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VEGETATION MAPPING OF THE NATIONAL PETROLEUM RESERVE IN ALASKA USING LANDSAT DIGITAL DATA

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ABSTRACT

The general vegetation associations of the 97,000-square-kilometer National Petroleum Reserve in Alaska have been mapped using computer-aided analysis of Landsat digital data. Digital analysis techniques used in the NPRA project utilized several computers which made it possible to use the most efficient system for each specific processing task. The land cover classification scheme devised was based on plant communities optimally delineated with multispectral data. The ten land cover categories include wet Meadow Tundra, Moist Meadow Tundra, Moist Meadow-Tussock Tundra Complex, Moist Tussock Tundra, Dry Mat and Cushion Tundra, Riparian Shrubland, Barrens, Deep Water, Shallow and Sedimented Water, and Ice and Snow. Recommendations for further research and potential applications for maximum utilization of the NPRA classification are discussed.

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INTRODUCTION

The immense size, inaccessibility, and harsh climatic conditions of the North Slope of Alaska make the acquisition of resource information very difficult. Vegetation mapping projects on the North Slope to date have been either site specific or highly generalized. Vegetation maps produced by the Institute of Arctic and Alpine Research, University of Colorado, as part of the Research on Arctic Tundra Environments Program (RATE) include relatively small, intensively studied test sites (1:10,500 and 1:21,000 scale) (Komarkova and Webber, 1980). Highly generalized vegetation maps include the Major Ecosystems of Alaska map (Joint Federal-State Land Use Planning Commission for Alaska, 1973) and the Potential Natural Vegetation Map of Alaska by Kuchler (U.S. Geological Survey, 1970). Both maps delineate broadly defined vegetation units at small scales (1:2,500,000 and 1:7,500,000). There exists a great need for a vegetation map of the entire North Slope which delineates useful vegetative communities with a high degree of accuracy and resolution.

Landsat digital data provide an attractive alternative to traditional photointerpretation methods in remote and extensive regions such as the North Slope of Alaska. Two satellites in phased orbits scan the same 185-kilometer-square area on the ground at the same time of day every 9 days (Taranik, 1978). The resolution of the system is 80 meters but overlap along scan lines results in individual pixels (picture elements) measuring 79 by 57 meters (approximately 0.45 hectare). Measurements of reflected electromagnetic radiation from each pixel are made in four wavelength bands, the visible green (0.5 to 0.6 microns), visible red (0.6 to 0.7 microns), and two near infrared (0.7 to 0.8 and 0.8 to 1.1 microns). Each scene contains 7.58 million pixels of four-band data.

Computer-aided analysis techniques have been developed to effectively generate maps and statistics from Landsat digital data. Several vegetation mapping projects within Alaska have utilized these techniques. The U.S. Fish and Wildlife Service is exploring the use of Landsat data for compiling an inventory of wetlands in Alaska as part of the National Wetlands Inventory. Virginia Carter, U.S. Geological Survey (USGS), and James Morrow, Jet Propulsion Laboratory, have investigated the feasibility of using Landsat digital data for wetland studies. Their study involved supervised clustering and classification of three test sites on the North Slope (Carter and Morrow, 1977, unpublished field trip report). The feasibility of using Landsat digital data for caribou habitat mapping in western Alaska has been investigated by Lent and LaPerrier (1974). Researchers from the University of Alaska have completed a number of land resource projects in Alaska (Lyon and George, 1979). In conjunction with the Alaska Southcentral Water Resources Level B Study, University of Alaska researchers have completed a regional resource inventory using Landsat Multispectral scanner (MSS) data for southcentral Alaska (Krebs and others, 1978). George and others (1977) have completed a reindeer range inventory of portions of the Seward Peninsula, Alaska, from Landsat digital data. Ecosystem units and coastal processes in four regions of the Alaskan coastal zone have been mapped with Landsat digital data (Belon and others, 1975; Miller and

George, 1976). As part of NASA's Applications Systems Verification and Transfer Program, with the Bureau of Land Management, researchers of the University of Alaska and USGS have recently completed an inventory of wild land resources in the Denali area (Miller and others, 1978).

USGS researchers have also been experimenting with Landsat in support of the Survey's national land use and land cover mapping effort (Ellefsen and others, 1977). Although this national effort relies upon high-resolution, high-altitude photographs, experience gained by those working with Landsat digital data indicates that it can be a reliable substitute for mapping certain vegetative cover classes in wild land areas at a detail comparable to that being achieved in the national program.

