The 1977 Tundra Fire in the Kokolik River Area of Alaska

INTRODUCTION

Widespread fires occurred on the Seward Peninsula, Alaska, during the summer of 1977. During this period there was also one large natural fire in the northern part of the state. Presumably caused by lightning, it occurred due east of Point Lay and several kilometres southwest of the Kokolik River (69°30′N, 161°50′W) on the boundary between the coastal plain and the northern foothills[1] (Fig. 1). According to the smoke-jumper record kept by the U.S. Bureau of Land Management (BLM) this was the farthest north a fire had ever been fought by the personnel of BLM in Alaska. No tundra fires had previously been reported from this area, although during the years 1969 to 1971 fires occurred on the North Slope of which four were stated to have been caused by lightning[2,3].

Climatic conditions in northern and western Alaska during the summer of 1977, as observed at the Cape Lisburne station of the U.S. Air Force, situated 185 km to the southwest of the area of the Kokolik River fire (the meteorological observation centre closest to it), were apparently ideal for tun-

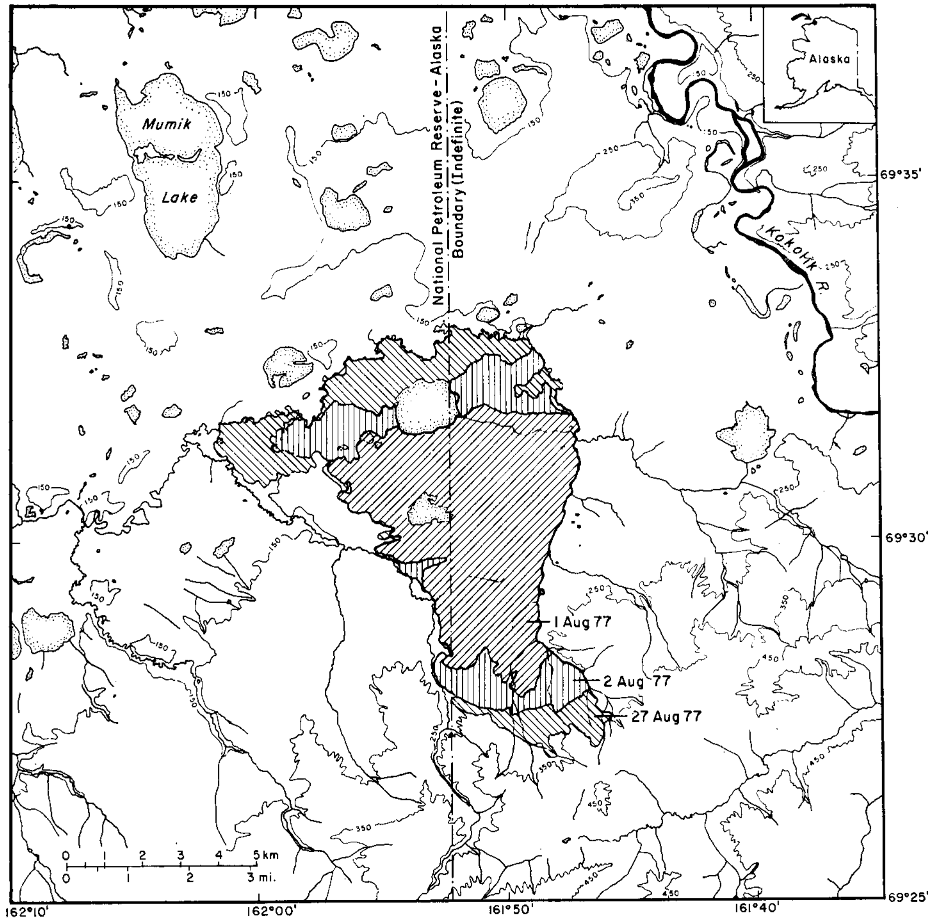

FIG. 1. Location map of Kokolik River tundra fire, with its extent on 1, 2 and 27 August 1977 indicated by shadings. Boundaries of the fire were drawn from 1:63,360 Landsat photographic enlargements prepared by Tom Marlar, U.S. Army Cold Regions Research and Engineering Laboratory.

dra fires. In July it was extremely dry (5.3 mm rainfall); and average air temperatures were above normal, maxima in the latter part of the month being in the mid-teens and low twenties (°C). The North Slope was in general extremely dry, no precipitation being reported from Umiat or Barrow for the period 9-24 July 1977.

