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Bureau of Land Management

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Ducks Unlimited, Inc.

# National Petroleum Reserve-Alaska Earth Cover Classification

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**Cover**

The cover photo depicts the remoteness of the area and the need to use helicopters for data collection.

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# National Petroleum Reserve - Alaska
# Earth Cover Classification

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# Abstract

The National Petroleum Reserve in Alaska (NPR-A) includes more than 9.3 million hectares (23.0 million acres) and is located on the North Slope of Alaska. The northern half of the NPR-A falls within the Arctic Coastal Plain physiographic province which contains one of the largest and most stable collections of wetlands in North America. Currently, with the potential for oil development extending into areas, other than Prudhoe Bay, an Environmental Impact Statement (EIS) is being prepared for the Northeastern Planning Area of the NPR-A.

The objective of this project was to create an updated and detailed earth cover inventory in computer database format for the entire NPR-A. The purpose of the project was to develop a tool for aiding in the management of the NPR-A and for developing baseline information that could be used in other studies. This inventory is currently included in the Environmental Impact Statement for the Northeastern Planning Area of the NPR-A. It is also included in the waterfowl earth cover selection analysis that created selection indexes based on earth cover types for seven different waterfowl species.

Landsat Thematic Mapper (TM) satellite imagery was chosen as the primary source for this mapping because it is a cost effective data source for regional mapping, can be processed using automated mapping techniques, and is collected on a repeat cycle, providing a standardized data source for future database updates. In addition, TM imagery includes a mid-infrared band, which is sensitive to both vegetation and soil moisture content and has proven useful in identifying water and wetland features. Eight Landsat TM satellite scenes and three *Systeme Pour l'Observation de la Terre* (SPOT ) satellite scenes were used to classify the NPR-A into earth cover categories. An unsupervised clustering or seeding technique was used to determine the location of field sites and a custom field data collection card was used to record field information. After initial on-the-ground sampling, a helicopter was used to access field sites throughout the project area. Global positioning system (GPS) technology was used to navigate to preselected sites and record locations of new selected sites. Data were collected on 1,667 field sites during a three year field season from 1994 through 1996. A portion (46%) of these field sites were set aside for accuracy assessment.

A combined supervised/unsupervised classification technique was performed to classify the satellite imagery into seven major classes and seventeen minor classes. As each scene was completed it was mosaicked and edge matched with adjacent scenes to produce a seamless database of the NPR-A.

The results of this classification suggest dominant earth cover of the NPR-A at 43% shrub, 31% moist tundra, 11% water, 6% flooded tundra, 5% wet tundra, 2% aquatic, and 2% barren ground. The overall accuracy of the major categories was 85%, with a 75% overall accuracy for the minor categories. The cooperators in this project included Bureau of Land Management-Alaska; Ducks Unlimited, Inc.; U.S. Fish and Wildlife Service; and North Slope Borough.

# National Petroleum Reserve – Alaska Earth Cover Classification

## Introduction

Presidential declaration established the 9.3 million hectare (23.0 million acre) Naval Petroleum Reserve No. 4 in 1923. In 1976, management responsibility of the Reserve was transferred to the Department of the Interior and the area was renamed the National Petroleum Reserve in Alaska (NPR-A). NPR-A is located on the North Slope of Alaska, much of which falls within the Arctic Coastal Plain physiographic province. The Arctic Coastal Plain contains one of the largest and most stable collections of wetlands in North America (Wellein and Lumsden, 1964). Lake and emergent marsh coverage is estimated at 50 % of the total area (Hussey and Michelson, 1966). These wetlands support large numbers of breeding and postbreeding waterfowl, loons, terns, gulls, and shorebirds, including the federally listed spectacled and Steller's eiders (listed as Threatened under the Endangered Species Act of 1973, as amended). The king eider migration is estimated at one million birds passing Point Barrow (King and Lensink, 1971). The interspersed tundra habitats are used by caribou, brown bear, polar bear, foxes, lemmings, ptarmigan, passerines, and raptors.

The NPR-A contains shallow soils overlying continuous permafrost and mimics desert precipitation levels with less than 10.9 cm (4.3 inches) during the average year. The cool summer growing season is approximately 6 weeks in length with continuous 24 hour daylight. In the northern part of the NPR-A that falls within the Arctic Coastal Plain, there are millions of thermokarst pits and large oriented-thaw-lakes. This region of the NPR-A has little or no relief. The southern part of the NPR-A is part of the Arctic Foothills Province and is typified by rolling hills and tussock tundra/dwarf shrub vegetation.

The most prominent features of the arctic coastal plain are the large oriented-thaw-lakes and second or later generation wetland landscape (Black and Barksdale, 1949; Walker and Acevedo, 1987; Markon and Derksen, 1994). Morphology of the oriented-thaw-lakes changes with stages of development (Figure 1). At the first stages, the formation of low centered polygons are caused by ice wedges. The second stage consists of low centered polygons connecting to form small round ponds. During the third stage the small ponds connect to form a mature oriented lake showing NNW-SSE axis. Prevailing winds cause faster erosion at the head and foot of the lake. In the fourth stage, all but the deepest parts of the lake are drained due to an outlet that was cut through the permafrost by the eroding head and foot of the lake. During the fifth and final stage, the polygonal substrate begins to reassert influence but the shoreline of the lake bed is still present. The satellite imagery used in this study can be used to identify the different stages of oriented-thaw-lake basin development (Figure 2).

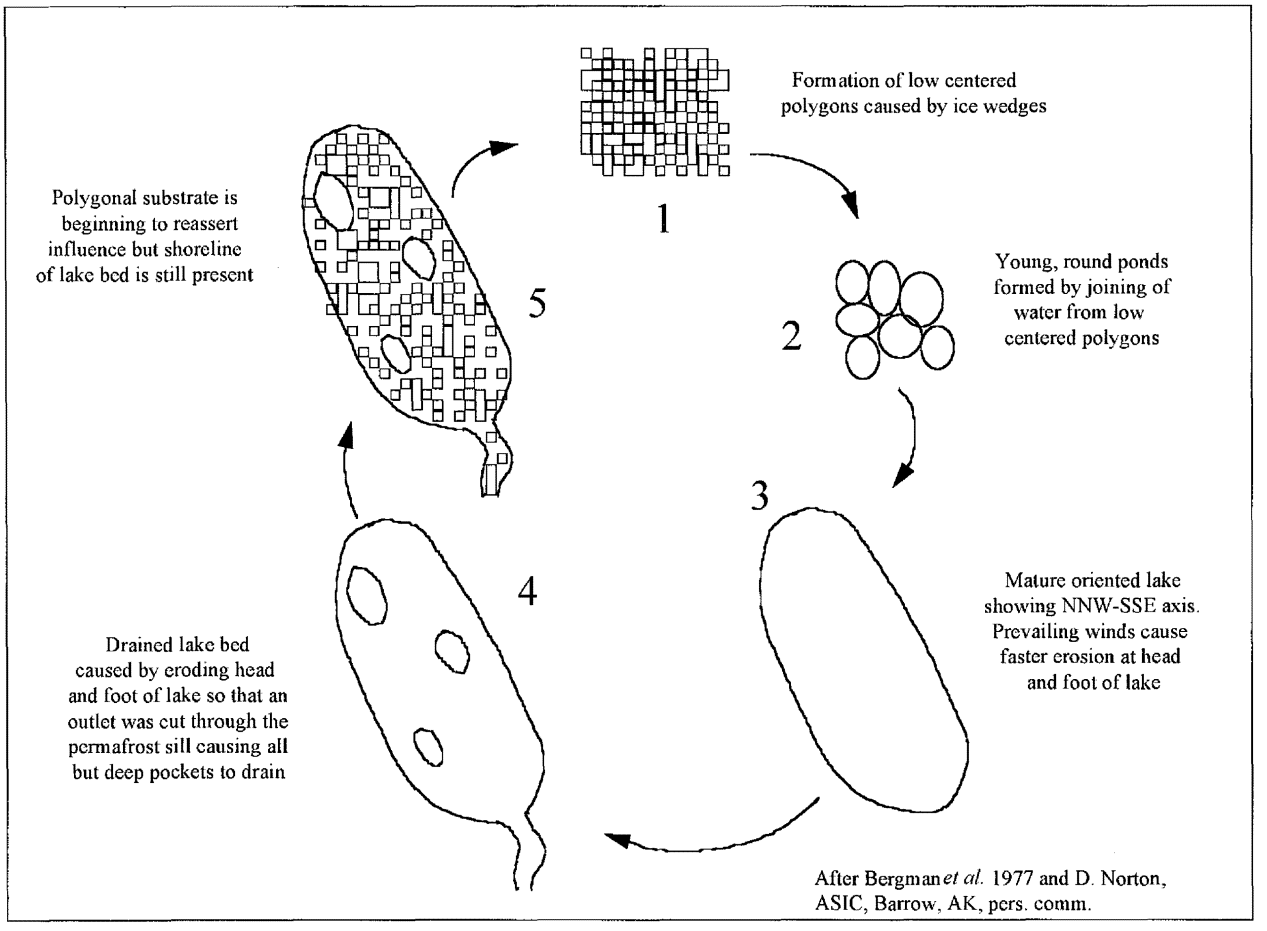


**Figure 1.** The morphology of the oriented -thaw-lakes of the NPR-A.

Land management decisions are often made about this region which has little or no information regarding the size, distribution, and type of earth cover categories. Federal and state agency resources staff responsible for managing projects and addressing public issues is relatively small in relation to the huge land mass in Alaska. Previous work has concentrated on the Teshekpuk Lake area using *Systeme Pour l'Observation de la Torre* (SPOT) satellite imagery from 1986 (Markon and Derksen, 1994) and the NPR-A using Landsat MSS data from 1977 (Morrissey and Ennis, 1981). The arctic coastal plain is very difficult to evaluate because of the numerous wetland basins, lack of roads, rapidly changing weather conditions, and numerous cloud cover days.

Landsat Thematic Mapper (TM) satellite imagery was chosen as the primary mapping source because it is a cost effective data source for regional mapping, can be processed using automated mapping techniques and is collected on a repeat cycle, providing a standardized data source for future database updates. In addition, TM imagery includes a mid-infrared band, which is sensitive to both vegetation and soil moisture content and is useful in identifying water and wetland features.

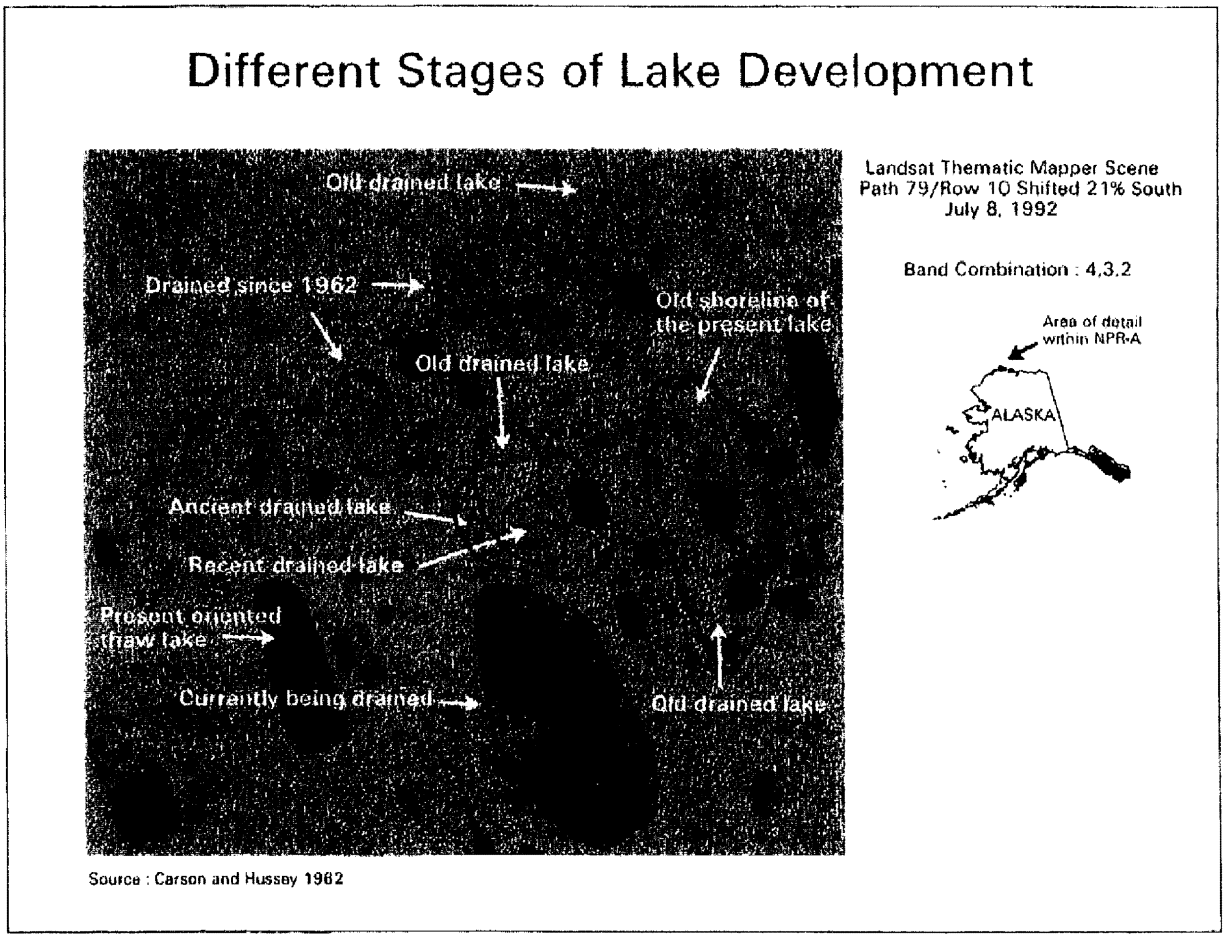


**Figure 2.** An example of ancient and present oriented-thaw lakes.

The need for natural resources data in this area of Alaska is a priority due to heightened interest in onshore oil development. In the past, the oil exploration and development has been principally east of the NPR-A in the vicinity of Prudhoe Bay. Currently, with the potential for oil development extending into other areas, an Environmental Impact Statement has been completed for the Northeastern Planning Area of the NPR-A (USDOI, BLM 1998). As development in the arctic expands, identification of critical wildlife habitats is essential to make viable land use decisions. This earth cover inventory is currently being included in the Environmental Impact Statement for the Northeastern Planning Area of the NPR-A. It is also used in the waterfowl earth cover selection analysis that created selection indexes for seven different waterfowl species (Morton *et al.* 1998).

The NPR-A project is split into three phases due to the immense size of the project area, limited field access caused by harsh climate regime, and lack of aircraft support infrastructure. These phases were planned for completion in 1995, 1996, and 1998. The cooperators in this project include BLM-Alaska, Ducks Unlimited, U.S. Fish and Wildlife Service, North Slope Borough and Pacific Meridian Resources.