The National Petroleum Reserve in Alaska (NPRA) is the subject of an intensive planning effort as directed by the Naval Petroleum Reserve Production Act of 1976. The USGS was responsible for compiling a resource inventory in compliance with Section 105B, Environmental Impact Assessment. The Bureau of Land Management (BLM) was responsible for Section 105C, Land Use Study. Both efforts required a comprehensive vegetation map of the region. The USGS has mapped the vegetation of the 97,000-square-kilometer NPRA using Landsat digital data. This mapping also served as a prototype for producing USGS land use and land cover maps using Landsat digital data rather than high-altitude photographs as primary source material. If successful, these techniques can be applied in other high interest areas of the State to gradually build up a series of land use and land cover maps for Alaska.

Study Area

The National Petroleum Reserve in Alaska, located on the North Slope of the Brooks Range, is bounded by the Beaufort Sea to the north, the Chukchi Sea to the west, the crest of the Brooks Range to the south, and the Colville River to the east (fig. 1). This large expanse of tundra includes three major physiographic provinces (Wahrhaftig, 1965): the Arctic Coastal Plain, the Arctic Foothills, and the Brooks Range. The Arctic Coastal Plain is characterized by thousands of lakes, extensive wetlands and polygonal ground features. The Arctic Foothills consist of tussock tundra on rolling terrain. The Brooks Range, with elevations up to 1,500 meters within the NPRA, is characterized by glaciated shale and sandstone outcrops supporting low-lying mat and cushion vegetation. The following discussion on tundra vegetation reflects the contributions of numerous investigators (Britton, 1967; Spetzman, 1959; and Murray, 1978).

Vegetation of the Arctic Coastal Plain consists of a mosaic of plant communities that reflect the patterns of ice wedge cracks of polygonal ground features. Polygonal ground patterns are produced by contraction of the ground in response to filling of the cracks by water, widening of the cracks by freezing and thawing in succeeding winters, and incremental expansion of the ice wedges (Lachenbruch, 1963). The size of the polygons vary from a few meters to 50 meters across. Polygonal patterns are the surficial expression of the vertical ice wedges and are of two general types: high-centered and low-centered polygons. High-centered polygons are characteristic of areas of integrated drainage with coarse

