	26.12	19.79
Wet Months (July-Sept)				
Average Inches of Precipitation	3.70	3.45	6.59	7.27
Average Annual No. of Lightning Fires	412	229	387	162
Average Annual Acres Burned	766	3262	847	468
Average Size Per Fire	0.17	14.24	2.19	2.84

(1) Precipitation averages calculated from data in Climate of the States (Arizona and New Mexico) Vol. II, NOAA, U. S. Dept. of Commerce, 1974.

III-2. Topography

Elevation Zone

In Region Three more than three fourths of the lightning fires occur at elevations above 6500 feet. During the period 1960-1974 a total of 22,209 lightning fires occurred in the elevation zones above 6500 feet (Table III-4). The peak occurrence zone is 6501 to 7500 feet with 40.15 percent of the lightning fires. This pattern of fire occurrence in the higher elevations is found in all national forest zones of the region except in the Southwest Zone where the largest number of fires are in the elevations of 5501 to 6500 feet.

Peak occurrence of high elevation fires is in the Eastern and Central Zones. In the Eastern Zone 95.66 percent of the lightning fires occur at elevations above 6500 feet with the greatest number of fires being at elevations of 7501 to 8500 feet. In the Central Zone 89.98 percent of the fires are above 6500 feet. In total number of fires the greatest concentration in Region Three is at elevations of 6501 to 8500 feet in the Central Zone. The Central Zone also leads in number of fires above 8500 feet. The second largest concentration of high elevation fires is from 6501 to 8500 feet and is in the Northwest Zone (Table III-4). These data reflect the importance of the high mountain ranges in lightning fire occurrence.

The greatest number of Class C or larger lightning fires originate at elevations of 4501 to 7500 feet. During the 1960-1974 period 486 fires of this size class originated in the elevation range of 4501 to 7500 feet. This was 59.05 percent of the total number of Class C or larger fires (Table III-5).

The greatest number of Class G lightning fires originated at elevations of 6501 to 8500 feet. In the 15 year study period 10 fires of more than 5000 acres in size occurred in these high elevation zones (Table III-5). This was 66 percent of the Class G fires. This concentration of very large fires at these high elevations probably reflects combined effects of fuel loadings, terrain difficulties and accessibility for fire control forces. A summary of all large fires is contained in Part IV of this report.

Table III-4. Lightning Fire Occurrence By Elevation in Each National Forest Zone of Region Three, (1960-1974.

Zone	No. of Fires and %	Elevation Below 2501	2501-3500'	3501-4500'	4501-5500'	5501-6500'	6501-7500'	7501-8500'	Over 8500'
Northwestern									
	No.	1	20	135	330	1433	4169	1036	149
	%	.01	.24	1.61	3.94	18.42	61.65	12.36	1.78
Southwestern									
	No.	58	138	351	855	1491	1112	682	209
	%	1.18	2.82	7.17	17.46	30.45	22.71	13.93	4.27
Central	No.	8	0	18	81	932	3973	3946	1413
	%	.08	-	.17	.78	8.99	38.31	38.05	13.62
Eastern									
	No.	19	1	4	24	157	1140	2355	1025
	%	.40	.02	.08	.51	3.32	24.13	49.84	21.69
Region Three									
	No.	86	159	508	1290	4124	11394	8019	2796
	%	.30	.56	1.79	4.55	14.53	40.15	28.26	9.85

Table III-5. Occurrence of Class C or Larger Lightning Fires By Size Class and Elevation Zone in Region Three, 1960-1974.

Elevation Zone	Size Class C	D	E	F	G	Total	% of Class C or Larger Fires
Below 2501	9	0	0	0	0	9	1.09
2501-3500	25	4	3	0	2	34	4.13
3501-4500	65	21	9	7	1	111	13.49
4501-5500	130	24	21	7	0	182	22.11
5501-6500	93	20	13	11	2	139	16.89
6501-7500	138	10	8	3	6	165	20.05
7500-8500	104	13	5	3	4	129	15.68
Above 8500	48	4	1	1	0	54	6.56
Total	623	96	60	29	15	823	

Aspect

Lightning fires are randomly distributed by aspect. In studies of 28,376 lightning fires only slight differences were found in occurrence on various aspects (Table III-6). Surprisingly nearly 27 percent of the fires occurred on north and northwest aspects as compared to 20 to 31 percent on other aspects. Earlier studies of lightning fires in the Northern Rocky Mountains have shown the greatest occurrence of fires on south and southwest aspects (Barrows, 1951). In Region Three it is probable that tree distribution on northerly aspects may be a factor contributing to somewhat greater occurrence of lightning fires.

Class C or larger lightning fires are also randomly distributed by aspect. The distribution of fires reaching Class C or larger size varied from 2.31 percent on north and northeast aspects to 3.78 percent on south and southwest aspects (Table III-6). The drier climate on the southerly aspects would be expected to influence development of larger fires. A total of 405 Class C or larger fires occurred on east-southeast and south-southwest aspects during the period 1960-1974).

Nearly one-half of the lightning fires burning more than 5000 acres originate on north and northeast aspects. A total of seven of the fifteen Class G fires ignited on these aspects. The distribution was as follows:

Aspect	No. of Class G Fires	% of Class C Fires
North and northeast	7	46.67
East and southeast	3	20.00
South and southwest	2	13.33
West and northwest	1	6.67
Ridgetop	2	13.33
Flat	0	0.

Table III-6. Distribution of Lightning Fires and Class C or Larger Fires by Aspect in Region Three, 1960-1974.

Aspect	Total Number of Fires	Number of Class C or Larger Fires	Percent Class C or Larger Fires
North and Northeast	7655 (26.98%)	177	2.31
East and Southeast	5786 (20.39%)	181	3.13
South and Southwest	5924 (20.88%)	224	3.78
West and Northwest	6030 (21.25%)	176	2.92
Ridgetop	954 (2.36%)	35	3.67
Flat	2027 (7.18%)	28	1.38
Total	28376	821	

Slope Steepness

More than fifty percent of the lightning fires occur on gentle slopes. During the 15 year study period 15,525 lightning fires, 54.71 percent of the total ignitions occurred on slopes of less than 20 percent (Table II-7). The distribution of these fires by national forest zones was as follows:

	Slope Steepness		
Zone	0-19%	20-39%	40% or more
Northwest	6157	1296	931
Southwest	1604	1164	2129
Central	5303	2373	2695
Eastern	2461	1174	1090

The Southwest national forest zone leads the region in percent of fires occurring on steep slopes. More than 43 percent of the lightning fires in the Southwest Zone occurred on slopes of 40 percent or more. In contrast only 11 percent of the fires in the Northwest Zone occurred on these steep slopes. This reflects the vast expanse of gentle topography on the Coconino Plateau where large numbers of lightning fires occur. The Eastern and Central Zones had 23 and 26 percent respectively of their lightning fires on slopes of 40 percent or more.

The percent of Class C or larger fires increased with slope steepness. Only 1.60 percent of the lightning fires originating on slopes of 0-19 percent spread to Class C or larger size. On slopes of 20-39 percent 2.88 percent of the fires spread to this size. The peak occurrence of Class C or larger fires was on slopes of 40 percent or more. On these steep slopes 400 fires or 5.84 percent spread to sizes of 10 acres or more (Table III-7).

Steep slopes are breeders of very large fires. More than half (53.33%) of the Class G lightning fires originated on slopes of 40 percent or more (Table III-7). These fires burning 5000 or more acres were all in the Southwest and Central Zones distributed on national forests as follows:

Coronado	2 fires
Tonto	2 "
Apache-Sitgreaves	3 "
Gila	1 "

Table III-7 Lightning Fire Occurrence and Size Class by Slope Steepness in Region Three, 1960-1974.

	Slope Steepness		
	0-19%	20-39%	40% or more
Number of Fires	15,525	6.007	6,845
Percent of Fires	54.71	21.17	24.12
Number of Class C or Larger Fires	249	173	400
Percent of Fires Reaching Class C or Larger Size	1.60	2.88	5.84
Number of Class G Fires	5	2	8
Percent of Class G Fires	33.33	13.33	53.33

III-3. Cover Type

In Region Three the individual fire report data permitted analyses of fires in seven vegetative cover types -- grass, brush, spruce, mixed conifer, ponderosa pine, aspen and woodland. The data reflects the dominate cover type at the fire site. Unfortunately standardized measure of the acres in each of these cover types was not available. As a result the fire data could not be analyzed on a unit area basis.

More than three-fourths of the lightning fires occur in forested areas. During the period 1969-1974 a total of 21,572 lightning fires occurred in the spruce, mixed conifer, ponderosa pine, aspen and woodland cover types (Table III-8). This was 76 percent of the total number of lightning fires. Fires in grass and brush fuels accounted for 24 percent of the total. In addition a small number of fires (24 in logging slash and 9 in clear cut areas) were not identified by forest cover type.

More than sixty percent of the lightning fires occur in ponderosa pine. A total of 17,067 fires, 68.38 percent, occurred in the ponderosa pine type. This is a very high fire occurrence rate and is estimated to be greatly in excess of other types on a unit area basis. While ponderosa pine is the major forest cover type of the region an even greater area consists of grass, brush and woodland types. Even in the Southwest Zone noted for expanses of grass, brush and woodland types the largest number of lightning fires occur in ponderosa pine. In each zone of Region Three the largest number of lightning fires is in ponderosa pine. The peak fire occurrence is in the vast ponderosa pine forests of the Northwest and Central Zones (Table III-8).

Large numbers of lightning fires occur in grass. As shown in Table III-8 5516 fires or 19.52 percent of the total occurred in grass. In all zones except the Eastern grass was the second most common cover type for lightning fire occurrence.

Lightning fire growth rates are very high in brush and grass cover types. During the 15 year study period 9.69 percent of the fires in brush and 7.12 percent in grass reached Class C or larger size (Table III-8). These fire growth rates are double or more those found in any other cover type. Fires in the woodland cover type rank third in percent spreading to Class C or larger size.

It is interesting to note that only 1.21 percent of the fires in ponderosa pine reached Class C or larger size. Only aspen and spruce had a smaller percentage of such fires. Not a single fire in aspen spread to Class C size and only one occurred in spruce.

The greatest number of big fires occur in grass. During the study period 113 (57.65 percent) of the fires burning more than 100 acres were in grass (Table III-9). The greatest concentration of these large grass fires was in the Southwest Zone., In that zone 71 Class D or larger grass fires accounted for 62.83 percent of the large grass fires in the region.

All of the Class G fires were in grass, brush or ponderosa pine. As shown in Table III-9 six fires burning more than 5000 acres occurred in both the grass and ponderosa pine types and 3 in the brush types. Each national forest zone had one or more Class G lightning fires in ponderosa pine. All of the Class G fires in brush occurred in the Southwest Zone.

Table III-8. Distribution of Lightning Fires By Cover Type In Each National Forest Zone of Region Three, 1960-1974.

	Grass	Brush	Spruce	Mixed Conifer	Ponderosa Pine	Aspen	Woodland
Northwestern Zone	1422	165	5	419	5612	4	742
Southwestern Zone	1295	677	3	288	2350	2	276
Central Zone	1952	184	54	907	6721	30	501
Eastern Zone	847	151	58	914	2384	20	274
Total Number of Fires	5516	1177	120	2528	17,067	56	1801
Percent of Fires in Region	19.52	4.16	.42	8.94	60.38	.20	6.37
Number of Class C or larger fires	393	114	1	35	206	0	65
Percent Class C or Larger Fires	7.12	.69	.83	1.38	1.21	0	3.61

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Table III-9. Number of Class D or Larger Lightning Fires By Cover Type In Each National Forest Zone of Region Three, 1960-1974.

Zone		Grass	Brush	Spruce	Mixed Conifer	Ponderosa Pine	Aspen	Woodland
Northwest	D	7	2	0	0	1		0
	E	1	0	0	1	2		0
	F	0	0	0	0	1		0
	G	0	0	0	0	1		0
	Total	8	2	0	1	5	0	0
Southwest	D	32	8	0	1	3		6
	E	29	6	0	0	1		3
	F	8	7	0	0	0		3
	G	2	3	0	0	2		0
	Total	71	24	0	1	6	0	12
Central	D	8	0	0	1	9		0
	E	4	0	0	0	3		0
	F	3	0	0	0	1		1
	G	3	0	0	0	2		0
	Total	18	0	0	1	15	0	1
Eastern	D	9	2	0	2	3		0
	E	2	2	0	1	1		0
	F	2	1	0	0	2		0
	G	1	0	0	0	1		0
	Total	14		0	3	7	0	0
Region Three	D	58	12	0	4	16		6
	E	36	8	0	2	7		3
	F	13	8	0	0	4		4
	G	6	3	0	0	6		0
	Total	113	31	0	6	33	0	13

III-4. Fuel Type

The fuel type classification system has been a good indicator of fuel flammability in Region Three. Under the system fuels were classified according to rate of fire spread and resistance to control efforts. For both categories fuels were given general ratings of Low, Medium, High and Extreme. As shown in Table III-10 an increasing percentage of fires reach Class C or larger size as the fuel rate of spread classification increases. In Region Three only 1.29 percent reach Class C or larger size in low rate-of-spread fuels as compared to 13.50 percent in the extreme classification.

