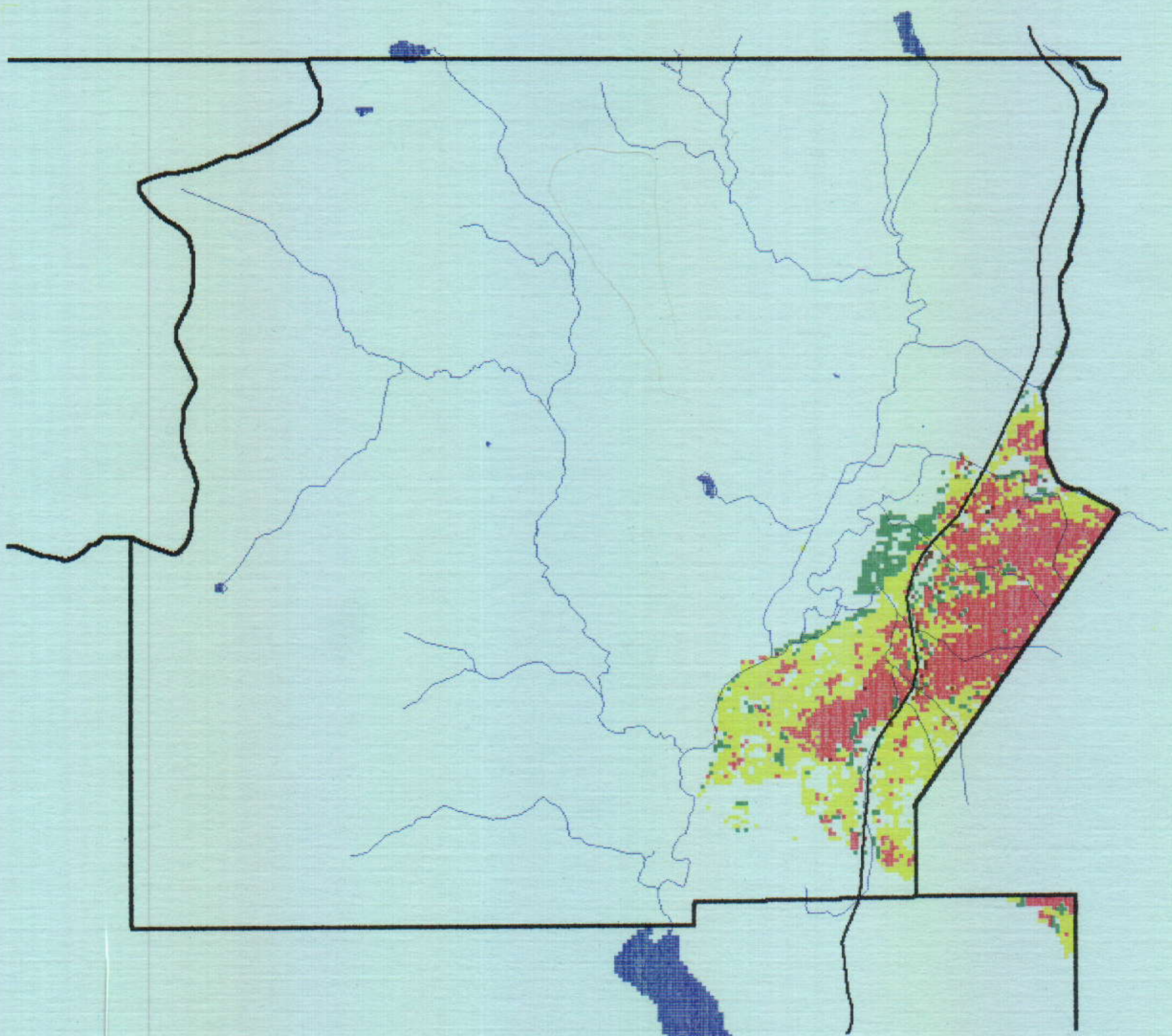
BURNED AREA SURVEY

OF

GRAND TETON NATIONAL PARK AND

JOHN D. ROCKEFELLER, JR. MEMORIAL PARKWAY:

THE FIRES OF 1988



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Division of Research

and

Geographic Information Systems Laboratory

Yellowstone National Park

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The report was completed by

Ann Rodman
Henry Shovic
Don Despain
Paul Schullery

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and

EROS Data Center, Sioux Falls, South Dakota

Geographic Information Systems Division, Washington Office, National Park Service

Kork Systems, Inc.