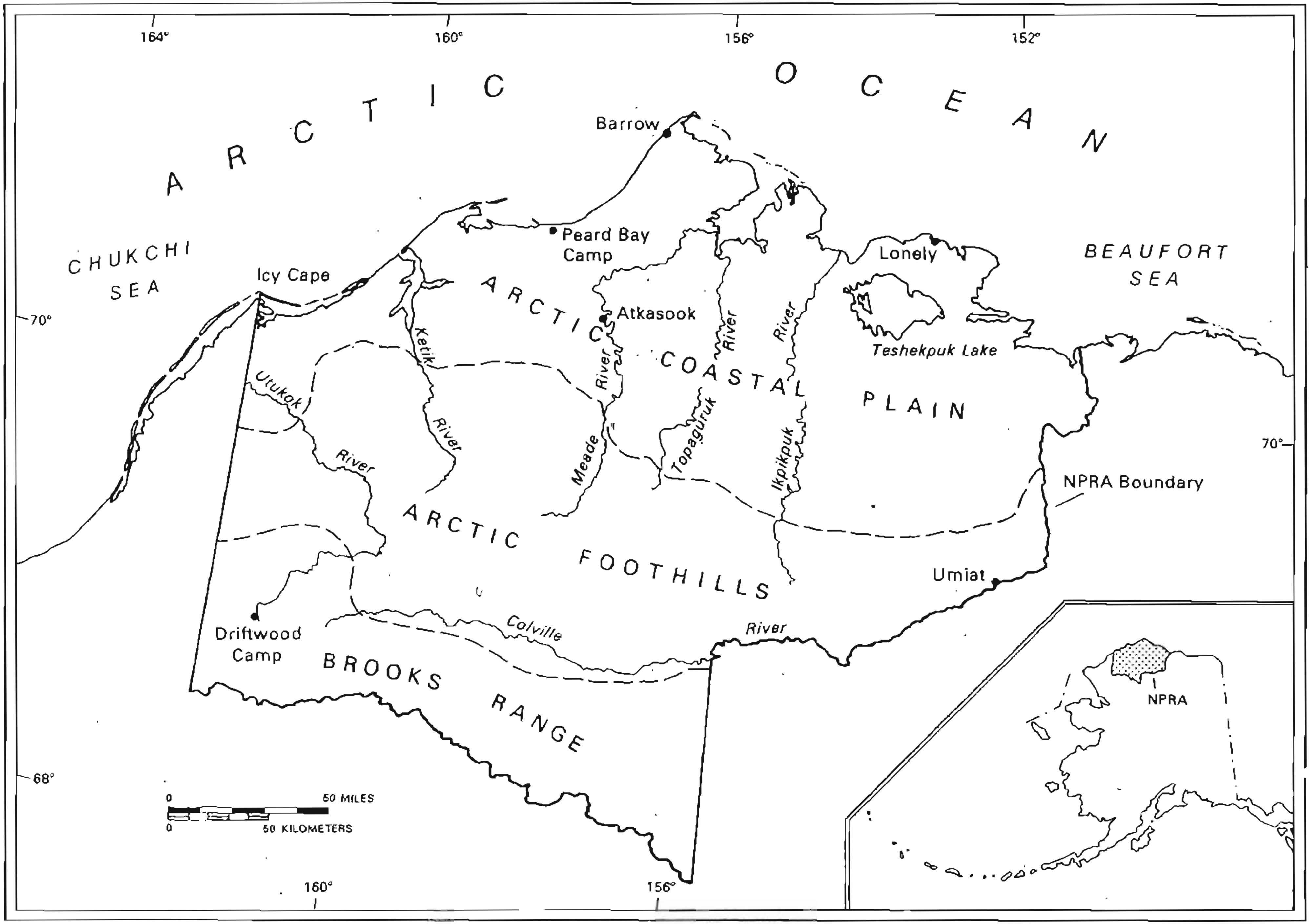

Figure 1.--Location map.

materials. They support mainly tussock-forming sedges in the center with marsh species along the troughs. Low-centered polygons have depressed cores with elevated rims and support grasses, sedges, mosses, and various forbs.

Tussock tundra is the dominant community of the Arctic Foothills province. Wet meadows occupy the low depressions and dry meadows with low mat and cushion vegetation cover the summits and ridges. Alder and willow thickets are found along major rivers and streams.

In the Brooks Range, rock outcrops on mountain ridges, and talus and rubble slopes in the higher elevations are sparsely vegetated while dry meadows occupy lower slopes and interfluves. Wet, boggy meadows are found adjacent to streams and lakes. Tussock tundra covers well-drained, gentle slopes.

Herbaceous perennials and prostrate shrubs are the most abundant life form in the Arctic (Johnson and Tieszen, 1973). Up to three layers can usually be distinguished in tundra plant communities. Meadow communities are represented by a surface layer of bare soil or moss with an upper layer of sedges, grasses, and shrubs. Tussock tundra areas consist of a base of moss or lichen, with an intermediate layer of heath and forbs, and an upper layer of tussock-forming sedges and prostrate shrubs. The layers are usually poorly developed since the total height of the vegetation rarely exceeds 45 centimeters.

Vegetation is one of the primary components of the Arctic Landscape and it is a fairly reliable and useful indicator of other environmental and ecological relationships. The interaction of Arctic plant communities with soils, soil moisture, depth of summer soil thaw, drainage, ground ice content of soil, and polygonal type has been summarized in table 1.

LANDSAT DATA PREPARATION

Acquisition of Landsat Scenes

Landsat scenes were selected on the basis of cloud cover, season of the year, and orbital path. Complete coverage of NPRA was obtained with portions of ten Landsat scenes. Dates range from July 6 to August 26, in a 2-year time span (1975-1976). All but one of the original ten scenes were cloud-free, and each frame was one of a pair or triplet of sequential scenes along an orbital path (fig. 2). From west to east, frame overlap was as great as 50 percent. This overlay was necessary to cover the entire NPRA, and allowed numerous options for the final mosaicking. One cloudy scene (covering the Barrow area) was replaced with a cloud-free scene from July 1977 after the preliminary classification was complete.

Computer Systems

Digital image analysis techniques, developed by USGS analysts at NASA-Ames Research Center, utilized several computers for the NPRA mapping project (fig. 3) which made it possible to use the most efficient system for each specific processing task.

Table 1.--Plant communities in relation to landscape elements.