The Kokolik River fire apparently started just west of the National Petroleum Reserve — Alaska (NPRA) boundary and then spread eastward into the NPRA itself (Fig. 1). It was discovered by personnel of the BLM on 26 July, at which time its extent was estimated at 0.4 km^2. High winds, which prevented the fire fighters from landing on 26 July, prevailed until 31 July and undoubtedly contributed to the intense nature of the fire. By noon on 27 July, when the first BLM fighters arrived, the extent was estimated at 4.0 km^2. The BLM personnel fought the fire from 27 July to 31 July, when they abandoned it in order to attend to outbreaks elsewhere. Apparently, light rains nearly extinguished the fire on 28 July, and after it had started up again fog slowed its progress once more on 30 July. Nevertheless, according to the Landsat imagery the fire was still burning on 2 August. It was stated in the BLM fire report that on 7 August the fire had not gained any "acreage" and was "controlled". It was declared out by the BLM on 12 August.

The information on the spread of the fire,

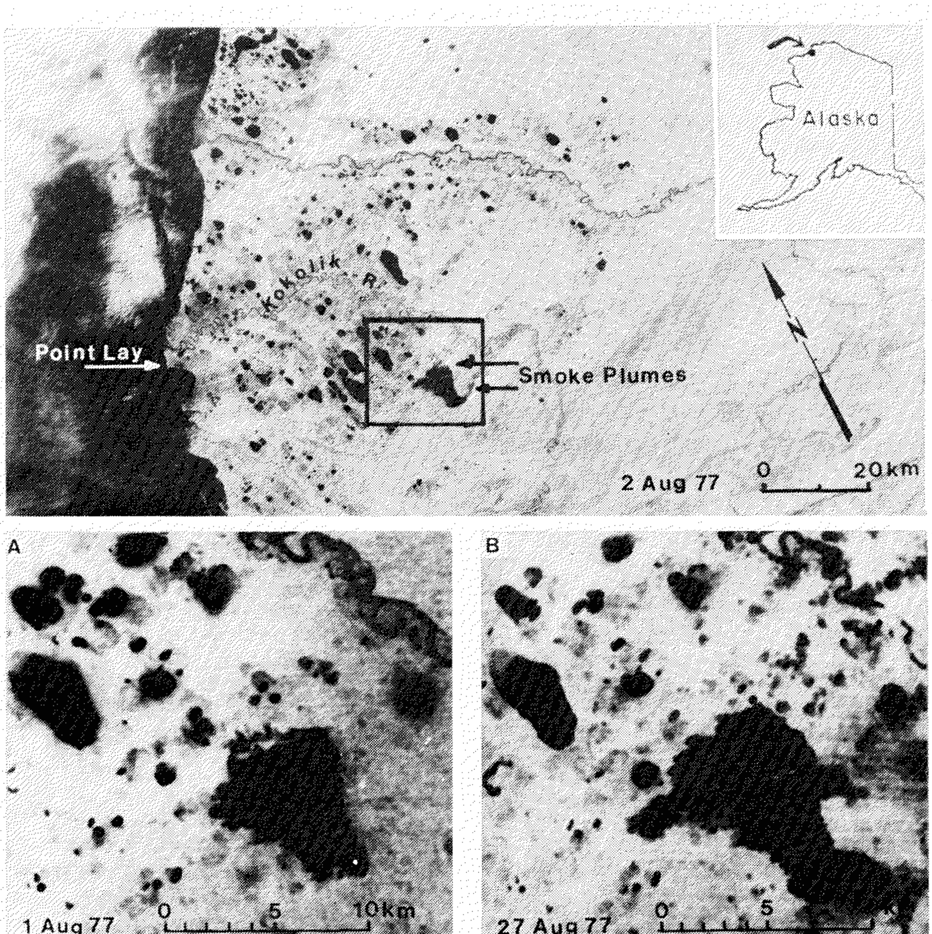

FIG. 2. TOP: Landsat band 7 scene (scene I.D. no. 2923-21342) of Kokolik River fire, showing extent and direction of smoke on 2 August 1977. BOTTOM: 1:250,000 enlargements of scenes of the fire area on (a) 1 August (scene I.D. no. 2922-21284) and (b) 27 August (scene I.D. no. 5861-20500).

as presented in this short paper, was gathered from Landsat imagery, meteorological observations, facts concerning the natural containment of the fire, and investigations of the affected area following the fire.

SATELLITE OBSERVATIONS

Landsat multispectral scanner subsystem (MSS) imagery has previously been employed to measure the progression and areal extent of wildfires[4]. Landsat provides repetitive coverage with a spatial resolution of 80 metres. The MSS on board the Landsat-1 and Landsat-2 provides imagery in four spectral bands: band 4 (0.5-0.6 μm) and band 5 (0.6-0.7 μm) in the visible range; and band 6 (0.7-0.8 μm) and band 7 (0.8-1.1 μm) in the near-infrared range. Only imagery from bands 5 and 7 were used in this study. Analysis of the 1977 Landsat imagery provided considerable information on the spread of the Kokolik River fire as well as the rapidly changing wind conditions which influenced it.