More than three-fourths of the lightning fires ignite in medium and high rate-of-spread fuels. During the period 1960-1974 a total of 22,260 fires occurred in these fuel types (Table III-10). Moreover a greater number of fires occurred in extreme than in low rate-of-spread fuels. In the Southweatern Zone 23.66 percent of all lightning fires occurred in extreme rate-of-spread fuels.

Eighty two percent of the area burned is in high and extreme rate-of-spread fuels. This striking relationship is strongly influenced by large burns in the Southwestern and Central Zones in high and extreme fuels (Table III-11). In the Northwestern Zone the largest area burned was in medium fuels. Also in the Central Zone the second largest area burned was in medium fuels.

Average fire size increases with an increase in fuel rate-of-spread classification. In Region Three the average fire size increases steadily from 3.05 acres in low fuels to 48.45 acres in extreme fuels. This scale of fire size by fuel type is most striking in the Southwestern Zone. Some variations are noted in other Zones. In the Northwestern Zone the largest average fire size occurred in medium rate-of-spread fuels (Table III-11).

Nearly two-thirds of the lightning fires occur in medium resistance-to-control fuels. In every zone of Region Three the largest number of fires are in medium resistance-to-control fuels (Table III-12). However, it is also notable that a relatively large number of fires in the Southwestern and Central Zones were recorded in extreme resistance-to-control fuels.

The largest number and percentage of Class C or larger fires are in low resistance-to-control fuels. As shown in Table III-12 more than ten percent of the fires reached Class C or larger size in low fuels. A much smaller percent of large fires was recorded in the medium and high classes and only 5.52 percent in the extreme resistance-to-control class.

Table III-10. Distribution of Lightning Fires by Fuel Rate-of-Spread Type in Each National Forest Zone, 1976-1974.

	Fuel Rate of Spread Class				Total # of Fires in Each Zone
	Low	Medium	High	Extreme	
Northwestern Zone	813	2293	4463	813	8382
% Fires in each class	9.7	27.36	53.25	9.7	
Southwestern Zone	304	2178	1252	1157	4891
% Fires in each class	6.22	44.53	25.6	23.66	
Central Zone	1110	5186	3153	914	10363
% Fires in each class	10.71	50.04	30.43	8.82	
Eastern Zone	718	2276	1459	249	4762
% Fires in each class	15.27	48.4	31.03	5.3	
Total Number of Fires	2945	11933	10327	3133	28338
Percent of Fires in Region	10.39	42.11	36.44	11.06	
Number of Class C or Larger Fires	38	186	176	423	
Percent Class C or Larger Fires	1.29	1.56	1.70	13.50	

Table III-11. Acres Burned and Average Fire Size by Fuel Rate-of-Spread Type in Each National Forest Zone, 1960-1974.

Fuel Rate of Spread Type		Zone				Region Three
		Northwest	Southwest	Central	Eastern	
Low	Acres Burned	749	1233	4201	2796	8979
	Average Size Per Fire	0.92	4.07	3.78	3.90	3.05
Medium	Acres Burned	9511	17282	13856	15778	56427
	Average Size Per Fire	4.15	7.93	2.67	6.93	4.73
High	Acres Burned	2521	42411	90763	6440	142135
	Average Size Per Fire	0.56	33.87	28.79	4.41	13.76
Extreme	Acres Burned	2179	83547	32966	33114	151806
	Average Size Per Fire	2.68	72.21	36.07	132.99	48.45

Table III-12. Distribution of Lightning Fires by Resistance-to-Control Classification in Each National Forest Zone, 1960-1974.

	Resistance to Control Class				
	Low	Medium	High	Extreme	Total # of Fires
Northwestern Zone	969	4598	2538	278	8383
% Fires in each class	11.56	54.85	30.28	3.32	
Southwestern	806	2736	937	412	4891
% Fires in each class	16.48	55.94	19.16	8.42	
Central	858	7532	1340	634	10364
% Fires in each class	8.28	72.67	12.93	6.12	
Eastern	456	3359	803	88	4706
% Fires in each class	9.69	71.38	17.06	1.87	
Total Number of Fires	3089	18225	5618	1412	28344
Percent of Fires in Region	10.90	64.30	19.82	4.98	
Number of Class C or Larger Fires	318	265	162	78	
Percent Class C or Larger Fires	10.29	1.45	2.88	5.52	

IV LIGHTNING FIRE CONTROL

The control of lightning-caused forest fires involves many significant factors. These include: prompt detection in remote areas; identification of potentially dangerous and damaging fires; selection of fire attack methods; determination of needed strength for attack forces; and mobilization of resources to control large fires. All of these factors in the Southwest are compounded by topography, fuels, weather, travel distances and large numbers of lightning fires occurring in short periods of time.

In this study of lightning fire control the goal has been to perform analyses that will aid in fire management decision making. The studies are centered on analysis of fire detection, initial fire attack, reinforcement of attacks and suppression of large fires.

IV-1. Fire Detection

One-half of the lightning fires in Region Three are detected within three hours. The elapsed detection time varies somewhat by size class of fire (Table IV-1). Class D or larger fires are detected faster than the Class A, B and C fires. During the 15 year study period 61.61 percent of the Class D or larger fires were detected within three hours and 51.51 percent within one hour. This indicates that these large fires often have highly visable burning characteristics shortly after ignition.

Long detection times for many lightning fires are common. During the 1960-1974 period a total of 2790 fires had elapsed detection times of more than 24 hours (Table IV-1). This is nearly ten percent of all lightning fires. It is significant to note that 20.51 percent of the Class C fires had elapsed detection times in excess of 24 hours. Moreover 39.90 percent of the Class C fires had detection times of more than 12 hours.

Little variation exists in elapsed detection time between national forest zones. The percent of fires detected within three hours varied from 46.07 percent in the Eastern Zone to 54.87 percent in the Southwest Zone (Table IV-2). The Central and Eastern Zones had the highest percentage of fires with detection times of more than 12 hours. The Southwestern Zone has a slightly better record than any other zone in all categories of elapsed detection time.

Forest Service lookouts and aircraft detect 72 percent of the lightning fires. As shown in Table IV-3 Forest Service lookouts and aircraft detected 55 and 17 percent respectively of the lightning fires. The third leading method of detection was other Forest Service personnel with 10 percent of the fires.

Forest Service ground based personnel, cooperators and permitees detect fires quickly. More than 50 percent of the fires detected by these personnel are detected within three hours. Forest Service patrolmen and lookouts lead all other categories in fast detection time (Tables IV-3 and IV-4). Patrolmen detected 57 percent of their fires within 3 hours and looks 55 percent in this elapsed time. Moreover patrolmen and lookouts detected 41 and 36 percent of their fires respecitvely within one hour.

Forest Service aircraft detect 59 percent of their fires within 12 hours. As shown in Table IV-4 aircraft also detected 38 percent of their fires within 3 hours. This is relatively fast detection time when it is recognized that many aircraft patrol flights are planned for operations during the best daylight hours for smoke visibility following lightning storms. Use of infrared scaners at night following lightning storms would probably speed up detection by aircraft.

Table IV-1. Summary of Elapsed Detection Time For Lightning Fires By Size Class in Region Three, 1960-1974.

Elapsed Detection Time		Class A and B Fires	Class C Fires	Class D or Larger Fires	All Fires
1 Hr	No	8825	256	102	9183
	%	32.03	41.03	51.51	32.36
2 Hrs	No	3101	53	15	3169
	%	11.25	8.49	7.57	11.17
3 Hrs	No	1821	28	5	1854
	%	6.61	4.49	2.53	6.53
4 Hrs	No	1088	9	4	1101
	%	3.95	1.44	2.02	3.88
6 Hrs	No	998	16	4	1018
	%	3.62	2.57	2.02	3.59
7-12 Hrs	No	1968	13	5	1986
	%	7.14	2.08	2.53	7.00
13-24 Hrs	No	7113	121	42	7276
	%	25.81	19.39	21.21	25.64
over 24 Hrs	No	2641	128	21	2790
	%	9.59	20.51	10.61	9.83
Total	No	27,555	624	198	28,377

Table IV-2. Distribution Of Lightning Fires By Elapsed Detection Time In Each National Forest Zone, 1960-1974.

Elapsed Detection Time	Northwest Zone	Southwest Zone	Central Zone	Eastern Zone
1 Hr	3188	1903	2789	1303
2 Hrs	884	485	1264	536
3 Hrs	445	299	772	338
4 Hrs	269	143	492	197
5 Hrs	164	97	257	115
6 Hrs	88	63	167	67
7-12 Hrs	627	435	575	349
12-24 Hrs	1891	1107	2959	1319
25-48 Hrs	473	232	661	310
Over 48 Hrs	355	133	435	191
Total	8384	4897	10371	4725
Summary				
Within 3 Hrs	53.88%	54.87%	46.52%	46.07%
More Than 12 Hrs	32.43%	30.06%	39.10%	38.52%
More Than 48 Hrs	4.23%	2.72%	4.19%	4.04%

Table IV-1. Elapsed Detection Time by Detection Method For Lightning Fires in Region Three, 1960-1974.

		1 Hr.	2 Hrs	3 Hrs	4 Hrs	5 Hrs	6 Hrs	7-12 Hrs	13-24 Hrs	25-48 Hrs	Over 48 Hrs	Total
F.S. Lookout	#	5690	1860	1080	601	301	179	1057	3727	794	475	15,764
	%	36.	12.	7.	4.	2.	1.	7.	24.	5.	3.	55
Other Lookout	#	41	18	9	2	3	0	3	48	14	14	152
	%	27	12	6	1	2	0	2	32	9	9	1
Patrolman	#	367	86	55	27	16	8	53	220	47	26	905
	%	41	10	6	3	2	1	6	24	5	3	3
Other F.S. Personnel	#	803	300	161	113	63	42	169	804	250	213	2,918
	%	28	10	6	4	2	1	6	28	9	7	10
Cooperator	#	170	44	20	12	10	6	20	102	36	27	447
	%	38	10	4	3	2	1	4	23	8	6	2
F.S. Permittee	#	296	82	44	25	20	17	35	214	66	43	842
	%	35	10	5	3	2	2	4	25	8	5	3
F.S. Aircraft	#	1022	506	324	223	147	94	514	1534	264	138	4766
	%	21	11	7	5	3	2	11	32	6	3	17
Other Aircraft	#	84	48	25	13	11	7	33	171	59	51	502
	%	17	10	5	3	2	1	7	34	12	10	2
Others	#	710	225	136	85	62	32	102	456	146	127	2081
	%	34	11	7	4	3	2	5	22	7	6	7
Total	#	9183	3169	1854	1101	631	385	1986	7276	1676	1114	28,377

Table IV-4. Summary Of Elapsed Detection Time By Detection Method For Lightning Fires in Region Three, 1960-1974.

Detection Method	Total Fires Detected	% Detected Within 3 Hrs	% Detected More than 12 Hrs	% Detected More than 48 Hrs
F.S. Lookout	15,764	55	33	3
Other Lookout	152	45	50	9
Patrolman	905	57	32	3
Other F.S. Personnel	2,918	44	44	7
Cooperator	447	52	37	6
F.S. Permitee	842	50	38	5
F.S. Aircraft	4,766	38	41	3
Other Aircraft	502	32	56	10
Others	2,081	52	35	6
Total	28,377	50	36	4

IV-2. Initial Attack

More than two-thirds of the lightning fires are initially attacked by ground forces using hand tools. During the period 1960-1974 the initial attack for 68.58 percent of the fires was by ground based fire fighters using hand tools. The second leading initial attack method was helitack forces (helicopter delivered fire fighters) accounting for 16.63 percent of the fires. Smoke jumpers made initial attack on 3.59 percent of the fires. Hand tool firefighters including both airborne and ground forces thus provided the initial attack for 88.80 percent of the lightning fires (Table IV-5).

Ground forces using power equipment made initial attack on less than nine percent of the lightning fires. These initial attack methods include 7.95 percent by ground tankers, 0.22 percent by plows or trenchers, and 0.12 percent by bulldozers (Table IV-5). Only 1.53 percent of the fires attacked with power equipment were class C or larger size.

More than half of the lightning fires are initially attacked by two fire fighters. During the 1960-1974 period 55.68 percent of the fires involved initial attack by two persons including either ground or airborne operations. Only 9.78 percent were attacked by one person. A steadily decreasing number of fires are attacked by more than two persons. Less than one percent of the fires are initially attacked by more than ten fire fighters (Table IV-6).

The strength of initial attack forces varies significantly by size class of fire. Only 0.56 percent of the class A fires were initially attacked by more than ten fire fighters. The studies of initial attack indicate good ability to identify fires with potential for spread to larger size class. For example the initial attack forces of more than 10 fire fighters were as follows (Table IV-6):

Class B	164 fires	3.42 percent
" C	57 "	9.13 "
" D	8 "	8.33 "
" E	6 "	10.34 "
" F	3 "	10.34 "
" G	1 "	6.67 "

Table IV-5. Number of Lightning Fires by Method of Initial Attack and Size Class in Region Three, 1960-1974.