Montana State University

United States Forest Service, Northern Region Geometronics Section, Missoula, Montana

United States Forest Service, Geometronics Service Center, Salt Lake City, Utah

Introduction

The Greater Yellowstone Area fires of 1988 comprised the largest complex of fires in the Northern Rockies during the last 50 years (Christensen et al. 1989). The Greater Yellowstone Area includes Yellowstone National Park, Grand Teton National Park (including John D. Rockefeller, Jr. Memorial Parkway) and the contiguous National Forest lands. The fires attracted intensive media attention and deep public concern (Smith 1989a,b). Because the fires were so extensive and because they occurred in relatively undisturbed areas, the fires also generated immense scientific interest (MSU 1988).

A constant question of interest was, "How much of the Greater Yellowstone Area was burned?" This question has many answers depending on the definition of burned area and the purposes for which the information will be used. It is fairly simple to determine how much of a warehouse burned and how much of the contents were destroyed. The uses to which this information is put are also fairly straightforward. The warehouse owner needs to know what inventory must be replaced. The insurance company needs to know how much they owe. But it is also necessary to distinguish between those goods totally destroyed and those slightly damaged, or to know how much was smoke damaged and how much can be salvaged.

Those concerned with wildland fires have parallel needs. For lands with commercial timber it is necessary to know how many board feet of lumber have been lost or how many acres will need to be salvage logged. Managers need to know how many fire fighters to put on the fire line and what equipment to order. The public has a natural curiosity about what is happening, and media people need to know how many acres have burned in order to satisfy that curiosity. The scientists trying to understand the process of fire and the effects of the fire on the ecosystem need to know how much of their study areas have burned, the intensity and distribution of the burns, and so on. Wildlife managers need to know how much habitat has been modified. Each of these needs are satisfied by different methods.

Complicating all this is the complex nature of wildland fire. For example, the fires may consume all the needles and small branches of the tree canopy over a large area, or they may creep around on the surface of the ground and cause very little change in the forest. An individual fire will often produce a central area of canopy burn and a fringe area of creeping surface fire that only kills some of the trees. Outside this area will be a number of isolated spots where canopy burn or surface burn occurred.

A further complication arises when erratic fire behavior or the joining of several separate fires leaves large unburned areas within the overall perimeter. The number of acres described as "burned" will vary depending on whether the perimeter line is drawn around the central area of canopy burn, the outer fringe of the surface burn, the outlying spots, or the entire complex. Each of these methods of defining the total acreage might be appropriate depending on the user's needs.

Preliminary estimates of the fires varied widely, depending on methods and the purposes of the estimates. These preliminary estimates were not satisfactory for long-term uses, such as postfire operational reviews and scientific research. More detailed analysis was necessary. In early September of 1988, before the fires were declared out, the Greater Yellowstone Coordinating Committee assembled the Burned Area Survey Team to produce a preliminary survey of burned areas in the Greater Yellowstone Area (GYPFRAC, BAST 1988). The magnitude of the fires compelled mappers to employ small scale (1:60,000) high-altitude (U2 aircraft) aerial photography to create the first generally accurate map of the burns.

This preliminary survey had a resolution of 200 acres, meaning that it depicted units 200 acres or larger. Because the mosaic of the fires often occurred on a much finer resolution than 200 acres, mappers realized that this preliminary survey did not fully reflect the complexity of the burn mosaic, nor did it result in a final total of acres affected by the fires. It was instead an important intermediate step between the earlier, coarser estimates and the more detailed and precise figures reported here.

The preliminary survey reported that a total of 1,405,775 acres in the Greater Yellowstone Area were affected in some way by fire. In Grand Teton National Park (including John D. Rockefeller, Jr. Memorial Parkway), the total affected acreage was 2,700. This estimate included only the Huck Fire. Canopy fires, wherein the needles or leaves and many smaller branches were consumed and the trees were totally or almost totally blackened (and killed), accounted for 1900 acres or a little more than three fourths of the total burn. The rest was a surface burn.

The preliminary survey was adequate for reconnaissance evaluations and emergency use in the Greater Yellowstone Area, but it was not of sufficient accuracy for long-term scientific work. Therefore, a second project was initiated by the Division of Research in Yellowstone National Park to provide a more detailed map and associated data base. The first report from that project is titled "Burned Area Survey of Yellowstone National Park: The Fires of 1988", and focuses on the burned areas within Yellowstone National Park. This report, concerning the burned areas within Grand Teton National Park and the John D. Rockefeller, Jr. Memorial Parkway is an extension of that analysis. Additional technical publications are in preparation. These will address such issues as accuracy, precision, and sampling methods in the project.