Examination of the band 5 (visible) image for 1 August clearly revealed two distinct smoke plumes emanating from the fire on its eastern boundary and a wind blowing from the east. The band 7 (near-infrared) image did not show well-defined smoke plumes and therefore provided a poor indication of wind direction; it did however provide the best available view of the 26 km^2 areal extent of the fire. The measurements of the areal extent of the fire are based on digital analysis of 1:1,000,000-scale Landsat imagery. Photographic enlargements of the burned areas were laid directly on top of a 1:63,360 topographic map of the U.S. Geological Survey (see Fig. 1).

The band 5 image for 2 August (Fig. 2) indicated a shift in wind direction, with smoke blowing to the east. National Weather Service synoptic maps indicate that there was a change in wind, from 5 knots (9 km per hour) northeasterly on 1 August tò 10 knots southwesterly on 2 August[5]. These data correlate well with the results of the Landsat observations.

Considerable haziness existed on the band 5 image of 2 August, probably due to the smoke from fires that were burning on the Seward Peninsula.

A comparison of the band 7 images of 1 August and 2 August reveals an increase from 26 km^2 in the extent of the fire over the 24-hour period to 34 km^2. The images of the fire of 21 August and of 27 August both indicate that a total of 44 km^2 had burned — an increase of about 10 km^2 since 2 August (Fig. 2).

By superimposing enlargements of the Landsat imagery of the burned areas on the topographic map of scale 1:63,360, it is apparent that the stream bordering the fire on the east had formed a natural fire barrier, and that the fire then spread northward and southward (Fig. 1). Again, the stream channel to the north seemed to have stopped the spread of the fire. These small channels were not apparent on the Landsat image.

GROUND OBSERVATIONS

Craig Johnson of the Forest Soil Laboratory, University of Alaska, together with one of the present authors (Johnson) spent 30 August on site after landing there by helicopter. Low-altitude observations from the helicopter indicated that the fire burned a range of vegetation and relief types which included low-polygonized and upland-tussock tundras. The fire was extremely hot and, although exposed mineral soils in the upland tundra did not constitute a high percentage of the total area, the extent of bare soils was several times greater in the burned areas than in comparable unburned areas. Some of the bare areas could have previously been exposed as frost scars or boils.