Method of Initial Attack	A	B	C	D	E	F	G	Total	Percent of Total Fires
Dozer	16	14	3	1	0	0	0	34	0.12
Plow/Trencher	34	25	4	0	0	0	0	63	0.22
Ground-Tanker	1934	290	17	5	4	2	0	2252	7.95
Ground-Hand	16144	2845	332	57	35	18	5	19436	68.58
Heli-Tanker	5	2	0	1	1	0	0	9	0.03
Air-Tanker	277	391	113	16	11	7	2	817	2.88
Smoke Jumper	847	162	8	0	0	0	0	1017	3.59
Helitack	3477	1057	147	17	7	1	8	4714	16.63
Total (1)	22734	4786	624	97	58	28	15	28342	

(1) Method of Initial Attack not coded for 35 fires

Table IV-6. Number of Lightning Fires by Strength of Initial Attack and Size Class in Region Three, 1960-1974.

No. of People	A	B	C	D	E	F	G	Total	Percent of Total Fires
1	2356	361	39	8	4	4	1	2773	9.78
2	13525	2036	178	29	14	6	4	15792	55.68
3	4288	905	97	15	8	3	3	5319	18.75
4	1453	665	95	11	9	5	1	2239	7.89
5	513	277	51	7	5	2	0	855	3.01
6-10	484	384	107	18	12	6	5	1016	3.58
11-20	79	88	26	4	4	0	1	202	0.71
21-30	39	52	15	3	0	1	0	110	0.40
Over 30	9	24	16	1	2	2	0	54	0.19
Total	(1)22746	4792	624	96	58	29	15	28360	

(1) No. of people not coded for 17 fires

Fast initial attack following discovery is common for lightning fires in Region Three. As shown in Table IV-7 more than 62 percent of the fires are attacked within one hour following discovery. Moreover 87 percent are attacked within three hours. Only four percent have initial attack times of more than 12 hours. These studies indicate that elapsed time from origin to discovery is a significant factor in the overall speed of attack (see Chapter IV-1).

Table IV-7. Distribution of Lightning Fires by Elapsed Time Discovery to Initial Attack in Each National Forest Zone, 1960-1974.

Initial Attack Time	NW	SW	Central	Eastern	Total	Percent of Total Fires
1 hr	5554	2766	6594	2734	17648	62.19
2 hrs	1452	861	1688	859	4860	17.13
3 hrs	613	437	752	419	2221	7.83
4-6 hrs	411	400	616	394	1821	6.42
7-9 hrs	82	128	119	51	380	1.34
10-12 hrs	60	97	110	57	324	1.14
13-24 hrs	197	194	423	180	994	3.50
24-48 hrs	12	13	53	28	106	0.37
Over 48 hrs	3	1	16	3	23	0.08

IV-3. Fire Suppression Operations

Reinforcement of Fire Attacks

Nearly one-fourth of the lightning fires require reinforcement of suppression forces following initial attack. During the 15 year study period 6397 lightning fires or 22.55 percent of the total fires attacked were reinforced. As shown in Table IV-8 the fires reinforced increased from a low of 13.17 percent for class A fires to a high of 96.36 percent for class E fires. The variation by national forest zones for all fires reinforced was as follows:

Zone	% of Fires Reinforced
Northwest	19.70
Southwest	26.38
Central	20.97
Eastern	27.77

The primary method of suppression reinforcement is employment of ground forces using hand tools. This method was employed on 54.55 percent of the fires requiring reinforcement action. Other ground forces including dozers, plows, trenchers and tank trucks were used as a primary reinforcement method on 1215 fires accounting for 18.99 percent of the fires. Tank trucks were used on 17.02 percent of the fires reinforced (Table IV-9).

Airborne units play a major role in fire reinforcement operations. Air and heli-tankers, smoke jumpers and helitack fire fighters were primary reinforcement units on 1699 fires accounting for 26.55 percent of the fires. Helitack forces were used on 15.96 percent of the fires and air-tankers on 8.83 percent. These two reinforcement methods were employed on 63 class D or larger fires or 35.59 percent of the large fires requiring reinforcement action (Table IV-9).

Table IV-8. Summary of Lightning Fires Requiring Reinforcement by Size Class in Region Three, 1960-1974.

	Total No. of Fires	% of Fires Requiring Reinforcement	% of Fires Requiring Reinforcement
A	22757	2996	13.17
B	4787	2708	56.57
C	624	515	82.53
D	95	87	91.58
E	55	53	96.36
F	30	25 (1)	83.33
G	17	13 (1)	76.47
Total	28365	6397	22.55

(1) As coded on fire reports. It is probable that 100 percent of these fires were reinforced.

Table IV-9. Distribution of Fires by Reinforcement Method and Size Class in Region Three, 1960-1974.

	Dozer	Trencher	Ground Tanker	Ground Hand	Heli-Tanker	Air Tanker	Smoke-Jumper	Helitack	Total
A	8	28	782	1707	6	108	36	321	2996
B	28	52	273	1429	4	310	58	554	2708
C	4	3	23	247	1	111	7	119	515
D	0	0	7	47	0	20	1	12	87
E	1	0	4	32	0	10	0	6	53
F	0	2	0	15	0	3	0	5	25
G	0	0	0	6	0	3	0	4	13
Total	41	85	1089	3483	11	565	102	1021	6397 (1)
% of Fires	0.64	1.33	17.02	54.45	0.17	8.83	1.59	15.96	

(1) Includes only fires with coded data on reinforcement method.

Summary of Fire Suppression Actions

Fast attack of lightning fires is a dominant feature of fire suppression action in Region Three. During the 1960-1974 period 87 percent of the fires were attacked within three hours and 96 percent within 12 hours. Little variation in speed of attack was noted between national forest zones. The Northwestern Zone had the highest percentage of fires attacked within three hours and 12 hours. The Central Zone had the highest number and percentage of fires with attack times of more than 12 hours. The Eastern Zone had the smallest number and percentage of fires attacked within three hours (Table IV-10).

Elapsed control time for lightning fires is relatively high. Only 36 percent of the fires were controlled within six hours after arrival of suppression forces. Twenty percent of the fires required more than 24 hours for control. The Northwest Zone fires were controlled faster than in any other zone. The Central Zone fires required the longest control times (Table IV-10).

Table IV-10. Summary of Lightning Fire Suppression Action in Each National Forest Zone, 1960-1974.

		Fires by Zone				
		NW	SW	Central	Eastern	Total
Initial Attack						
Within 3 hrs	#	7619	4064	9034	4012	24729
	%	90.9	83.0	87.1	84.9	87.1
Within 12 hrs	#	8172	4689	9879	4514	27254
	%	97.5	95.8	95.3	95.5	96.0
More than 12 hrs	#	212	208	492	211	1123
	%	2.5	4.2	4.7	4.5	4.0
Total		8384	4897	10371	4725	28377
Control						
Within 6 hrs	#	4076	1923	2966	1364	10329
	%	49	39	29	29	36
Within 12 hrs	#	6445	3289	6012	3138	18884
	%	77	67	58	66	67
Within 24 hrs	#	7513	3838	7641	3850	22842
	%	90	78	74	81	80
Within 48 hrs	#	8089	4282	8933	4334	25638
	%	96	87	86	92	90
More than 48 hrs	#	295	615	1438	391	2739
	%	4	13	14	8	10
Total		8384	4897	10371	4725	28377

IV-4. Large Fires

Large fires are very important in terms of impact on costs of fire control and overall planning and management of forest resources and interrelated fire operations. As discussed in other sections of this report lightning is the principal ignition source for large fires in Region Three. Accordingly a special study of these fires has been made to determine the patterns of occurrence, periods of burning, areas burned and personnel requirements in each national forest, wilderness area and zone in Region Three during the 15 year period 1960-1974. Summary data is presented for each fire. The large fires studied include all of the following:

Class D	100 to 299.9 acres in size
" E	300 to 999.9 " " "
" F	1000 to 4999.9 " " "
" G	5000 or more acres

Less than one percent of the lightning fires account for more than ninety percent of the area burned. During the 1960-74 period 197 lightning fires reached Class D or larger size. This is only 0.69 percent of the total number of lightning fires. These fires burned 333,491 acres accounting for 91.51 percent of the total area burned by lightning fires (Table IV-11).

Great differences exist in the annual occurrence of large lightning fires. In 1972 only three Class D or larger fires occurred. In 1974 a total of 32 large fires were reported. In addition 15 or more large fires occurred in 1960, 1961, 1969, 1970 and 1971. The 15 year average annual occurrence is 13.13, Class D or larger fires (Table IV-12.).

Large lightning fires occur in every month from March through October. June is the leading month for large fires. During the 1960-1974 period 77 Class D or larger fires occurred in June accounting for 39.09 percent of the large fires. May and July are the next leading large fire months with 20.30 and 24.87 percent respectively. More than 84 percent of all large lightning fires occur in the May through July period. Peak loads were 12 large fires in May 1960 and 1961, 15 in June 1971 and 20 in June 1974. Large fires were recorded during August and September in only five years (Table IV-12).

Table IV-11. Summary of Class D or larger Lightning Fires in Each National Forest and Zone, 1960-1974.

National Forest and Zone	No. of Fires By Size Class				Total Fires	Acres Burned
	D	E	F	G		
Coconino	6	1	1	0	8	2,946
Kaibab	1	1	0	2	4	17,989
Prescott	4	1	0	0	5	1,300
N W Zone TOTAL	11	3	1	2	17	22,235
Coronado	29	30	14	3	76	85,469
Tonto	22	8	4	5	39	57,421
S W Zone TOTAL	51	38	18	8	115	142,890
Apache-Sitgreaves	10	2	4	3	19	82,357
Gila	8	5	1	2	16	39,509
Central Zone TOTAL	18	8	4	5	35	121,866
Carson	0	0	0	0	0	0
Cibola	9	2	4	0	15	8,942
Lincoln	5	2	1	1	9	19,283
Santa Fe	1	2	2	1	6	18,275
Eastern Zone TOTAL	15	6	7	2	30	46,500
Region Three TOTAL	95	54	31	17	197	333,491

Table IV-12. Number of Class D or Larger Lightning Fires By Year and Month of Occurrence for Region Three, 1960-1974.

	April	May	June	July	Aug.	Sept.	Oct.	Total
1960		12	3	2				17
1961		12	3	1				16
1962	1		5	1		1		8
1963	1		1	2				4
1964			6	3	1		1	11
1965			1	10				11
1966		3	7	1				11
1967		3	1	3				8 (1)
1968			8	2		2	1	13
1969		5	3	6	8	1		23
1970		1	4	7	2	1		15
1971	1	1	15	3				20
1972				3				3
1973				1	4			5
1974		3	20	4	3	2		32
TOTAL	3	40	77	49	18	7	2	197
%	1.52	20.30	39.09	24.87	9.13	3.55	1.02	

(1) 1 fire in March.

Class G lightning fires account for nearly two-thirds of the area burned. Seventeen Class G fires (0.06 percent of the total of all lightning fires) burned 217,039 acres accounting for 59.56 percent of the total area burned. As shown in Table IV-13 seven national forests recorded Class G fires during nine of the fifteen years studied. The Tonto National Forest had five Class G fires. The Apache-Sitgreaves National Forest recorded 68,340 acres burned by three Class G fires with all of them starting on June 14, 1971.

The Southwestern Zone leads all zones in Region Three in both number of large fires and area burned by these fires. In this zone 115 Class D or larger fires burned 152,890 acres during the 15 years studied (Table IV-11.). The Coronado National Forest recorded 76 large fires which burned 85,469 acres. The Tonto National Forest had 39 large fires which burned 57,421 acres. In the Central Zone 35 large fires burned 121,866 acres. The Apache-Sitgreaves National Forest record of 19 large fires burning 82,357 acres was strongly influenced by a 56,790 acre fire starting on June 24, 1971. This was the largest fire recorded in Region Three. A summary of all Class D or larger fires is contained in Table IV-14.

Table IV-13. Summary of Class G Lightning Fires on Individual National Forests.

Year	Date	Acres Burned							Total for Year
		Kaibab	Coronado	Tonto	Apache-Sitgreaves	Gila	Lincoln	Santa Fe	
1960	5-21	8673							
	7-9					5000			13,673
1961	5-12		6664						6,664
1962	7-23	8660							8,660
1964	6-27			5000					5,000
1966	5-14			12720					
	6-14			8000					20,720
1968	6-19		18430						18,430
1970	7-3			6300					6,300
1971	6-24				6000				
	6-24				5550				
	6-24				56790				
	6-26							12929	81,260
1974	6-23			8320					
	6-26		5087						
	6-28					27413			
	6-29						15512		56,332
Total Fires		2	3	5	3	2	1	1	17
Total Acres Burned		17,333	30,181	40,340	68,340	32,413	15,512	12,920	217,039

Table IV-14. Summary of Class D or Larger Lightning Fires in Region Three National Forests, 1960-1974.

