ANALYSIS OF VEGETATION CHANGE
FOLLOWING WILDFIRE

by

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ABSTRACT

Color-infrared (CIR) aerial photography at a nominal scale of 1:15,840 was used to construct a post-fire vegetation map of the Walsh Ditch Fire area on the Seney National Wildlife Refuge in Upper Michigan. An overlay was prepared from CIR, and black and white photography to show the fire boundary, areas within the perimeter left unburned and vegetation cover type changes resulting from the fire. Areas where extensive post-fire tree mortality occurred were also mapped.

Manual interpretation of LANDSAT imagery for mapping fire boundary and vegetation recovery was also investigated. Mapping of the fire boundary was possible from the LANDSAT images, and assessment of vegetation recovery appears promising.

Infrared Line-scan imagery in the 3 to 5 micrometer band used for mapping fire hotspots during the Walsh Ditch Fire was evaluated for its usefulness in determining the degree of burn. Much of this imagery had begun to deteriorate and no conclusive results were obtainable.

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On 30 July 1976 a thunderstorm resulted in a lightning fire on a remote part of the Seney National Wildlife Refuge located in Michigan's upper peninsula. In accordance with refuge policy, the fire was allowed to burn as long as there was no threat to the wilderness resource, human life or damage to property. By 11 August, it was determined that an emergency existed and fire suppression efforts were initiated. Final containment was not complete until 21 September, when an estimated 74,000 acres had been burned in the Walsh Ditch Fire. A map of the refuge and fire boundary is presented in Figure 1.

Present day occurrence of large fires in the Lakes States is rare and the remote sensor data obtained before, during and after the Walsh Ditch Fire provided a unique opportunity to demonstrate the utility of remote sensing techniques for monitoring and evaluating ecological change following wildfire. Mapping of vegetative cover from seasonal CIR photography has been reported by different researchers (Seher and Tueller, 1973; Gammon, et al., 1976), but little work on vegetation mapping in disturbed areas has been reported.

This report describes the techniques used in mapping and comparing vegetation change following wildfire on the Seney National Wildlife Refuge. In addition, thermal infrared scanner imagery acquired during the fire and LANDSAT multi-spectral scanner imagery were evaluated for their usefulness in making post-fire vegetation assessments. Most of the information found in this report can also be found in the paper, "Analysis of Vegetation Change Following Wildfire, and Its Effects Upon Wildlife Habitat", presented at the PECORA IV Symposium, Sioux Falls, South Dakota, October 10-12, 1978. (Sugarbaker, 1978)

Description of Area

Treeless string bogs and topographically oriented strips of bog forest cover much of the area that was burned in the Walsh Ditch Fire.

