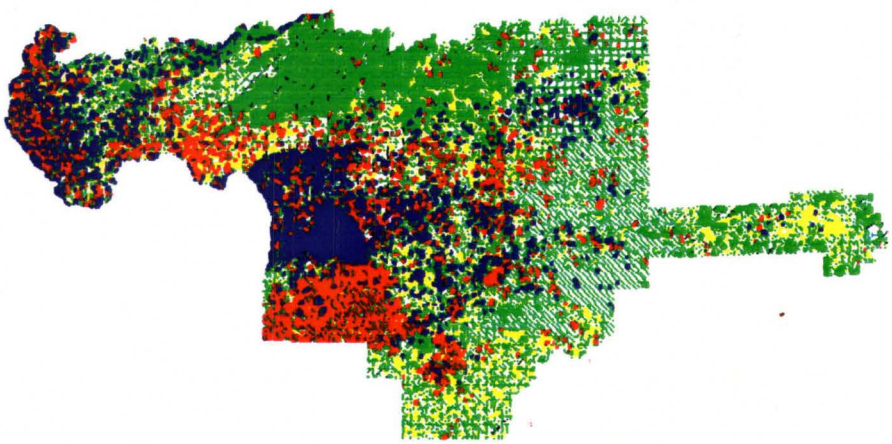
SELAWIK
NATIONAL WILDLIFE REFUGE
LAND COVER MAPPING PROJECT
USERS GUIDE



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USGS/EROS
ANCHORAGE, ALASKA
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INTRODUCTION

Title III of the Alaska National Interest Lands Conservation Act (ANILCA, 1980) established the Selawik National Wildlife Refuge (SNWR). Section 304 of the Act requires the Secretary of Interior to "prepare, and from time to time revise, a comprehensive conservation plan" for the refuge. Before developing a plan for the refuge, the Secretary shall "identify and describe--a) the populations and habitats of the fish and wildlife resources of the refuge; b) the special values of the refuge as well as any other archeological, cultural, ecological, geological, historical, palentological, scenic, or wilderness value of the refuge; c) areas within the refuge that are suitable for use as administrative sites or visitor facilities...; d) present the potential requirements for access with respect to the refuge...; and e) significant problems which may adversely affect the populations and habitats of fish and wildlife identified and described..." (ANILCA, 1980). Vegetation, water, and terrain (elevation, slope, and aspect) are the components of habitat and can be used in the determination of the above requirements.

The U. S. Fish & Wildlife Service (USFWS) has the responsibility for collecting the resource information to address the research, management, development and planning requirements identified in Section 304. Because of the brief period provided by the Act for data collection, habitat mapping, and habitat assessment, the USFWS in cooperation with the U.S. Geological Survey's EROS Field Office, used digital Landsat multispectral scanner (MSS) data and digital terrain data to produce land cover and terrain maps. A computer assisted digital analysis of Landsat MSS data was used because coverage by aerial photographs was incomplete for the refuge and because the level of detail obtained from Landsat data was adequate to meet most USFWS research, management and planning needs. Relative cost and time requirements were also factors in the decision to use the digital analysis approach.

OBJECTIVES

The primary objectives of the mapping project were to:

1) produce digital land cover/terrain classifications for the SNWR, using digital Landsat and terrain data,

2) provide Landsat MSS data for the entire study area defined as the SNWR,

3) provide other derivative products and output products as required.

The primary objectives of this user guide are to give a brief discussion of the methodology used and describe the different types of data products produced.

AREAS OF COVERAGE

The SNWR encompasses approximately 3.2 million acres of land and water in the west central portion of Alaska. The northwest and southeast latitude/longitude coordinates of the mapped area are 67 00'/112 30' and 66 00'/156 00' respectively. The entire study area covers roughly 1 degree of latitude by 6 degrees of longitude and involves five USGS 1:250,000-scale topographic maps (Figure 1). Portions of three Landsat scenes (Table 1) were required to provide complete coverage of SNWR and the surrounding areas (Figure 2).

METHODOLOGY

A computer compatible tape (CCT) was obtained for each Landsat scene covering refuge lands. Training blocks (sample areas containing representative land cover types) were selected for field study, and training statistics were derived from them. Figure 3 shows the location of the training blocks used in this study. A modified clustering technique (Fleming, 1975) was used to generate initial spectral classifications, using the EROS Field Office computer system (HP-3000) and IDIMS software (ESL 1981). The classified scenes were radiometrically and geometrically corrected (registered to a 50-meter Universal Transverse Mercator [UTM] grid) and the boundaries of the refuge and the corresponding 1:250000-scale USGS quadrangles digitized. This made it possible to summarize land cover information for each quadrangle and the refuge as a whole.