Year	Date Start	Date Control	Nat'l Forest	Size Class	Acres Burned	No. of Personnel[1/]
1960	5-2	5-2	Coronado	D	285	2
	5-2	5-5	"	E	538	58
	5-2	5-4	"	F	3148	291
	5-2	5-4	"	F	2216	367
	5-3	5-5	"	F	2785	284
	5-5	5-5	"	E	500	16
	5-19	5-21	"	E	980	X
	5-20	5-21	"	F	1400	9
	5-20	5-20	"	F	1205	100
	5-20	5-20	Santa Fe	E	390	X
	5-21	5-28	Kaibab	G	8673	X
	5-23	5-23	Coronado	E	530	57
	6-2	6-2	"	D	295	150
	6-16	6-16	"	E	318	95
	6-20	6-20	Prescott	D	106	6
	7-5	7-7	"	E	685	300
	7-9	7-9	Gila	G	5000	25
1961	5-11	5-14	Coronado	F	2625	200
	5-12	5-12	"	E	310	18
	5-12	5-14	"	F	1160	65
	5-12	5-15	"	G	6664	X
	5-16	5-16	"	D	280	18
	5-20	5-22	Tonto	E	540	600
	5-24	5-26	Apache-Sitgreaves	D	110	290
	5-25	5-25	Coronado	D	263	X
	5-26	5-26	"	D	180	X
	5-27	5-28	Apache-Sitgreaves	D	210	235

1/ As coded on fire reports. X = unknown

Table IV-14. (cont.)

Year	Date Start	Date Control	Nat'l Forest	Size Class	Acres Burned	No. of Personnel
1961 (cont)	5-28	5-28	Kaibab	D	211	110
	5-30	5-30	Coronado	D	160	6
	6-10	6-10	"	D	240	60
	6-11	6-15	"	D	252	252
	6-20	6-20	Cibula	F	1088	X
	7-11	7-11	Coconino	D	148	23
1962	4-27	4-29	Coronado	D	280	18
	6-9	6-9	Santa Fe	F	1585	X
	6-26	6-26	Coronado	D	277	40
	6-26	6-26	"	D	100	15
	6-26	6-26	"	D	285	40
	6-26	6-27	"	E	500	16
	7-23	7-23	Kaibab	G	8660	813
	9-19	9-19	Tonto	D	225	50
1963	4-15	4-15	Santa Fe	D	270	X
	6-14	6-14	"	F	1585	85
	7-25	7-25	Cibola	F	1088	27
	7-26	7-26	"	D	105	X
1964	6-25	6-25	Coconino	D	260	18
	6-25	6-25	Prescott	D	127	9
	6-25	6-25	Tonto	D	120	23
	6-27	7-1	"	F	5000	185
	6-27	6-27	Gila	D	135	X
	6-28	6-29	Coronado	E	500	170
	7-4	7-4	Lincoln	D	159	43
	7-12	7-12	Prescott	D	262	19
	7-12	7-12	Tonto	D	267	10
	8-22	8-22	Apache-Sitgreaves	D	120	36
	10-25	10-30	"	D	281	5

Table IV-14. (cont.)

Year	Date Start	Date Control	Nat'l Forest	Size Class	Acres Burned	No. of Personnel
1965	6-24	6-24	Tonto	E	305	57
	7-5	7-7	Coronado	E	545	79
	7-5	7-5	"	E	352	X
	7-5	7-5	"	E	506	37
	7-5	7-5	"	F	1722	180
	7-5	7-7	"	E	642	29
	7-6	7-6	"	D	288	5
	7-7	7-7	Tonto	F	2510	600
	7-11	7-11	"	D	106	33
	7-13	7-13	"	D	132	190
1966	5-1	5-1	Cibola	D	165	6
	5-14	5-19	Tonto	G	12720	380
	5-23	5-23	Lincoln	D	133	X
	6-14	6-16	Coronado	E	450	X
	6-14	6-19	Tonto	G	8000	150
	6-14	6-16	"	D	125	35
	6-15	6-15	Coronado	E	320	X
	6-15	6-15	"	D	190	4
	6-16	6-17	"	F	1030	61
	6-18	6-19	Kaibab	E	445	X
	7-16	7-16	Tonto	D	101	36
1967	3-23	3-23	Coronado	E	432	X
	5-8	5-9	Coconino	E	865	300
	5-18	5-18	Coronado	D	250	70
	5-19	5-21	Apache-Sitgreaves	F	2947	283
	6-21	6-21	Coconino	F	1000	305
	7-2	7-2	Tonto	D	120	81
	7-2	7-3	Cibola	E	310	250
	7-4	7-4	Gila	E	712	15

Table IV-14. (cont.)

Year	Date Start	Date Control	Nat'l Forest	Size Class	Acres Burned	No. of Personnel
1968	6-3	6-3	Apache-Sitgreaves	D	112	6
	6-19	6-22	Coronado	F	4060	129
	6-19	6-20	"	E	307	60
	6-19	6-21	"	E	480	35
	6-19	6-25	"	G	18430	500
	6-20	6-20	"	D	230	91
	6-21	6-22	Apache-Sitgreaves	F	2143	121
	6-22	6-22	"	E	369	192
	7-18	7-19	Coronado	D	130	32
	7-20	7-20	Coconino	D	188	3
	9-26	9-27	Coronado	E	605	171
	9-29	9-29	"	D	120	9
	10-15	10-17	"	D	118	177
1969	5-12	5-12	Prescott	D	120	14
	5-23	5-25	Gila	D	180	165
	5-23	5-26	"	E	970	71
	5-23	5-23	"	D	172	15
	5-30	5-30	"	D	230	42
	6-5	6-5	Coronado	E	365	15
	6-5	6-6	Tonto	D	170	65
	6-6	6-6	Coronado	D	110	81
	7-1	7-2	"	D	280	30
	7-1	7-2	"	E	380	54
	7-2	7-2	"	D	160	33
	7-2	7-4	"	F	1970	475
	7-4	7-6	"	E	320	120
	7-5	7-5	Cibola	E	310	51
	8-1	8-1	Tonto	D	150	7

Table IV-14. (cont.)

Year	Date Start	Date Control	Nat'l Forest	Size Class	Acres Burned	No. of Personnel
1969 (cont)	8-2	8-2	Tonto	E	310	14
	8-4	8-5	Coronado	E	470	56
	8-4	8-5	"	D	280	215
	8-4	8-5	Tonto	E	800	15
	8-5	8-5	"	D	230	14
	8-8	8-11	Apache-Sitgreaves	D	250	57
	8-22	8-23	Tonto	D	260	22
	9-5	9-6	"	D	220	24
1970	5-28	5-29	Apache-Sitgreaves	D	230	134
	6-26	6-26	Tonto	D	180	45
	6-26	6-26	Gila	D	210	39
	6-28	6-28	Coronado	E	497	80
	6-28	6-28	"	E	690	30
	7-3	7-7	Tonto	G	6300	318
	7-3	7-6	"	F	4700	448
	7-3	7-6	"	F	2400	281
	7-4	7-5	"	E	650	40
	7-6	7-6	"	E	540	2
	7-9	7-9	Coronado	E	590	30
	7-27	7-27	Tonto	D	160	50
	8-7	8-26	Gila	E	900	6
	8-31	9-1	Coronado	D	182	60
	9-16	9-20	Gila	F	1400	6
1971	4-5	4-6	"	E	878	193
	5-26	5-26	Lincoln	F	1575	72
	6-16	6-17	Coronado	E	322	112
	6-17	6-17	Apache-Sitgreaves	D	150	16

Table IV-14. (cont.)

Year	Date Start	Date Control	Nat'l Forest	Size Class	Acres Burned	No. of Personnel
1971 (cont)	6-17	6-17	Coconino	D	150	25
	6-18	6-18	Apache-Sitgreaves	E	550	30
	6-19	6-19	Lincoln	D	200	36
	6-22	6-23	Cibola	D	100	36
	6-23	6-24	Apache-Sitgreaves	D	270	120
	6-24	6-31	"	F	1900	300
	6-24	6-27	"	F	4100	400
	6-24	6-31	"	G	6000	500
	6-24	6-26	Coronado	F	1210	130
	6-24	6-28	Apache-Sitgreaves	G	5550	772
	6-24	7-2	"	G	56790	2440
	6-26	6-30	Santa Fe	G	12920	1454
	6-30	6-30	Lincoln	D	115	13
	7-11	7-12	Coronado	F	1400	50
	7-13	7-15	Tonto	D	130	428
	7-15	7-17	Coconino	D	135	45
1972	7-1	7-2	Coronado	D	130	88
	7-2	7-2	Cibola	F	2640	30
	7-16	7-16	Coronado	D	290	12
1973	7-4	7-4	Cibola	D	164	8
	8-3	8-3	Tonto	E	300	6
	8-14	8-14	"	D	125	51
	8-14	8-14	"	D	120	10
	8-23	8-23	"	D	240	47
1974	5-10	5-11	Santa Fe	F	1525	290
	5-27	5-27	Gila	E	750	42

Table IV-14. (cont.)

Year	Date Start	Date Control	Nat'l Forest	Size Class	Acres Burned	No. of Personnel
1974 (cont)	5-27	5-28	Lincoln	E	408	433
	6-3	6-4	"	D	256	250
	6-15	6-15	Tonto	D	175	2
	6-16	6-16	Coronado	E	420	70
	6-23	7-1	Tonto	G	8320	33
	6-24	6-24	Coronado	E	410	36
	6-25	7-2	"	D	120	1672
	6-25	6-25	Cibola	D	202	105
	6-25	6-29	"	D	275	476
	6-26	7-1	Coronado	G	5087	1672
	6-27	6-28	"	E	540	39
	6-27	6-28	"	E	344	9
	6-28	6-31	Gila	D	249	31
	6-28	6-31	"	G	27413	406
	6-29	6-31	Coronado	F	2400	32
	6-29	6-29	Cibola	D	102	34
	6-29	6-30	"	E	670	450
	6-29	6-29	"	D	168	3
	6-29	7-3	Lincoln	G	15512	660
	6-29	6-30	"	E	925	70
	6-30	6-30	Apache-Sitgreaves	D	278	22
	7-1	7-1	Coronado	D	155	9
	7-1	7-2	"	D	150	39
	7-1	7-1	Cibola	D	108	57
	7-2	7-2	Gila	D	135	17
	8-9	8-9	Tonto	D	200	35
	8-23	8-23	Coconino	D	200	24
	8-23	8-24	Tonto	D	120	114
	9-8	9-10	Gila	D	175	55
	9-17	9-17	Tonto	E	350	21

V. LIGHTNING FIRES IN WILDERNESS

Lightning fires in wilderness areas are of special interest to fire and overall resource management. In keeping with the objectives of wilderness area designation it is desirable to have selected fires play a natural role in wilderness ecosystems. Obviously these are lightning fires. Selection of the fires to be allowed to burn involves consideration of many factors including possible spread of these fires to other areas, effects on other resources, safety of people, problems of multiple ignitions in short periods of time and the impacts on the total fire load at given times and places. Accordingly, to provide information for possible use in fire management planning and decision making special studies were made of lightning fires in the wilderness areas of Region Three.

In this research special computer programs were utilized to identify lightning fires occurring in present wilderness and primitive areas and wilderness study areas designated by the Chief of the Forest Service (U.S. Forest Service, October 15, 1974). The total area studied includes 1,690, 240 acres in wilderness and primitive areas and 825,531 acres in wilderness study areas. The total area of 2,551,771 acres amounts to 11.52 percent of the national forest areas in Region Three. This total wilderness area does not include the possible additions under the RARE II program. Constraints on coded fire report information restricted the study period to fires occurring in the years of 1960, 1961 and 1970 through 1974.

V-1. Wilderness Fire Phenomena

Nearly 2500 lightning fires occurred in wilderness during a seven year period. As shown in Table I-1 1936 fires occurred in wilderness and primitive areas and 551 fires in wilderness study areas. This amounts to 15.16 percent of the lightning fires in Region Three during the years 1960, 1961 and 1970 through 1974. The annual occurrence of wilderness lightning fires varied from a low of 219 fires in 1973 to a high of 436 fires in 1961. Fires in all of the various wilderness designations accounted for 19.92 percent of the class C or larger fires in the region during the seven year study period.

Lightning fires in wilderness burned more than 12,000 acres. The area burned includes 4072 acres in wilderness and primitive areas and 7949 acres in wilderness study areas (Table I-1). This amounts to 4.93 percent of the area burned in the region. The area burned in a single year in all wilderness designations varied from a low of 78 acres in 1972 to a high of 6595 acres in 1970. The area burned in 1970 amounted to 54.86 percent of the total area burned by wilderness fires in the seven year study period.

Wilderness fires are smaller in average size than non-wilderness fires. The average size of lightning fires in all of the various wilderness designations was only 4.83 acres as compared to 16.70 acres for non-wilderness fires. The average size of wilderness fires varied from 2.10 acres in designated wilderness and primitive areas to 14.43 acres in wilderness study areas (Table V-1).