Community	Depth of[2] Soil Thaw	Soil[2] Moisture	Drainage[3]	Ground Ice[4] Content	Ice Wedge[5] Polygons	Soil Type[6]
Dry Mat and Cushion Tundra[1]	deep	low	integrated	low	N/A	Arctic Brown
Moist Tussock Tundra	shallow	low	integrated	high	high-centered	Plant Tundra
Moist Meadow-Tussock Tundra Complex	intermediate	intermediate	integrated	intermediate	high and low-centered	Upland Tundra
Moist Meadow Tundra	intermediate	intermediate	impeded	low	low-centered	Meadow Tundra
Wet Meadow Tundra	shallow	high	impeded	low	low-centered	Meadow Tundra

Sources:

[1] Johnson and Tieszen 1973

[2] Webber and others 1977

[3] Everett 1975

[4] Hussey and Michelson 1966

[5] Webber and Walker 1975

[6] Tedrow 1977

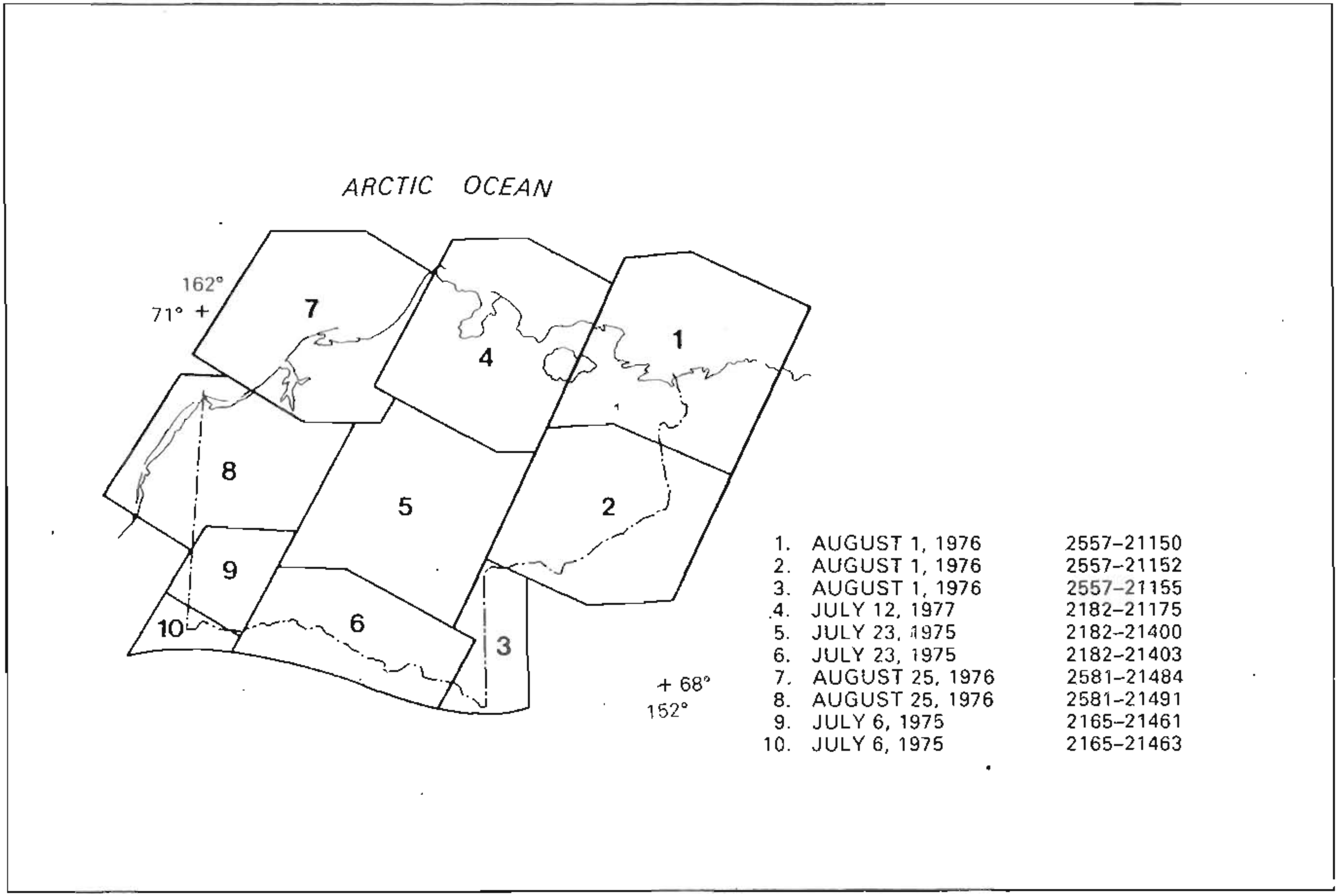

Figure 2.--Index to Landsat scenes used in the NPRA analysis.