## Project Objective

The objective of this project is to develop a baseline earth cover inventory using Landsat TM and SPOT XS satellite imagery in geographic information system (GIS) form for the NPR-A. This project will result in a GIS database that can be used for improved natural resources planning, such as monitoring the condition of various wetland communities. These data will also be valuable in modeling the type of habitat that is being used by various wildlife species, such as the threatened spectacled and Steller's eiders.

## Project Area

The NPR-A is located on the North Slope of Alaska and encompasses 9.3 million hectares (23.0 million acres) (Figure 3). Due to its immense size, the project area was divided into a Western, Eastern, and Southern phase. (Figure 3). The Western phase was completed in May 1995 and is dominated by the large, flat expanses of lake and wetland complexes of the Arctic Coastal Plain. The Eastern phase was completed in May 1996 and is composed of the large flat expanses of lake and wetland complexes typical of the Arctic Coastal Plain in the north, and shrub and herbaceous types in the Arctic Foothills Province to the south. The Southern phase was completed with this report and is characterized by upland shrub and herbaceous types intermixed with wetland complexes of the Arctic Foothills Province and large bare and sparsely vegetated mountains and river valleys of the Brooks Range. The boundary of the NPR-A was buffered by 3 km along the coast and 15 km inland for the final classification.

The NPR-A encompasses three Physiographic regions. The first region is the Arctic Coastal Plain, which is an emergent portion of the coastal shelf that has characteristically long cold winters and short cool summers (Carson and Hussey, 1962). In areas near the coast, snow remains on the ground until late June and ice is on the deeper lakes until late July. Shallow soils remain frozen from mid-September to

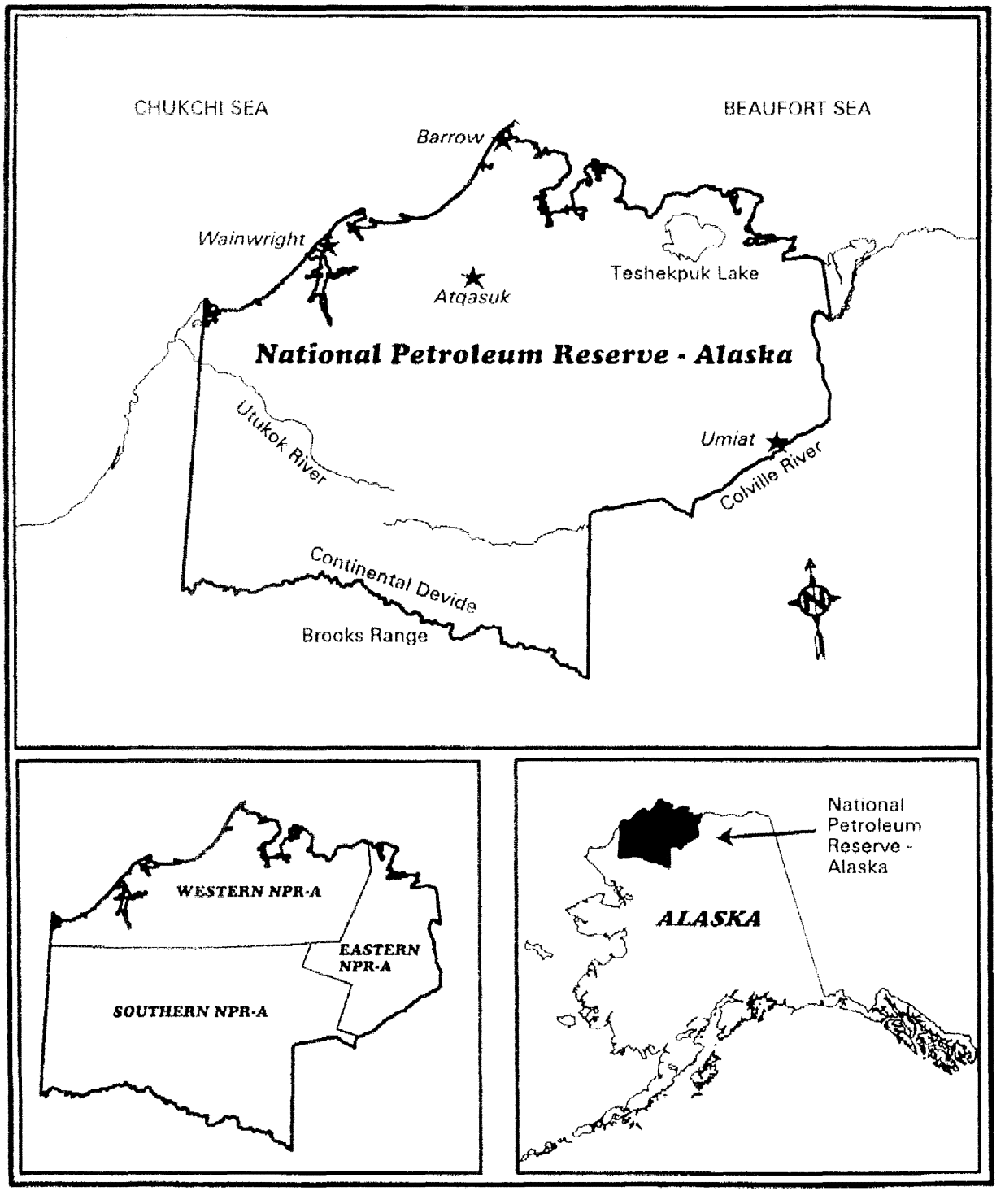


**Figure 3.** The Project Location for the NPR-A Earth Cover Mapping.

mid-May and are underlain by continuous permafrost, which contains marine silts, sands, and gravels of the Pleistocene Gubik Formation (Felix and Binney, 1989; Carson and Hussey, 1962). In the Arctic Coastal Plain the size of the lakes ranges from a few meters to approximately 7 km by 2 km (4.3 miles by 1.2 miles)(Black and Barksdale, 1949). The only major relief in the Arctic Coastal Plain is caused by the gentle undulations characteristic of most continental shelves (Carson and Hussey, 1962). The local relief is consistent with most tundra regions where there is permafrost below 24-48 cm (9-19 inches). It consists of polygonal patterned ground caused by the accumulation of ice in large contraction cracks and thaw basins. The diameter of the polygonal areas range from 3 to 30 meters (10 to 100 feet) (Carson and Hussey, 1962). The vegetation is composed of tundra with low-growing plants, including dwarf shrubs, sedges, grasses, forbs, mosses, and lichens (Felix and Binney, 1989; Derksen *et al.* 1981).

The second ecological zone is the Arctic Foothills Province. This region is characterized by low, rolling hills and east-west-trending ridges covered by dwarf shrub and tussock tundra. The Arctic Foothills Province starts about 90 miles inland from the coast and continues to the Brooks Range. The elevation ranges from 500 feet to 1150 feet. The region is underlain by continuous permafrost as in the Arctic Coastal Plain, but the lakes are fewer and deeper. The third region is the Brooks Range, characterized by large bare and sparsely vegetated mountains and river valleys. The southern boundary of the NPR-A is the continental divide of the Brooks Range.

## Data Acquisition

The entire 9.3 million hectare NPRA was mapped using eight Landsat Thematic Mapper (TM) images and three SPOT XS images. The SPOT images were used in the Eastern phase in an area where no suitable Landsat TM imagery was available. The ancillary data used in this project included: National Aeronautics and Space Administration (NASA) 1:60,000 aerial photographs (color prints, 1977; color infrared prints 1985; and color infrared transparencies, 1979); Digital hydrographic data from United States Geological Survey (USGS) Digital Line Graph data edited by the North Slope Borough (1993); National Wetlands Inventory (NWI) 1:63,360 hard copy maps from the U.S. Fish and Wildlife Service; and point locations of eider sightings from the U.S. Fish and Wildlife Service surveys in the spring of 1994.

For the Western Phase, two Landsat TM images were used to classify the project area (Figure 4). One Landsat Thematic Mapper image and three SPOT XS satellite images were used to classify the Eastern phase and portions of five Landsat TM images were used to classify the Southern phase (Figure 4) (Table 1).

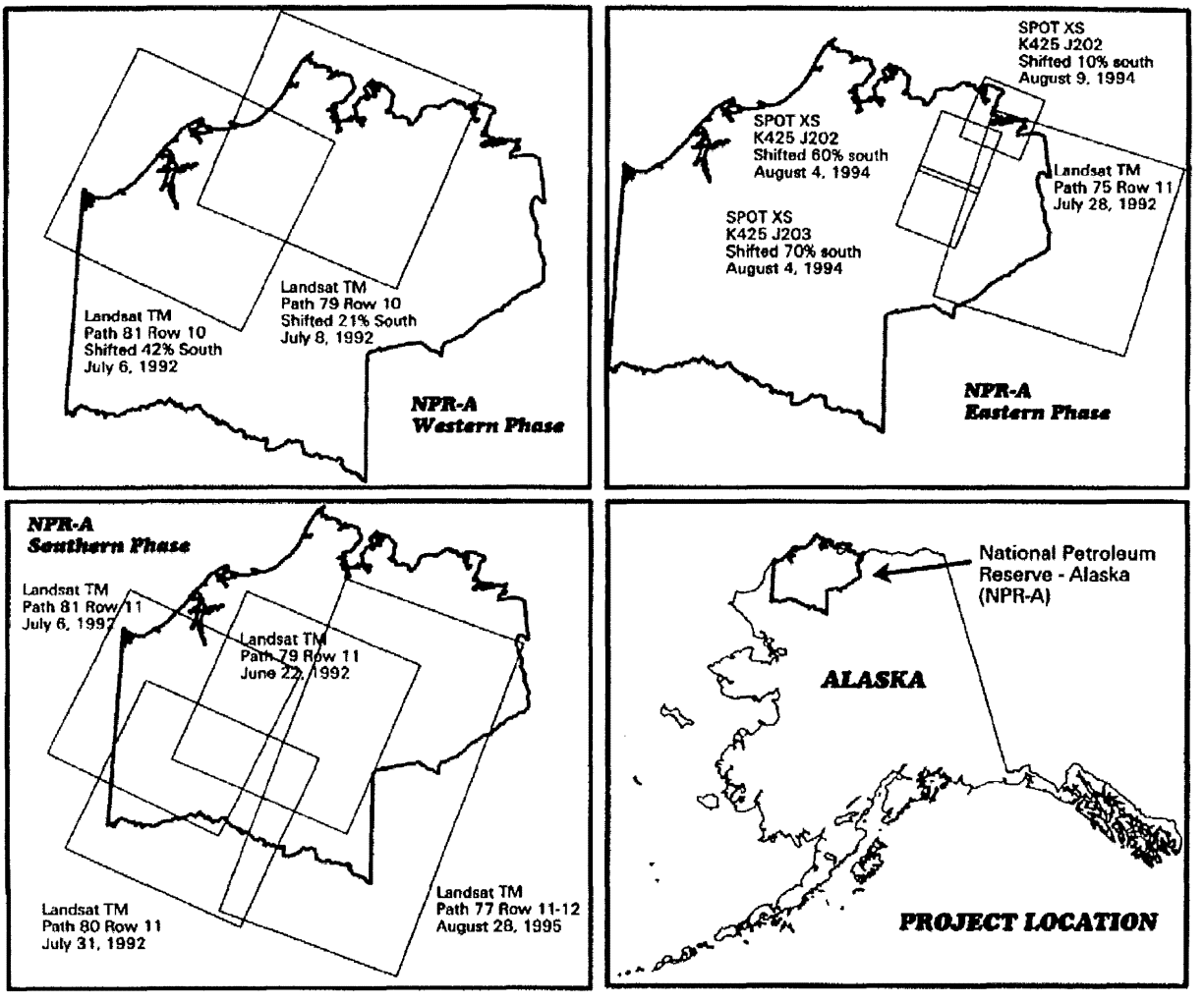


**Figure 4.** Scene Location for the Western, Eastern, and Southern NPR-A.

**Table 1.** The satellite imagery used for the NPR-A earth cover mapping project.

| PHASE # | SENSOR | PATH/ROW | % SHIFT | DATE |
|---|---|---|---|---|
| 1 | Landsat Thematic Mapper (TM) | 81/10 | 42% | 6-Jul-92 |
| 1 | Landsat Thematic Mapper (TM) | 79/10 | 21% | 8-Jul-92 |
| 2 | Landsat Thematic Mapper (TM) | 75/11 | 0% | 28-Jul-92 |
| 2 | SPOT XS | k425/j202 | 10% | 9-Aug-94 |
| 2 | SPOT XS | k425/j202 | 60% | 4-Aug-94 |
| 2 | SPOT XS | k425/j203 | 70% | 4-Aug-94 |
| 3 | Landsat Thematic Mapper (TM) | 77/11 | 0% | 28-Aug-95 |
| 3 | Landsat Thematic Mapper (TM) | 77/12 | 0% | 28-Aug-95 |
| 3 | Landsat Thematic Mapper (TM) | 80/11 | 0% | 31-Jul-92 |
| 3 | Landsat Thematic Mapper (TM) | 81/11 | 0% | 6-Jul-92 |
| 3 | Landsat Thematic Mapper (TM) | 79/11 | 0% | 22-Jun-92 |

# Methods

## Classification Scheme

The first step in any mapping project is the definition of a classification system that categorizes the features of the earth to be mapped. The system is derived by anticipated uses of the map information and discernable features of the earth (e.g., satellite imagery, aerial photography, or field information) used to create the map. A classification system has two critical components: (1) a set of labels (e.g., forest, shrub, water); and (2) a set of rules, or a system of assigning labels. It is important that the rules for assigning labels be both mutually exclusive and totally exhaustive (Congalton 1991). Any area to be classified should fall into one and only one category or class and every area should be included in the classification.

The classification scheme for the land cover inventory was developed through a series of meetings with biologists familiar with the vegetation and previous work, i.e. Markon and Derkson 1994. The classification scheme consisted of seven major categories and seventeen subcategories (Table 2). The definitions for the classification scheme, a decision tree, and written descriptions were developed in order to eliminate any confusion in the classification (see Appendices A-C). Examples of each class are located in Appendix D.