Objectives

The primary objective of this mapping effort was to produce a map and accompanying tabular data that represented a finer scale estimate of burned area within Grand Teton National Park, including burn intensities and levels of soil heating. This would provide a more precise estimate of actual burned acreage than did the preliminary map produced in 1988. A secondary objective was to evaluate the suitability of satellite imagery for detecting burned areas. The project was initiated in October of 1988 with the acquisition of aerial photography and Landsat imagery. The study area for this report is about 30 thousand acres, including John D. Rockefeller, Jr. Memorial Parkway and the northern portion of Grand Teton National Park. This only includes burned areas associated with the major fires in Yellowstone National Park and the Bridger-Teton National Forest.

Methods

Aerial Photography Interpretation.

Mapping was accomplished in different and often concurrent stages. Vertical, stereo, color infrared photography was employed, using photographs taken in early October 1988. A team of scientists and technicians, experienced in the interpretation of aerial photography and vegetation mapping, used standard soil and vegetation mapping techniques to delineate areas by intensity of burn, degree of soil heating, and type of vegetation burned (U.S. Forest Service, 1986; Paine, 1981; Soil Survey Staff, 1985). The scale of photography was 1:24,000, and minimum map unit size (resolution) was 5 acres.

It was recognized that even a 5-acre resolution does not fully portray the details of all burn mosaics; patterning often occurs even on a scale of inches. A 5-acre resolution was the best compromise of cost and efficiency and provided sufficient accuracy to be of use to researchers investigating landscape-scale effects of the fires.

While aerial photography was being analyzed, field investigations were conducted to verify that analysis. This process, known informally as "ground truthing," allowed mappers to determine the precision and accuracy of the aerial photography analysis and to improve and refine their photographic interpretive procedure. Ground truthing was accomplished by investigating 5 sites at each of 30 locations (150 total sites) that were representative of the major burn types in Yellowstone National Park. Actual fire effects on these 30 locations were compared against photographic interpretations. This information was extrapolated to Grand Teton National Park and verified with field observations. As an additional check on aerial photography analysis, fixed-wing overflights were used to further verify interpretations of aerial photography.

In order to economize and take advantage of readily available digital satellite imagery, representative samples of aerial photographic analysis were digitized. These samples gave mappers the opportunity to use satellite imagery to complete the project at a substantial financial savings compared to the digitizing of all aerial photographic data. By using representative samples of aerial photographic analysis to check the accuracy of the satellite imagery (which was already in a digital format), it was possible to acquire consistent, reliable information about all burned areas at less expense and in less time.

Satellite Image Interpretation.

Fortunately the October 2 pass of the Landsat satellite was on a day free of clouds and smoke and included all the fires. Some of the most spectacular of these images have been published in books and periodicals, but the scientific application of satellite imagery may be unknown to most people. In brief, Landsat does not make photographs in the traditional sense. Instead, Landsat measures the reflectance from 25 meter squares (0.15 acres) of the earth's surfaces in selected wavelength bands (Johannsen and Sanders, 1982). These values can then be used to drive a light source that produces an image resembling a photograph. More importantly, these values can be subjected to statistical routines that classify each square. In each of these wavelength bands, burned areas reflect different amounts of light than unburned areas, allowing them to be distinguished from one another.

Preliminary analysis of that imagery, conducted by the EROS Data Center in Sioux Falls, South Dakota, revealed 32 distinct classes of burned areas. By visually comparing the same area on the satellite image and interpreted aerial photographs, these 32 classes were reduced to 7 classes or burn types.

Computers make it possible to analyze very large areas consistently and objectively on a very fine scale. Each and every square of reflected data is analyzed in exactly the same manner, and decisions as to which class a square belongs in are made by the machine. Once this is done the image can be projected onto a screen and printed on paper in minutes. The total acres in each type can be quickly calculated, and analyses and comparisons can be made with other digital data.

On the other hand, the satellite cannot make inferences about what is probably burned based on how the surrounding area is burned (a human interpreter can) and it is not able to readily distinguish between dark shadows and blackened tree trunks. For example, large areas in the Greater Yellowstone Area experienced a surface burn, in which ground vegetation was burned but the forest canopy was not. Landsat, measuring only reflectance of what it "sees" from space, may have missed some of the burn that occurred under an unchanged forest canopy. Therefore, some form of ground truthing was required to identify and correct these kinds of problems.