Peak lightning fire occurrence in wilderness areas is in July. During the seven years studied 934 fires occurred in July accounting for 37.56 percent of the total. July was the peak month of lightning fire occurrence in both wilderness and primitive areas and wilderness study areas (Table V-2). June was the second leading month for lightning fire occurrence with 28.39 percent of the fires. This monthly occurrence pattern in wilderness follows the same general distribution as found for lightning fires in the entire region except that in wilderness there are more fires in May and fewer in August. The peak monthly load in a single year in wilderness was 203 fires in May 1961.

Table V-1. Number of Lightning Fires by Size Class and Acres Burned In Wilderness and Primitive Areas, Wilderness Study Areas and Non-Wilderness Areas, 1960-1961 and 1970-1974.

Year	Area [1/]	Size Class A	B	C	D	Et	Total Fires	Acres Burned
1960	WPA	193	52	5			250	181
	WSA	61	11	2		2	76	1371
	NWA	1879	293	33	3	12	2220	29938
	Total	2133	356	40	3	14	2546	31490
1961	WPA	294	44	1	1		340	393
	WSA	68	25	3			96	117
	NWA	2026	326	38	9	6	2405	15911
	Total	2388	395	42	10	6	2841	16421
1970	WPA	213	87	5	2	1	308	1491
	WSA	50	25	7	1	1	84	5104
	NWA	1383	371	44	2	9	1809	15181
	Total	1646	483	56	5	11	2201	21776
1971	WPA	189	100	12			301	428
	WSA	43	24	2	1		70	248
	NWA	1489	427	45	7	12	1980	95985
	Total	1721	551	59	8	12	2351	96661
1972	WPA	231	37	1			269	26
	WSA	70	18	1			89	52
	NWA	1795	284	22	2	1	2104	3721
	Total	2096	339	24	2	1	2462	3799
1973	WPA	128	37	5			170	92
	WSA	35	12	2			49	39
	NWA	1130	260	33	4	1	1428	1979
	Total	1293	309	40	4	1	1647	2110
1974	WPA	187	79	31	1		298	1461
	WSA	60	17	7	3		87	1018
	NWA	1500	370	79	13	15	1977	69855
	Total	1747	466	117	17	15	2362	72334
Total	WPA	1435	436	60	4	1	1936	4072
	WSA	387	132	24	5	3	551	7949
	NWA	11202	2331	294	40	56	13923	232570
	Total	13024	2899	378	49	60	16410	244591

[1/] WPA = Wilderness and Primitive Areas
WSA = Wilderness Study Areas
NWA = Wilderness Areas

Table V-2. Number of Lightning Fires by Months in Wilderness, Primitive and Wilderness Study Areas in Region Three, 1960-1961 and 1970-1974.

Year	Area[1/]	April	May	June	July	August	Sept.
1960	WPA	0	59	74	87	23	6
	WSA	1	19	25	22	8	1
	Total	1	78	99	109	31	7
1961	WPA	0	170	35	39	2	3
	WSA	5	33	15	18	4	3
	Total	5	203	50	57	6	6
1970	WPA	0	12	145	126	15	10
	WSA	0	0	27	52	5	1
	Total	0	12	172	178	20	11
1971	WPA	4	8	109	108	54	17
	WSA	1	1	13	41	12	2
	Total	5	9	122	149	66	19
1972	WPA	0	19	81	124	40	5
	WSA	0	12	25	38	12	2
	Total	0	31	106	162	52	7
1973	WPA	0	18	16	90	36	9
	WSA	0	2	8	26	11	1
	Total	0	20	24	116	47	10
1974	WPA	0	12	103	132	22	29
	WSA	0	4	30	31	12	10
	Total	0	16	133	163	34	39
Total	WPA	4	298	563	706	192	79
	WSA	7	71	143	228	64	20
	Total	11	369	706	934	256	99

1/ WPA = Wilderness and Primitive Areas
WSA = Wilderness Study Areas

Ten or more wilderness lightning fires have occurred in a single day on 64 occasions. This level of lightning fire occurrence in a single day varied from a low of three days in 1973 to a high of 14 days in 1962. The peak single day occurrence was 34 lightning fires on July 19, 1970. Twenty or more lightning fires occurred on seven separate days (Table V-3).

Peak wilderness lightning fire loads of more than 40 fires in a three to seven day period have occurred on five occasions. As shown in Table V-3 these peak loads occurred as follows:

May 24-28, 1961	79 fires	13.17 fires per day
July 7-9, 1970	45 "	15.00 "
July 18-20, 1970	65 "	21.67 "
June 23-26, 1971	62 "	15.50 "
June 24-30, 1974	112 "	16.00 "

Thirteen Class D or larger fires occurred in wilderness during the seven year study period. A summary of each fire is contained in Table V-4. These fires burned a total of 8558 acres accounting for 71.14 percent of the area burned in wilderness, primitive and wilderness study areas. The largest fire burning 4700 acres occurred July 3, 1970 in the Alder Creek Wilderness Study Area, Tonto National Forest. The Gila Wilderness Area, Blue Range Primitive Area and Alder Creek Wilderness Study Area each had two large fires. The distribution of large fires was as follows:

	Size Class				
	D	E	F	Total	Acres Burned
Wilderness and Primitive Areas	4	1		5	1697
Wilderness Study Areas	5	2	1	8	6861
Total	9	3	1	13	8558

Table V-3. Summary of Fire Load on Days When Ten or More Lightning Fires Started in Wilderness, Primitive and Wilderness Study Areas 1960-1961 and 1970-1974.

		Wilderness and Primitive Areas		Wilderness Study Areas		Total	
Year	Date	No. of Fires	Acres Burned	No. of Fires	Acres Burned	No. of Fires	Acres Burned
1960	5-5	13	18	3	5	16	23
	6-18	11	2	4	0	15	2
	6-30	10	7	2	1	12	8
	7-4	10	6			10	6
	7-6	13	40	2	0	15	40
	7-10	8	8	2	0	10	8
1961	5-16	27	1	4	0	31	1
	5-17	14	0	3	4	17	4
	5-20	8	0	3	0	11	0
	5-24	11	4	7	6	18	10
	5-25	10	1	3	0	13	1
	5-26	15	4	2	0	17	4
	5-27	16	222	1	0	17	222
	5-28	14	0			14	0
	6-1	10	3	2	0	12	3
	6-6	11	0			11	0
	6-10	8	0	3	0	11	0
	6-14	10	0			10	0
	6-29	7	0	3	2	10	2
	6-30	12	0	3	0	15	0
1970	6-4	11	0	3	0	14	0
	6-5	9	0	5	27	14	27
	6-21	18	0			18	0
	6-23	13	0	1	0	14	0
	6-26	20	0			21	0
	6-27	20	12			20	12
	7-7	10	0	5	0	15	0

Table V-3. (cont.)

Year	Date	No. of Fires	Acres Burned	No. of Fires	Acres Burned	No. of Fires	Acres Burned
1970 (cont)	7-8	12	0	6	0	18	0
	7-9	8	0	4	0	12	0
	7-18	12	0	9	0	21	0
	7-19	26	0	8	35	34	35
	7-20	7	0	3	0	10	0
1971	6-16	11	0	4	0	15	0
	6-17	11	0			11	0
	6-23	12	0	2	0	14	0
	6-24	23	0			23	0
	6-25	14	0	1	0	15	0
	6-26	70		3	0	10	0
	7-1	14	60			14	60
	7-19	7	0	4	0	11	0
	8-1	12	18			12	18
1972	6-3	14	0	2	0	16	0
	6-11	15	0	2	0	17	0
	7-5	12	0	2	52	14	52
	7-6	11	0	3	0	14	0
	7-7	13	0	4	0	17	0
	7-10	8	0	3	0	11	0
	7-15	9	0	1	0	10	0
	7-16	14	0			14	0
	8-5	11	0	1	0	12	0
1973	7-3	8	0	3	0	11	0
	7-7	15	0	1	0	16	0
	7-8	18	0	3	0	21	0
1974	6-24	12	108	4	0	16	108
	6-25	10	34	4	275	14	309
	6-26	11	0	3	0	14	0
	6-27	16	20	1	0	17	20

Table V-3. (cont.)

Year	Date	No. of Fires	Acres Burned	No. of Fires	Acres Burned	No. of Fires	Acres Burned
1974 (cont)	6-28	22	34	1	0	23	34
	6-29	14	229	2	0	16	229
	6-30	7	95	5	0	12	95
	7-1	8	25	2	0	10	25
	7-2	22	0	3	0	25	0
	7-3	19	0	3	0	22	0
	7-9	9	15	1	0	10	15

Table V-4. Summary of Class D or Larger Lightning Fires in Wilderness, Primitive and Wilderness Study Areas, 1960-1961 and 1970-1974.

Year	Date	Wilderness Area and Forest	Size Class	Acres Burned	Total Lightning Fires On Forest	Total Lightning Fires In Region
1960	5-23	Portal Peak WSA (Coronado)	E	530	3	24
	7-5	Castle Creek WSA (Prescott)	E	685	4	33
1961	5-27	Blue Range PA (Apache)	D	210	4	62
1970	5-28	Blue Range PA (Apache)	D	230	5	14
	7-3	Alder Creek WSA (Tonto)	F	4700	23	48
	7-27	Superstition Adn. WSA (Tonto)	D	160	2	10
	8-7	Gila WA (Gila)	E	900	10	10
	8-31	Galiuro WA (Coronado)	D	182	1	7
1971	7-15	Secret Mtn. Red Rock WSA (Coconino)	D	135	17	55
1974	6-3	S. Guadalupe Mtns. WSA (Lincoln)	D	256	2	23
	6-25	Apache Kid WSA (Cibola)	D	275	3	71
	8-23	Alder Creek WSA (Tonto)	D	120	8	23
	9-8	Gila WA (Gila)	D	175	4	13

More than 85 percent of the wilderness lightning fires occur at elevations above 8500 feet. In the Wilderness and Primitive Areas 87.71 percent of the fires were above 6500 feet with the peak occurrence zone between 6501 and 7500 feet. The same general pattern is found in the Wilderness Study Areas with 75.86 percent of the fires above 6500 feet (Table V-5).

More than 50 percent of the wilderness lightning fires occur in ponderosa pine. In all types of wilderness areas ponderosa pine stands are the dominant zone of lightning fire occurrence. Grass and mixed conifer cover types rank second and third respectively in the wilderness, primitive and wilderness study areas. Relatively few fires occur in brush, woodland, spruce and aspen types (Table V-6).

Nearly 45 percent of the wilderness lightning fires occur in high rate-of-spread fuels. As shown in Table V-7 a total of 1108 fires occurred in high rate-of-spread fuels accounting for 44.62 percent of the fires in both wilderness and primitive areas and wilderness study areas. Extreme rate-of-spread fuels accounted for 18.87 percent of the fires in wilderness and primitive areas and 17.30 percent in wilderness areas. On 61.86 percent of the wilderness fires fuels were classified as medium in resistance-to-control. A very high total of 340 fires had fuels classified as extreme in both rate-of-spread and resistance-to-control.

Table V-5. Distribution of Wilderness Lightning Fires by Elevation Zone, 1960-1961 and 1970-1974.

	Wilderness and Primitive Areas	Wilderness Study Areas	Total	
	No. Fires	No. Fires	No.	%
500-2500	3	4	7	0.28
2501-3500	5	7	12	0.48
3501-4500	20	13	33	1.33
4501-5500	33	37	70	2.81
5501-6500	177	72	249	10.01
6501-7500	640	190	830	33.37
7500-8500	783	137	920	36.99
Over 8500	275	91	366	14.72
Total	1936	551	2487	

Table V-6. Distribution of Wilderness Lightning Fires by Cover Type, 1960-1961 and 1970-1974.

	Wilderness and Primitive Areas	Wilderness Study Areas	Total	
	No. Fires	No. Fires	No.	%
Grass	631	178	809	32.73
Spruce	16	6	22	0.89
Mixed Conifer	177	63	240	9.71
Brush	62	28	90	3.64
Ponderosa Pine	999	240	1239	50.12
Aspen	6	2	8	0.32
Woodland	41	23	64	2.59
Total	1932	540	2472[1/]	

[1/] Total number of fires with cover type coded

Table V-7. Distribution of Wilderness Lightning Fires by Fuel Rate-of-Spread and Resistance-to-Control Classification, 1960-1961 and 1970-1974.

Rate-of-Spread	Res.-to-Control	Wilderness and Primitive Areas	Wilderness Study Areas	Total	
		No. Fires	No. Fires	No.	%
Low	Low	47	56		
	Medium	78	15		
	High	12	6		
	Extreme	0	0		
Low	Total	137	77	214	8.62
Medium	Low	5	3		
	Medium	560	117		
	High	4	12		
	Extreme	0	0		
Medium	Total	569	132	701	28.23
High	Low	1	4		
	Medium	631	120		
	High	190	110		
	Extreme	41	11		
High	Total	863	245	1108	44.62
Extreme	Low	33	15		
	Medium	6	9		
	High	26	31		
	Extreme	300	40		
Extreme	Total	365	95	460	18.53
Grand Total		1934	549	2483	

V-2. The Wilderness Fire Load

Wilderness and Primitive Areas

The combined Gila Wilderness and Primitive Areas Account for more than half of the lightning fires. During the seven year study period 1000 lightning fires occurred in these areas on the Gila National Forest accounting for 51.65 percent of the total in the designated Wilderness and Primitive Areas. Also the Gila areas lead in area burned with 2028 acres or 49.80 percent of the total (Table V-8).