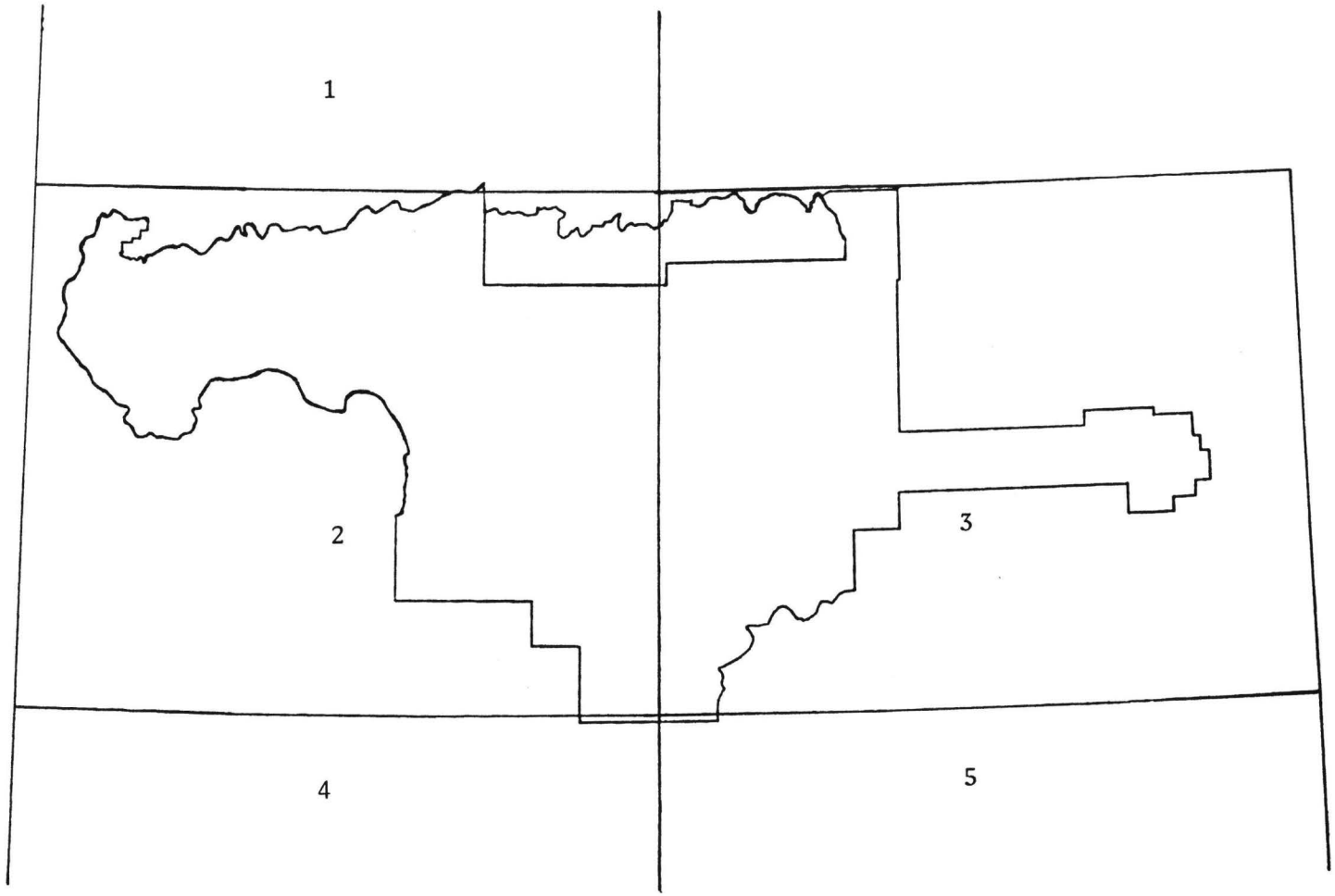

Figure 1. The 1:250,000-scale USGS quadrangles covering the Selawik National Wildlife Refuge.

Table 1. List of Landsat scenes acquired to cover the Selawik National Wildlife Refuge.

Path/Row	Scene I.D.	Date
87/13	21297-21155	11 Aug. 1978
85/13	21691-21184	9 Sep. 1979
83/13	30494-21462	12 July 1979

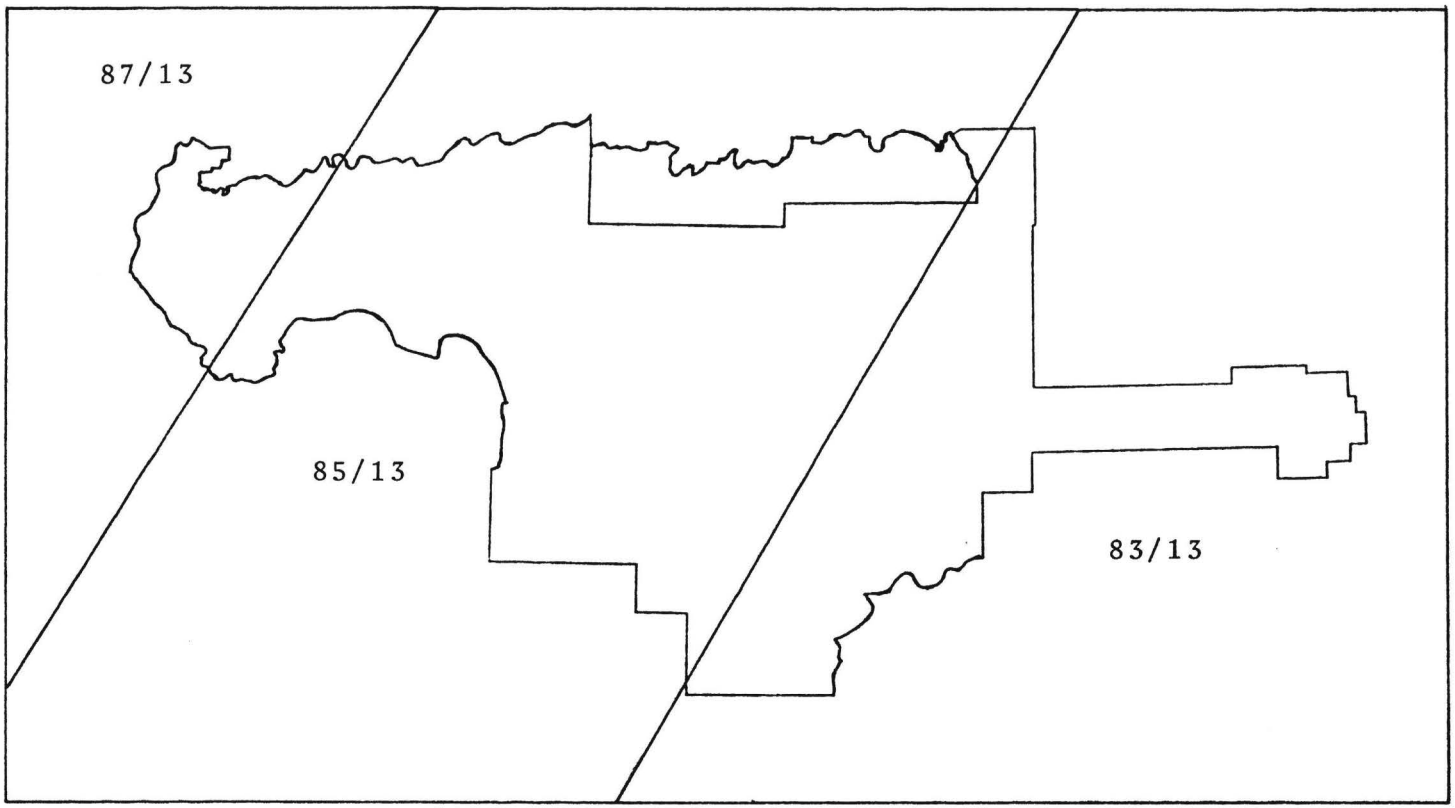

Figure 2. Path/Row numbers identifying the Landsat scene locations for the Selawik National Wildlife Refuge.