Comparison and Evaluation.

Ground truthing for Landsat was provided by the aerial photographic interpretation project described above. Ten areas in Yellowstone National Park, containing a representative variety and distribution of burn types as well as unburned areas, were selected for a comparison analysis with Landsat imagery. These areas were about the size of United States Geological Survey (USGS) 7.5 minute topographic quadrangle maps.

Individual burned areas within the ten sample areas were digitized directly from the aerial photographs using stereoplotter/microcomputer techniques. Because aerial photographs vary in scale across the image, USGS high elevation photography of Yellowstone National Park (produced prior to the fires) was used to provide digitizers with scale corrections.

The results of the two processes were compared and analyzed using the Yellowstone National Park Geographic Information System (GIS). This system uses Geographic Resource Analysis Support System (GRASS) software and is compatible with the Grand Teton National Park GIS. Within the GIS system, Landsat categories of burned areas were compared with digitized photographic data. In this comparison, the resolution of the Landsat imagery was 0.60 acres. This information was used to further condense the 7 categories into four final burned categories included in the map: Canopy Burn, Mixed Burn, Nonforested Burn, and Undifferentiated Burn. An additional category, Undelineated Burn, was calculated from the unburned area to account for surface burns under unburned canopies.

The composition of each map unit was based on a sample of interpreted aerial photography from Yellowstone National Park, correlated to Landsat categories. On the average, 10 percent of the total acreage of each map unit was investigated. These areas were selected from a sample of the 10 digitized sample areas of photographic data. This data base represented about 165,800 acres of burned area or about 20 percent of the total burned area in Yellowstone National Park. This information was extrapolated to burned areas within Grand Teton National Park. These areas were visually checked on 1:24,000 aerial photographs.

Results

The map in Figure 1 depicts the distribution and character of burned areas in Grand Teton National Park and John D. Rockefeller, Jr. Memorial Parkway as of October 2, 1988. Figure 2 is a detailed enlargement of the burned areas in Figure 1. The resolution of these maps is 0.60 acres and the accuracy is five acres (see Accuracy and Precision for an explanation).

As was anticipated, total burn acreage was reduced significantly from the totals in the preliminary burned area survey. Total area affected by the Huck Fire in Grand Teton National Park (including John D. Rockefeller, Jr. Memorial Parkway) was 2,400 acres. Of that, 950 was Canopy Burn(categories are explained below); 1090 was Mixed Burn; 250 was Nonforested Burn; 30 was Undifferentiated Burn; and 80 was Undelineated Burn. Table 1 gives the extent of burned areas in John D. Rockefeller, Jr. Memorial Parkway. Table 2 gives this information for the remainder of the study area in Grand Teton National Park.