More than 300 lightning fires occurred in two other Primitive Areas. As shown in Table V-8 the Blue Range Primitive Area on the Apache National Forest had 320 fires and the Black Range Primitive Area on the Gila National Forest had 316 fires. The area burned on the Blue Range was 947 acres, second highest among the designated Wilderness and Primitive Areas. The area burned on the Black Range was only 91 acres.

Wilderness and Primitive Areas on the Apache and Gila National Forests Recorded 85 percent of the lightning fires and 75 percent of the area burned. A summary of these concentrations of wilderness fires on the two national forests is shown in Table V-9. The fire occurrence exceeded 170 fires in a single year on six occasions in the two areas on the Gila National Forest. More than 50 fires were recorded in three years on the Blue Range Primitive Area of the Apache National Forest. Burns of more than 300 acres in a single year were recorded in 1970 and 1974 on the Gila and in 1970 on the Apache.

The peak single day lightning fire occurrence has been recorded in the Gila Wilderness Area. The Gila is the only wilderness or primitive area to record more than 15 lightning fires in a single day. This high level of fire occurrence was recorded five times in the Gila Wilderness Area as follows:

May 16, 1961	23 fires
July 19, 1970	16 "
June 24, 1971	17 "
July 2, 1974	18 "
July 3, 1974	17 "

Table V-8. Summary of Lightning Fires in Wilderness and Primitive Areas in Region Three National Forests (7 year period 1960 and 1961, 1970 thru 1974).

National Forest	Area	Acres in Area	No. of Fires	Fires Per Million Acres (An Ave.)	No. Class C or Larger Fires	% Class C or Larger	Acres Burned
Apache	Blue Range P.A.	211,710	320	216	18	5.62	947
"	Mt. Baldy W.A.	7,106	0	0	0	0	0
Carson	Wheeler Peak W.A.	6,029	0	0	0	0	0
Carson and Santa Fe	Pecos W.A.	167,416	10	9	1	10.00	42
Coronado	Chiricahua W.A.	18,000	79	627	2	11.39	174
"	Galiro W.A.	52,717	15	41	2	13.33	232
Coconino, Kaibab & Prescott	Sycamore Canyon W.A.	47,762	63	188	2	3.17	35
Gila	Gila W.A. and P.A.	566,704	1000	252	26	2.60	2,028
"	Black Range P.A.	169,984	316	266	2	0.63	91
Lincoln	White Mtns W.A.	31,283	9	41	1	11.11	76
Prescott & Tonto	Pine Mtn W.A.	20,061	14	100	0	0	6
Santa Fee	San Pedro Parks W.A.	41,132	9	31	0	0	0
Tonto	Mazatzal, W.A.	205,346	43	30	4	9.30	80
"	Sierra Ancha W.A.	20,850	34	233	5	5.88	100
"	Superstition	124,140	24	28	5	20.83	261
TOTALS		1,690,240	1936	164	65	3.36	4,072

Table V-9. Summary of Wilderness and Primitive Area Lightning Fires, Apache and Gila National Forests, 1960-1961 and 1970-1974.

Year	Apache National Forest Blue Range P.A.		Gila National Forest Gila W.A. and P.A.		Gila National Forest Black Range P.A.	
	No. Fires	Acres Burned	No. Fires	Acres Burned	No. Fires	Acres Burned
1960	31	17	142	53	30	21
1961	37	218	202	53	60	45
1970	51	325	139	984	58	0
1971	65	121	162	117	43	0
1972	47	0	139	26	39	0
1973	30	60	77	0	33	0
1974	59	206	139	795	53	25
TOTAL	320	947	1000	2028	316	91
Average Size Per Fire		2.96		6.42		0.29

More than 215 fires per million acres occur in five Wilderness and Primitive Areas. As shown in Table V-8 the Blue Range and Black Range Primitive Areas and the Chiricahua, Gila and Sierra Ancha Wilderness Areas all have average annual lightning fire occurrence densities of more than 215 fires per million acres. The peak density of 627 fires per million acres is in the Chiricahua Wilderness Area. This is the greatest lightning fire density of any wilderness area in Region Three, but as shown later is exceeded by two wilderness study areas.

Wilderness Study Areas

The twenty wilderness study areas in Arizona recorded 256 lightning fires in seven years. Five of these areas - the Secret Mountain Red Rock (Coconino), Portal Peak and Black Rock (Coronado), Castle Creek (Prescott) and Alder Creek (Tonto) had more than 15 lightning fires during the study period. The Secret Mountain Red Rock Wilderness Study Area had 76 fires to lead all areas in Arizona (Table V-10).

The average annual lightning fire density in Arizona Wilderness Study Areas is 96 fires per million acres. This may be compared to the occurrence densities of 111 and 68 fires in the Northwest and Southwest Zones of Arizona National forests (Table II-G). Nine of the Wilderness Study Areas in Arizona recorded an annual average of more than 150 fires per million acres. The Sierra Ancha Addition, Tonto National Forest recorded the highest occurrence rate of any type of area in Region Three. The 11 lightning fires on only 1500 acres in this wilderness study area amount to an average annual occurrence of 1048 fires per million acres (Table V-10).

The area burned in Arizona Wilderness Study Areas by Lightning Fires was 7103 acres. The Portal Peak (Coronado), Castle Creek (Prescott) and Alder Creek (Tonto) Wilderness Study Areas all burned more than 500 acres. Alder Creek lead all areas with 5247 acres burned accounting for 73.87 percent of the area burned in Arizona Wilderness Study Areas. Class C or larger fires accounted for 7.49 percent of the total wilderness study area fires in the state (Table V-10).

The 24 wilderness study areas in New Mexico recorded 295 lightning fires in seven years. No lightning fires occurred in six of these areas. As shown in Table V-11 there were seven areas with more than 20 lightning fires. The Frisco Wilderness Study Area, Gila National Forest recorded 80 fires to lead all areas in New Mexico.

The average annual lightning fire density in New Mexico Wilderness Study Areas is 99 fires per million acres. Seven of the areas recorded an average annual occurrence of more than 120 fires per million acres and three more than 200. Peak occurrence density was 802 lightning fires per million acres in the Frisco Wilderness Study Area. This is the second highest lightning fire occurrence rate of any type of area in Region Three. It again illustrates the

potential magnitude of lightning fires in the various types of wilderness areas in the Gila National Forest (Tables V-9 and V-11).

A relatively small area has been burned by lightning fires in New Mexico Wilderness Study Areas. Only nine areas reported any acres burned. In these areas 843 acres were burned in the seven year study period. The Apache Kid (Cibola) and Southern Guadalupe (Lincoln) Wilderness Study Areas recorded burns of 345 and 332 acres respectively to account for 80.31 percent of the area burned in New Mexico. Only 4.07 percent of the fires in the New Mexico areas were Class C or larger in size (Table V-11).

Table V-10. Summary of Lightning Fires in New Wilderness Study Areas in Arizona National Forests (7 year period 1960 and 1961, 1970 thru 1974).

National Forest	Wilderness Study Area	Acres in Area	No. of Fires	Fires Per Million Acres (An Ave.)	No Class C or Larger	% Class C or Larger	Acres Burned
Coconino	Secret Mtn Red Rock	30,743	76	290	1	1.32	145
"	Fossil Creek Headwaters	11,720	13	158	0	0	0
"	Wet Beaver	8,794	8	325	0	0	0
Coronado	Portal Peak	16,000	20	179	1	5.00	530
"	Jones Ridge	3,500	4	163	0	0	0
"	Erickson	9,000	10	159	0	0	0
"	Black Rock	14,100	16	162	1	6.25	27
"	Tumacacori	39,600	10	36	3	30.00	95
Kaibab	Kanab Creek	71,000	8	16	0	0	0
"	Saddle Mtn	8,400	15	255	0	0	0
Prescott	Granite Mtn	5,500	2	52	0	0	0
"	Castle Creek	15,000	18	171	2	11.11	730
Tonto	Verde	31,840	3	13	2	66.67	102
"	Hells Gate	32,840	11	48	0	0	0
"	Sierra Ancha Addition	1,500	11	1048	0	0	5
"	Salome	14,900	5	48	1	20.0	62
"	Alder Creek	30,500	18	80	8	47.06	5247
"	Goldfield	11,300	0	0	0	0	0
"	Lime Creek	21,800	6	39	0	0	0
"	Superstition Additions	20,500	2	14	1	50.00	160
TOTALS		398,577	256	96	20	7.49	7103

Table V-11. Summary of Lightning Fires in New Wilderness Study Areas in New Mexico National Forests (7 year period 1960 and 1961, 1970 thru 1974).

National Forest	Wilderness Study Area	Acres in Area	No. of Fires	Fires Per Million Acres (An. Ave.)	No. Class C or Larger	% Class C or Larger	Acres Burned
Apache	Aspen Mtn	17,600	15	122	0	0	0
Carson	Latir Peak	18,600	2	15	0	0	0
"	Columbine Hondo	34,600	8	33	0	0	0
"	South Fork	9,400	0	0	0	0	0
"	Jicarita Creek	10,440	0	0	0	0	0
"	Cruces Basin	17,600	3	24	0	0	0
"	Sierra Negra	8,300	0	0	0	0	0
"	Canjilon Mtn	5,000	0	0	0	0	0
Cibola	Guadalupe	6,320	0	0	0	0	0
"	Apache Kid	61,400	30	70	3	10.00	345
"	Ryan Hill	28,000	25	128	2	8.00	20
"	Manzano	27,000	16	85	1	6.25	88
Gila	Frisco	14,246	80	802	0	0	14
"	Gila Additions	16,493	6	52	0	0	0
"	Gila Contiguous	19,000	17	128	0	0	1
Lincoln	Capitan Mtn	29,600	44	212	1	2.27	16
"	Southern Guadalupe	19,800	6	43	4	66.67	332
"	White Mtns	12,880	22	244	1	4.55	21
Santa Fe	San Pedro Park Addition	5,500	4	104	0	0	0
"	North Fork Lake	1,420	0	0	0	0	0
"	Bear Creek	4,550	3	94	0	0	6
"	Santa Fe River	7,545	0	0	0	0	0
"	Parito Basin	33,700	9	38	0	0	0
"	Macho Canyon	18,000	5	40	0	0	0
TOTALS		426,994	295	99	12	4.07	843

Summary of Wilderness Fire Load

Table V-12 presents a summary of the lightning fire load in wilderness, primitive, wilderness study and non-wilderness areas in Region Three. The following are major features of the total present and possible future lightning fire load in wilderness and the relationships to the overall load in the region.

1. Lightning fire occurrence per million acres is greater in present wilderness and primitive areas than in non-wilderness areas.
2. Addition of the Wilderness Study Areas to the officially designated wilderness system will increase number of lightning fires to be managed under wilderness policies by 59 percent.
3. The average annual area burned per million acres by lightning fires in present wilderness and primitive areas is only one-fifth that burned in non-wilderness areas.
4. The average annual area burned per million acres by lightning fires in wilderness study areas is four times greater than in present wilderness and primitive areas, but slightly smaller than in non-wilderness areas.
5. A higher percentage of lightning fires reach Class C or larger size in all types of wilderness areas than in non-wilderness areas.
6. The average size per lightning fire in present wilderness and primitive areas is only one-eighth as large as fires in non-wilderness areas.
7. The average size per lightning fire is 7 times greater in wilderness and primitive areas, but slightly smaller than in non-wilderness areas.
8. The total lightning fire load in all types of wilderness areas accounts for 15 percent of the fires and 5 percent of the area burned in Region Three.

Table V-12. Summary of Lightning Fire Load in Wilderness, Primitive, Wilderness Study and Non-Wilderness Areas in Region Three, 1960-1961 and 1970-1974.

	Wilderness and Primitive Areas	Wilderness Study Areas	Non-Wilderness Areas	Total All Areas
Total No. of Fires	1936	551	13923	16410
Annual Average No. of Fires	277	79	1989	2344
Acres in Area	1,690,240	825,531	19,626,040	22,141,811
Annual Average No. of Fires Per Million Acres	164	96	101	106
Total Acres Burned	4072	7949	232,570	244,591
Annual Average Acres Burned	582	1136	33224	34,942
Annual Average Area Burned Per Million Acres	344	1376	1693	1578
Total No. Class C or Larger Fires	65	32	390	487
% Class C or Larger Fires	3.36	5.81	2.86	2.97
Average Size Per Fire	2.10	14.43	16.70	14.90
% of Total Fires in R-3	11.80	3.36	84.84	100
% of Total Burn in R-3	1.66	3.25	95.09	100

V-3. Control of Wilderness Lightning Fires

The great majority of wilderness lightning fires are detected from lookout stations. During the seven year study period 63.41 percent of the fires were detected by Forest Service lookouts. In both wilderness and primitive areas and wilderness study areas lookouts are the dominant method of lightning fire detection (Table V-13). It was not determined how many of these lookouts were in wilderness or in adjacent non-wilderness areas. It is significant to note, however, that lookout stations including their supporting communication, transportation and supply systems have played a major role in providing detection and continuing information on wilderness fires.