**Table 2.** The classification scheme for the NPR-A earth cover classification.

| | |
|---|---|
| 1.0 Water | 5.0 Moist Tundra |
| 1.1 Clear | 5.1 Sedge/Grass Meadow |
| 1.2 Turbid | 5.2 Tussock Tundra |
| 1.3 Ice | 5.3 Moss/Peat/Lichen |
| 2.0 Aquatic | 6.0 Shrub |
| 2.1 Carex aquatilis | 6.1 Dwarf |
| 2.2 Arctophylla fulva | 6.2 Low |
| | 6.3 Tall |
| 3.0 Flooded Tundra | |
| 3.1 Low-centered Polygons | 7.0 Barren Ground |
| 3.2 Non-patterned | 7.1 Dunes/Dry Sand |
| | 7.2 Sparsely Vegetated |
| 4.0 Wet Tundra | 7.3 Other |

## Image Preprocessing

The Landsat TM images were purchased with the terrain corrected for the Western and Eastern phase. The SPOT XS images from the Eastern phase were purchased with only system distortions corrected (not georeferenced) due to funding limitations. The three SPOT XS scenes were georeferenced and resampled to a 30 meter pixel size using ground control points (GCP) on the overlap areas on the existing Landsat TM scenes and USGS 1:63:360 quadrangles. SPOT XS images have a spatial resolution of 20 meters, whereas the Landsat TM images have a spatial resolution of 30 meters. Therefore, the SPOT XS images were resampled to 30 meters. The root mean square (RMS) error of the three SPOT scenes were 0.98 pixels for scene K425/J202 (9 Aug. 1994), 0.15 pixels for scene K425/J202 (4 Aug. 1994), and 1.16 pixels for scene K425/J203 (4 Aug. 1994) (Table 3). The Landsat TM scenes for the Southern phase were also purchased terrain corrected with the exception of Path 79 Row 11 (22 June 1992) and Path 81 Row 11 (6 August 1992). These two scenes were georeferenced using the overlapping terrain corrected scenes and USGS 1:63,360 quadrangles. The RMS for Path 79 Row 11 (22 June 1992) was 1.19 pixels and Path 81 Row 11 (6 August 1992) was 0.84 pixels.

An unsupervised clustering and seeding technique was used to initially generate spectrally unique areas within the study area. These spectrally unique areas were then refined and selected as sample sites for the field work using aerial photography and a preliminary decision tree of the land cover classification. These spectrally unique areas were plotted on field maps for field verification and the coordinates of their center points were programmed for use with aircraft global positioning systems. In addition, 1:63,360 scale quadrangle color infrared plots of the Landsat TM data were produced for the placement of additional field sample sites and for navigational purposes in the helicopters.

| Sensor | Path/Row | % Shift | Date | Number of GCP Points | X RMS | Y RMS | Total RMS |
|---|---|---|---|---|---|---|---|
| SPOT XS | k425/j202 | 10% S | 8/9/94 | 37 | 0.63 | 0.74 | 0.98 |
| SPOT XS | k425/j202 | 60% S | 8/4/94 | 45 | 0.11 | 0.1 | 0.15 |
| SPOT XS | k425/j203 | 70% S | 8/4/94 | 48 | 0.61 | 0.98 | 1.16 |
| Landsat TM | 79/11 | 0% | 6/22/92 | 66 | 0.92 | 0.59 | 1.19 |
| Landsat TM | 81/11 | 0% | 8/6/92 | 76 | 0.62 | 0.57 | 0.84 |

**Table 3**. The number of GCP points and RMS error of the SPOT scenes.

## Field Verification

The purpose of field data collection is to assess, measure, and document the on-the-ground vegetation variation within the project area. This variation will then be correlated with the spectral variation in the satellite imagery during the image classification process. Low-level helicopter surveys are a very effective field data collection method since a much broader area can be covered with an orthogonal view from above, similar to a satellite sensor. Helicopter surveys are sometimes the only transportation alternative in Alaska due to vast remote areas that are difficult to access (Figure 5).

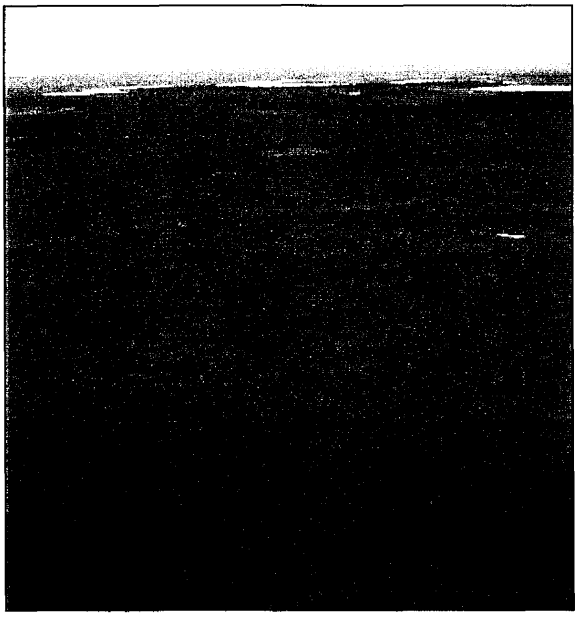

**Figure 5.** Helicopters are used in this remote and vast project area to effectively acquire data.

In order to obtain a reliable and consistent field sample, a custom field data collection card (Kempka *et al.* 1994) was developed and used to record field information (Figure 6). A five person helicopter crew performed the field assessment. Each crew had a pilot, biologist, recorder, navigator, and alternate. The navigator, operates the GPS equipment and interprets the satellite image derived field maps and occupies the co-pilot seat. The biologist has the most knowledge about the vegetation, and the recorder, records species percentages and other data on the field form, occupy the remaining two seats in the back of the helicopter. The alternate is responsible for flight following, data entry of the previous day's work, and substituting in case of sickness. On the first day, sampling was performed by landing the aircraft on the ground to verify and standardize the classification and sampling techniques. After the first day, the majority of the sites were observed in flight to determine the percent cover for each species and an overall earth cover class. Ground verification was performed when identification of dominant vegetation and/or species was uncertain.

## Classification

Every image is unique and can present challenges in the classification process. The approach that was used in this project has been tried and proven successful for many years (Figure 7). The image processor's site specific experience and knowledge in combination with high quality ancillary data can overcome some of the spectral differences to produce a high quality and extremely useful product. Therefore, the image processor should be actively involved in the field data collection and hopefully have first hand knowledge of every training site.

### Generation of New Bands

New bands can be derived from the raw data by simple operations like dividing one band by another or complex statistical computations like principle components transformations. The idea behind generating

Rev 7/30/96

## National Petroleum Reserve Alaska - Field Form

| Site Number | Soil Type | Observer | Obs. Date (Mo Day Year) | Obs. Level | %Slope (Avg) | Aspect (Avg) | Elev'n |
|---|---|---|---|---|---|---|---|
| 926 | | JS/DY | 8/16/96 | 1 (2) 3 4 | | 6 | |

Air Photo: Flight Line ____ Photo ____ Quad ____ Photo Source: ____ 1:63K Quad: Utukok R.D-3

LAT (GPS) ____:____:____ Degrees Min. Seconds LONG (GPS) ____:____:____ Degrees Min. Seconds GPS/Local Time: ____:____:____ Hr. Min. Seconds

| WATER | BARREN GROUND | FLOODED TUNDRA | WET TUNDRA | MOIST TUNDRA | SHRUB | AQUATIC | ☒ High Centered Polygons Present |
|---|---|---|---|---|---|---|---|
| Clear | Dunes/Dry Sand | Low Centered Polygon | | Sedge/Grass Meadow | Dwarf | Carex aquatilis | |
| Turbid | Other | Non-Pattern | | Tussock Tundra | Low | Arctophylla fulva | |
| Ice | Sparse Vegetation | | | Moss/Peat/Lichen | Tall | | |

| NOAA Coastwatch Classification | |
|---|---|
| Viereck Classification | |

| % Coverage | SHRUBS | | Height |
|---|---|---|---|
| | Tundra dwarf birch | Betula nana | |
| | Arctic bell-heather | Cassiope tetragona | |
| | Black crowberry | Empetrum nigrum | |
| | Greenland labrador tea | Ledum palustre | |
| | Cloudberry | Rubus chamaemorus | |
| 15 | Willow ✓ | Salix spp. | |
| | Bog blueberry | Vaccinium uliginosum | |
| | Mountain cranberry | Vaccinium vitis-idaea | |
| | Mountain avens | Dryas spp. | |
| | Diapensia | Diapensia lapponica | |
| | Shrubby cinquefoil | Potentilla fruticosa | |
| | Alder | Alnus crispa | |
| | Bearberry | Arctostaphylos spp. | |
| | Andromeda | Andromeda spp. | |
| | | | |

| % Coverage | HERBACEOUS | |
|---|---|---|
| | Moss | Bryoid spp. |
| | Common marsh marigold | Caltha palustris |
| | Milkvetch | Astragulus spp. |
| | River Beauty | Epilobium latifolium |
| | Lichen | Lichen |
| | Arctic poppy | Papaver spp. |
| | Lousewort | Pedicularis spp. |
| | Arctic sweet coltsfoot | Petasites frigidus |
| | Buckwheat | Polygonum spp. |
| | Marsh cinquefoil | Potentilla palustre |
| | Buttercup | Ranunculus spp. |
| | Saxifrage | Saxifraga spp. |
| | Groundsel | Senecio spp. |
| | Low starwort | Stellaria spp. |
| | Lupine | Lupinus arcticus |
| | Locoweed | Oxytropis spp. |
| | Hedysarum | Hedysarum spp. |
| | Silene | Silene acaulis |
| | | |
| | | |
| 15 | Subtotal % Cover | |

| % Coverage | GRASS/SEDGE/... | |
|---|---|---|
| 60 | Broadlf arctic bentgrass ✓ | Arctagrostis latifolia |
| | Pendant grass | Arctophylla fulva |
| | Water sedge | Carex aquatilis |
| | Sedge cother | Carex spp. |
| | Bigelow sedge | Carex bigelowii |
| | Tufted hairgrass | Deschampsia ceaspitosa |
| | Horsetail | Equisetum spp. |
| | Tussock cotton-grass | Eriophorum vaginatum |
| | Mare's tail | Hippuris spp. |
| | Rush | Juncus spp. |
| | Woodrush | Luzula spp. |
| | Wool bluegrass | Poa lanata |
| 5 | Arctic bluegrass ✓ | Poa arctica |
| | Alkali grass | Puccinellia spp. |
| | Cotton-grass A. | Eriophorum angustifolium |
| 15 | Cotton-grass R. ✓ | Eriophorum russeolum |
| | Foxtail | Alopecurus alpinus |
| | Dupontia | Dupontia fischeri |
| | Lyme grass | Elymus spp. |
| | | |
| | | |
| | | |

| % Coverage | NON-VEGETATED | |
|---|---|---|
| | Clear water | |
| | Gravel | |
| | Ice | |
| 5 | Mud ✓ | |
| | Plant Debris | |
| | Rock | |
| | Sand | |
| | Silt | |
| | Turbid Water | |
| | | |
| | | |
| 85 | Subtotal % Cover | |
| 100 | GRAND TOTAL % COVER | |

| C# | COMMENTS |
|---|---|
| | R1 F33 |
| | |
| | |

**Figure 6.** Field data collection card for the NPR-A.

new bands is that unique information will be derived from the process and will enhance the classification. The possibilities of generating new bands from the raw imagery are infinite. A few of the more popular ones are principle components, tassel cap, band ratios, and Normalized Difference Vegetation Index (NDVI). It is beyond the scope of this project to generate and test every possible combination. However, based on past experience and some analysis from the Western phase (see Phase 1 TM data for this project). The new bands were generated by dividing the digital number (DN) of band 4 by the DN of band 3 and by calculating the first principal component of the visible bands (bands 1-3). From past experience in Alaska and other vegetation studies the 4/3 ratio was chosen for this project (Congalton *et al.* 1993). The 4/3 ratio typically reduces the shadow effects and enhances the differences between vegetation types. The first principal component of the visible bands was used to reduce the processing time since the visible bands are typically highly correlated and their first principal component will typically account of 99% of the variation. These new bands were subset with bands 3, 4, and 5 to produce a five-banded file to be used in the classification.

### Removal of Clouds and Shadows

The clouds and cloud shadows are removed from the image before the classification is started. This eliminates the confusion in distinguishing the clouds or cloud shadows from actual earth cover types. Clouds are removed using an unsupervised classification and manual on-screen editing. The clouds are separated from the shadows and the two classes are recorded to their prospective class number. The cloud/shadow layer is then combined with the rest of the classified image during the last step in the classification process.

### Seeding Process

The field sites designated as training areas were "seeded" (generate statistics from the imagery) in ERDAS Imagine using spectral bounds as the limit for seed growth. The standard deviations of the seeded areas were kept to about 3 and all seeded areas were required to be more than 15 pixels (approximately 3.75 acres) in size. Along with the field training areas, additional "seeds" were generated for water, turbid water, ice, and snow. These classes were easily recognized on the imagery and aerial photography. The output of the seeding process in Imagine is a signature file that contains all of the statistics for the training areas. The signature file is then used in the modified supervised/unsupervised classification.

### Generation of Unsupervised Signatures

An unsupervised classification is generated using the five banded image described in the "Generation of New Bands" section. One hundred and fifty signatures were derived from the unsupervised classification using the ISODATA program in Imagine. The output of this process is a signature file similar to that of the seeding process containing 150 unsupervised signatures. A maximum likelihood classification of the 150 unsupervised signatures is generated using the supervised classification program in Imagine.