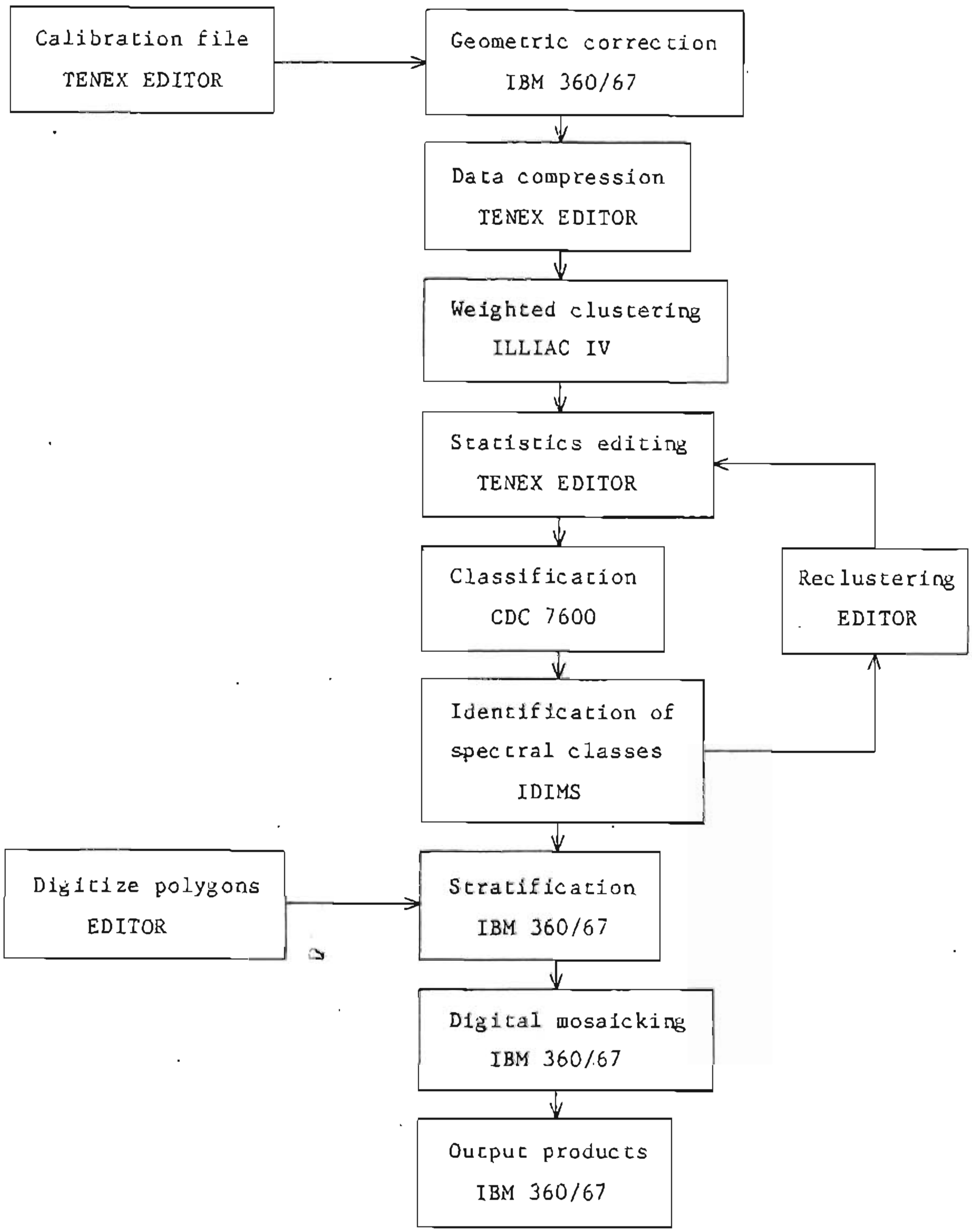

Figure 3.—Major processing tasks and computer systems utilized for the NPRA analysis.

Figure 4.--Wet Meadow Tundra and Moist Meadow Tundra communities.