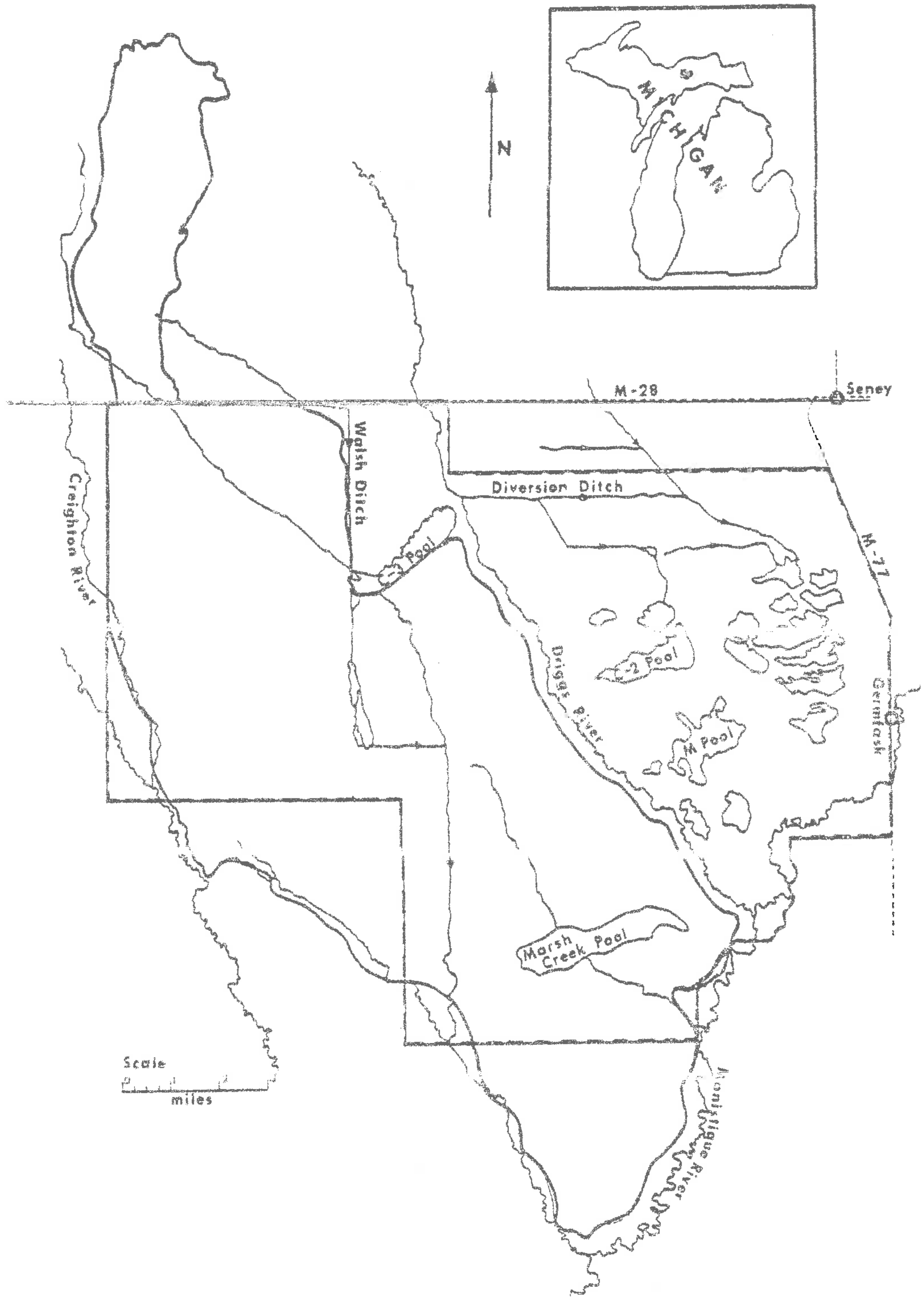

Figure 1. Seney National Wildlife Refuge, Upper Michigan

This patterned complex has been described in detail by Heinselman (1965). The entire region associated with these peatlands is a vast sandplain produced by the deposition of outwash from the recession of the last (Valders) ice sheet. A continuous peat blanket several feet thick covers much of the sandplain, but is interrupted by many sand knolls which appear to be extinct sand dunes that formed sometime after the deposition of the sandplains.

The bog forests covering much of the area consist primarily of tamarack (*Larix laricina* (DuRoi) K. Koch) and occasional black spruce (*Picea mariana* (Mill.) B.S.P.). These forests are generally several hundred feet wide, often more than a mile long, oriented parallel to the slope (which is about 6-12 feet per mile), and are always found trailing downslope from the sand "islands". Intermediate to these bog forests are long narrow strips of string bog. The bogs consist of alternating low bog ridges (German *Stränge*) and wet sedgy hollows (Swedish flarke, English flarks) which form crossbanding that can be easily seen on air photos. The sand knolls support upland vegetation which is dominated by red and white pine (*Pinus resinosa* Ait. and *P. strobus* L.). The ground cover consists of sedges and grass sod. Bracken fern and low sweet blueberry (*Vaccinium pennsylvanicum* Lam.) are also common.

Downslope from the string bog and forest complex, the peatlands support a different vegetation cover type. Intermittent sand knolls are surrounded by a vast meadow which has very little resemblance to the tamarack forest and bog complex found to the north. Dominant vegetation in these meadows consists of sedges (*Carex* spp.) or cotton-grasses (*Eriophorum* spp.).

The area north of the patterned forests consists of long trailing grass meadows, which are waterways, and appear too wet to support any kind of forest growth other than some willow (*Salix* spp.) and tag alder (*Alnus rugosa* (DuRoi) Spring.). On either side of the grass meadows a diversity of forest types exist, including tag alder lowlands, spruce-fir, aspen, and upland pine forests.

Methods and Materials

A post-fire vegetative cover map was prepared and compared to pre-fire vegetation cover to determine what changes took place as a result of the fire. The post-fire vegetation cover was mapped directly onto United States Geological Survey (USGS) 7.5 minute quadrangle sheets at a scale of 1:24,000. Cover type changes and the actual fire perimeter were mapped as an overlay to this map base.