### Modified Supervised/Unsupervised Classification

A modified supervised/unsupervised classification approach (Chuvieco and

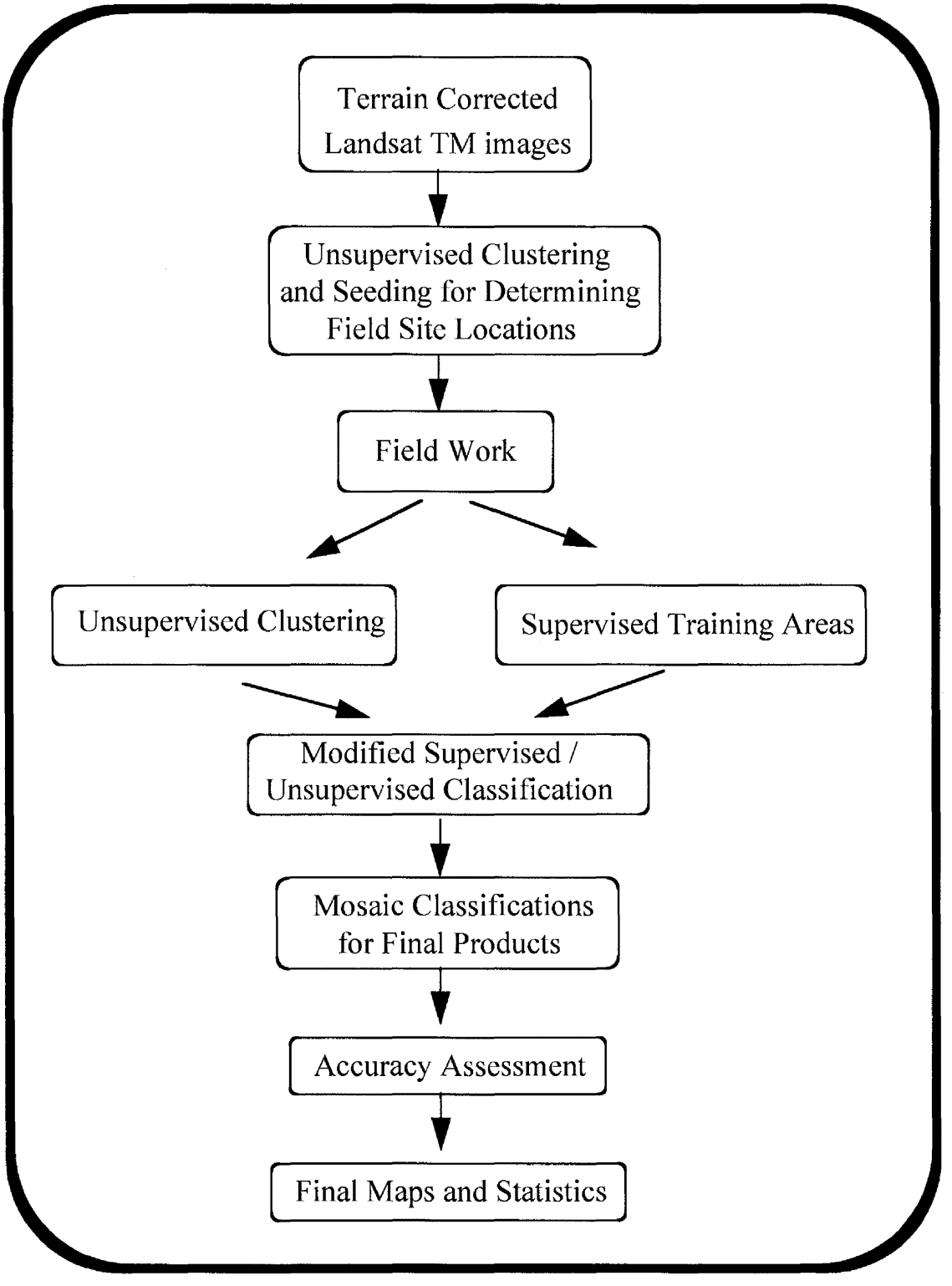


**Figure 7.** The classification process of the NPR-A.

Congalton, 1988) was used. This approach uses a statistical program to group the spectrally unique signatures from the unsupervised classification with the signatures of the supervised training areas. In this way, the spectrally unique areas were labeled according to the supervised training areas. This is a repetitive process because all of the supervised signatures will not cluster perfectly with the unsupervised signatures the first time. The unsupervised signatures that match well with the supervised signatures were inspected and removed from the classification process. The remaining confused clusters were grouped into general categories (forest, shrub, non-vegetation, etc.) and re-run through the process. The process was repeated until all of the spectral classes were adequately matched and labeled. This classification approach provides three major benefits: (1) aids in labeling unsupervised classes by grouping them with known supervised training sites; (2) helps identify classes that possess no spectral uniqueness, (i.e. training sites that are spectrally inseparable); and (3) identifies areas of spectral reflectance present in the imagery that were not represented by a training site.

### Editing and Modeling

The final classification step was to model the remaining confusion and make final edits. There may be a few problem areas in the classification that the spectral data cannot separate, but a simple model can take care of the problem. For instance, water may be classified where there are terrain shadow effects, which can be easily modeled out of the classification using Digital Elevation Models (DEM's). In the end, there may be a few classification problems which cannot be addressed with either spectral separation or modeling. When this happens, the image processor must use aerial photographs and on screen digitizing to remedy the classification situation.

## Accuracy Assessment

The purpose of quantitative accuracy assessments is the identification and measurement of map errors. Primary motivations for accuracy assessment are: to understand the errors in the map (so they can be corrected), and to provide an overall assessment of the map's reliability (Gopal and Woodcock, 1992). Factors to consider when designing an accuracy assessment, include how to determine the sample size, how to allocate this sample, and which sampling scheme to employ. Congalton (1991) suggests that as a rule 50 samples be selected for each map category. This empirical value derived from many projects. A second method of determining sample size is using the multinomial distribution and specifying a given confidence in the estimate (Tortora 1978). The results of this calculation tend to favor Congalton's rule. Once the sample size is determined, it then is allocated among categories in the map. Only a strictly proportional allocation is possible. However, the smaller categories in areal extent will have only a few samples that may severely hamper future analysis. The other extreme is to force a given number of samples from each category. Depending on the extent of each category, this approach can significantly bias the results. Finally, a sampling scheme must be selected. A purely random approach has excellent statistical properties, but is practically difficult and expensive to apply. A purely systematic approach is easy to apply, but could result in limited sampling areas.

## Error Matrix

The standard method for assessing the accuracy of a map is to build an error matrix (also know as a confusion matrix or contingency table). The error matrix compares the reference data (field site or photo interpreted site) with the classification. The matrix is a square array of numbers set in rows and columns that express the number of sites assigned to a particular category in the reference data relative to the number of sites assigned to a particular category in the classification. The columns usually represent the reference data while the rows indicate the classification (Lillesand and Kiefer, 1994). An error matrix is an effective way to represent accuracy since the individual accuracy of each category is described with both the errors of inclusion (commission errors) and errors of exclusion (omission errors) present in the classification. A commission error occurs when an area is wrongly included in a category where it does not belong. An omission error is excluding that area from the category in which it does belong. Every error is an omission from the correct category and a commission to a wrong category. It is important that the error matrix and accuracy assessment is based on the assumption that the reference data is 100% correct. This assumption is not always true, especially when the reference data is derived from aerial photographs.

By clearly showing errors of omission and commission, the error matrix can be used to compute overall accuracy, producer's and user's accuracy (Story and Congalton, 1986). Overall accuracy is the sum to the major diagonal (i.e., the correctly classified samples) divided by the total number of samples in the error matrix. This value is the most commonly reported accuracy assessment statistic. Producer's and user's accuracies are ways of representing individual category accuracy instead of just the overall classification accuracy.

## Kappa Analysis

A Kappa analysis is performed on the error matrix as a further measure of accuracy (Congalton 1991). Cohen's coefficient of agreement (Kappa) is a measure of overall agreement in the error matrix after chance agreement is removed from consideration. Kappa attempts to provide a better measure of agreement by adjusting the overall accuracy for chance agreement or the agreement that might be contributed solely by chance matching of the two maps. The result of the Kappa analysis is the KHAT statistic. Landis and Koch (1977) characterized the possible ranges for KHAT into three groupings: a value greater then 0.80 (i.e., 80%) represents strong agreement; a value between 0.40 and 0.80 (i.e., 40 - 80%) represents moderate agreement; and a value below 0.40 (i.e., 40%) represents poor agreement.

In addition to calculating KHAT, confidence intervals can be calculated using the approximate large sample variance. The large sample variance can then be used to test if the agreement between the classification and reference data is significantly different from zero or a random classification with the Z statistic. The Z statistic in the Kappa analysis can also be used to test if a classification is significantly different from another classification. A Z statistic of 1.98 or less means that the classification is not significantly different from a random classification at the 99% confidence level.

## Alaskan Perspective

Obtaining adequate reference data for performing an accuracy assessment can be

extremely expensive in remote areas. Aircraft is the primary mode of transportation throughout most of Alaska. Aerial photographs are available for most of Alaska, but at a scale which, in most cases make it difficult and sometimes impossible to distinguish certain vegetation classes. Ideally, field work would be performed during one summer, the classification would be performed during the winter, and the reference data would be collected the next summer. This procedure would allow a stratified random sample of the classification and ensure adequate sampling of all the classes. Unfortunately, this methodology is not typically feasible due to the cost of obtaining the field data.

For this project, the field work for obtaining the training sites for classifying the imagery and the reference data for the accuracy assessment was accomplished at the same time. Special care was taken during the preprocessing stage and in the field to make sure adequate samples were obtained. However, funding limitations did not allow for the number of samples suggested for each class (50) for the accuracy assessment. The first priority for the field data was to make the best map possible, so few field sites were withheld for the accuracy assessment. Obviously, this means that there is little measure of confidence for those classes in the accuracy assessment. However, withholding a percentage of sites for the accuracy assessment does give us some confidence in the classification and guides the image processor to certain areas of confusion in the classification.

## Some Considerations

While the accuracy assessment performed in this project is by no means a robust test of the classification, it does give the user some confidence in using the classification. It also provides enough detail for the end user to determine where discrepancies in the classification may cause a problem while using the data. It is also important to note the variations in the dates of the imagery, aerial photographs, and field data. For this project, the date of the imagery varied from June 22 to August 28 and from 1992 to 1995. The aerial photographs were from 1977 to 1985, and the field data was collected from July and August 1994 through 1996. Differences due to environmental changes from the different sources may have a major impact on the accuracy assessment. This difference was apparent during the collection of one particular field site in 1995. The field crew arrived at a site that the imagery showed to be an aquatic site and there was only bare sand remaining from a drained lake.

A major assumption of quantitative accuracy assessments is that the label from the reference information represents the "true" label of the site and that all differences between the remotely sensed map classification and the reference data are due to classification and/or delineation error (Congalton and Green, 1993). Unfortunately, error matrices can be inadequate indicators of map error because they are often confused by non-map error differences. Some of the non-map errors that can cause confusion are: registration differences between the reference data and the remotely sensed map classification, digitizing errors, data entry errors, changes in land cover between the date of the remotely sensed data and the date of the reference data, mistakes in interpretation of reference data, and variation in classification and delineation of the reference data due to inconsistencies in human interpretation of vegetation.

# Results

## Field Verification

The field verification for the Southern phase occurred from August 3 to August 19, 1996. During that time period, 600 field sites were visited (Table 4). Approximately 49% (293) of the field sites were reserved for the accuracy assessment. Field camps were located at Ivotuk and along Carbon Creek. The field crew consisted of Jim Sisk as the vegetation caller, Dave Yokel as the recorder, and Robb Macleod as the navigator. At one time during the field work, approximately four inches of snow fell during the night at Carbon Creek. However, most of the snow had melted by mid-afternoon.

Over the three field seasons, field information was collected on 1,667 sites throughout the NPR-A (Table 5). From 1,667 field sites where collections were made, approximately 44% (740) were reserved for the accuracy assessment. The training sites were fairly well distributed throughout the project area (Figure 8). Additional analysis was performed on the field site database to extract additional information about the plant species within each class. The field data from all three phases were used in the analysis. The first analysis was to sum all of the species that occurred in each of the earth cover classes (Table 6). The most diverse class (class that had the highest number of plant species) was the sedge/grass meadow class with 47 different species. The dwarf shrub class was the next most diverse classes with 45 different species, followed by the low shrub class with 40 and sparse vegetation at 38.

The next analysis summed all of the species that were recorded during the field collection to produce a list of all species that were observed during the field work (Appendix E). The final analysis looked at all of the species that occurred in a class and calculated the percentage of occurrence of that species within that class (Appendix F).

## Classification

The final results of the classification are: 43% shrub, 31% moist tundra, 11% water, 6% flooded tundra, 5% wet tundra, 2% aquatic, and 2% barren ground. The area and percentage for each of the seven major classes (Table 7) and the seventeen minor classes (Table 8) were calculated. The Western and Eastern classifications were then mosaicked with the Southern classification in order to produce a continuous and seamless classification of the entire NPR-A (Figure 9). The classification of the Southern phase had some unique difficulties compared to the Western and Eastern phases. Due to the large percentage of tussock tundra and dwarf shrub in the southern region and the intermixing of these classes, it was often difficult to separate these two classes. The presence of the dwarf shrub mountain avens (*Dryas spp.*) around the Brooks Range created some confusion between the dwarf shrub class and the sparse vegetation and barren ground classes. There was also a spectral difference between the dwarf shrub classes with a large percentage of mountain avens and those shrub classes with birch (*Betula spp.*) and willow (*Salix spp.*) species. Since this spectral difference was

**Table 4.** The number of field sites and accuracy assessment sites for each phase

| | 1994 | | 1995 | | 1996 | |
|---|---|---|---|---|---|---|
| CLASS NAME | TOTAL FIELD SAMPLES | ACCURACY ASSESSMENT | TOTAL FIELD SAMPLES | ACCURACY ASSESSMENT | TOTAL FIELD SAMPLES | ACCURACY ASSESSMENT |
| Clear Water | 14 | 49 * | 12 | 8 | 25 | 25 |
| Turbid Water | 6 | 3 | 25 | 13 | 4 | 4 |
| Ice | 5 | 20 * | 0 | 0 | 0 | 0 |
| Carex Aquatilis | 30 | 12 | 51 | 17 | 2 | 0 |
| Arctophylla Fulva | 31 | 16 | 15 | 5 | 25 | 6 |
| Low Centered Polygons | 54 | 20 | 31 | 15 | 26 | 8 |
| Non-pattern | 53 | 24 | 24 | 6 | 32 | 14 |
| Wet Tundra | 100 | 29 | 24 | 8 | 98 | 38 |
| Sedge/Grass Meadow | 68 | 27 | 42 | 17 | 55 | 26 |
| Tussock Tundra | 70 | 22 | 35 | 15 | 57 | 28 |
| Moss/Lichen | 18 | 0 | 3 | 1 | 6 | 0 |
| Dwarf Shrub | 54 | 7 | 81 | 31 | 133 | 78 |
| Low Shrub | 55 | 24 | 28 | 12 | 52 | 24 |
| Tall Shrub | 0 | 0 | 28 | 11 | 9 | 3 |
| Dunes/Dry Sand | 21 | 11 | 12 | 5 | 0 | 0 |
| Sparsely Vegetated | 23 | 5 | 23 | 9 | 26 | 14 |
| Other | 18 | 0 | 13 | 5 | 50 | 25 |
| Total | 620 | 269 | 447 | 178 | 600 | 293 |

* Additional accuracy assessment sites were generated using random location on the imagery and aerial photography.