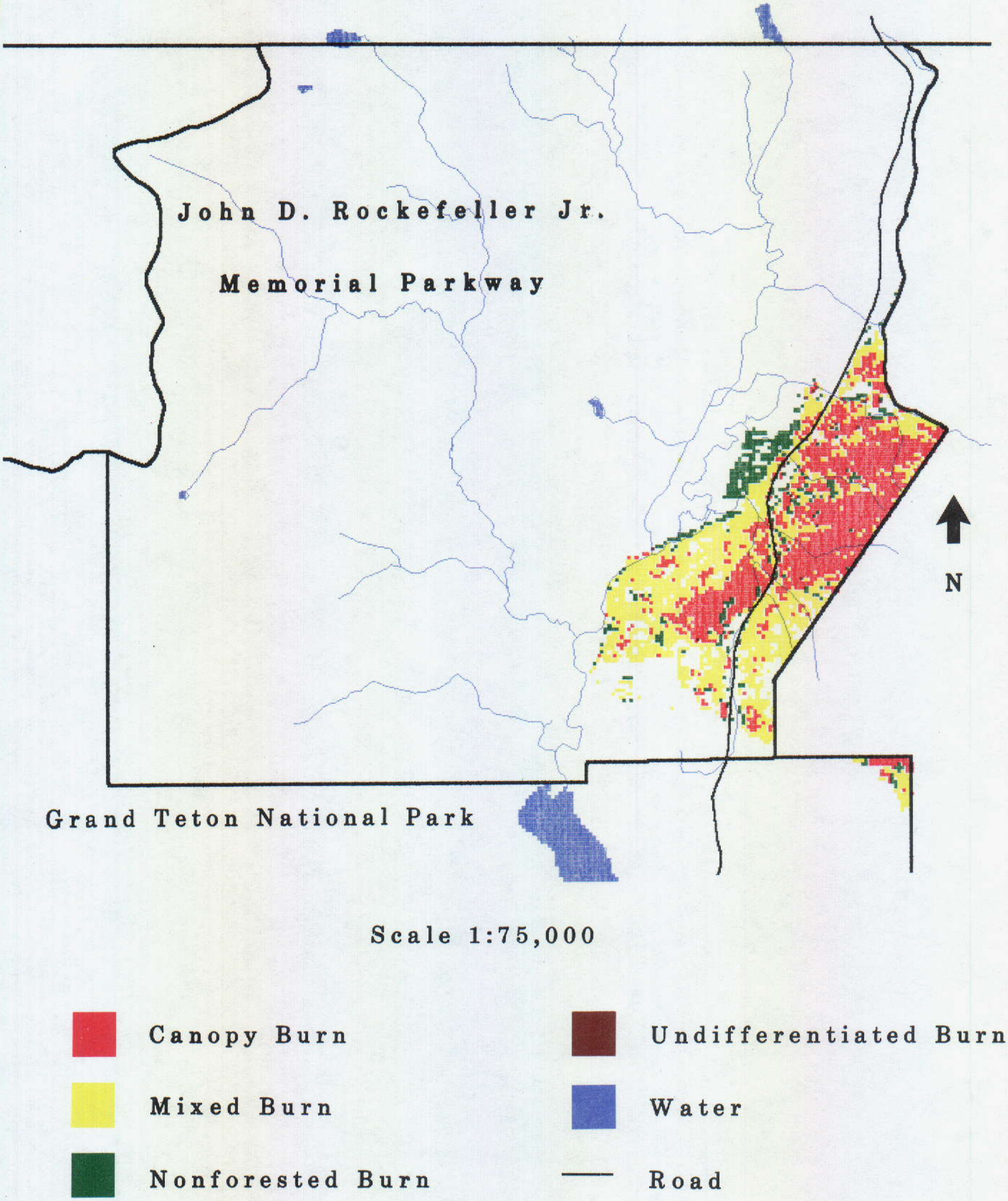

Figure 1. The 1988 Burned Area Survey of Grand Teton National Park and John D. Rockefeller Memorial Parkway. Computations were completed in May, 1990.