Reproductions of the Mylar map sheets were made on an OZALID Printmaster 900. In addition, negative and positive 1:48,000 scale transparencies were prepared from the original 1:24,000 Mylar cover type map sheets. (Contact OZALID copies from the 1:48,000 scale transparencies are in an envelope in the back of this report.)

Classification Procedures

The Michigan Land Cover/Use Classification System (MLUCRC, 1976), a four level expansion of the land-use classification scheme prepared by Anderson, et al. (1976) for the U.S. Geological Survey was used. Levels one and two of the Michigan system are similar to the Anderson classification system and are outlined in Table 1. Where vegetation cover types could not be classified beyond the second or third level, zeros were added to provide consistent four-digit classification codes.

The smallest area that can be consistently classified and identified on a 1:24,000 map sheet is about two acres in size (MLUCRC. 1976). The presence of sand knolls as an integral part of the patterned forests and their effect on quality of wildlife habitat made their identification and mapping important for this study. Those smaller than two acres in size were identified by point symbols which indicated whether or not they supported overstory vegetation.

Table 1. Michigan Land Cover/Use Classification System, levels one and two.

- 1 URBAN & BUILT UP
  - 11 Residential
  - 12 Commercial, Services, & Institutional
  - ~~13 Industrial~~
  - 14 Transportation, Communication & Utilities
  - [15] Map Industrial Parks under appropriate category in Commercial Services & Institutional (12) or Industrial (13)
  - 16 Mixed
  - 17 Extractive
  - 19 Open & Other
- 2 AGRICULTURAL LAND
  - ~~21 Cropland, Rotation & Permanent Pasture~~
  - 22 Orchards, Bush-Fruits, Vineyards & Ornamental Horticulture Areas
  - 23 Confined Feeding Operations
  - [28] Inactive Land (These plant communities will be mapped under herbaceous rangelands (31).
  - 29 Other Agricultural Land
- 3 RANGELAND
  - 31 Herbaceous Rangeland
  - ~~32 Shrub Rangeland~~
- 4 FOREST LAND
  - 41 Broadleaved Forest (generally deciduous)
  - 42 Coniferous Forest
  - 43 Mixed Conifer-Broadleaved Forest
- 5 WATER
  - 51 Streams & Waterways
  - 52 Lakes
  - 53 Reservoirs
  - 54 Great Lakes
- 6 WETLANDS
  - 61 Forested (wooded) Wetlands
  - 62 Non-Forested (non-wooded) Wetlands
- 7 BARREN
  - 71 Salt Flats (not applicable to Michigan)
  - 72 Beaches & Riverbanks
  - ~~73 Sand Other than Beaches~~
  - 74 Bare Exposed Rock
  - 75 Transitional Areas
  - 79 Other
- 8 TUNDRA (not applicable to Michigan)
- 9 PERMANENT SNOW & ICE (not applicable to Michigan)

Post-fire vegetation cover. Color-infrared (CIR) aerial photography (nominal scale, 1:15,840) obtained by the U.S. Fish and Wildlife Service (FWS) on 11 May 1977 was the primary data source for mapping post-fire vegetative cover. In addition, CIR photography obtained on 18 September 1976 (nominal scale, 1:68,000), and CIR photography (nominal scale, 1:15,840) from 3 October 1977 were used as supporting information.

Vegetation type boundaries were traced on Mylar overlays from alternate photos. When fall-off at the edge of a frame or other image defects prevented a clear distinction of type boundaries, intermediate photos were used to solve these ambiguities. Most information on the Mylar sheets was transferred to quadrangle map sheets with the use of a Map-O-Graph reflecting projector, or with a Bausch and Lomb Zoom Transfer Scope when it was necessary to correct for photo tilt. A final Mylar master showing cover type and base map information was prepared and used to reproduce additional copies of the map.

Pre-fire vegetation cover was determined in approximately the same manner as post-fire cover. It was not, however, necessary to produce a finished map of the pre-fire conditions. By overlaying a manuscript copy of the pre-fire map onto the post-fire cover map, it was possible to document changes in cover types. These changes were recorded on a new overlay.

USGS black and white aerial mapping photography from May 1971 was the primary source for documenting pre-fire vegetative cover; however, it was often easier to determine pre-fire vegetation boundaries from the CIR post-fire photography. Burned over forest, for example, could usually be seen as either standing or windblown snags, and burned shrublands produced a different texture than areas that were previously grasslands.