**Table 5.** The total number of field sites and accuracy assessment site for all phases.

| | 1994-1996 | |
|---|---|---|
| CLASS NAME | TOTAL FIELD SAMPLES | ACCURACY ASSESSMENT |
| Clear Water | 51 | 82 |
| Turbid Water | 35 | 20 |
| Ice | 5 | 20 |
| Carex Aquatilis | 83 | 29 |
| Arctophila Fulva | 71 | 27 |
| Low Centered Polygons | 111 | 43 |
| Non-pattern | 109 | 44 |
| Wet Tundra | 222 | 75 |
| Sedge/Grass Meadow | 165 | 70 |
| Tussock Tundra | 162 | 65 |
| Moss/Lichen | 27 | 1 |
| Dwarf Shrub | 268 | 116 |
| Low Shrub | 135 | 60 |
| Tall Shrub | 37 | 14 |
| Dunes/Dry Sand | 33 | 16 |
| Sparsely Vegetated | 72 | 28 |
| Other | 81 | 30 |
| Total | 1667 | 740 |

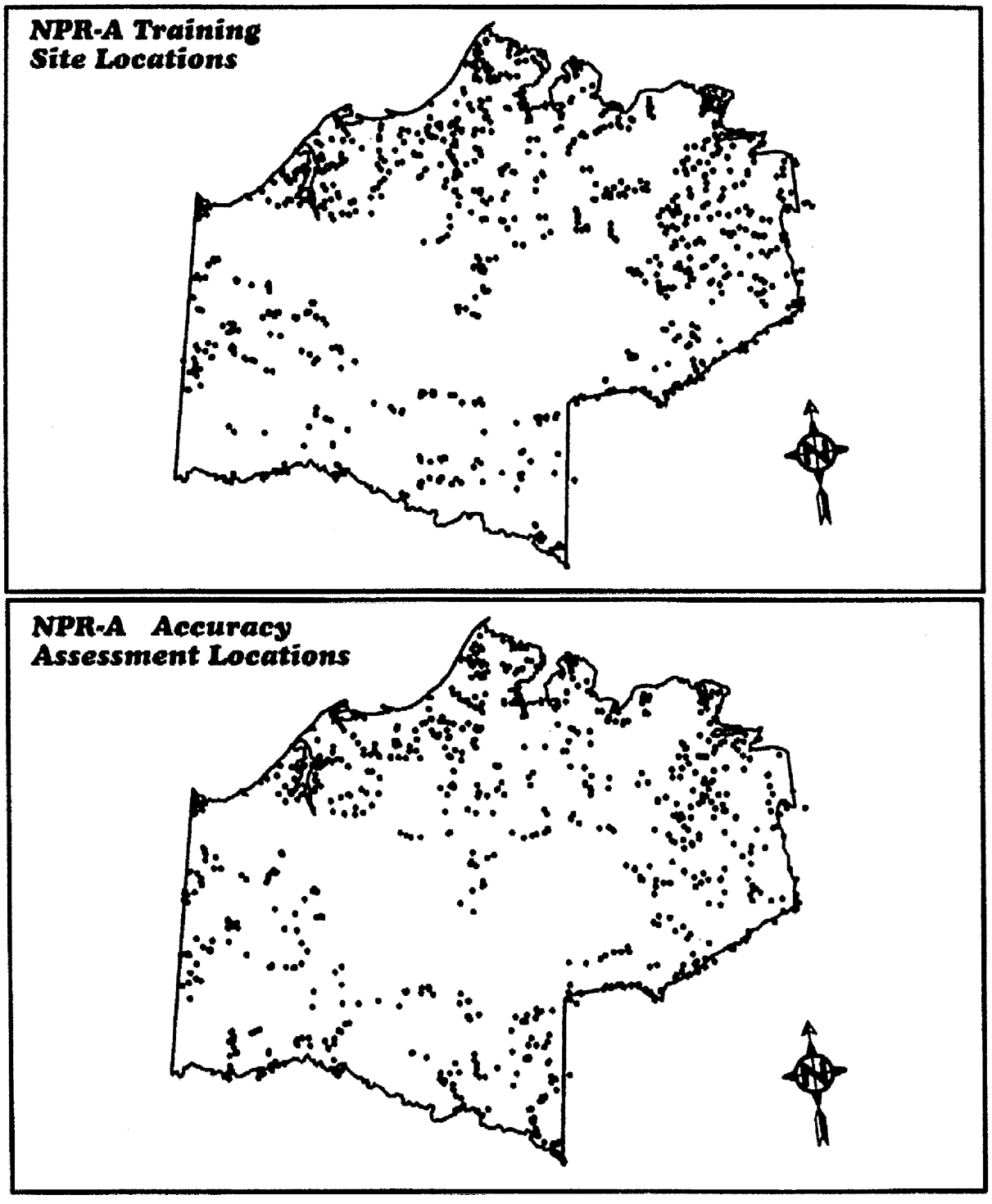


**Figure 8.** The spatial distribution of the field sites for all three phases.

**Table 6.** Sum of species that occurred in each earth cover class.

| | |
|---|---|
| Sedge/Grass Meadow | 47 |
| Dwarf Shrub | 45 |
| Low Shrub | 40 |
| Sparse Vegetation | 38 |
| Wet Tundra | 37 |
| Low Centered Polygon | 33 |
| Tussock Tundra | 30 |
| Carex Aquatilis | 26 |
| Non-Pattern | 23 |
| Tall Shrub | 20 |
| Other | 19 |
| Dunes/Dry Sand | 18 |
| Byroid | 16 |
| Arctophila Fulva | 10 |
| Clear Water | 10 |
| **Total # of Species** | 63 |

**Table 7.** The area and percentage of the seven major classes.

| Class Name | Hectares | Acres | Percentage |
|---|---|---|---|
| Water | 981,416.70 | 2,425,135.19 | 10.53% |
| Aquatic | 178,231.23 | 440,419.27 | 1.91% |
| Flooded Tundra | 577,889.82 | 1,427,997.85 | 6.20% |
| Wet Tundra | 429,816.69 | 1,062,100.92 | 4.61% |
| Moist Tundra | 2,898,785.34 | 7,163,059.62 | 31.10% |
| Shrub | 4,001,825.88 | 9,888,734.07 | 42.94% |
| Barren Ground | 217,315.71 | 536,999.19 | 2.33% |
| Clouds/Shadows/Other | 34,751.70 | 85,873.38 | 0.37% |
| **TOTAL** | **9,320,033.07** | **23,030,319.50** | **100.00%** |

**Table 8.** The area and percentage of the seventeen minor classes.

| Class Name | Hectares | Acres | Percentage |
|---|---|---|---|
| Clear Water | 489,986.28 | 1,210,783.32 | 5.26% |
| Turbid Water | 412,079.31 | 1,018,270.87 | 4.42% |
| Ice | 79,351.11 | 196,081.00 | 0.85% |
| Carex aquatilis | 147,527.64 | 364,548.99 | 1.58% |
| Arctophylla fulva | 30,703.59 | 75,870.28 | 0.33% |
| Low Centered Polygons | 356,298.84 | 880,434.23 | 3.82% |
| Non-pattern | 221,590.98 | 547,563.62 | 2.38% |
| Wet Tundra | 429,816.69 | 1,062,100.92 | 4.61% |
| Sedge/Grass Meadow | 515,337.84 | 1,273,428.43 | 5.53% |
| Tussock Tundra | 2,288,946.51 | 5,656,113.99 | 24.56% |
| Moss/Lichen | 94,500.99 | 233,517.20 | 1.01% |
| Dwarf Shrub | 3,664,280.34 | 9,054,640.29 | 39.32% |
| Low Shrub | 336,564.00 | 831,668.34 | 3.61% |
| Tall Shrub | 981.54 | 2,425.44 | 0.01% |
| Dunes/Dry Sand | 27,019.35 | 66,766.31 | 0.29% |
| Sparsely Vegetated | 95,681.43 | 236,434.13 | 1.03% |
| Barren Ground Other | 94,614.93 | 233,798.75 | 1.02% |
| Clouds/Cloud Shadows | 24,767.28 | 61,201.32 | 0.27% |
| Mountain Shadows | 9,984.42 | 24,672.06 | 0.11% |
| **TOTAL** | **9,320,033.07** | **23,030,319.50** | **100.00%** |

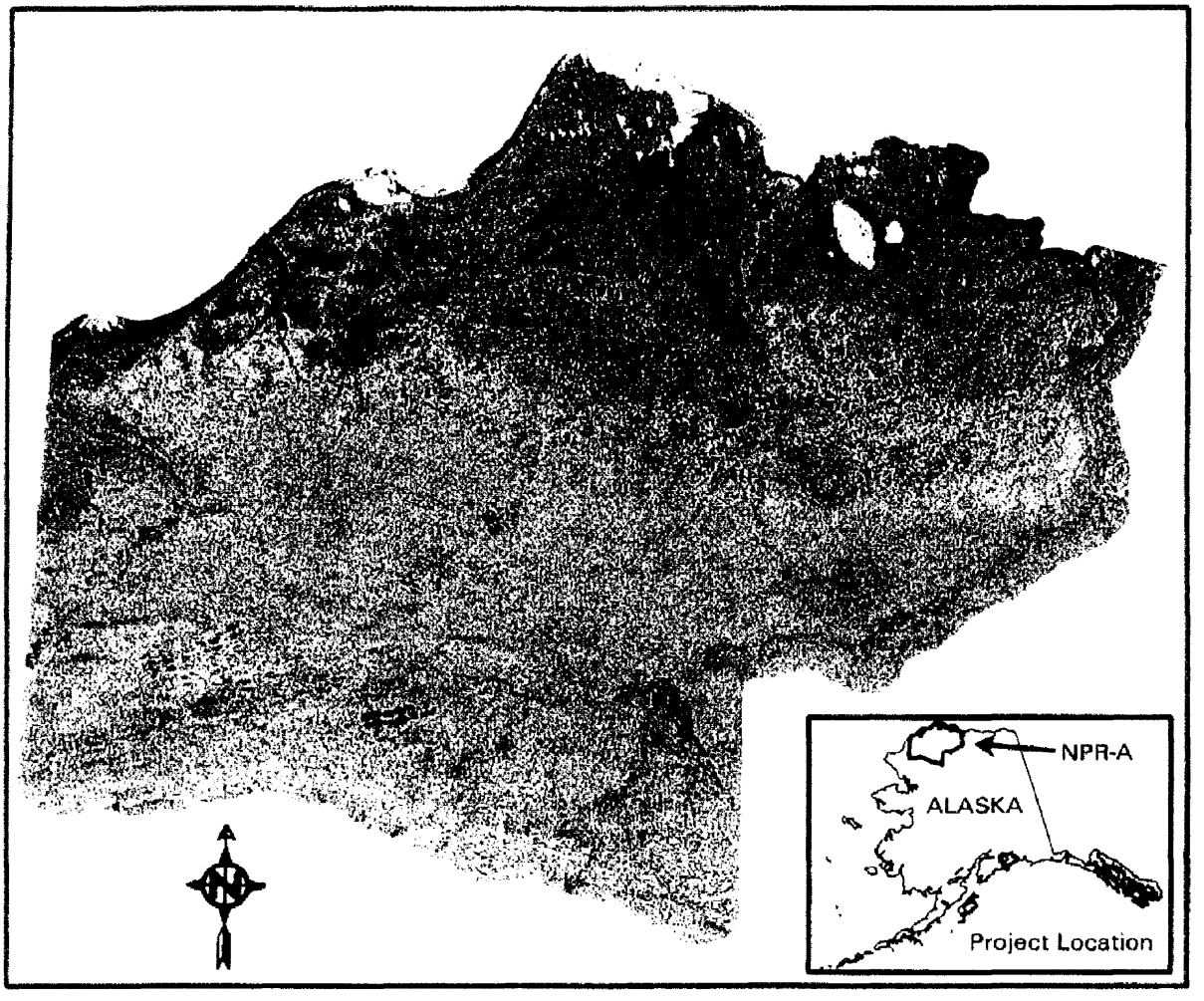


**Figure 9.** The mosaicked classification of the entire NPR-A.

easy to separate, an alternative classification was developed that differentiates these two sub-types of the dwarf shrub class.

## Accuracy Assessment

The overall accuracy of the major classes for the Southern phase was 81% and the overall accuracy of the minor classes for the Southern phase was 73%. The classification for both the major and minor classes was significant when using the Z statistic from the Kappa analysis (Table 9).

All classes with the exception of turbid water were included in the accuracy assessment. The turbid water was not included because of the temporal difference in the field data collection and the satellite image acquisition date. In addition, there were no accuracy assessment points for the ice category because there was no ice on any of the images. The moss/lichen, carex aquatilis, and dunes/dry sand classes were also not existent in the accuracy assessment for the Southern phase due to the rare occurrence of these classes in this portion of the NPR-A.

Due to the complex nature of the environment and the classification scheme, the error matrix of the classification should be studied (Appendix G). Most errors occurred between the dwarf shrub and tussock tundra classes and the dwarf shrub and barren classes. Fourteen of the dwarf shrub accuracy assessment sites were classified as tussock tundra. Likewise, eight of the tussock tundra accuracy assessment sites were classified as dwarf shrub. These two classes presented many problems in the classification due to their close association in habitat preferences. Six of the dwarf shrub accuracy assessment sites were also classified as either sparsely vegetated or other. These errors were most likely due to the spectral similarity of the prostrate dwarf shrub *Dryas spp.* that grows in association with barren sites.

The overall accuracy of the major classes for the entire NPR-A was 85% and the overall accuracy of the minor classes for the entire NPR-A was 75%. The classification for both the major and minor classes was significant when using the Z statistic from the Kappa analysis (Table 10). These accuracies were obtained by combining the error matrices from all three phases and generating the overall accuracy and Kappa analysis from that matrix (Appendix G).

A comparison between the Western, Eastern and Southern NPR-A classification accuracy assessments was made to determine if there is any significant difference between the classifications. The accuracy of the major classes for the Eastern classification had a 4% higher overall accuracy and a 3% higher KHAT accuracy then the Western classification (Table 11). The accuracy of the minor classes for the Eastern classification had a 2% lower overall accuracy and a 2% lower KHAT accuracy then the Western classification. The Southern phase had the lowest overall and KHAT accuracy of the three phases. However, the differences were not significant when compared in the Kappa analysis (Table 12).

**Table 9.** The accuracy assessment of the Southern NPR-A classification.

| | Overall Accuracy | Khat Accuracy | Z statistic |
|---|---|---|---|
| Major categories | 81% | 76% | 25.83 * |
| Minor categories | 73% | 68% | 22.75 * |

* Significant at the 99% confidence level

**Table 10.** The accuracy assessment of the entire NPR-A classification.

| | Overall Accuracy | KHAT Accuracy | Z statistic |
|---|---|---|---|
| Major categories | 85% | 82% | 51.99* |
| Minor categories | 75% | 72% | 41.40* |

* Significant at the 99% confidence level

**Table 11.** Comparison between the overall and KHAT accuracy of the three phases.

| | Overall Accuracy | KHAT Accuracy | Z statistic |
|---|---|---|---|
| Western NPR-A Major classes | 84% | 81% | 33.16 * |
| Western NPR-A Minor classes | 77% | 74% | 29.07 * |
| Eastern NPR-A Major classes | 88% | 84% | 28.15 * |
| Eastern NPR-A Minor classes | 75% | 72% | 20.52 * |
| Southern NPR-A Major Classes | 81% | 76% | 25.83 * |
| Southern NPR-A Minor Classes | 73% | 68% | 22.75 * |

* Significant at the 99% confidence level.

**Table 12.** Significance test of the Western, Eastern, and Southern NPR-A accuracy assessment.

* Significant at the 99% confidence level.

| | Z statistic | Significant* |
|---|---|---|
| Western vs Eastern Major classes | 1.1375 | NO |
| Western vs Eastern Minor classes | -0.3445 | NO |
| Western vs Southern Major classes | 1.1452 | NO |
| Western vs Southern Minor classes | 1.4396 | NO |
| Eastern vs Southern Major classes | 2.0811 | NO ** |
| Eastern vs Southern Minor classes | 0.9388 | NO |

** Significant at the 95% confidence level

## Final Products

The primary product of this project is a digital database of the seventeen earth cover classes for the NPR-A and associated Metadata (Appendix H). Hard copy maps were also created of the entire project area at a scale of 1:250,000 and selected 1:63,360 scale maps were also produced. For viewing purposes and future analysis, the 1667 field sites were digitized from the field maps into ArcInfo and the field site database was related to the ArcInfo coverage. The result was ArcInfo coverage of field sites with the attribute data. A final report describing the analysis and technical design was also produced.