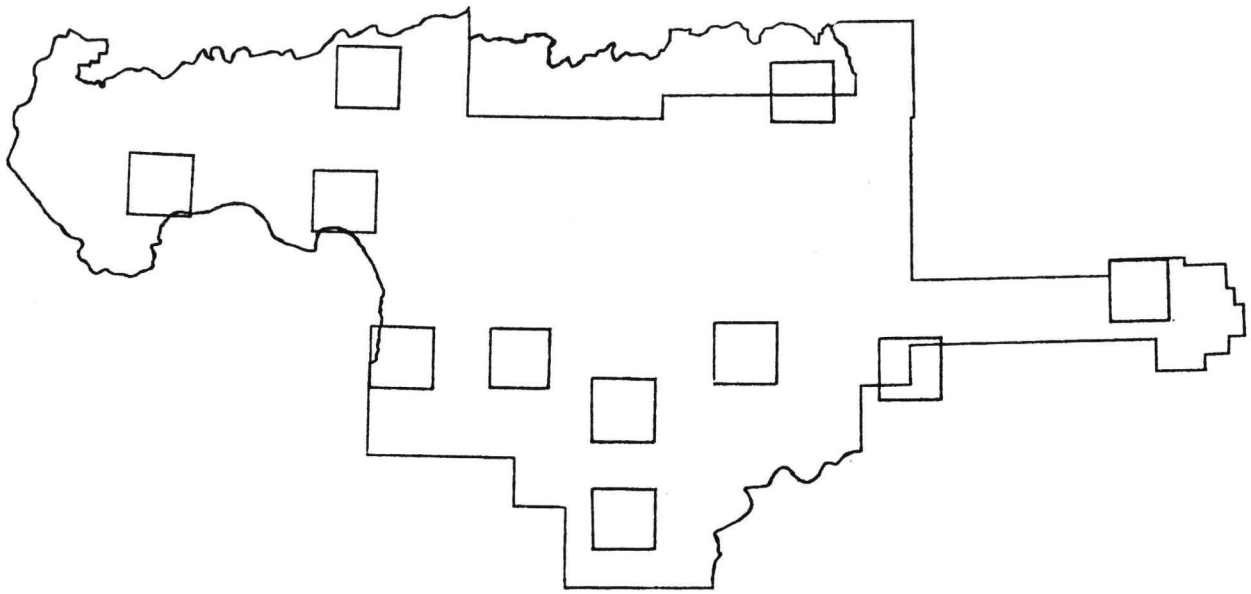

Figure 3. Location of training blocks used for the Selawik National Wildlife Refuge Landsat classification.

Field data on vegetation cover, structure, and composition were collected in each training block to identify land cover types corresponding to computer-derived spectral classes. Final land cover classifications, designated by USFWS personnel, were produced after applying stratification techniques to improve classification accuracy. Land cover classifications were merged with digital terrain data derived from 1:250,000-scale USGS quadrangles to improve classification accuracy and to make possible the production of additional resource data products such as elevation, slope, and aspect. Specific procedures used in producing land cover/terrain classifications and output products are detailed in Appendix A.

Land cover classifications centering on the Selawik and Shungnak quadrangles were extracted from each classified Landsat scene (where applicable) and mosaicked together. Further enhancement was applied to the classification using terrain data and information obtained from USFWS personnel. A schematic diagram of the mapping process is shown in Figure 4.

USFWS personnel worked with EROS personnel to conduct the digital analysis required to produce land cover classifications for the refuge and coordinated with USFWS Information Resource Management personnel to ensure that the digital data were compatible with the USFWS geobased information system.

PRODUCTS

The following products were produced for the mapping project:

1) Computer tapes containing land cover and terrain data classifications.

2) Ink jet plots of the land cover and terrain maps at a 1:250,000 scale.

3) Acreage estimates for each land cover type in the refuge for the areas centering on the Selawik and Shungnak USGS quadrangles, and for the entire refuge.

4) Computer tapes of resampled land cover and terrain data.

5) This users guide.

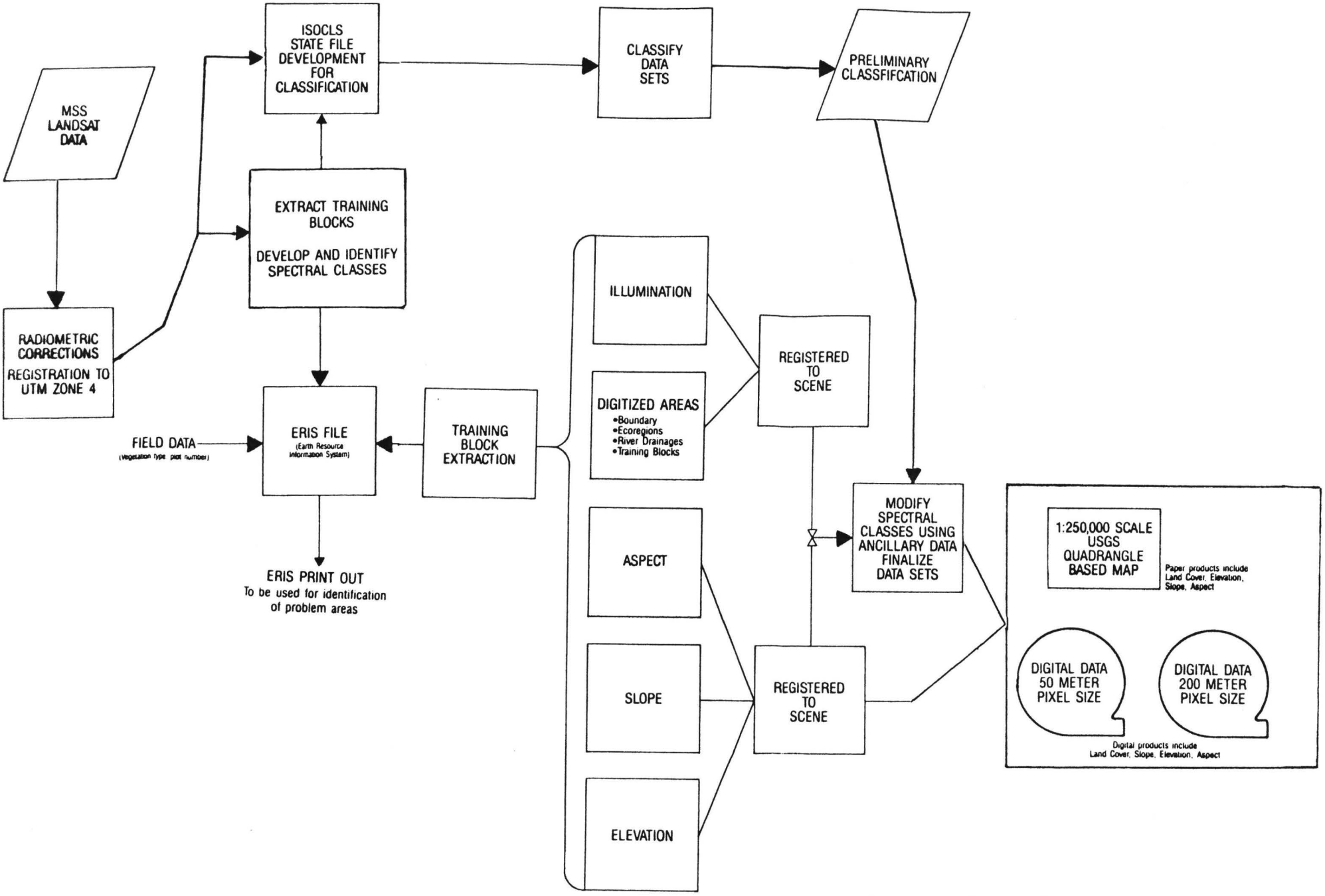

Figure 4. Schematic diagram of the mapping process used to produce the land cover classification of the Selawik National Wildlife Refuge.