A transect within the upland tundra was established from approximately 180 metres within the burn to the edge of the burn, across a small creek and up onto the unburned tundra. The exact ground location of the transect was difficult to ascertain, due to poor visibility from the air, but it is most likely located on the eastern edge of the burn (Fig. 1). Three one-metre-square quadrats were established in each of the following burned areas: severely burned tussock tundra; moderately burned wet tundra; lightly burned shrub tundra at the edge of the fire; and unburned tussock tundra. The percentage of area covered by live vascular plants, mosses, lichens and charred surface was observed within each quadrat. Soil samples were obtained for subsequent nutrient analysis. Depth of thaw was measured at five points within the quadrat and at 25-m intervals along the 180-m transect.

On the basis of a comparison with the unburned vegetation, which had large, well-developed tussocks, it was estimated that 80-90% of the biomass of the tussocks was consumed in the fire. All areas of raised relief, which characteristically consisted of tussock tundra, were severely burned, averaging less than 10% live-plant cover. This may have been due to either more fuel (litter and standing dead vegetation) being available, drier soils being associated with higher terrain, or both conditions. In contrast, irregu-

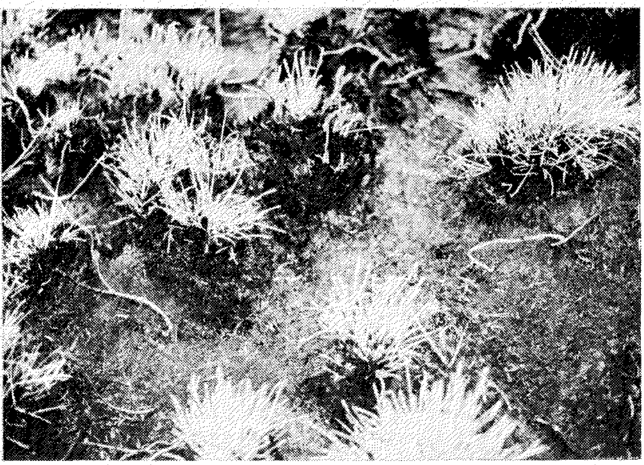

FIG. 3. Close-up view of severely burned tussocks. Individual tussocks show regrowth. Photograph by L. Johnson, 30 August 1977.

larly distributed areas of low relief, such as swales, were moderately burned, averaging 30% live plant cover, while in lightly burned areas live vascular-plant cover averaged 40%. It appeared that all shrub parts present above ground, in both severely and moderately burned areas, had been consumed by the fire, and if any below-ground shrub parts were still living, they had not sprouted by the end of August. In contrast, 80% of the tussocks already showed regrowth, as was evidenced by their shoots (Fig. 3); and there was also regrowth in wetter areas containing *Carex* spp. and *Eriophorum angustifolium*. Such regrowth of tussocks in the late summer was also observed in the tussock fire at Elliott Highway in 1969 [6,7].

The burned area appeared wetter on the surface than the unburned area, due to a lack of moisture-absorbing organic matter and the possible release of moisture from the deeper-thawed zone. Depth of thaw between tussocks averaged 35.4 cm in the burned areas, as compared to 26.6 cm in the unburned ones. Mackay[8] reports that after the Inuvik fire of 1968 there was a continued seasonal increase in thaw following an average initial increase of 24 cm. Kryuchkov[9] discusses the fact that an initial increase in thaw was followed by a subsequent decrease in it, after tundra fires in Siberia.

POSSIBLE FUTURE INVESTIGATIONS

The site of the Kokolik River fire is excellent for continued investigations, similar to those undertaken at Inuvik[10], of the effects of fire on tundra and permafrost terrains. It is desirable to:

(a) compare the nutrient runoff and change in primary productivity between the burned and unburned areas. The influence of anticipated increases in nutrient and sediment loads on the lakes contained within the fire area (Fig. 1) could also be investigated.

(b) monitor depth-of-thaw changes and thermokarst development under areas of different intensity of burn and different moisture conditions. The hypothesis proposed by L. Viereck, U.S. Forest Service (personnel communication), that intensity of frost action may be directly related to fire frequency on the Seward Peninsula could be tested at this site.