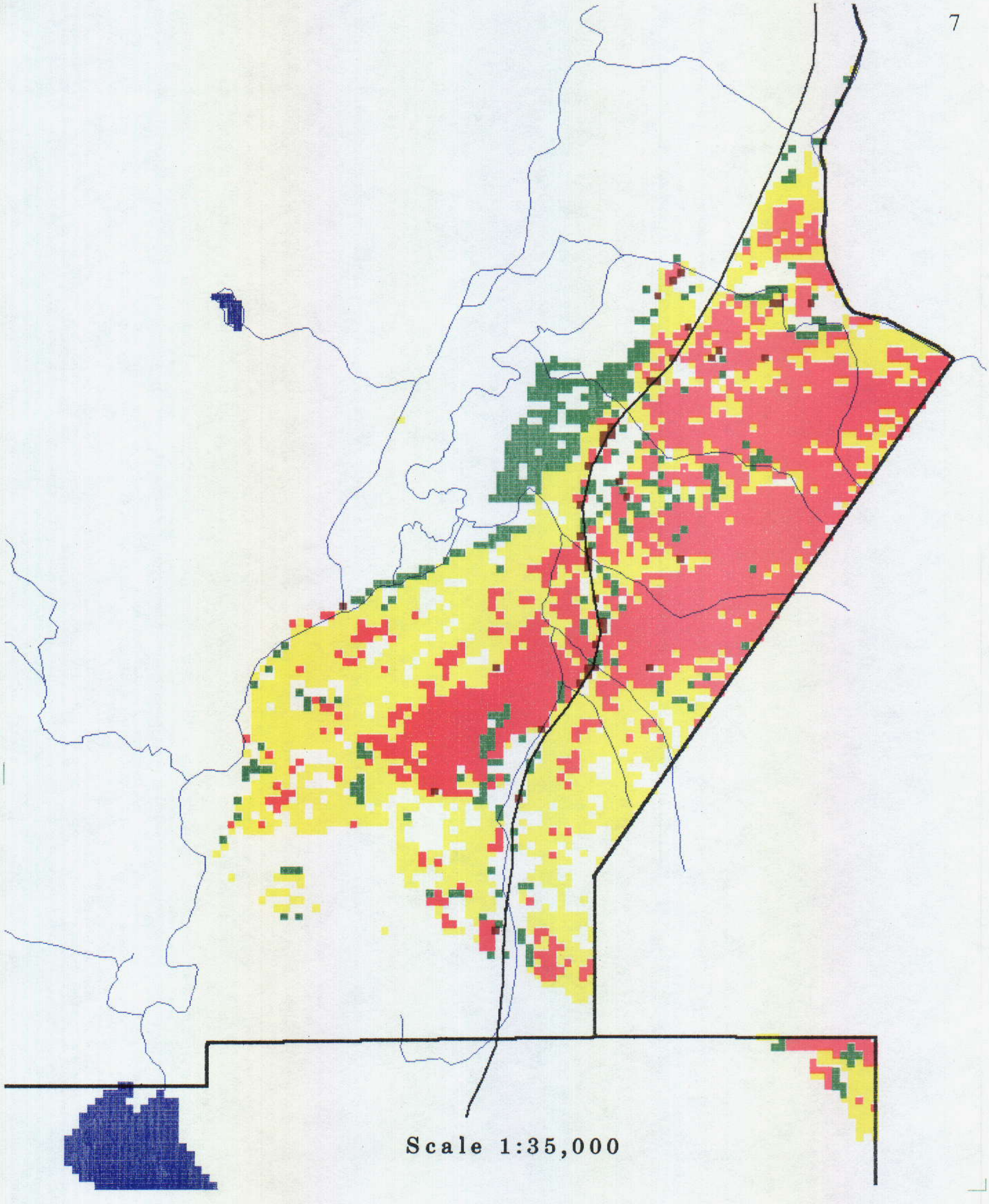

Figure 2. Detail from Figure 1 of the 1988 burn in John D. Rockefeller Memorial Parkway and Grand Teton National Park. All map unit colors are the same as in Figure 1.

Table 1. Burned area acreages within John D. Rockefeller, Jr. Memorial Parkway

Burn Type	Burned Area (acres)	Percentage of Burned Area	Percentage of Total JDRMP Area*
Canopy	930	41	4
Mixed	1060	45	5
Nonforested	240	10	1
Undifferentiated	30	1	<1
Undelineated	80	3	<1
Total Burned Area	2340	100	10

* Total Area of J.D. Rockefeller, Jr. Memorial Parkway is 23780 acres.
Total Unburned area is 21440 acres.

Table 2. Burned area acreages within Grand Teton National Park

Burn Type	Burned Area (acres)	Percentage of Burned Area	Percentage of Total GTNP Area*
Canopy	20	33	<1
Mixed	30	50	<1
Nonforested	10	17	<1
Undifferentiated	0	0	0
Undelineated	<1	<1	<1
Total Burned Area (only includes Huck Fire)	60	100	<1

* Total Area of Grand Teton National Park (excluding John D. Rockefeller, Jr. Memorial Parkway) is 286,740 acres.
Total Unburned area is 286,680 acres.

Burn Category Descriptions

Following is a description of the final burn categories. Four of these categories appear on the map and are called map units. The fifth category (Undelineated Burn) is not shown on the map but is calculated from the area mapped by Landsat as unburned.

Proportions given for map unit composition are averages for the entire park. For example, there is some variation from one area of Canopy Burn to the next, but for the purposes of this analysis an average has been computed and applied to all Canopy Burns. Figure 3 shows the composition of these units in a graphical format.

Canopy Burn Map Unit - The forest overstory burned. Needles were consumed, and bare, black branches remained. If trees were dead before the fire, branches were burned from tree trunks, and the trunks were partially consumed. Ground cover was also consumed, and a layer of gray or black ash covered the surface.

Soil was charred from 0.5 cm to 5 cm in depth, and in some places to 10 cm. These more deeply burned soils may have tan or reddish surface layers, and occurred only where roots or large logs on the surface burned out.

On the average, 90 percent of this map unit was canopy burn as described above. Five percent was overlap (the term "overlap" refers to small discrepancies at map unit boundaries due to differences in resolution between aerial photography and Landsat imagery). Five percent was a combination of areas that did not burn (for example, areas of bare rock); surface burns in old burns that had standing dead trees that did not burn in 1988; or areas of dark ground in nonforested expanses that may or may not have burned.