PRODUCT DESCRIPTIONS-HARD COPY

LAND COVER CLASS DESCRIPTIONS

Based on information acquired in the field, discussions with USFWS personnel, and Landsat spectral discrimination, seven major land cover classes were recognized: Barren, Forest, Herbaceous, Shrub, Dwarf Scrub, Water, and Other. Included in these major classes are 21 subclasses (Table 2). A general description of each of the major classes and subclasses is in Appendix B.

Acreage estimates for each land cover class within the refuge boundary were summarized (Table 3). Final hard copy land cover maps were produced for the refuge in the form of ink jet plots. Map collar information included: map title, a list of vegetation classes, locational diagram of the refuge with respect to the State of Alaska, scale bar, and latitude/longitude tick marks. Each land cover class was depicted on the map as a color. The color scheme used was based on input from USFWS and USGS/EROS personnel.

TERRAIN CLASS DESCRIPTIONS

Terrain class maps were produced from the elevation, slope, and aspect digital data. Elevation classes were broken into the following catagories (in meters): 0-6, 7-30, 31-122, 123-304, 305 and higher. Slope classes were broken into 0-2%, 3-5%, 6-15%, 16-25%, 26-50%, and 51% and higher. The aspect classes were broken into north, northeast, east, southeast, south, southwest, west, and northwest. All of the maps contained the water classes, and the aspect map contained the 0-2% slope class. Collar information included: map title, scale, locational diagram, map legend, latitude/longitude, and tick marks.

PRODUCT DESCRIPTIONS-DIGITAL

GENERAL

Digital data are stored at USGS/EROS on CCT's in either an IDTRANS or TRANSFER format. Digital data stored in the IDTRANS format are used at USGS/EROS for internal processing. The TRANSFER format is usually used when data are shipped to other U.S. government agencies or the private sector. Images are generally written on a TRANSFER tape with one image line per record and one image per file. Images may be band-by-band or line-by-line. If the data format is floating point, either a Hewlett-Packard 3000 or IBM format may be specified. Data may

Table 2. List of land cover classes and subclasses used during the mapping process.

DESCRIPTION	CLASS NUMBER
BARREN	
Scarcely Vegetated Flood Plain	1
Scarcely Vegetated Scree	2
Dunes	3
Open Forested Dunes	4
FOREST	
Closed Needleleaf	5
Open Needleleaf	6
Needleleaf Woodland	7
Deciduous Forest/Tall Shrub	8
HERBACEOUS	
Wet Graminoid	9
Wet/Moist Graminoid Tundra	10
Mosaic: Wet Graminoid-Erect Dwarf Scrub	11
SHRUB	
Dry Prostrate	12
Low Shrub	13
Medium Shrub	14
Tall Shrub	15
DWARF SCRUB	
Dwarf Scrub Graminoid Tussock	16
Erect Dwarf Scrub/Dwarf Scrub-Lichen	17
WATER	
Offshore	18
Clear	19
OTHER	
Shadow	20
Digitized Streams	21

Table 3. Acreage estimates of land cover occurring within the Selawik National Wildlife Refuge boundary.

	CLASS	ACRES REFUGE	PERCENT	ACRES WILDERNESS	PERCENT	TOTAL ACRES	PERCENT OF TOTAL
1	Scarcely Vegetated Flood Plain	15149.09	0.51%	1.85	.00%	15150.95	0.47%
2	Scarcely Vegetated Scree	10131.52	0.34%	2153.92	0.89%	12285.44	0.38%
3	Dunes	1712.26	0.06%	846.25	0.35%	2558.51	0.08%
4	Open Forested Dunes	813.51	0.03%	1630.11	0.67%	2443.62	0.08%
5	Closed Needleleaf	5179.41	0.17%	1542.40	0.64%	6721.81	0.21%
6	Open Needleleaf	136706.28	4.59%	59749.50	24.71%	196455.78	6.10%
7	Needleleaf Woodland	40607.60	1.36%	21605.91	8.93%	62213.51	1.93%
8	Deciduous Forest/Tall Shrub	92768.66	3.11%	3763.65	1.56%	96532.30	3.00%
9	Wet Graminoid	225484.59	7.57%	6666.22	2.76%	232150.81	7.21%
10	Wet/Moist Graminoid Tundra	55263.77	1.85%	2741.97	1.13%	58005.74	1.80%
11	Mosaic: Wet Graminoid-Erect Dwarf Scrub	67741.92	2.27%	5072.55	2.10%	72814.48	2.26%
12	Dry Prostrate	5291.22	0.18%	30.27	0.01%	5321.49	0.17%
13	Low Shrub	327699.73	11.00%	12428.74	5.14%	340128.47	10.56%
14	Medium Shrub	28370.96	0.95%	2859.95	1.18%	31230.91	0.97%
15	Tall Shrub	135590.71	4.55%	31697.28	13.11%	167287.98	5.19%
16	Dwarf Scrub Graminoid Tussock	766196.32	25.71%	41119.67	17.00%	807315.99	25.06%
17	Erect Dwarf Scrub/Dwarf Scrub-Lichen	634881.94	21.31%	41720.08	17.25%	676602.02	21.00%
18	Offshore	7464.90	0.25%	0.00	0.00%	7464.90	0.23%
19	Clear	398422.68	13.37%	323.67	0.13%	398746.35	12.38%
20	Shadow	24308.97	0.82%	5865.06	2.43%	30174.03	0.94%
	TOTALS	2979786.04	100.00%	241819.05	100.00%	3221605.08	100.00%

be read onto the tape at either 1600 or 6250 bits/inch (bpi). All data relating to this project have been delivered to USFWS at 1600 bpi using the Hewlett-Packard 3000 floating point format.