Vegetation change and fire boundary. As just described, vegetation change was documented by superimposing the pre-fire map over the post-fire vegetation cover map. The areas where cover type changes occurred were classified as they existed in the pre-fire condition. The fire boundary was also documented on this overlay using the CIR photography from May 1977 as the primary data source. Very little green-up had occurred in this area by May, so most of the burned area was still blackened. The September 1976 CIR photography could have been used for mapping the fire boundary, but the photography obtained in May 1977 proved to be superior to the 1976 photography. The 1976 photos were slightly underexposed, and additional fire spread occurring into October would not have been documented had that imagery been used. Areas of extensive post-fire mortality could be identified on the 25 September 1978 CIR photography made available near the end of the study. Such areas were delineated, and are shown on the fire boundary map. (Figure 2 in envelope at end of report).

Ground Investigations

Three trips were made to the study area to gather groundtruth information and field check the map product. The initial trip provided familiarity with vegetation types occurring in the study area. As many cover types were photographed from the ground as possible, and their locations on the aerial photographs determined. These ground photographs provided a partial key for the initial classification of cover types. A second trip was made to the refuge to check questions that had arisen during image interpretation and to field-check areas already mapped. A final trip was taken to the study area when the post-fire vegetation maps were nearly completed to field-check problem areas and check map accuracy.

Satellite Data

LANDSAT imagery acquired during and after the Walsh Ditch Fire provided an additional remote sensing data set for evaluating the effects of the fire. LANDSAT imagery was acquired for several dates including 3 June 1976 (pre-fire), 23 August 1976 (fire), 10 September 1976 (fire), 11 May 1977 (post-fire and same date as CIR photography), and 9 August 1977 (post-fire). Imagery was acquired for bands five and seven (0.6-0.7 μm and 0.8-1.1 μm respectively) in 18.5 centimeter film positive format for all five scenes. The entire burn and refuge area occupied only a small portion of the scene, and a 5.2 by 5.2 centimeter section was cut out of each film positive and placed in an I^2S color additive viewer. When projected into the I^2S viewer, the image from 18.5 centimeter film positives is at a scale of 1:150,000. Small scale maps of the burned area and major vegetation changes were prepared from the LANDSAT bands five and seven composite scenes using the I^2S viewer. The information acquired from manual interpretation of the LANDSAT imagery was then compared with the fire boundary and vegetation maps that were prepared from the color-infrared aerial photography.

Thermal Line-Scan Imagery

A thermal line-scanner from the Boise Inter-Agency Fire Center was flown over the fire on several occasions to obtain data to assist in fire suppression. Polaroid photographs of the image screen in the aircraft (Hirsch, et. al., 1968) were stored as part of the fire record. These photographs were examined to see if fire intensity and duration of burn could be determined and severity of burn in different areas deduced. During this evaluation it was discovered that much of the imagery had begun to deteriorate and some was unusable.

Results and Discussion

Use of CIR photograph for mapping vegetation communities as they appeared during the year following the Walsh Ditch Fire on the Seney National Wildlife Refuge proved to be an effective method of documenting major cover type alterations resulting from the fire disturbance. This documentation was accomplished by comparing pre-fire vegetation cover with post-fire cover and presenting the change in the form of an overlay to the post-fire map. The fire perimeter, including islands of unburned vegetation, are also shown on the Mylar overlay.

Delineation of vegetation boundaries for the burned areas and the classification of some vegetation types could not be accomplished solely from the use of the May 1977 photography. Little green-up had occurred when these photographs were taken and it was difficult to separate vegetation types, particularly the lowland herbaceous types on burned surfaces. Photography from October 1977 was obtained to delineate vegetation types that recovered after one growing season. Unfortunately, this film was under-exposed and subsequent efforts to correct this problem produced poor quality prints. It was still possible to separate upland deciduous vegetation from conifers, but attempts to delineate the several wetland vegetation boundaries were unsuccessful. Seher and Tueller (1973) reported that they were able to differentiate several wetland vegetation types and species from late summer CIR photography, and it is believed that the negative results achieved in this study stemmed from the poor quality of the October 1977 photography.