Mixed Burn Map Unit - This was characterized by a combination of unburned, scorched, and blackened trees. The ratio of unburned to burned trees varied widely; the forest canopy was not burned uniformly, though the ground surface was usually burned.

Soil charring was variable depending on the type of burn. Where the canopy was burned, soil was charred from 0.5 to 5 cm in depth. Where surface logs burned out, soil may have been charred to 10 cm and the soil surface may have turned reddish or tan in color. Other areas may have had charring only in the surface 0.5 cm.

The unburned/scorched/canopy burn mosaic occupied an average of 50 percent of the map unit. Forty percent consisted of large areas of canopy burn in sparse stands of trees. Scattered scorched trees occurred, and the ground surface was a lighter color than in the areas mapped in the Canopy Burn map unit. Five percent of this map unit was a combination of small, burned meadows; islands of burned trees surrounded by unburned areas; areas in shadow; unburned steep slopes and talus slopes; and burned shrublands along drainages. Five percent of this unit was overlap.

Nonforested Burn Map Unit - This unit was made up of burned sagebrush shrublands, grasslands, meadows, wet meadows, and alpine meadows.

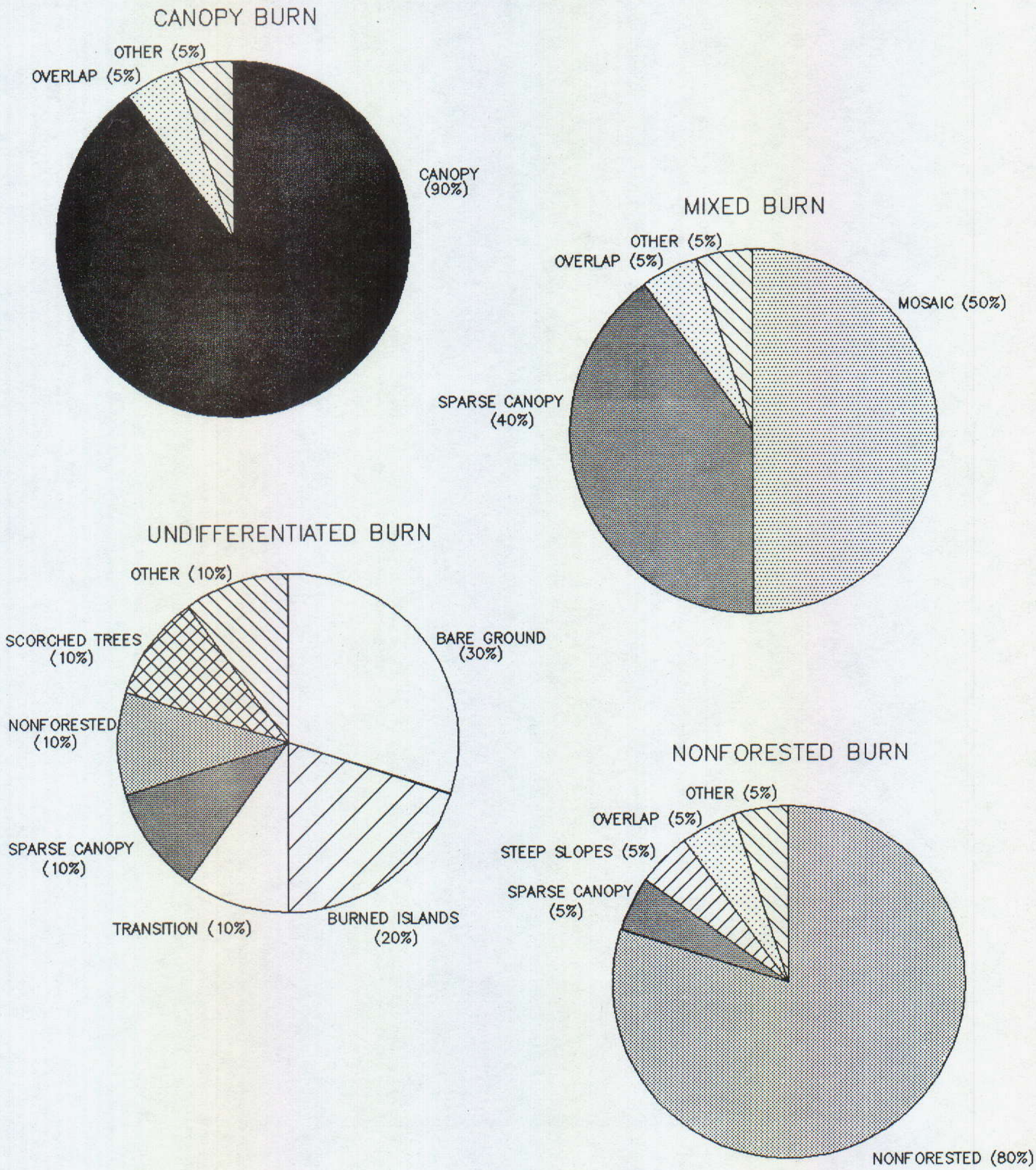

Figure 3. Composition of each map unit as estimated from aerial photographic data from 10 test areas (295,420 acres). See text for description.