Aircraft provide the second leading method for detection of wilderness lightning fires. Forest Service aircraft detected 20.31 percent of the fires. Other aircraft detected 1.97 percent. In all types of wilderness only 14.11 percent of the fires were detected by ground based personnel other than lookouts (Table V-13).

Wilderness lightning fires are detected relatively fast. As shown in Table V-15 more than 50 percent of them are detected within three hours. However, it should be noted that 34 percent of the fires had elapsed detection times of more than 12 hours.

Airborne control forces provide the primary method of initial attack for wilderness lightning fires. Air tankers, smokejumpers and helitack crews were used in initial attack on 60.32 percent of the fires. Helitack crews lead all other methods of initial attack accounting for 39.88 percent of the fires (Table V-14). In the wilderness and primitive areas smokejumpers made initial attack on 18.41 percent of the fires.

Plow-trenchers and ground tankers have been used in initial attack of wilderness fires. In established wilderness and primitive areas plow-trenchers were used on 7 fires and ground-tankers on 17 fires. In wilderness study areas ground tankers were used on 19 fires (Table V-14).

Table V-13. Distribution of Wilderness Lightning Fires By Detection Method, 1960-1961 and 1970-1974.

Detection Method	Wilderness and Primitive Areas No. Fires	Wilderness Study Areas No Fires	Total No.	Total %
F.S. Lookout	1307	270	1577	63.41
Other Lookout	3	2	5	0.21
Patrolman	16	36	52	2.09
Other F.S.	121	45	166	6.67
Cooperator	8	6	14	0.56
F.S. Permittee	20	20	40	1.61
F.S. Aircraft	399	106	505	20.31
Other Aircraft	35	14	49	1.97
Others	27	52	79	3.18
TOTAL	1936	551	2487	

Table V-14. Distribution of Wilderness Lightning Fires By Initial Attack Method, 1960-1961 and 1970-1974.

Initial Attack Method	Wilderness and Primitive Areas	Wilderness Study Areas	Total	
	No. Fires	No Fires	No.	%
Plow-Trenches	7	0	7	0.28
Ground-Tanker	17	19	36	1.45
Ground-Hand	607	335	942	37.91
Heli-Tanker	1	0	1	0.04
Air-Tanker	78	49	127	5.11
Smoke-Jumper	356	25	381	15.33
Helitack	868	123	991	39.88
TOTAL	1934	551	2485	

Table V-15. Summary of Wilderness Lightning Fire Detection, Initial Attack and Control, 1960-1961 and 1970-1974.

	Wilderness and Primitive Areas No. Fires	Wilderness Study Areas No. Fires	Total No.	Total %
Elapsed Detection Time				
Within 3 Hours	975	284	1259	50.62
3 - 12 Hours	299	82	381	15.32
Over 12 Hours	662	185	847	34.06
Total	1936	551	2487	
Elapsed Initial Attack Time				
Within 3 Hours	1616	428	2044	82.19
3 - 12 Hours	197	86	283	11.38
Over 13 Hours	123	37	160	6.43
Total	1936	551	2487	
Elapsed Fire Control Time				
Within 3 Hours	385	131	516	20.75
3 - 12 Hours	474	140	614	24.69
Over 12 Hours	1077	280	1357	54.56
Total	1936	551	2487	

Fast initial attack is common on wilderness lightning fires. The studies of fire control show that 82.19 percent of all wilderness fires were attacked within three hours following discovery. Only 6.43 percent of the fires had elapsed initial attack times of more than 12 hours. These records for initial attack are generally similar in both wilderness and primitive areas and wilderness study areas (Table V-15).

Most wilderness lightning fires have control times of more than 12 hours. The individual fire reports show that 54.56 percent of the fires had control times of more than 12 hours following arrival of attack forces. Only 20.75 percent were controlled within 3 hours (Table V-15).

VI. CRITICAL LIGHTNING FIRE SITUATIONS

Occasional great peaks in fire occurrence, area burned and control requirements are an exceedingly important characteristic of lightning fires. Natural resource and fire managers have long recognized these features of the lightning fire problem. The word "critical" has often been used to describe the periods, years or locations of great outbreaks of lightning fires. In this study we have focused efforts on a definition of critical lightning fire situations and on analysis of their significant features.

The study of critical lightning fire situations in Region Three is patterned after a similar study made in Region One (Barrows, Sandberg and Hart, 1976). The definition of critical situations presented in Chapter VI-1 correspond to those developed for the earlier studies in Region One. However, it is recognized that major differences in lightning fire situations exist between the two regions. These differences include:

> Region Three has a much longer lightning fire season (actually two seasons, one dry and one wet), records more total fires but has fewer fires in short time periods. Region Three has a greater average annual area burned. Region One has a shorter lightning fire season, records fewer total fires but experiences greater peak loads in short time periods.

VI-1. Definition of Critical Lightning Fire Situations.

It has often been said that "beauty is in the eyes of the beholder." The same may be said for critical lightning fire situations. What is critical to one person or group of persons may not be judged in the same way by others. We recognize the complexity of precisely defining a critical lightning fire situation. However, the wealth of data now available on lightning fires does permit identification of those specific situations placing a critical load on fire management organizations or producing severe impacts on natural resources and society.

Critical lightning fire situations involve many factors and dimensions. These include:

(1) Time span -- single day, series of days, month, year.

(2) Location -- individual national forests, groups of forests, zones, total region.

(3) Values at stake -- timber, forage, wildlife, watersheds, recreation areas, scenic beauty, developed facilities, industries, communities, air and water pollution control, public safety.

(4) Fire occurrence -- numbers of fires by size class, time and location.

(5) Fire weather and fire danger rating -- at time of occurrence and following occurrence.

(6) Acres on fire -- by time and location.

(7) Fire control requirements -- personnel, equipment, supplies, transportation.

(8) Costs -- fire control, damage.

Complex interrelationships exist between each of these factors and their dimensions. Because of this complexity and the lack of appropriate data on many items no attempt is made to use all of the factors in developing definitions for critical situations. The available data on specific outbreaks of fires when examined in specific time periods and locations can provide a useful basis for critical definitions. In the future when additional data is available these definitions can be further examined and refined.

Fire management experience indicates that strictly from a fire viewpoint (exclusive of resource values and social concerns) the following are ingredients in a critical situation:

(1) Buildup. A period of dry weather makes fuels become highly flammable.

(2) Fire Occurrence. Combinations of large numbers of fires in a short time period (1 to 10 days) or continued new ignitions over longer periods requiring full deployment of the available initial attack forces.

(3) Fire Weather. The weather conditions during and immediately following fire ignitions provide a high potential for fire spread.

(4) Large Fires. The existence of Class D or larger fires requires a massive deployment of fire suppression forces recruited primarily from external sources.

Our analysis of lightning fires in Region Three indicates that all four of these ingredients must be present to generate a critical situation. For example:

(1) Buildup (highly flammable fuels) is a dangerous situation, but is only a threat until fires occur.

(2) Large numbers of fires even in the absence of buildup and severe fire weather can result in large scale deployment of fire attack forces. However, the experience in Region Three shows that fire management organizations have been able to effectively handle situations where the only critical ingredient is large numbers of fires.

(3) Large numbers of lightning fires may not create a critical situation if precipitation during and following the storm lowers fuel flammability. On the other hand severely dry and windy weather following ignitions can cause a high potential for a critical situation.

(4) Large uncontrolled fires impact the overall fire management organization including commitment of fire suppression resources and the continuing availability of forces to attack new fires that may occur during the periods when existing fires are being fought.

In defining critical lightning fire situations consideration also is given to the size of the area that may be impacted. The great mobility of modern fire fighting organizations strongly influences this factor. An individual national forest at some period of time may have each of the four ingredients of a critical lightning fire situation (buildup, fire occurrence, severe fire weather and large fires) and yet the result may be less than a critical situation. Other fire fighting forces within the region or available from outside the region can most often prevent full development of a critical situation. Our studies indicate that virtually every truly critical situation was of a multi-forest, regional or interregional dimension.

VI-2. Analysis of Critical Lightning Fire Situations

As explained in the previous chapter the peak load factors of total fire occurrence, numbers of large fires and area burned are ingredients in a critical lightning fire situation. In this study we present data for each of these factors to permit judgements in identification of critical situations. Analyses of the specific weather factors related to critical situations are beyond the scope of this study. However, we have identified specific time periods and locations of peak loads which can be related to future studies of both lightning and weather factors.

Peak Single Day Fire Loads

Peak single day lightning fire occurrence in the region exceeds 100 fires. During the 1960-1974 period there were 12 days when more than 100 lightning fires occurred. The peak occurrence of any day in the 15 years studied was June 28, 1960 when 143 lightning fires started. In 1970 there were three days with more than 100 fires including successive days on July 18 and 19. Days with more than 100 fires were recorded twice in May, four times in June, five times in July and once in August (Table VI-1).

Peak single day fire occurrence does not always signify large areas burned. Fires starting on the 12 peak occurrence days burned a total of 76,607 acres. However 98.83 percent of this area burned on a single day. The area burned exceeded 100 acres on only three other days. The average size for the 1347 fires starting on peak occurrence days was 56.87 acres (Table VI-1).

Twenty or more lightning fires occur on a single day in individual national forests. On two occasions more than 50 fires have occurred on a single day in individual forests. These peak outbreaks of lightning fires were recorded on June 28, 1960 when 57 fires started on the Coconino and July 2, 1974 when 55 started on the Gila. The six national forests recording 20 or more fires were as follows:

	20 + fires	40 + fires
Apache-Sitgreaves	26 days	1 day
Coconino	28 "	2 days
Coronado	4 "	
Kaibab	7 "	
Gila	33 "	2 "
Tonto	5 "	

Three or more large lightning fires start in the Region on a single day. During the 1960-1974 period 3 or more Class D or larger fires started on 15 days as follows:

May 2, 1960	4 fires
May 20, 1960	3 "
May 12, 1961	3 "
June 26, 1962	4 "
June 25, 1964	3 "
July 5, 1965	5 "
June 14, 1966	3 "
June 19, 1968	4 "
May 23, 1969	3 "
Aug. 4, 1969	3 "
July 3, 1970	3 "
June 24, 1971	6 "
June 25, 1974	3 "
June 29, 1974	6 "
July 1, 1974	3 "

Five National Forests have had three or more large fires start in a single day. This level of single day occurrence of Class D or larger fires was recorded on individual national forests as follows:

Apache-Sitgreaves	June 24, 1971	5 fires
Coronado	May 2, 1960	4 "
"	May 12, 1961	3 "
"	June 26, 1962	4 "
"	July 5, 1965	5 "
"	June 19, 1968	4 "
Cibola	June 29, 1974	3 "
Gila	May 23, 1969	3 "
Tonto	July 3, 1970	3 "

Lightning fires ignited on a single day may cause more than 5000 acres to be burned in the region. During the 1960-1974 period there were 17 days when

lightning fire ignitions resulted in burns of more than 5000 acres (Table VI-2). These "5000 plus" days accounted for burning 258,286 acres or 70.88 percent of the area burned in Region Three during the 15 year period. These days exhibit many of the characteristics of critical lightning fire situations including multiple ignitions, many Class D or larger fires and requirements for large numbers of fire fighters. More than 25 lightning fires started on 15 of the 17 "5000 plus" days. There were 41 Class D or larger fires. The average size per fire was 315.37 acres. June 24, 1971 was the most critical lightning fire day in the 15 year period with 103 fires and 75,713 acres burned.

Table VI-1. Number of Fires by Size Class and Area Burned on Days When More Than 100 Lightning Fires Occurred in Region Three, 1960-1974.

Date	A	B	C	D	E	F	G	Total	Acres Burned
6-28-60	119	23	1					143	41
5-16-61	90	11	1	1				103	319
5-24-61	93	18	4	1				116	246
6-29-62	110	2						112	12
8-16-62	105	20						125	27
7-7-70	91	11	2					104	59
7-18-70	87	16						103	0
7-19-70	97	20	2					119	105
6-24-71	53	38	6			3	3	103	75,713
7-16-71	90	20	2					112	40
6-3-72	95	11						106	30
7-8-73	88	12	1					101	15
Total	1118	202	19	2		3	3	1347	76,607

Average Size Per Fire 56.87

Table VI-2. Summary of Fire Load on Days When Lightning Fire Ignitions Resulted in Burning More Than 5000 Acres in Region Three, 1960-1974.