# Conclusions

The National Petroleum Reserve in Alaska is expected to experience increased use during the next decade. Management issues require current information on land cover inventory and critical habitat data for more than 9.3 million hectares of the NPR-A. Phases were completed in 1995, 1996, and 1998, respectively. This joint project by the BLM-Alaska, Ducks Unlimited, U.S. Fish and Wildlife Service, and North Slope Borough has provided a low cost and efficient means to gain valuable information on the earth cover types in the NPR-A.

The Southern portion of the project used portions of five Landsat Thematic Mapper satellite scenes to classify the project area into earth cover categories. Use of rotary aircraft (helicopters) and global positioning system (GPS) technology were used to acquire field data at 600 sites. Three hundred seven of which were used in the computer aided classification process as training sites and 293 were used for accuracy assessment. The classification scheme consisted of seven major categories and seventeen subcategories. A modified supervised/unsupervised classification approach was used to classify the imagery. The classification of the Southern phase of the NPR-A was then mosaicked with the Western and Eastern phases to produce a seamless classification of the NPR-A. Results of this classification suggest dominant habitats for the NPR-A are 43% shrub, 31% moist tundra, 11% water, 6% flooded tundra, 5% wet tundra, 2% aquatic, and 2% barren ground. The overall accuracy of the major categories was 85%, with a 75% overall accuracy for the minor categories.

This seamless earth cover classification for the NPR-A will be an invaluable tool for managers and researchers in the future. It will also be a good base to monitor changes in the NPR-A. The classification procedures worked well to produce an accurate classification in a relatively short time. The field data were also entered into a database that can be accessed for future projects.

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# APPENDICES

## APPENDIX A

The definitions for the classification scheme

1.0 WATER ( ≥ 80% water)
- 1.1 Clear Water - (depth ≥ 1 meter)
- 1.2 Turbid Water - (depth <1 meter)
- 1.3 Ice - (ice ≥ 60%)

2.0 AQUATIC (≥50% water and <80% water and > 10cm in depth)
- 2.1 Carex aquatilis - (> 15% Carex aquatilis and < 15% Arctophila fulva)
- 2.2 Arctophila fulva - (>15% Arctophila fulva and < 15% Carex aquatilis)

3.0 FLOODED TUNDRA ( ≥25% water and <50% water and < 10cm in depth)
- 3.1 Low Centered Polygons ( ≥ 5% Sedge/Grass)
- 3.2 Non -pattern ( < 5% sedge/Grass)

4.0 WET TUNDRA ( ≥ 10% and < 25% water)

5.0 MOIST TUNDRA ( <10% water, < 40% shrub, composed mostly of sedges, grasses, rushes and moss/peat/lichen complex)
- 5.1 Sedge/Grass Meadow - ( ≥ 50% sedge/grass and <40% tussock cotton grass)
- 5.2 Tussock Tundra - ( ≥ 40% tussock cotton grass)
- 5.3 Moss/lichen - ( ≥ 50% moss and/or lichen)

6.0 SHRUB (< 10% water and ≥40% shrub)
- 6.1 Dwarf - ( ≤ 30cm in height)
- 6.2 Low - ( > 30cm in height and < 1.5 m)
- 6.3 Tall – (≥ 1.5 m in height)

7.0 BARREN GROUND (0-30% vegetated)
- 7.1 Dunes/dry sand - ( <10% vegetation and ≥ 50% dry sand)
- 7.2 Sparsely Vegetated - (10-30% vegetated)
- 7.3 Other - (< 10% vegetation and < 50% sand)

## APPENDIX B

The decision tree for the classification

A) Ice.....Ice
Water.....B

B) ≥ 80% water .....C
< 80% water.....D

C) depth ≥ 1 meter.....Clear Water
depth < 1 meter.....Turbid Water

D) ≥ 50% water and < 80% water.....E
< 50% water.....F

E) > 15% Arctophila and < 15% Carex aquatilis.....Arctophila fulva
< 15% Arctophila and > 15% Carex aquatilis.....Carex aquatilis

F) ≥ 25% water and < 50% water.....G
< 25% water.....H

G) ≥ 5% sedge/grass.....Flooded Tundra LCP
< 5% sedge/grass.....Flooded Tundra NP

H) ≥ 10% water and < 25% water.....Wet Tundra
< 10% water.....I

I) > 30% vegetated.....J
≤ 30% vegetated.....O

J) < 40% shrub.....K
≥ 40% shrub.....M

K) ≥ 40% tussock cotton grass.....Tussock Tundra
< 40% tussock cotton grass.....L

L) ≥ 50% graminoids.....Sedge/Grass Meadow
< 50% graminoids .....Moss/lichen

M) Shrubs ≤ 30cm in height.....Dwarf Shrub
Shrubs > 30cm in height.....N

N) Shrubs < 1.5 meters in height.....Low Shrub
Shrubs ≥ 1.5 meters in height.....Tall Shrub

O) ≥ 10% vegetated.....Sparsely Vegetated
< 10% vegetated.....P

P) ≥50% sand.....Dunes/Dry Sand
< 50% sand.....Other

## APPENDIX C

The written descriptions for the classification scheme

1.1 Clear Water - Fresh or saline waters with little or no particulate matter. Clear water areas are typically deep (greater than one meter). The clear water class may contain small amounts of *Arctophila fulva* or *Carex aquatilis* but generally less than 15% surface coverage of these species.

1.2 Turbid Water - Waters that contain particulate matter or shallow (<1m), clear water bodies that are spectrally different from class 1.1. This class typically occurs in shallow lake shelves, deltaic plumes, and rivers and lakes with high sediment loads. The turbid water class may contain small amounts of *Arctophila fulva* or *Carex aquatilis* but generally less than 15% surface coverage of these species.

1.3 Ice - May last into late summer on lakes and larger ponds. Ice is present year-round in many of the larger lakes.

2.1 Carex aquatilis - Associated with lake or pond shorelines and composed of 50 - 80% clear or turbid water that was greater than 10 centimeters deep. The dominant species was *Carex aquatilis*. A small percentage of *Arctophila fulva, Hippuris vulgaris, Potentilla palustris,* and *Caltha palustris* may be present.

2.2 Arctophila fulva - Associated with lake or pond shorelines and composed of 50 - 80% clear or turbid water that was greater then 10 centimeters deep. The dominant species was *Arctophila fulva*. A small percentage of *Carex aquatilis, Hippuris vulgaris, Potentilla palustris,* and *Caltha palustris* may also be present.

3.1 Flooded Tundra-Low Centered Polygons Polygon features that retain water throughout the summer. This class is composed of 25 - 50% water; *Carex aquatilis* is the dominant species in the permanently flooded areas. The drier ridges of the polygons are composed mostly of *Eriophorum russeolum, Eriophorum vaginatum, Sphagnum* spp., *Salix* spp., *Betula nana, Arctostaphylos* spp., and *Ledum palustre*.

3.2 Flooded Tundra-Non-pattern - Continuously flooded areas are composed of 25-50% water. *Carex aquatilis* are the dominant species. Other species may include *Hippuris vulgaris, Potentilla palustris,* and *Caltha palustris*. Non-pattern is distinguished from low centered polygons by the lack of polygon features and associated shrub species that grow on the dry ridges of low centered polygons.

4.0 Wet Tundra - Associated with areas of super saturated soils and standing water. Wet tundra often floods in early summer and usually drains excess water during dry periods but remains saturated throughout the summer. It is composed of 10-25% water; *Carex aquatilis* is the dominant species. Other species may include *Eriophorum*

*angustifolium*, and other sedges, grasses, and forbs.

5.1 Sedge/Grass Meadow - Dominated by the sedge family. This class commonly consists of a continuous mat of sedges and grasses with a moss and lichen understory. The dominant species were *Carex aquatilis, Eriophorum angustifolium, Eriophorum russeolum, Arctagrostis latifolia* and *Poa arctica*. Associated genera include *Cassiope* spp., *Ledum* spp., and *Vaccinium* spp..

5.2 Tussock Tundra - Dominated by the tussock-forming sedge *Eriophorum vaginatum*. Tussock tundra is common throughout the Arctic Foothills and may be found on well-drained sites in all areas. Cottongrass tussocks are the dominant landscape elements, while moss is the common understory. Lichen, forbs, and shrubs are also present in varying densities. Associated genera include *Salix* spp., *Betula nana*, *Ledum palustre*, and *Carex* spp..

5.3 Moss/Lichen - Associated with low lying lakeshores and dry sandy ridges dominated by moss and lichen species. As this type grades into a sedge type, graminoids such as *Carex aquatilis* may increase in cover, forming an intermediate zone.

6.1 Dwarf Shrub - Associated with ridges and well-drained soils and dominated by shrubs less than 30 centimeters in height. It is the most species diverse because of the relative dryness of the sites where this cover type occurs. Major species included *Salix* spp., *Betula nana, Ledum palustre, Dryas* spp., *Vaccinium* spp., *Arctostaphylos* spp., *Eriophorum vaginatum, and Carex aquatilis.* This class frequently occurs over a substrate of tussocks.

6.2 Low Shrub - Associated with small streams and rivers, but also occurring on hillsides in the southern portion of the NPR-A. This class is dominated by shrubs between 30 centimeters and 1.5 meters in height. Major species included *Salix* spp., *Betula nana, Alnus crispa*, and *Ledum palustre.*

6.3 Tall Shrub - Found along the Colville River and some of its major tributaries, and dominated by *Salix* spp. over 1.5 meters in height. This class may also contain significant presence of *Alnus crispa* over 1.5 meters in height.

7.1 Dunes/Dry Sand - Associated with streams, rivers, lakes and coastal beaches. Dominated by dry sand with less than 10% vegetation. Plant species may include *Poa* spp., *Salix* spp., *Astragulus* spp., *Carex* spp., *Stellaria* spp., *Arctostaphylos* spp., and *Puccinellia phryganodes.*

7.2 Sparsely Vegetated - Occurred primarily along the coast in areas affected by high or storm tides, in recently drained lake or pond basins, and where there is bare mineral soil that is being re-colonized with vegetation. Dominated by non-vegetated material with 10-30% vegetation. The vegetation in these areas may include rare plants but some of the more commonly found species include *Stellaria* spp., *Poa* spp., *Salix* spp., *Astragulus* spp.,

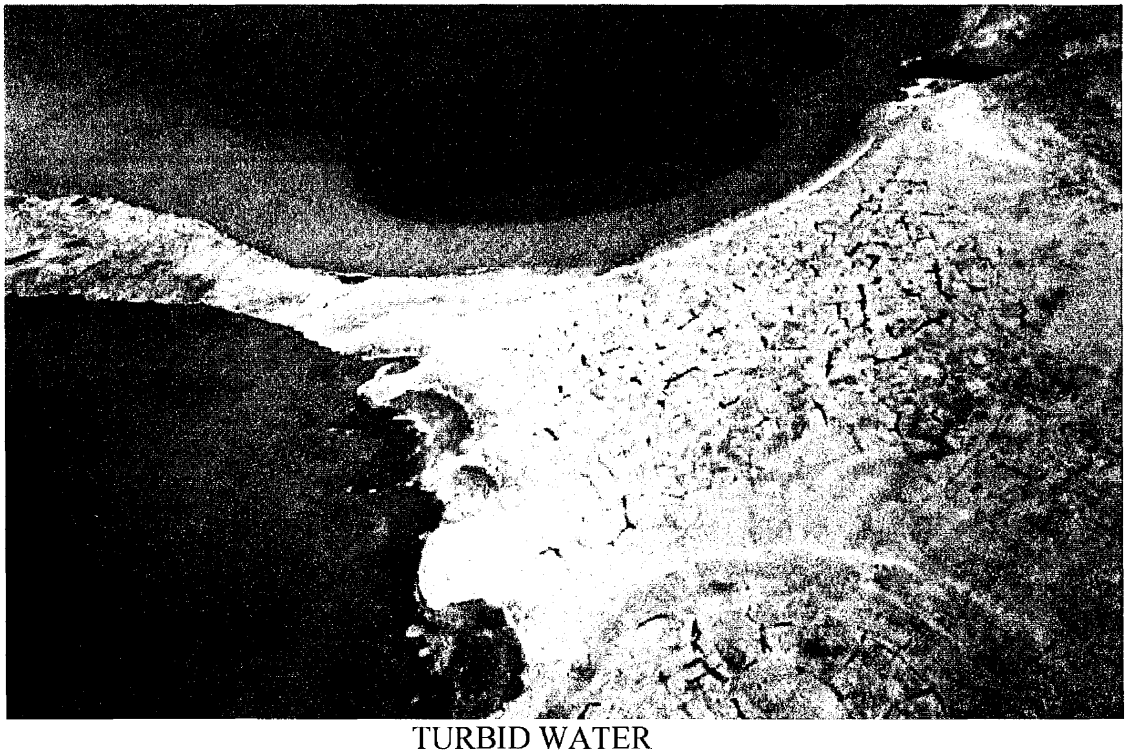
*Carex* spp., *Stellaria* spp., *Arctostaphylos* spp., and *Puccinellia phryganodes.*

7.3 Barren Ground/Other - Associated with river and stream gravel bars, mountainous areas, and urban areas. Includes less than 10% vegetation. May incorporate dead vegetation associated with salt burn from ocean water.