(c) monitor revegetation and successional changes on the burned areas. The increased flowering of *Eriophorum vaginatum*, which normally occurs after a fire, could provide a harvestable seed source for revegetation elsewhere. Digital analyses of the available Landsat imagery for August 1977 can be used to classify burn intensity as a function of reflectance differences.

(d) acquire ground-truth data, particularly on vegetation succession, which can be correlated with those obtained from detailed digital analyses of future Landsat imagery. Data obtained from the latter during the spring and summer of 1978 should reveal valuable information on the initial response of vegetation in the burned areas.

CONCLUSIONS

The Kokolik River fire of 1977 affected an area of 44 km^2, according to measurements made using Landsat imagery. On the evidence obtained from an analytical study of this fire by ground observations, Landsat imagery and topographic maps, it appears that natural drainages form effective fire breaks on the subdued relief of the Arctic coastal plain and northern foothills. Furthermore, this study served to reconfirm the fact that the intensity of fire is related to vegetation type and moisture content for organically-rich soils.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support rendered them by the U.S. Army Cold Regions Research and Engineering Laboratory, through its Cold Regions Environmental Factors project, as well as from the results of the environmental investigations conducted by it, with U.S. Geological Survey support, in the National Petroleum Reserve — Alaska. They also gratefully acknowledge the assistance given them by Mr. Kenneth Lehtonen of the National Aeronautics and Space Administration in the digital analyses of the Landsat imagery, and also other staff members of NASA. Finally they wish to thank Dr. Leslie Viereck of the U.S. Forest Service, Fairbanks, Alaska, for a critical review of, and valuable contribution to, the manuscript, and also Mr. John Santora of the U.S. Bureau of Land Management, Fairbanks, who made a helicopter available for surveys of the fire and provided other information on it.

Dorothy K. Hall
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771, U.S.A.

Jerry Brown
U.S. Army Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire 03755, U.S.A.

Larry Johnson
U.S. Army Cold Regions Research and Engineering Laboratory
Fairbanks, Alaska 99701, U.S.A.

REFERENCES

[1]McCulloch, D.S. 1967. Quaternary geology of the Alaskan shore of the Chukchi Sea. In: Hopkins, D.M. (ed.), *The Bering Land Bridge*. Stanford, California: Stanford University Press. pp. 91-120.

[2]Wein, R.W. 1976. Frequency and characteristics of Arctic tundra fires. *Arctic*, 29(4): 213-22.

[3]Barney, R.J. and Comiskey, A.L. 1973. Wildfires and thunderstorms on Alaska's North Slope. *U.S., Department of Agriculture, Forest Service, Research Note* PNW-212.

[4]Haugen, R.K., McKim, H.L., Gatto, L.W. and Anderson, D.M. 1972. Cold regions environmental analysis based on ERTS-1 imagery. *Proceedings, Eighth International Symposium on Remote Sensing of Environment, 1972*. Ann Arbor, Michigan: Environmental Research Institute of Michigan. Vol. 2, pp. 1511-21.

[5]N.W.S. 1977. National Weather Service 6-hourly synoptic maps. Ashville, North Carolina.

[6]Wein, R.W. and Bliss, L.C. 1973. Changes in Arctic *Eriophorum* tussock communities following fire. *Ecology*, 54(4):845-52.

[7]Brown, J., Rickard, W. and Vietor, D. 1969. The effect of disturbance on permafrost terrain. *U.S. Army Cold Regions Research and Engineering Laboratory, Special Report* 138.

[8]Mackay, J.R. 1977. Changes in the active layer from 1968 to 1976 as a result of the Inuvik fire. *Canada, Geological Survey, Paper* 77-1B, Part B. pp. 273-75.

[9]Kryuchkov, V.V. 1968. Soils of the Far North should be preserved. *Priroda*, no. 12: 72-74.

[10]Wein, R.W., Sylvester, T.W. and Weber, M.G. 1975. Vegetation recovery in Arctic tundra and forest-tundra after fire. *Arctic Land Use Research* 47-75-62.