An attempt was made to standardize the pixel size and UTM origins of the data. For this project most, if not all, of the final data sets were produced at two different pixel sizes: 50 x 50 meter and 200 x 200 meter. Pixel sizes were predetermined by the USFWS prior to the finalization of the land cover classification. UTM origins were based on the location of the refuge boundary and final image size. For the SNWR mapping project, UTM origins were based on the Selawik and Shugnak USGS 1:250,000 quadrangles, because 90% of the refuge is contained in these two quadrangles. All of the data which have been transferred to the USFWS covered under the Interagency Service Agreement are summarized in Appendix C. This summarization contains image name, data type, number of lines and samples, UTM origins and pixel size.

LAND COVER

The land cover images contain up to 21 different classes (Table 2). The data is byte data. The lowest class, 0, is a background or fill class. The general class descriptions corresponding to each class number may be found in Appendix B.

ELEVATION DATA

The digital elevation data were derived from digital terrain data created by the Defense Mapping Agency (DMA). The DMA generated the data by digitizing contour lines, spot elevations, and stream and ridge line data from the 1:250,000-scale USGS quadrangles. The contour intervals range from 50 to 200 feet. These data were then converted to a rectangular grid of values, producing elevation estimates spaced every 0.01 inches on each 1:250,000-scale map (approximately 200 feet on the ground). The data are integer data and can range in values from 0 to about 3000 meters. The data is recorded in one meter increments.

SLOPE DATA

The slope data were computed using the digital elevation data. Slope is computed as percent slope, i.e. units of rise per 100 units of run. The data is byte data and is recorded in one percent increments. Values can range from 0 to 255.

ASPECT DATA

The aspect data were computed using the digital elevation data. Aspect is computed clockwise from north in degrees. The data are byte data with values from 0 to 180: 0 and 180 = north, east = 45, south = 90, and west = 135. Values increase in two degree increments.

ACKNOWLEDGEMENTS

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ANILCA, 1980. Alaska National Interest Lands Conservation Act, Public Law 96-487, Washington, D.C.

ESL Incorporated, 1981. IDIMS Functional Guide, Technical Manual ESL-TM705. ESL Incorporated, Sunnyvale, California. Vol. I, 716 p., Vol. II, 319 p.

Fleming, M. D., 1975, Computer aided analysis of Landsat data: a comparison of three approaches including modified clustering approach: West Lafayette, Indiana, Purdue University Laboratory for Applications of Remote Sensing, LARS Information Note 072475, 9 p.

APPENDIX A

PROCEDURES FOR LAND COVER CLASSIFICATION USING LANDSAT CCT'S

Preprocessing

1. Enter Landsat Data (CCT format) into IDIMS
2. Display and select Landsat subscenes
3. Perform radiometric corrections
    a. Destrip to correct for detector miscalibration
    b. Fix bad data lines
4. Perform geometric corrections
    a. Select control points from Landsat data and maps for image registration
    b. Digitize control points and map boundaries
    c. Generate transformations and rotate Landsat scenes
    d. Register Landsat image to 50 meter UTM grid
5. Produce strata mask for study areas
6. Digitize refuge boundaries
7. Mosaic and register DEM data

Image Training and Classification

1. Select training blocks for study area in each Landsat scene
2. Apply IDIMS clustering algorithm (ISOCLAS)
3. Produce statistics of the spectral classes within the training blocks
4. Produce photographic image of each Landsat training block and color coded cluster map
5. Prepare for field investigations
    a. Acquire aerial photographs of cluster blocks for annotation in field
    b. Develop strategy for aerial reconnaissance and on-the-ground investigations

APPENDIX A

6. Field verification

   a. Describe land cover type associated with each cluster class
   b. Collect auxiliary information when appropriate, e.g. wildlife habitat value, soils, quantitative plant description, etc.

7. Return to IDIMS and edit cluster statistics and pool and/or delete cluster classes

8. Produce preliminary classification based on edited cluster statistics

9. Evaluate preliminary classification based on edited cluster statistics

10. Post-classification refinement where necessary to improve classification accuracy. This step may be facilitated by several approaches, two of which are presented:

    a. Stratification based upon physiognomic, soil or other resource data

       (1) Digitize boundaries of strata
       (2) Produce and apply strata mask
       (3) Identify cluster classes for each strata
       (4) Combine classifications for all strata
       (5) Reclassify entire study area

    b. Merge DEM digital terrain data with Landsat data

       (1) Define control points for DEM
       (2) Generate transformation between latitude/longitude (DEM) and UTM grid
       (3) Register DEM to UTM grid
       (4) Generate slope and aspect data
       (5) Define strata based on combinations of elevation, slope, and aspect
       (6) Identify cluster classes within each strata

APPENDIX A

Generate Output Products

1. Generate digital tape file for classification of refuge

2. Produce acreage estimate for refuge or units (quadrangles) within refuge area

3. Produce ink jet plots for the final classification of the refuge

APPENDIX B

VEGETATION CLASSIFICATION FOR THE SELAWIK NATIONAL WILDLIFE REFUGE LAND COVER MAP*

Scarcely Vegetated Areas:

In this class, plants are scattered or absent and bare mineral soil or rock determines the overall appearance of the landscape.

Scarcely Vegetated Floodplain. -- This subclass is a result of the initial invasion of plants on recent river alluvium. Plant cover averages 5 to 20%.

Within the refuge, this cover type is found in many locations where current or recent rivers have produced bars or beaches as a result of overflow from water channels. Slopes that produce such flooding conditions are frequently in the lower 2 to 4% ranges, partiuclarly in the western half of the refuge and near the Seward Peninsula. Exposed soils of these areas are typically fine to coarse sands with a light tan to light gray color, and may form beaches 150 feet wide.

Vascular plant species include grasses like Arctagrostis latifolia, Bromus spp., and Festuca rubra. Non-graminoid species include Epilobium latifolium, Crepis nana, Hedysarum alpinum, H. mackenzii, Artemisia tilesii, A. arctica, Salix alaxensis, S. lanata, Astragalus sp., Aster sibericus, and Equisetum sp.

A part of the Scarcely Vegetated Floodplain subclass is less vegetated (less than 5% cover) and consists of alluvium which includes silt, sand, and rocks. The plant species that are part of the cover of this grouping are similar to those of the Scarcely Vegetated subclass, and further studies will be needed to determine if this grouping should be separated as a distinct subclass.

Scarcely Vegetated Scree. --This subclass, with 5 to 20% plant cover, is comprised of more or less unstable steep slopes with stones and weathering rocks. It is a very open fellfield and often grades into the Dry Prostrate Shrub subclass.