Mapping of cover types in the unburned areas proved to be much easier than mapping burned areas. Although a large and diverse set of cover types is represented on the refuge, any given type was nearly uniform in image appearance within unburned areas and criteria for classifying vegetation remained constant for most types. In burned areas snags, burned shrubs and a varying degrees of vegetation recovery in given areas made it difficult to evaluate vegetation cover on the basis of rigid mapping criteria. Consequently, more extensive ground verification was required for these areas and the classification procedure was much more subjective.

Of the many examples of varying returns from burned areas, the following are typical of the problems encountered. In many places where the photographs showed a coniferous forest overstory, fire scars on tree boles indicated that the surface fire had been intense even though there had been no crown fire. Many of these trees showed obvious signs of stress, or were dead, one year after the burn. The May 1977 photography was taken before the foliage on the killed trees had faded, making it difficult to identify areas with extensive post-fire mortality. The poor quality of the October 1977 photography resulted in continued mis-classification of many of these areas as healthy coniferous forest. Since the post-fire vegetation cover type map (Figure 3) was prepared, as of 1977, some areas identified as "Upland Conifers" on this map actually contained fire-killed trees. Areas of post-fire mortality were readily detectable on the September 1978 CIR photography, and are identified as such on the fire boundary map (Figure 2).

When fire burned through black spruce stands, all that remained were charred upright snags, most of which were standing one year after the burn. Recolonization of these areas by aspen (Populus tremuloides Michx.), jack pine, occasional black spruce and herbaceous invaders was prompt, but residual snags prevented the detection of vegetative recovery on CIR photography, and these areas were classified as "transitional."

In burned areas where lowland shrubs were the dominant vegetation types prior to the fire, lowland grasses and forbs responded quickly during the following spring. In this case, areas that were previously shrublands, and adjacent areas which were low grasslands, are now all classified as grasslands, even though the burned over shrublands give a very mottled appearance on the imagery.

It could be argued that since pre-fire maps and post-fire maps are available, vegetation changes and successional trends could be established based on the information obtained from the two maps. It is important to remember, however, that all areas are mapped according to the dominant vegetation type present at the time the imagery was obtained. In most lowland grasslands, for example, the encroachment of alder and willow shrubs seem inevitable, but where fire passed through these areas the invasion of shrubs is at least temporarily set back. Here, both the pre-fire and post-fire maps indicate that this entire area is dominated by grasses and, indeed, this is the case, but the appearance of these grasslands has changed considerably. A second example occurs on the burned uplands and sand knolls. In most cases, surface fires burned through these areas leaving more than half of the overstory (usually dominated by red pine) intact. Here, both pre-fire and post-fire maps indicate that upland conifers are the dominant vegetation type, but as a result of fire, future vegetation composition will be greatly affected. Knowing whether or not a fire occurred in a given area can affect future management decisions.

For all examples given to this point, except the black spruce, intensity of burn was *relatively light. Areas that experienced a* hot burn (that is, areas where all available fuel was nearly consumed and mineral soil was left exposed) are in a transitional state. The Michigan Land Cover/Use Classification System has provisions for mapping such barren ground as transitional (Table 1). In some of these areas, however, seed bed conditions were favorable, and regeneration, particularly aspen, was quickly established. At the time of mapping, the dominant vegetation type was aspen. The probability that aspen will survive on these areas is low, and it would seem more appropriate to label them transitional, also. Surely, all areas are dynamic, and the point at which we recognize something as being at least temporarily static in terms of its classification is arbitrary.

LANDSAT Data

Interpretation of the combined images from bands five and seven for LANDSAT scenes dated 11 May 1977 and 9 August 1977 was completed with the aid of an I^2S color additive viewer. Mapping of the fire boundary from the 11 May 1977 imagery proved to be accurate for all areas burned with the exception of light surface fire which produced little or no effect on the overstory forest canopy. In such areas, post-fire mortality was minimal and the burn could not be detected beneath the forest canopy.

Attempts were made to interpret relative severity of burn and then compare severity ratings with vegetation recovery interpreted from the 9 August 1977 LANDSAT image. Some relationship between the severity of burn index mapped in Figure 4 and the amount of vegetation recovery mapped in Figure 5 seems apparent, particularly in the Walsh Ditch area (center of refuge) where the severest burns occurred and vegetation recovery has been very slow.