Soil charring was variable depending on pre-fire vegetation. In some areas beneath burned sagebrush, soil char depths were as much as 5 cm. In most grasslands and grassy areas in shrublands, soil charring was less than 1 cm. Wet meadows that had a thick organic layer had soil char depths up to 10 cm or deeper.

Eighty percent of this unit was composed of burned, nonforested areas. About 5 percent of the unit was made up of canopy burn in sparsely forested areas. Five percent of the unit was either unburned areas in shadow or canopy burns on steep slopes. Five percent was made up of areas of bare rock or unburned dark areas on flood plains. Five percent was overlap.

Undifferentiated Burn Map Unit - This unit was not extensive in the area. It was made up of a variety of diverse burn types. Composition varied across the park, and the distribution of burns was not predictable. The unit was mainly composed of burned areas that could not be reliably placed in one of the other map units. Soil charring varied with vegetation and character of burn.

On the average, 30 percent of this unit was composed of small areas of bare, unburned ground, often on steep slopes. Twenty percent was made up of isolated islands of burned trees surrounded by non-forested burns and unburned areas. Ten percent of this map unit occurred as edges of forested burned areas in the transition zone between forested and non-forested areas. Ten percent of the unit was canopy burn in sparsely forested areas. Ten percent was burnt shrubland. Ten percent was surface burn under a scorched tree canopy. Ten percent was dark areas in drainages surrounded by unburned areas and isolated unburned areas killed by insects.

Unburned Areas - Eighty-eight percent of the area mapped as unburned by Landsat was unburned. Five percent was made up of areas that had an unknown burn status; i.e., steep, north-facing slopes in shadow. Small burned areas in shrublands, grasslands, or meadows were also included in this 5 percent. About 7 percent of the area "seen" as unburned by the satellite had a surface burn under a dense, unburned forest canopy. This area falls into the Undelineated Burn Category explained below.

Undelineated Burn Category - This category is composed of surface burn under dense, unburned canopies. Because Landsat was not always reliable in sensing this type of burn, an indirect calculation, based on field transect data, was used to determine the acreage of this category. This was a "high-end" estimate to ensure that all burns of this type were included in the acreage total. The actual acreage of surface burn under unburned canopies was probably less than given here.

Accuracy and Precision

The precision of acreage estimates was dependent on the minimum map unit size used in the mapping process. Because Landsat used a 0.60 acre map unit, it was very precise. In terms of accuracy, however, the "ground truth" used a 5-acre minimum. Therefore, though areas as small as 0.60 acre were delineated, the reported accuracy is 5 acres. This provided the most realistic estimate of accuracy when comparing these results to other mapping efforts.

Additional Documentation

The preliminary survey, completed on December 1988, was a reconnaissance-level survey that can be used for large scale investigations and preliminary analysis. This survey included a report titled "Preliminary Burned Area Survey of Yellowstone National Park and Adjoining National Forests; Project Summary and Tabular Areas," and a 1:400,000 scale color map titled "Preliminary Survey of Burned Areas: Yellowstone National Park and Adjoining National Forests." The map has a resolution of 200 acres. The color infrared aerial photographs used to make this map were at a scale of 1:60,000 and date from September 15, 1988.

All of the 1988 fires within Yellowstone National Park have been interpreted and mapped on 1:24,000 scale color infrared aerial photographs. These photographs extend into the study area for John D. Rockefeller, Jr. Memorial Parkway and northern Grand Teton National Park. The photographs were taken in October 1988 and are suitable for site selection and detailed investigation of burned areas.

For further information on the Burned Area Survey of Grand Teton National Park and John D. Rockefeller, Jr. Memorial Parkway, the Burned Area Survey of Yellowstone National Park, the preliminary survey, or the photographic data bases contact:

Henry Shovic or Ann Rodman
Division of Research
Box 168
Yellowstone National Park, WY 82190

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