The main locations of this subclass within the refuge include the slopes and mountain tops lying near or above the 1000 foot elevation in the Hockley and Waring Mountains to the north, in the northeast corner of the Selawik hills along the southern boundry, and in places in the eastern extension of the refuge where the Purcell Mountains and Zane Hills enter the boundry. This is not as abundant a subclass within the refuge as it is elsewhere to the north where the taller Brooks range present many locations where the 5 to 20% cover is realized.

*From: USFWS, 1987. Selawik National Wildlife Refuge, Comprehensive Conservation Plan, Environmental Impact Statement and Wilderness Review, Final, U.S. Fish and Wildlife Service, Region 7, Anchorage, Alaska, p. 262-268.

APPENDIX B

Some of the shrubs commonly found in this type in prostrate or decumbent forms include Betula nana, Dryas integrifolia, D. octopetala, Vaccinium uliginosum, Cassiope tetragona, and Salix phlebophyla. Other species that may occur include Cystopteris sp., Diapensia lapponica, Cetraria sp., Lupinus arcticus, Carex bigelowii, Carex sp., Crustose lichens, Selaginella siberica, Minuartia arctica, Smelowskia calycina, Draba spp., Saxifraga eschscholtzii, Saxifraga sp., Oxytropis nigrescens, Arctostaphylos alpina, Silene acaulis, Androsace chamaejasme, Loiseleuria procumbens, Salix arctica, Empetrum nigrum, Phyllodoce caerulae, and numerous lichen species.

Within the Scarcely Vegetated Scree subclass, there is a grouping of sites with less than 5% plant cover and less vegetated than the usual Scarcely Vegetated condition. A type of lichen cover may be present that is dominated by blackish lichens that may include the genera Umbilicaria, Cetraria, Corniculata, and Pseudophebe. Occasionally, a few dwarf individuals from the genera listed for the Scarcely Vegetated condition may be found as small outcrops of life in these borderline habitats. Often, the sites of this grouping are devoid of flowering plants, except in microsites which are slightly sheltered such as crevices. This grouping may be separated from the Scarcely Vegetated Scree in the future if additional studies indicate a distinct character.

Barren Dunes. -- A barren subclass that is characterized by a predominance of dry, coarse-grained sands and sparcely occurring vegetation. The plants present provide less than 5% cover and are usually less than 2 meters tall (more commonly less than 1 meter).

There appear to be two localities for such dunes, along the coast and scattered within the interior. Coastal sand dunes, which were not clearly indicated on the map products due to the quality of the satellite tape data, may have a vegetation component including such specis as Elymus arenarius, Arctagrostis latifolia, Epilobium anguistifolium, E. latifolium, Angelica lucida, Conioselium chinense, Carex spp., Ligusticum scoticum, Achillia borealis, Lathyrus maritimus, Lupinus arcticus, Valariana capitata, Aconitium delphinifolium, Artemisia tilesii, Potentilla spp., Wilhelmsia physodes, Mertensia meritima, and Gentiana propinqua. The interior dunes of the refuge are much smaller than the larger conspicuous dunes to the north of the refuge near the Waring Mountains. The vegetation of these interior sites will have many of the same species listed for the coast and may include Spirea sp., dwarf Salix, dwarf Betula, and occasional short Picea glauca (0.3 to 2 meters).

Forest:

Forests are formed of tree species at least 5 meters tall. Included within the concept of forest is secondary tree growth that is temporarily less than 5 meters in height, i.e., intermediate succession stages. The major forest subclasses identified within the study area are: 1) Closed Needleleaf Forest, 2) Open Needleleaf Forest, 3) Needleleaf Woodland, 4) Deciduous Forest-Tall Shrub, and 5) Open Forested Dunes.

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Closed Needleleaf Forest. -- This forest subclass is defined as having a percentage of ground cover that may range from 60 to 100%, and frequently the spruce canopies are touching in much of the area. Major tree species are Picea glauca and P. mariana.

In the northwest part of the state, there are felt to be two types of white spruce forest: the upland type with large densely growing trees and a sparse shrub understory, and a lowland type that is found on well-drained floodplains and dry slopes. Associated understory species include Salix spp., Alnus crispa, Rosa acicularis, Betula nana, Vaccinium uliginosum, V. vitis-idaea, Empetrum nigrum, Ledum palustre, Epilobium angustifolium, Equisetum sylvaticum, Lycopodium spp., Pyrola sp., Carex spp., Oxycoccus microcarpus, lichens and mosses.

Open Needleleaf Forest. --This subclass contains open stands of Picea glauca and P. mariana, and has an overall 30 to 60% cover value. Within the refuge, this subclass occurs as bands along parts of the Selawik and Kugarak Rivers, on islands and banks of the Kobuk River drainage, in intermountian passes of the Waring Mountians, as pockets in the more interior parts of the Kobuk River Delta, and in the southern parts of the eastern end of the refuge near the Purcell Mountains.

The shrub layer usually consist of Salix glauca and Alnus crispa on alluvial and moist to well-drained sites. The dwarf shrub layer is the more common type of understory occurring with this subclass. Plant species frequently found include Ledum palustre, Vaccinium uliginosum and V. vitis-idaea, Betula papyrifera, Empetrum nigrum, Eriophorum vagintum, Arctostaphylos rubra, Dryas integrifolia, Rhododendron lapponicum, Salix reticulata, S. lanata, S. alaxensis, S. planifolia, Carex bigelowii, Festuca altaica, Equisetum arvense, Hylocomium splendens, Potentilla fruiticosa, Rosa acicularis, Epilobium latifolium, Rubus arcticus, Ribes triste, Calamagrostis candensis, Spirea beauverdiana, Aconitium delphinifolium, Boschniakia rossica, Pyrola sp., Mertensia paniculata, Galium boreale, Artemisia tilesii, Peltigera sp., and various lichens.

A subgrouping of this forest subclass demonstrates a set of reflectance values that appear to indicate a greater lichen component than that of the usual Open Needleleaf condition. The plant species would be similar.

At present, the data available do not confirm whether there is a discrete cut-point between the grouping and the established subclass, and future studies will determine if combining the two subclasses will be a more appropriate representation of what is on the ground.

Needleleaf Woodland. -- This subclass is dominated by a shrub layer, but contains an important stratum containing Picea mariana or P. glauca with a 5 to 30% tree cover and greater than 3 meters in height.