Mapping criteria for severity of burn and vegetation recovery were based on spectral signatures of major cover types as well as the association of types. Most of the burn area consisted of grassland and shrubland associations that appeared uniformly dark on the 11 May 1977 satellite image. It was difficult to assign any burn severity ratings to these areas directly, but the degree of burn on associated sand islands was used as an indicator of the severity of burn on adjacent areas. Therefore, in areas where most of the sand island overstories were destroyed, the surrounding grasslands and shrublands were assigned a higher severity of burn index than areas associated with islands of unburned tree canopies. This mapping criteria did not appear to be consistent with the rate of recovery documented on the 9 August 1977 satellite image.

Although interpretation of the 11 May 1977 LANDSAT image alone did not give good results in mapping severity of burn, comparative interpretation of the May and August imagery was more successful. As described earlier, the May image permitted accurate mapping of the fire boundary, except for light surface fires under forest overstories. Areas which were most severely burned were closely associated with the slow vegetation recovery areas mapped from the August image. Comparison of the two images also permitted mapping of areas where extensive post-fire mortality occurred (Figure 2).

<u>Thermal Line-Scan Imagery</u>

Of primary concern in evaluating the effects of the fire is the degree of burn. Degree of burn is a function of fire intensity and

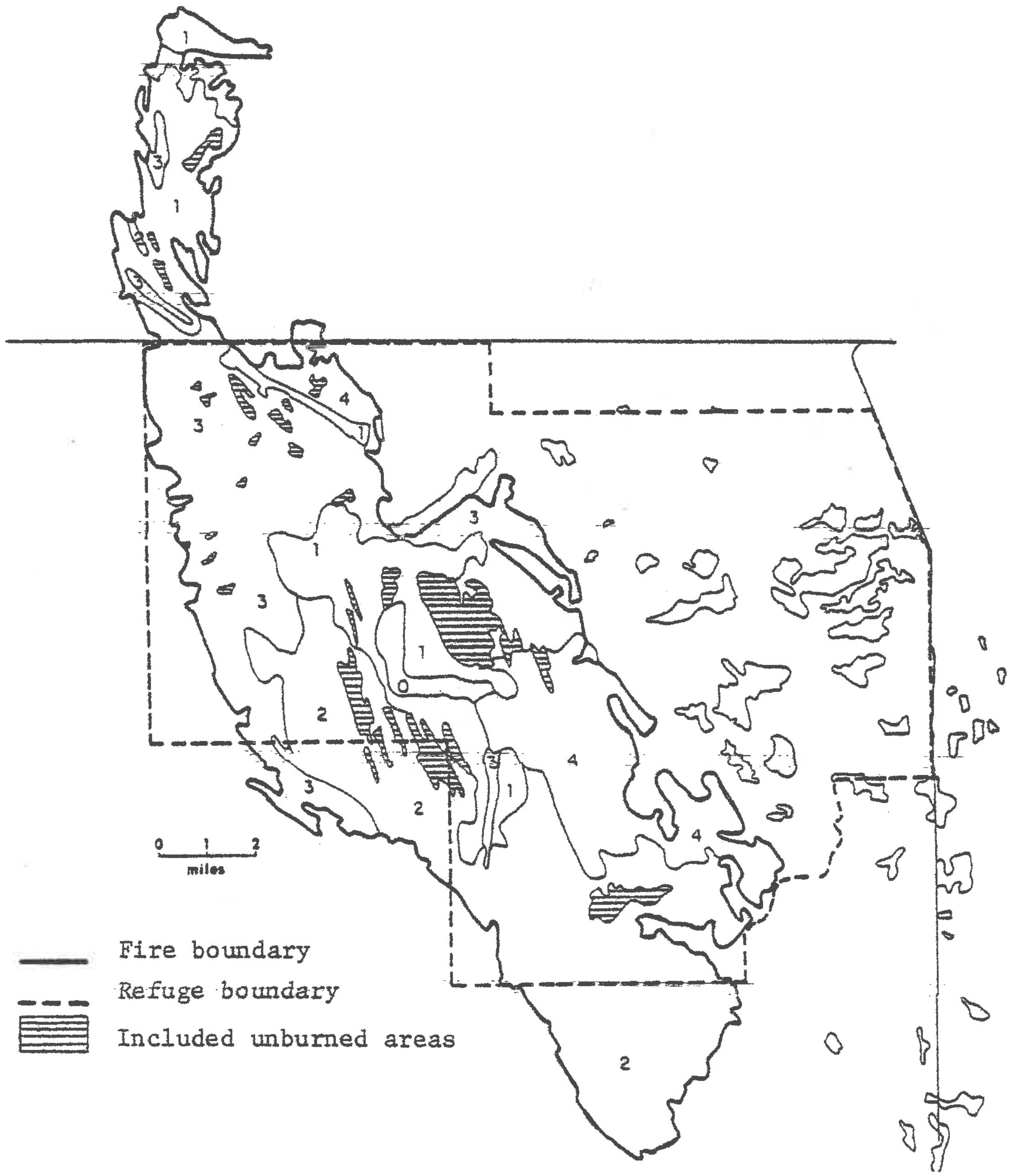

Figure 4. Interpretation of LANDSAT scene (11 May 1977) for degree of burn. On a relative scale, a zero indicates a complete burn and four indicates a light burn.

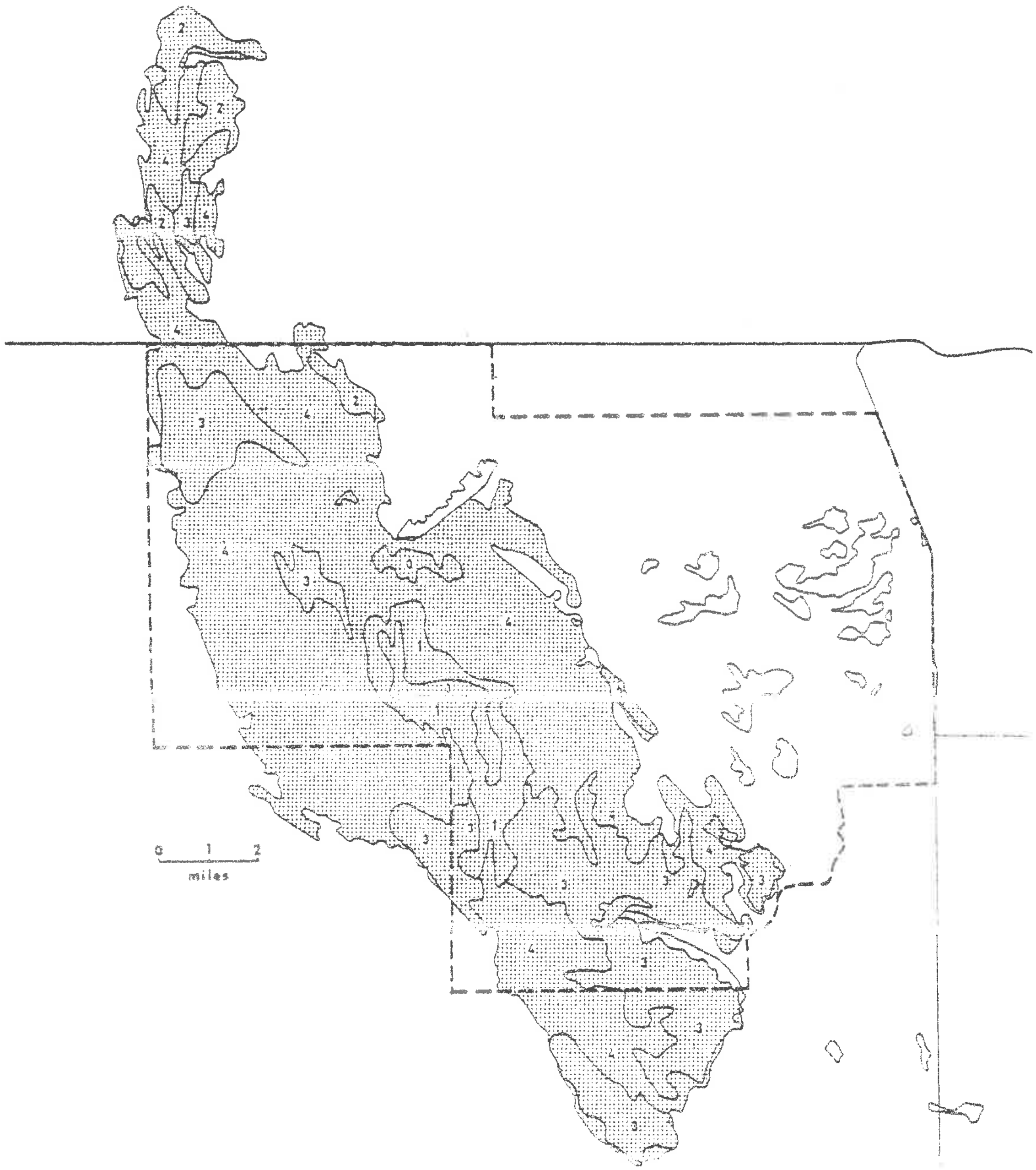

Figure 5. Interpretation of LANDSAT scene (9 August 1977) for relative vegetation recovery zones combined with burn boundary information from 11 May 1977 LANDSAT scene. Zeros indicate areas where no vegetation recovery could be detected and areas coded four had sufficient recovery to preclude their delineation from unburned areas.