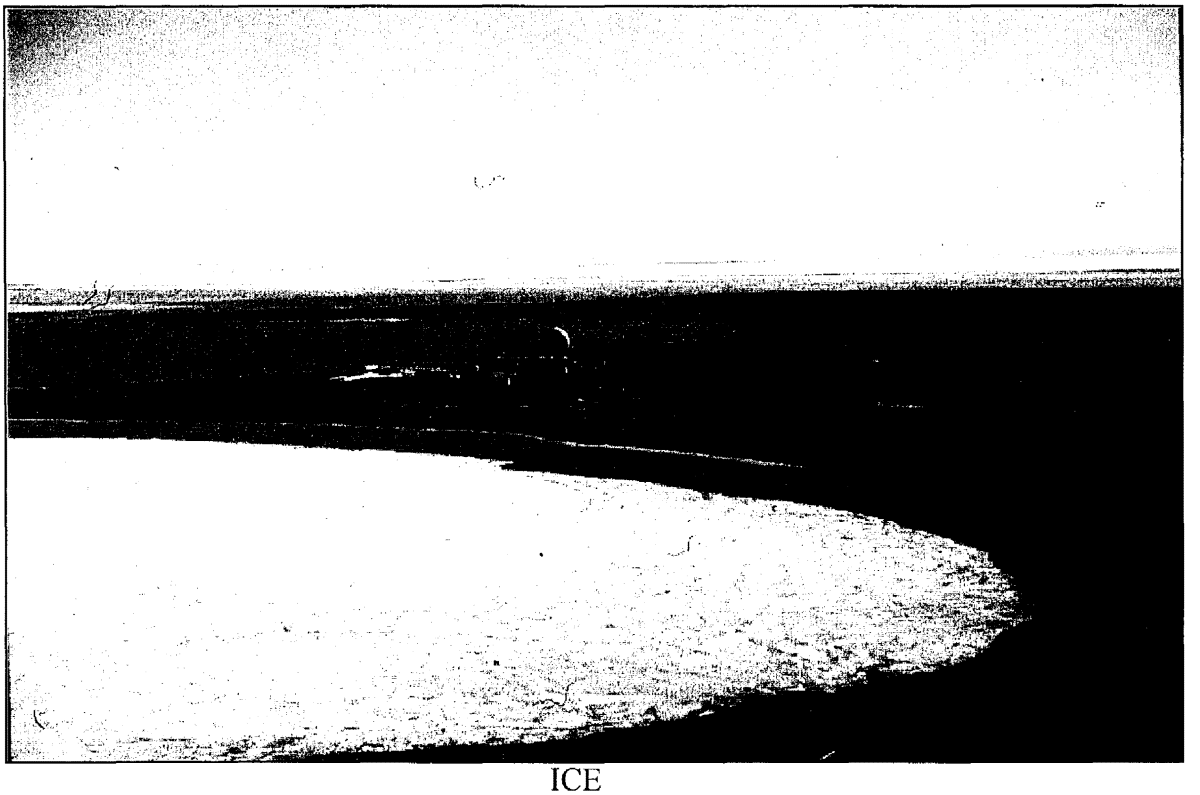
## APPENDIX D

Examples of the earth cover classes for the NPR-A

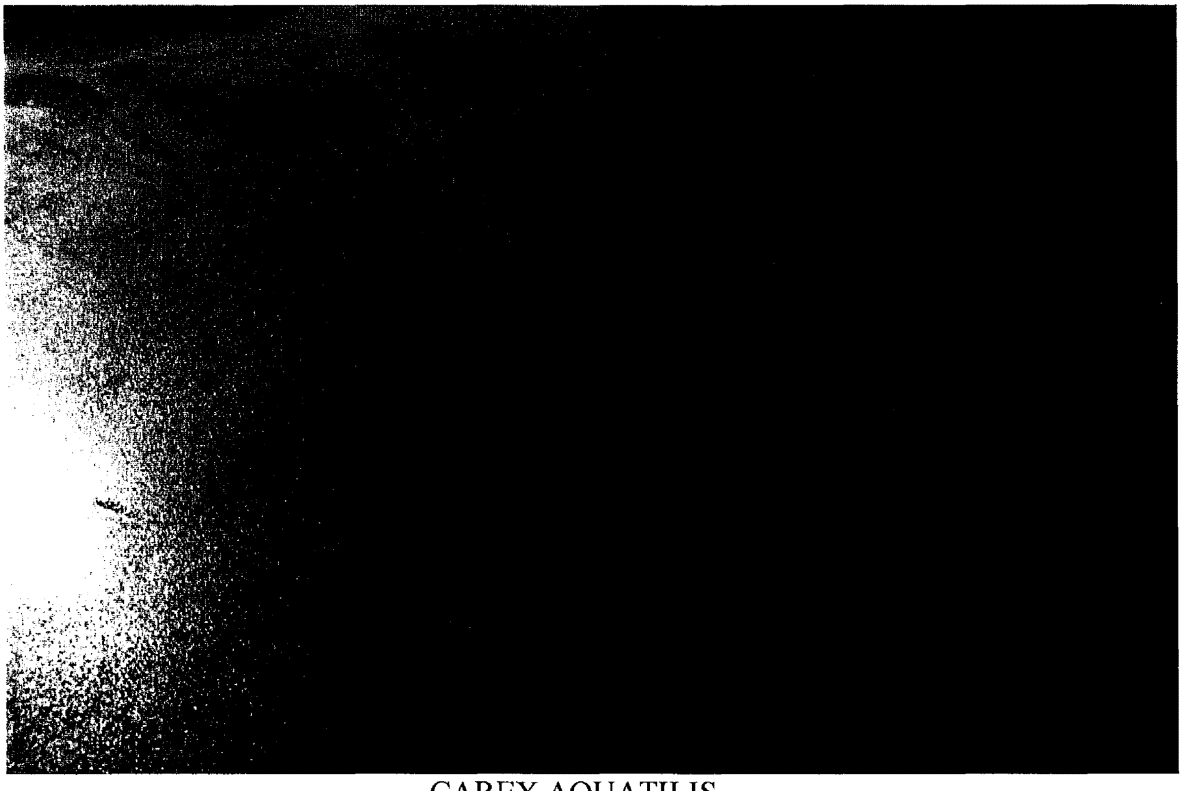
CLEAR WATER (Not including islands)