Year	Date	Regional Totals		National Forests With Class D or Larger Fires					
		No. of Fires	Acres Burned		No. of Fires	Acres Burned		No. of Fires	Acres Burned
				Coronado					
1960	5-2	34	7212		4	6187			
				Kaibab					
	5-21	4	8703		1	8673			
				Gila					
	7-9	63	5013		1	5000			
				Coronado					
1961	5-12	32	8166		3	8134			
				Kaibab					
1962	7-23	77	8702		1	8660			
				Tonto					
1964	6-27	54	5142		1	5000			
				Coronado			Tonto		
1965	7-13	54	6805		1	6664	1	132	
				Tonto			Coronado		
1966	5-14	2	12,720		1	12,720			
	6-14	53	8817		2	8125	1	450	
				Coronado					
1968	6-19	60	23,335		4	23,277			
				Tonto					
1970	7-3	48	13,412		3	13,400			
				Apache-Sitgreaves			Coronado		Santa Fe
1971	6-24	103	75,713		5	74,340	1	1210	
	6-26	27	13,110						1 12,920
				Tonto			Coronado		
1974	6-23	28	8320		1	8320			
	6-26	45	5150				1	5087	
									Gila
	6-28	59	27,846						2 27,662
				Cibola			Coronado		Lincoln
	6-29	76	20,120		3	940	1	2400	2 16,437
Total		819	258,286						
Average Size Per Fire			315.37						

Peak Multiple Day Fire Loads

Peak lightning fire loads during four to ten day periods have occurred in Region Three. During the 1960-1974 period there were 14 periods when combinations of multiple lightning fire ignitions and large fires generated major fire loads for four or more successive days (Table IV-3). The 86 days included in these 14 periods accounted for 3707 lightning fires and 291,741 acres burned. There were 220 Class C or larger fires or 5.93 percent. All of the Class G fires during the 15 years studied occurred during the 14 peak load periods. The average size per fire during these periods was 78.70 acres. The area burned amounted to 80.06 percent of the 15 year regional total.

Peak lightning fire loads may last for nearly three weeks. During the 18 day period June 16 through July 3, 1971 a total of 617 lightning fires burned 92,218 acres (Figure VI-1.). New fires occurred on every day of the period and 30 or more occurred on 9 days. In one three day period 223 lightning fires occurred. These were 14 Class D or larger fires. On all but one day of the period large fires were out of control. Another long period of intensive fire activity occurred June 23 through July 5, 1974 (Figure VI-2.). During this period 781 lightning fires burned 62,245 acres. There were 28 or more new fires every day of the period. In one four day period 301 fires started. There were 21 Class D or larger fires. Large fires were out of control for 12 straight days.

Man-caused fires may compound critical lightning fire situations. It was not the purpose of this study to evaluate man-caused fires. However, it is recognized that the critical lightning fire situations may have been further amplified by requirements for control of man-caused fires. A total evaluation of both lightning and man-caused fires is needed.

Table VI-3. Summary of Lightning Fire Load During Critical Periods of Days in Region Three, 1960-1974.

Year	Dates	A	B	C	D	E	F	G	Total	Acres Burned
1960	5,1-5	178	53	11	1	2	3	0	248	10,761
	5,19-23	30	11	3	0	3	2	1	50	13,269
	7,5-9	223	20	5	0	1	0	1	250	5,851
1961	5,11-17	277	47	4	1	1	2	1	333	11,284
1962	7,21-24	191	8	1	0	0	0	1	201	8,822
1964	6,24-29	228	30	5	4	1	1	0	269	6,419
1965	7,3-8	163	32	17	1	3	2	0	218	7,147
	7,10-14	269	24	2	2	0	0	1	298	7,207
1966	5,14-20	26	9	0	0	0	0	1	36	12,732
	6,14-20	219	61	13	2	3	1	1	300	12,036
1968	6,17-22	99	55	7	1	3	2	1	168	26,344
1970	7,2-9	371	56	9	0	3	2	1	442	15,522
1971	6,22-26	148	103	11	2	0	3	4	271	89,229
1974	6,23-7,2	390	166	46	11	5	1	4	623	65,118
Total		2812	675	134	25	25	19	17	3707	291,741

Summary of Critical Lightning Fire Period, June 16 - July 3, 1971,

617 Fires. 92,218 Acres Burned

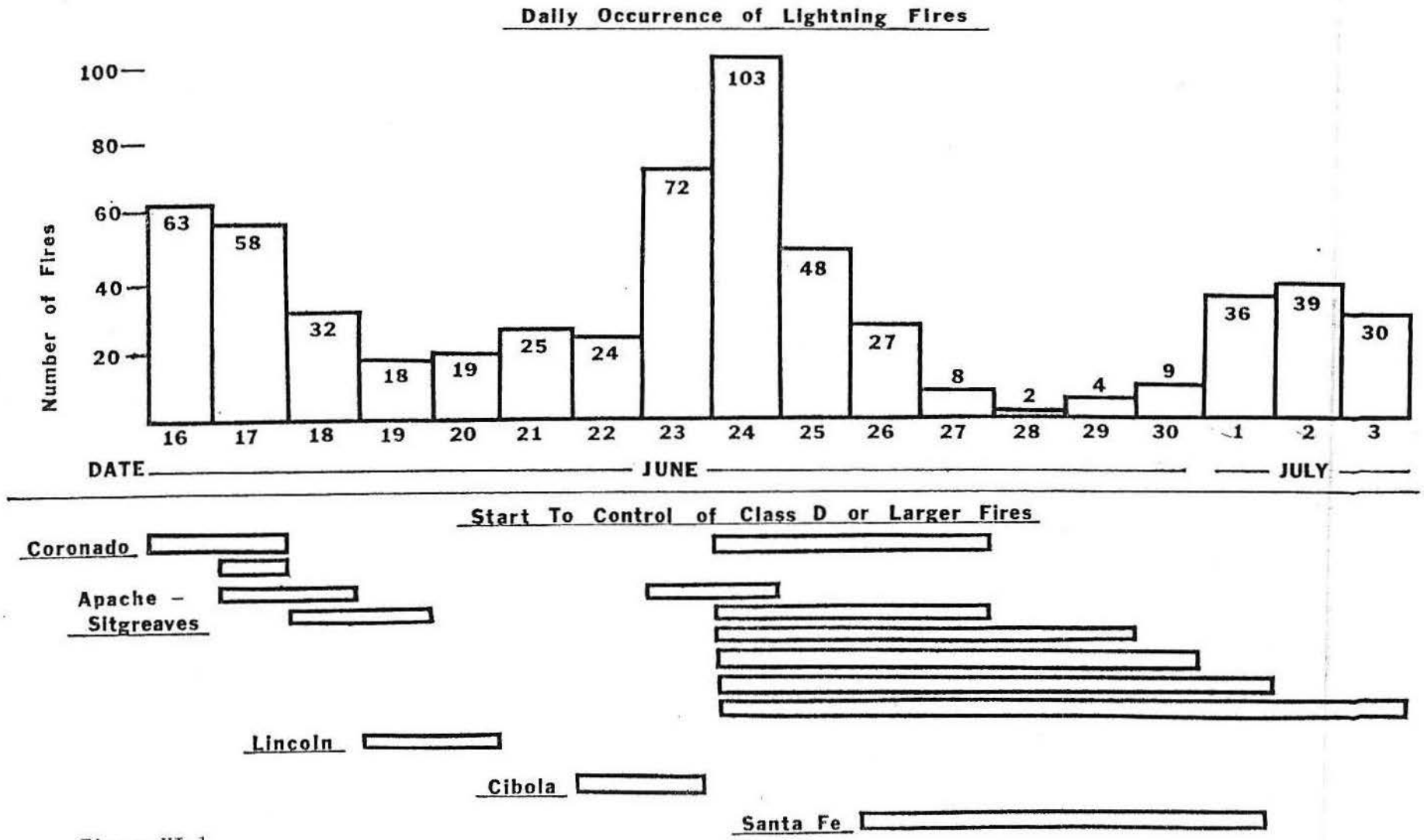

Figure VI-1.

June 23 - July 5, 1974, 781 Fires. 62,245 Acres Burned

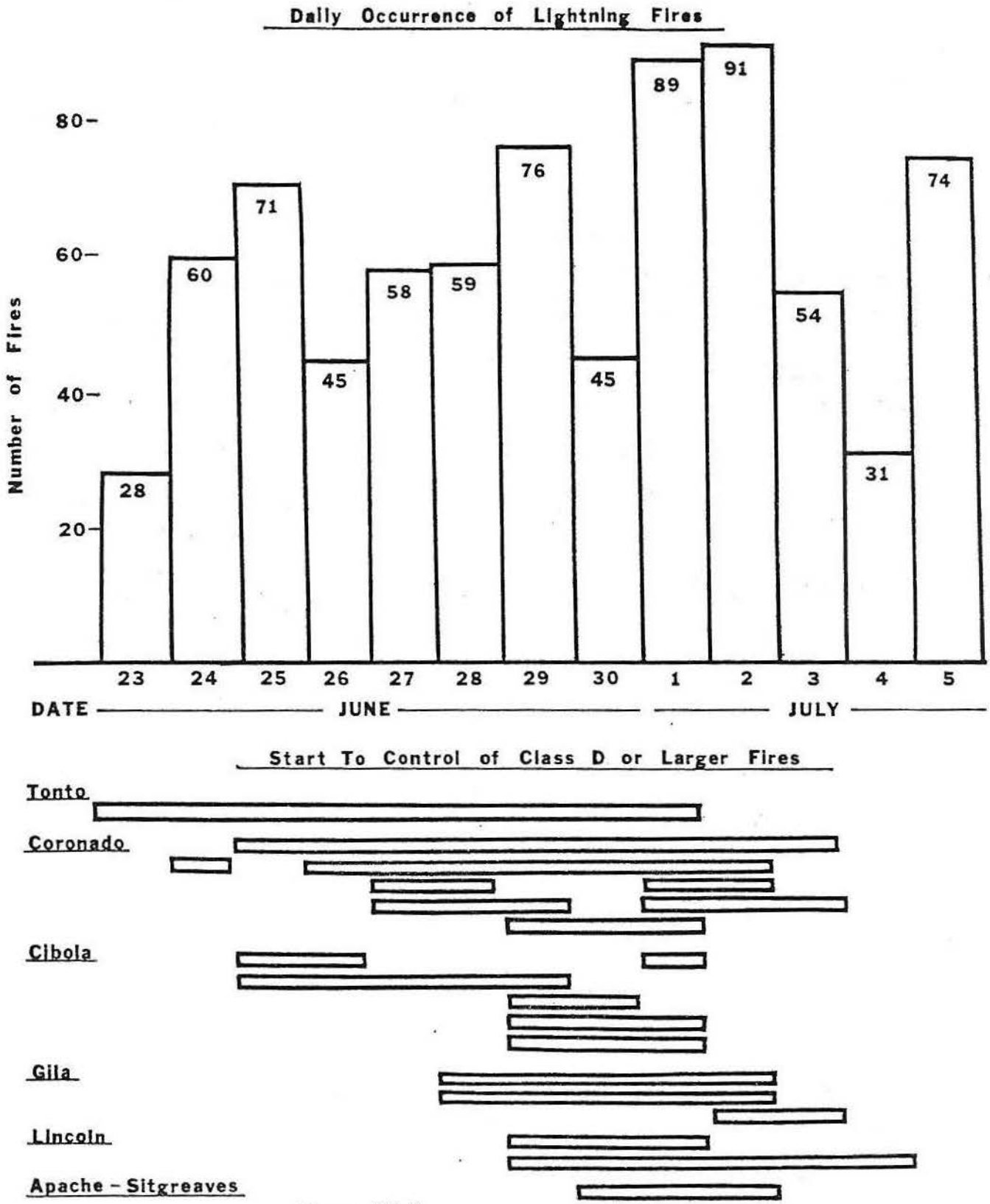

Figure VI-2.

Summary of Critical Situations

The analyses of lightning fires shows that critical situations may occur in all zones in Region Three. The following periods appear to be major candidates for designation as critical situations:

Date	Total Fires	Class D or Larger Fires	Acres Burned	
Single Day				
June 24, 1971	103	6	75,713	Central and SW Zones
Multiple Days				
June 17-22, 1968	168	7	26,344	Central and SW Zones
July 2-9, 1970	442	6	15,222	SW Zone
June 16-July 3, 1971	617	14	92,218	Central and Eastern Zones
June 23-July 5, 1974	781	20	62,245	SW, Central and Eastern Zones

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APPENDIX

Appendix

To supplement the data tables contained in the report a voluminous amount of data from computer runs of 28377 individual fire reports are available. The magnitude of the total data is too great for inclusion in the appendix. Computer tapes and hard copy printouts are available as follows:

1. Complete listing of all coded data for all fires.
2. Regional analysis of fire load by individual days, ten day periods, months and years.
3. Fire load analysis for each national forest by individual days, ten day periods, months and years.
4. Abnormal fire load analysis by days for each national forest.
5. Fire environment analysis for each zone and national forest.
6. Fire control analysis for each zone and national forest.
7. Analysis of fire load by dates and fire environment and fire control for each wilderness, primitive and wilderness study area.