the length of time that fire burned on a given area. The number and size of hot spots recorded on the thermal infrared imagery in an area should be related to the fire intensity at that time. Comparison of sequential thermal imagery should permit identification of areas of persistently high fire intensity, an indication of severe burn in those areas.

The thermal imagery acquired by the fire mapping scanner used for the Walsh Ditch Fire was not adequately "fixed" and had begun to deteriorate before this study began. This made it impossible to obtain good imagery for successive days during the fire. Although relative fire intensity can be determined on a single piece of imagery, variable gain control settings on the image recorder (Hirsh et al., 1968) and different rates of film deterioration over time made it impossible to reliably compare fire intensity from one image to another.

The potential for evaluating the intensity of burn from thermal imagery seems feasible. A quantitative scanner with a built in temperature reference system (such as the Daedaelus Q-scanner) would permit determination of absolute temperatures for each pass and facilitate comparison of fire intensity between image acquisition periods. Secondly, at the time of acquisition, data should be properly recorded, fixed and stored to prevent deterioration. From an operational standpoint, this may prove impractical. Any time the fire mapping scanner is in operation, the primary concern is to deliver reliable data to the fire boss in the shortest possible time. The extra care required to insure image longevity may be detrimental to fire suppression efforts and may not be justified.

Summary and Conclusions

Color-infrared and black and white aerial photography obtained before and after the Walsh Ditch Fire on the Seney National Wildlife Refuge were used to prepare post-fire vegetation cover and fire boundary maps. Areas where vegetation cover type changes and extensive post-fire mortality occurred were also mapped successfully. The original maps were prepared on 1:24,000 scale USGS topographic map sheets. Copies prepared for field use at 1:48,000 scale are found in the jacket in the back of this report.

Vegetation and fire boundaries can be most accurately mapped from post-fire color-infrared aerial photography. The 11 May photography obtained prior to any vegetation recovery provided an excellent data source for mapping fire boundaries. The late summer set of imagery could provide a good source for mapping post-fire vegetation and vegetation recovery. The imagery acquired prior to green-up is, by itself, inadequate for mapping post-fire vegetation.

Interpretation of LANDSAT imagery provided valuable information on the utility of satellite data for mapping fire boundaries and vegetation recovery. The Walsh Ditch Fire boundary could be mapped from the 11 May 1977 LANDSAT image obtained before green-up occurred following the August-September wildfire, except where only light surface fires had burned under coniferous forest canopies. It did not appear that the degree of burn interpreted from the May image was closely related to vegetation recovery interpreted from the August imagery, except that areas interpreted as being severely burned on the May imagery showed low levels of recovery on the August imagery. By comparing the two images, the major areas of post-fire tree mortality could be identified.

LANDSAT coverage of burn areas can provide valuable information about extent of burn and vegetation recovery. It appears that the potential to accurately map fire boundaries by manual interpretation, as well as computer assisted interpretation, is possible for all but light surface fires which occur under forest canopies. Mapping the severity of burn from pre green-up imagery is inconclusive for this study, but indications are that monitoring classification of vegetation recovery later in the growing season would be a better indication of the severity of burn.

Fire intensity studies based on thermal infrared line-scan imagery acquired during the fire indicated that mapping relative fire intensity at the time of acquisition is possible. It was not possible, however, to determine severity of burn because fire intensity and duration could not be determined accurately enough from the two year old imagery which had begun to deteriorate in storage.

The situations encountered during image acquisition of thermal line-scan data of fires may preclude the retrieval and storage of quality thermal data for later study. Under controlled situations, however, obtaining a set of thermal imagery for studying fire intensity and degree of burn may be warranted. The potential for using this type of data source for determining the severity of burn and, thus, future vegetation recovery could provide an invaluable source of information for reforestation efforts and management decisions following wildfires.

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