APPENDIX B

The class occurs in moderately well-drained riparian floodplains with low valued slopes and near the peripheries of boggy areas that may contain small lakes or potholes. Frequently, this class will be near and intergrading into areas of Open Needleleaf or Open Needleleaf-Lichen. A tussocky tundra is also a frequent component to the ground surface within the subclass or may be evident in neighboring communities.

Major shrub species include Betula nana and B. glandulosa, Ledum palustre, Rubus chamaemorus, Vaccinium uliginosum and V. vitis-idaea, Salix reticulata, S. glauca, S. lanata, Alnus crispa, and Dryas integrifolia. Other species may include Epilobium angustifolium, Lupinus arcticus, Potentilla spp., Equisetum arvense and E. scirpoides, Eriophorum vaginatum, Carex bigelowii, C. scirpoides, Calamagrostis canadensis, Festuca sp., Cetraria sp., Cladina sp., Sphagnum sp., Polytrichum sp., Hylocomium splendens, and Dicranum sp.

Deciduous Forest-Tall Shrub. -- A subclass with Betula papyrifera, Populus tremuloides, and P. balsamifera showing 25 to 100 % tree cover. Salix alaxensis may also be classified in this class on alluvial terraces or by itself or mixed with P. balsamifera. This class is normally found on well-drained to moist soils associated with hills and alluvial terraces, riparian areas, drier margins of lake and bog areas, and similar mesic locations.

This class is reasonably distinct and is often easily identified in the field when encountered. The lower height range for many of the indicator species listed above may cause some confusion with the taller stands of certain other classes which can occur in similar habitats.

Plant species that may occur include Alnus crispa, Salix spp., Rosa acicularis, Shepherdia canadensis, Calamagrostis canadensis, Ribes triste, Vaccinium vitis-idaea and V. uliginosum, Festuca altaica, Aconitium delphinifolium, Bupleurum triradiatum, Equisetum arvense, Galium boreale, Epilobium angustifolium, Linnaea borealis, Ledum palustre, Rubus arcticus, Spirea beauverdiana, Oxycoccus microcarpus, Carex sp., Delphinium glaucum, Polomonium acutiflorum, Aster sibericus, the mosses Rhytidium rugosum and Polytrichum sp., and the lichens Cladonia mitis and Cladonia sp., and Cetraria nivalis.

There appears to be a subgroup of the forest class that has a mixed character (namely broadleaf and evergreen needleleaf tree species) and gives cover values of 25 to 100%. This subgroup occurs on well-drained to moist sites in the uplands. Primary species include Picea glauca and Betula papyrifera and occasionally Populus balsamifera, P. tremuloides, or Salix spp. (some over 5 meters tall).

This mixed subgroup is only moderately abundant and is largely restricted to the north half of the refuge near the Waring Mountains and Kobuk River drainage. Understory species common to the needleleaf and deciduous classes may be found in this subgroup. Further studies will be required to determine whether this assemblage is sufficiently distinct to be separated as a major subclass.

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Open Forested Dunes. --This subclass occurrs southeast of the Waring Mountains in an area that is heavily influenced by active and inactive eolian sand dunes formed principally during the pleistocene period. Tree species in this category may include Picea glauca or Populus tremuloides. A plant cover value of 30 to 60% is normal. Understories are usually poorly developed and sparce, but when present may include numerous lichen species (with cover values of 50 to 100%), Shepherdia canadensis, Lupinus arcticus, Spirea beauverdiana, and Empetrum nigrum.

Herbaceous (Graminoid):

Herbaceous species are without significant woody tissue and die back to the ground surface each year. There are two major growth forms: graminoids and forbs. Graminoid forms include all non-woody grasses and grass-like plants such as Carex and Eriophorum. Forbs are broad-leaved herbaceous plants like Petasites and Epilobium. Three subclasses of the herbaceous type are recognized: 1) Wet Graminoid, 2) Wet/Moist Graminoid Tundra, and 3) Mosaic: Wet Graminoid-Erect Dwarf Shrub.

Wet Graminoid. -- The communities in this subclass are graminoid dominated formations that may be associated with open water bodies that are fresh or brackish, low areas near river channels, low center polygons, strangmoor, deltas, and other poorly drained sites. The subclass, while found throughout most all of the refuge, is very common in the regions near the coast, the wetter interior near Inland and Selawik Lakes, and in the major river drainages.

Major species that are found in these sites include Arctophyla fulva, Carex spp., and Eriophorum spp. where the deeper water occurs. Other species that may occur include Equisetum fluviatile, Scirpus spp., Pedicularis sp., Valeriana capitata, Polygonum sp., Tomenthypnum nitens, Drapanocladus sp., Calamagrostis canadensis, Ledum palustre, Empetrum nigrum, and Sphagnum sp.

Also included in this subclass are those wet to moist graminoid communities which have colonized drained lake basins. These areas can be readily distinguished on the land cover maps by their characteristic oval or oblong shape which may or may not be associated with remnant lakes or ponds. These lake basins are normally dominated by graminoid species such as Calamagrostis canadensis, Eriophorum angustifolium and Carex sp.

Wet/Moist Graminoid Tundra. -- This subclass, while having moist to wet soils, is generally restricted to areas which show polygonal ground features and tussocky surfaces. Although the graminoid component of the community is evident, there is frequently a distinction that can be made between the wetter polygon centers and depressions between rims, and the drier sides and tops of the rims and tops of tussocks.

APPENDIX B

A high degree of variation in surface morphology often results in very complex vegetation patterns at the microsite level within this subclass. Frequently encountered plant species include dwarf Betula spp., dwarf Salix spp., Alnus crispa, Carex bigelowii and Carex spp., Eriophorum angustifolium, Vaccinium uliginosum, Calamagrostis canadensis, and Ledum palustre. Other species that may be found include Epilobium angustifolium, Rubus chamaemorus, Picea glauca (rare), Oxycoccus microcarpus, Myrica gale, Empetrum nigrum, and Aconitium delphinifolium.

Mosaic: Wet Graminoid-Erect Dwarf Shrub. -- This herbaceous class is a third stage in a transition from the wet mostly graminoid communities to the wet graminoid and dwarf shrub communities. In some respects, the character of this class can be likened to a wet savannah-like situation with plants of reduced stature. The dominant feature is that of a graminoid marsh or bog with Calamagrostis canadensis, Eriophorum angustifolium, and Carex sp. being evident, and raised dwarf scrub or peat hummocks with small Salix sp., Betula sp., Ledum palustre growing locally.

Shrub:

This vegetation class is predominately composed of shrubs that provide greater than 25 % cover and are 0.5 to 5 meters in height, and that shed their foliage annually in response to unfavorable weather.

Dry Prostrate. -- This formation occupies slightly elevated microsites in the interior, upper slope positions in the foothills and mountains, and may occur on dry alluvial terraces or fans above several hundred meters in the mountains. Bare soil is often an important component of the ground surface as a result of frost action. Because of the harsh environment, plants do not usually achieve heights greater than 20 to 25 cm. Some of the more commonly occurring species are Dryas integrifolia and D. octopetala, Arctostaphylos rubra, Salix phlebophyla and Salix spp., Saxifraga sp., Carex sp., Festuca sp., Equisetum sp., Lupinus arcticus, Bupleurum triradiatum, Androsace chamaejasme, Alectoria nigrescens, Silene acaulis, Arnica sp., Phlox sp., Selaginella sp., Hierochloe alpina, and Diapensia lapponica.

The Low / Medium / Tall Shrub subclasses are based primarily on height differences although certain species are more prevalent in one subclass than another. The ability to, separate these vegetation subclasses was accomplished by using winter Landsat MSS data in combination with solar illumination, slope, aspect, elevation, and summer Landsat MMS data.

Low Shrub. --A subclass with plant forms that demonstrate a height range from 0.5 to 1.0 meters. Frequently the characteristic species present are Betula nana, B. glandulosa, Salix planifolia, S. lanata, S. glauca, S. hastata, Shepherdia canadensis, and Vaccinium uliginosum.

Medium Shrub. --The shrub subclass with plants having a height range of 1.0 to 3.5 meters. Species present may include those mentioned for the Low Shrub plus Salix alaxensis and Alnus crispa.

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Tall Shrub. -- The subclass with plants normally in the 3.5 to 5 meter height range. The species listed for the Low and Medium Shrub may be present in fewer numbers in these communities along with Betula papyrifera and Populus tremuloides.

Within any of the Low, Medium, or Tall Shrub communities, other species that might occur are Salix brachycarpa, S. reticulata, Arctostaphylos rubra, Potentilla palustris, Dryas integrifolia, D. drumondii, Equisetum sp., Carex aquatilis, and Petasites sp.

Dwarf Scrub:

This class is chiefly composed of dwarf species primarily from the genera Betula and Salix and ericacious species. These shrubs are usually 0.1 to 0.5 meters in height and occur in areas with a shallow active soil layer, in burn areas, or areas underlain by permafrost. Graminoid species such as Carex aquatilis, C. bigelowii, Calamagrostis canadensis, and Eriophorum vaginatum are often intermixed with the shrubs and may produce tussocks.

Dwarf Scrub Graminoid Tussock. -- This subclass is common in rolling hills and includes species like Betula nana, Salix lanata, S. pulchra, Vaccinium vitis-idea, V. uliginosum, Empetrum nigrum, and Ledum decumbens. Carex bigelowii is the main tussock producing graminoid which may appear to dominate the sites of this subclass at times. Other species that may occur include Pedicularis sp., Oxycoccus microcarpa, Equisetum sp., and lichen species.

Erect Dwarf Scrub/Dwarf Scrub-Lichen -- This subclass is common on the refuge, especially in the northern and western parts. Fruticose and crustose lichens are a common, if not major, component of this type along with erect dwarf shrubs. The associated plant species for this subclass include many of the same species given above for the Dwarf Shrub Graminoid Tussock condition.

Water:

Offshore Water. -- The shoreline and waters seaward from the terminus of the Kobuk River delta to the southern boundry of the refuge that touches the coast.

Clear Water. -- Clear water including lakes, ponds, and rivers.

Other:

Shadow. -- A subclass that represents those areas obscured from the sensor by clouds or shadows in mountainous terrain or a reduced level of vegetation reflectance with corresponding unusable data.

Digitized Streams. -- Those stream tracks that are displayed on the 1:250,000 scale U.S.G.S. topographic maps, were digitized and incorporated into the land cover data.

APPENDIX C

The following source data is relevant to all images listed below.

Coverage: Selawik Unit

UTM Northing	= 7460000	Number of Lines	= 3200
UTM Easting	= 365000	Number of Samples	= 2900
UTM Zone	= 4	Pixel Size (in meters)	= 50
		Tape Format	= IDTRANS

TYPE OF IMAGE	DATA TYPE	EROS FIELD OFFICE TAPE LOCATION	FILE
Landcover	Byte	IDT 1386	2
Elevation	Integer	IDT 1375	1
Slope	Byte	IDT 1377	6
Aspect	Byte	IDT 1377	5
Refuge Mask	Byte	IDT 1379	6

The following source data is relevant to all images listed below.

Coverage: Shungnak Unit

UTM Northing	= 7460000	Number of Lines	= 3200
UTM Easting	= 490000	Number of Samples	= 3000
UTM Zone	= 4	Pixel Size (in meters)	= 50
		Tape Format	= IDTRANS

TYPE OF IMAGE	DATA TYPE	EROS FIELD OFFICE TAPE LOCATION	FILE
Landcover	Byte	IDT 1386	1
Elevation	Integer	IDT 1374	2
Slope	Byte	IDT 1377	4
Aspect	Byte	IDT 1377	3
Refuge Mask	Byte	IDT 1379	3

APPENDIX C

The following source data is relevant to all images listed below.

Coverage: Selawik Unit

UTM Northing	= 7460000	Number of Lines	= 800
UTM Easting	= 365000	Number of Samples	= 725
UTM Zone	= 4	Pixel Size (in meters)	= 200
		Tape Format	= IDTRANS

TYPE OF IMAGE	DATA TYPE	EROS FIELD OFFICE TAPE LOCATION	FILE
Landcover	Byte	IDT 1387	2
Elevation	Integer	IDT 1387	4
Slope	Byte	IDT 1387	5
Aspect	Byte	IDT 1387	3
Refuge Mask (Solid)	Byte	IDT 1379	4
Refuge Mask (Boundary)	Byte	IDT 1380	5

The following source data is relevant to all images listed below.

Coverage: Shungnak Unit

UTM Northing	=	Number of Lines	= 800
UTM Easting	=	Number of Samples	= 750
UTM Zone	=	Pixel Size (in meters)	= 200
		Tape Format	= IDTRANS

TYPE OF IMAGE	DATA TYPE	EROS FIELD OFFICE TAPE LOCATION	FILE
Landcover	Byte	IDT 1387	1
Elevation	Integer	IDT 1387	7
Slope	Byte	IDT 1387	8
Aspect	Byte	IDT 1387	6
Refuge Mask (Solid)	Byte	IDT 1379	1
Refuge Mask (Boundary)	Byte	IDT 1380	6