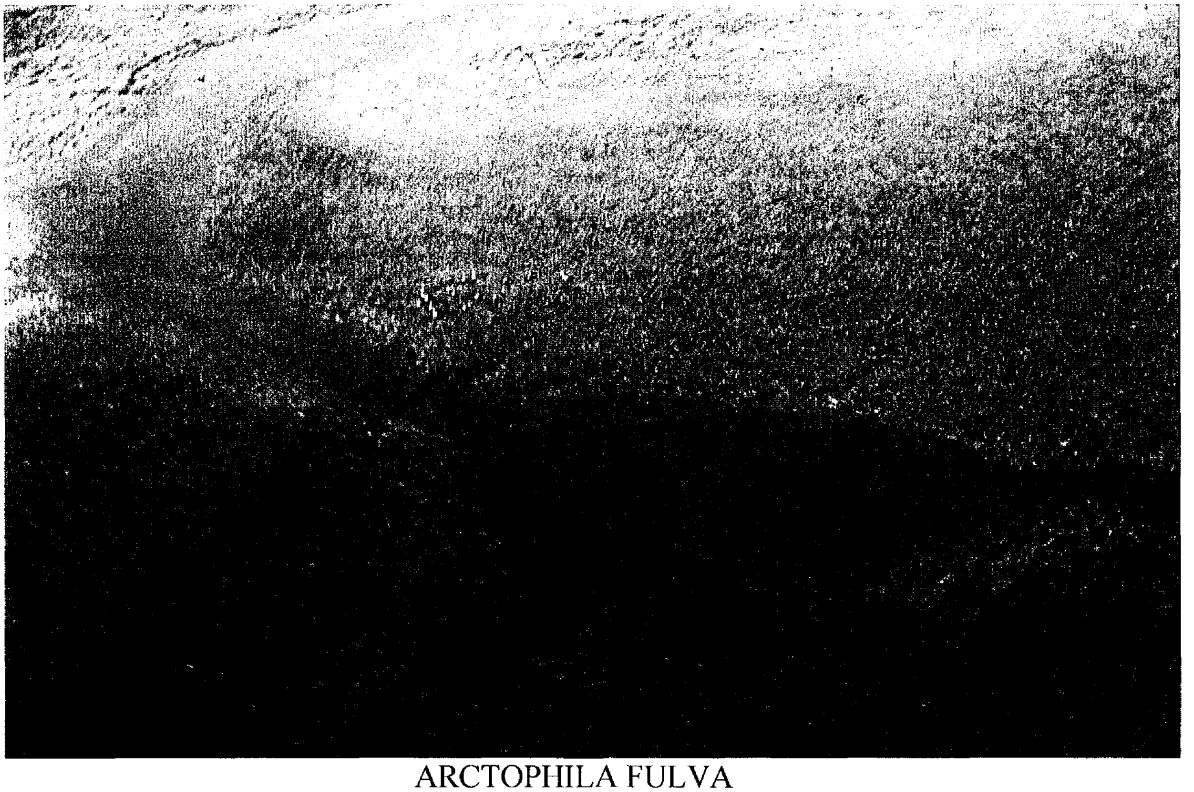
TURBID WATER



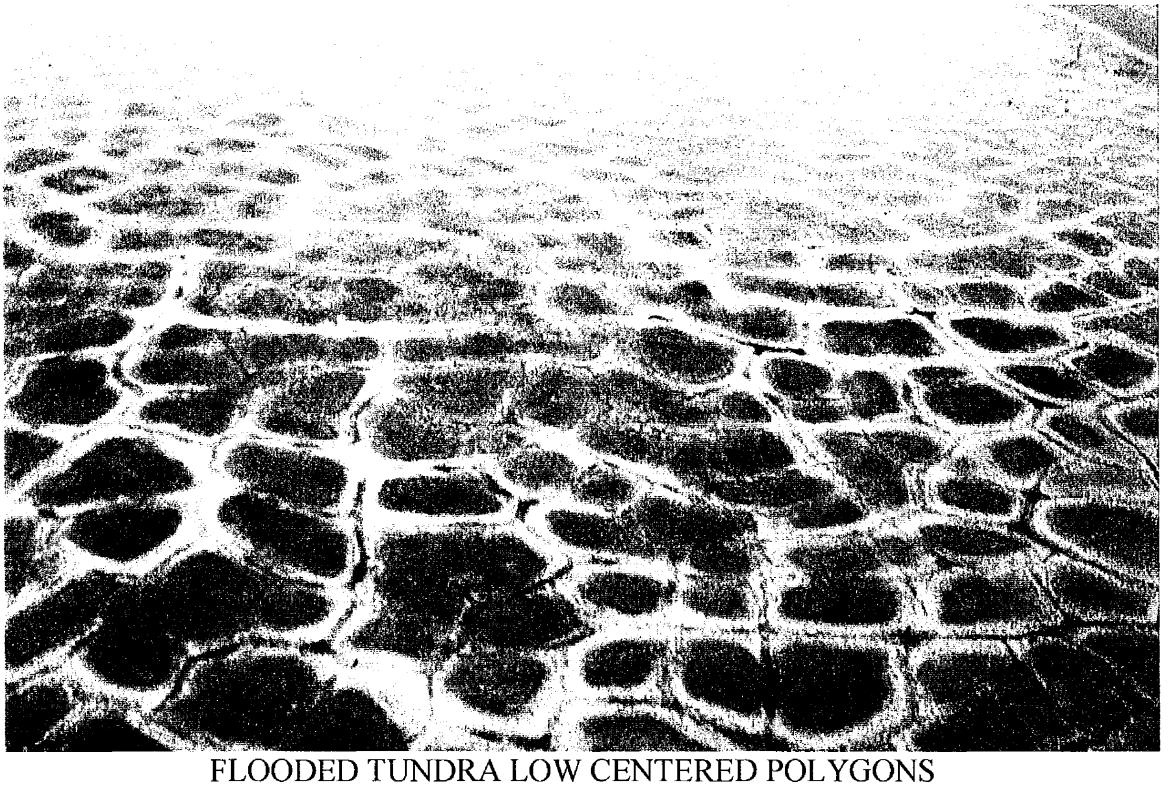
ICE



CAREX AQUATILIS

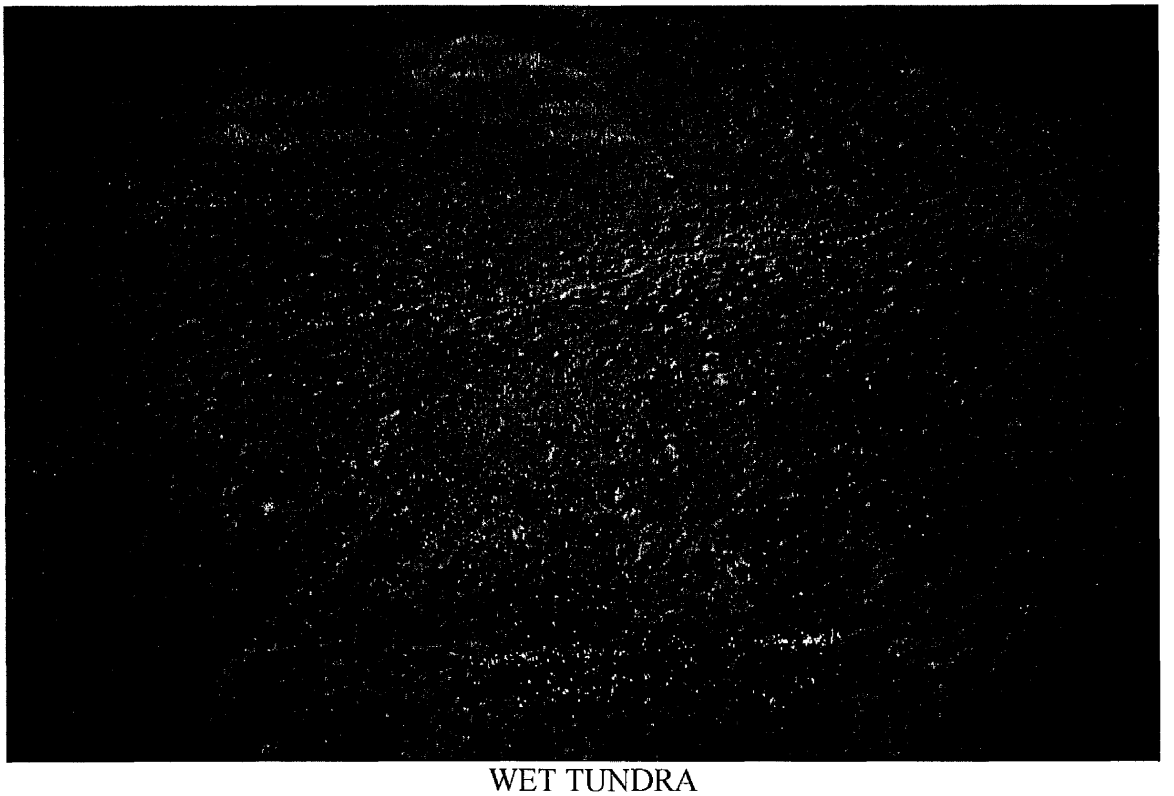


ARCTOPHILA FULVA



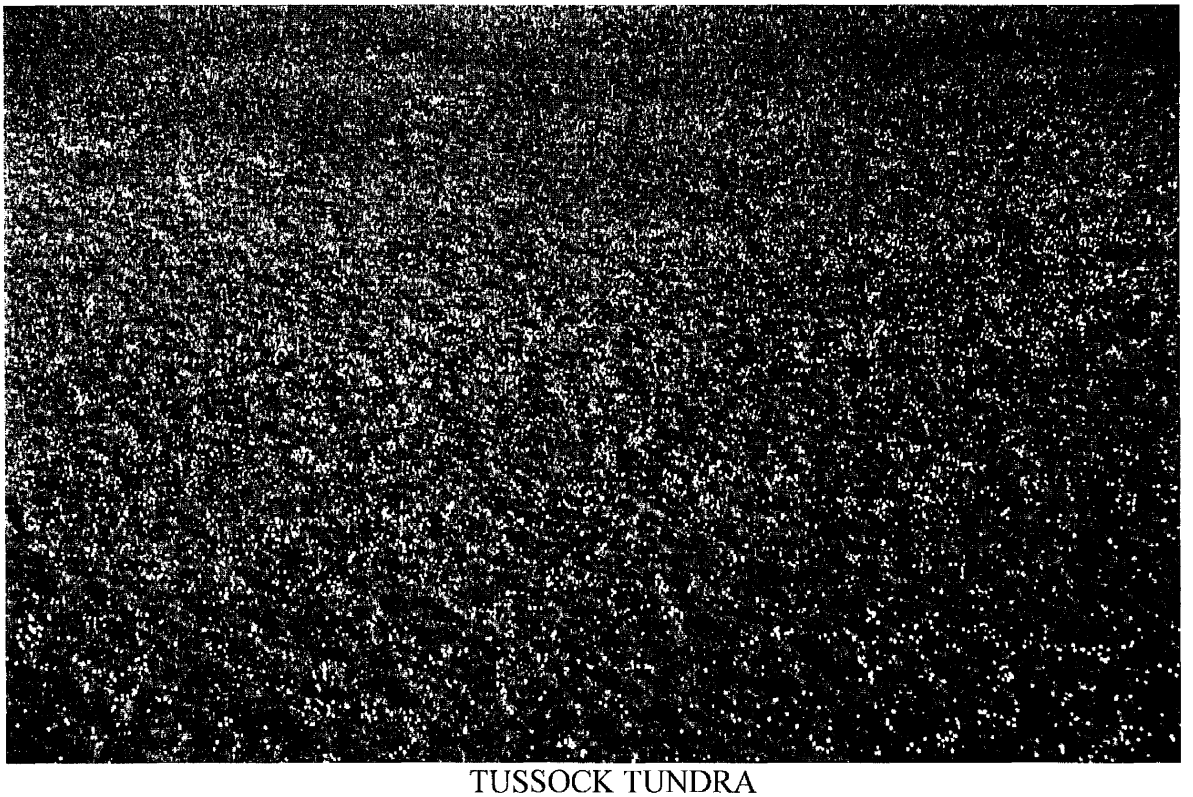
FLOODED TUNDRA LOW CENTERED POLYGONS

FLOODED TUNDRA NON-PATTERN



WET TUNDRA

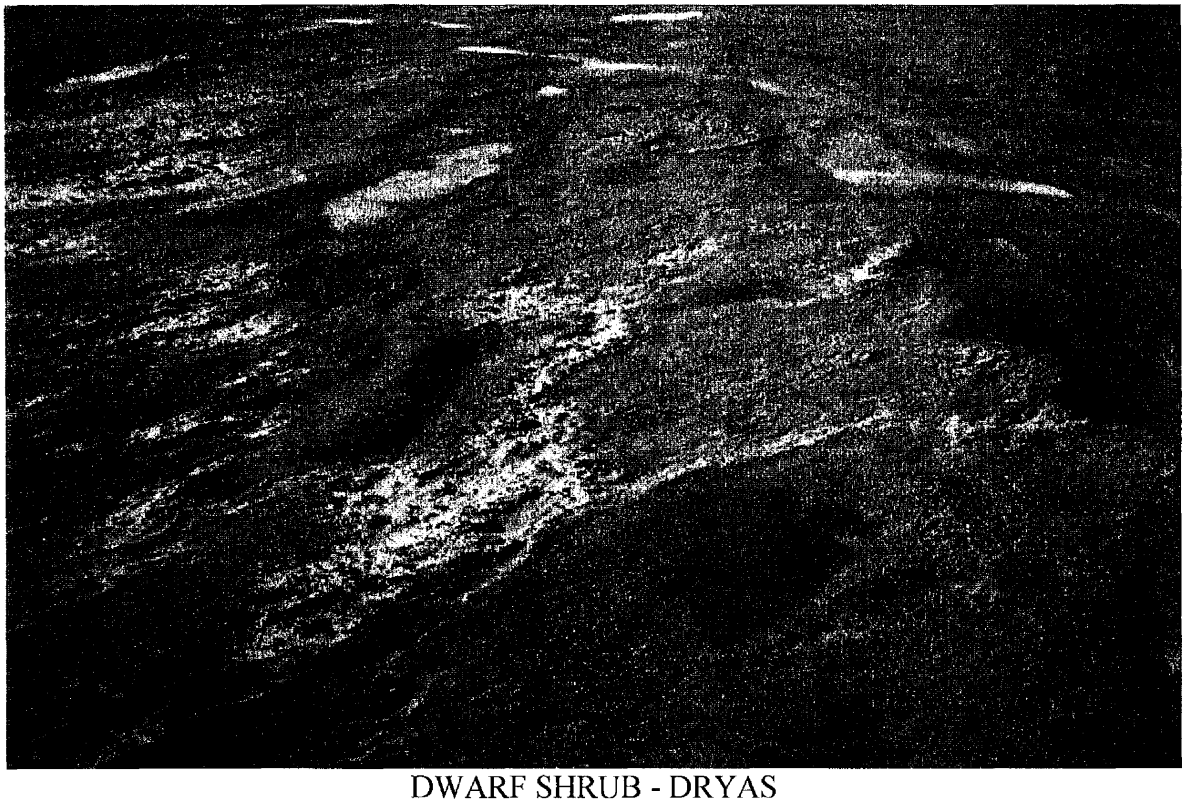
SEDGE/GRASS MEADOW



TUSSOCK TUNDRA

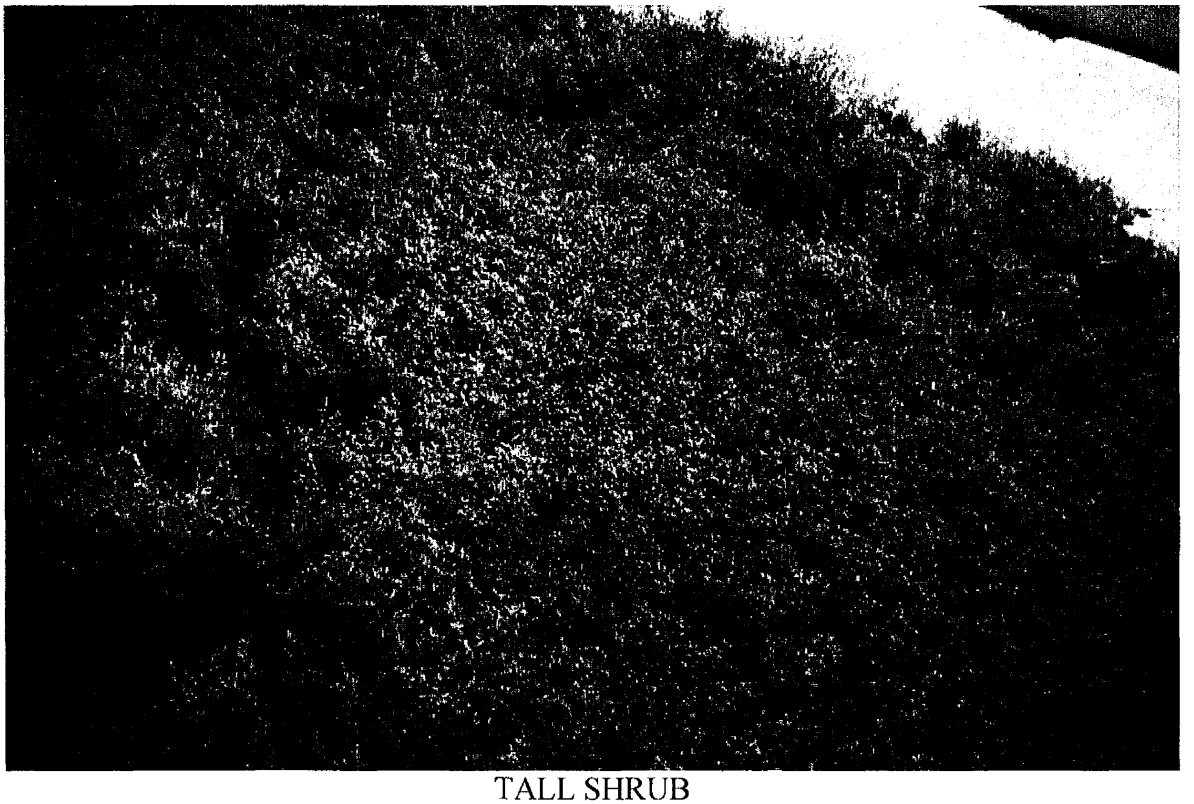
MOSS/LICHEN

DWARF SHRUB



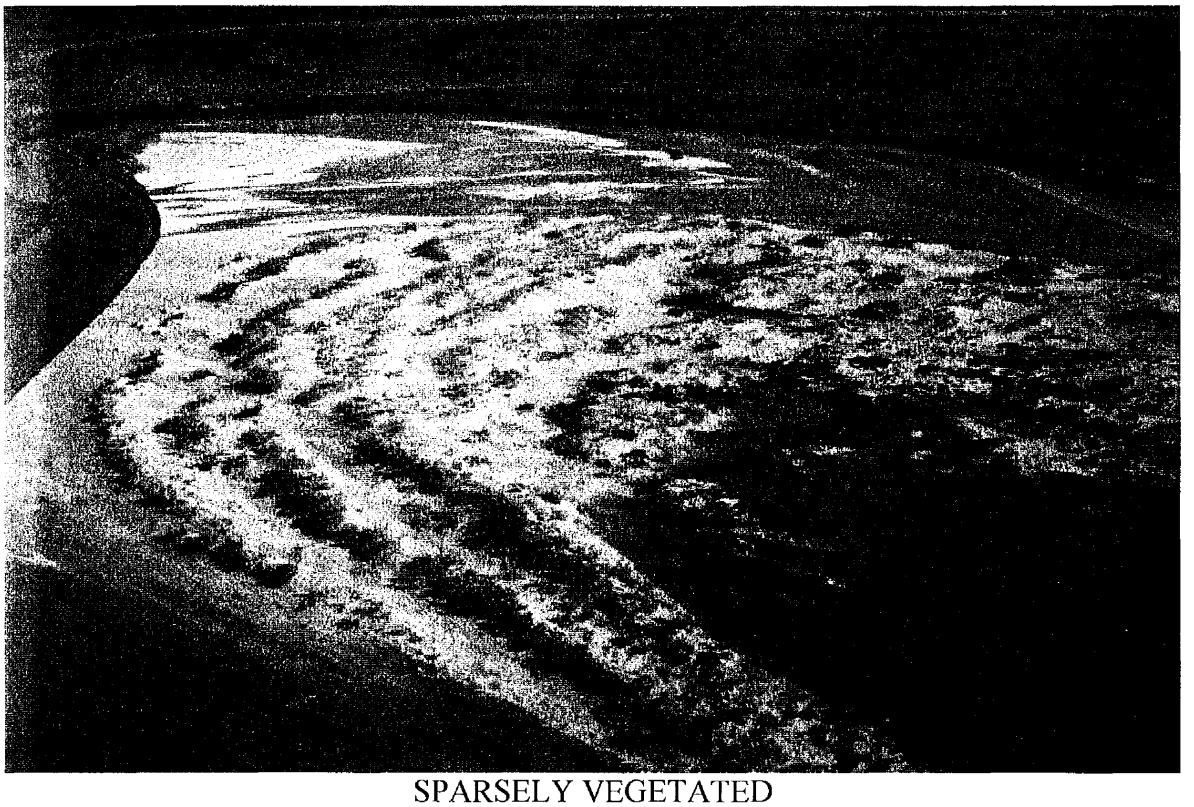
DWARF SHRUB - DRYAS

LOW SHRUB

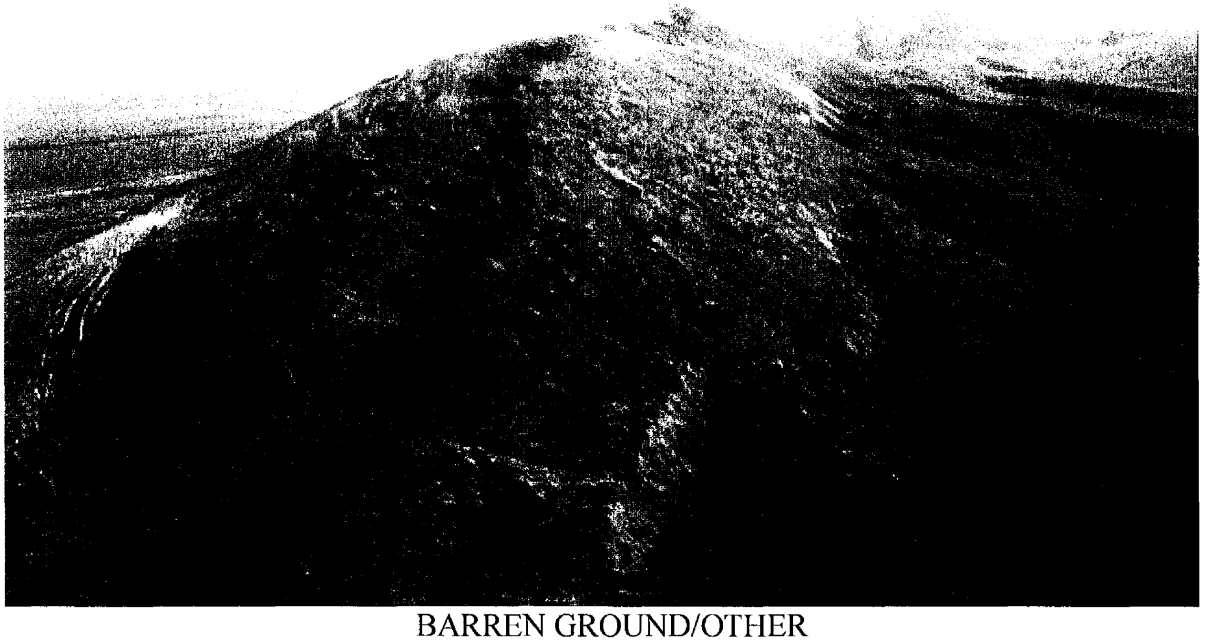


TALL SHRUB

DUNES/DRY SAND



SPARSELY VEGETATED



BARREN GROUND/OTHER

# APPENDIX E

All species that were observed during the field data collection from 1994-1996

| Latin-Name | Common-Name |
|---|---|
| Agropyron spp | Wheatgrass |
| Alnus spp | Alder |
| Alopecurus alpina | Foxtail |
| Andromeda polifolia | Bog rosemary |
| Arctagrostis latifolia | Broadleaf arctic bentgrass |
| Arctophila fulva | Pendant grass |
| Arctostaphylos spp | Bearberry |
| Arenaria spp | Sandwort |
| Artemisia | Artemisia |
| Astragalus spp | Milk vetch |
| Betula glandulosa | Tundra dwarf birch |
| Boykinia Richardsonii | Boykinia |
| Caltha palustris | Common marsh marigold |
| Carex aquatilis | Water sedge |
| Carex spp | Sedge other |
| Cassiope tetragona | Arctic bell-heather |
| Castilleja spp | Paintbrush |
| Cochlearia officinalis | Scurvy grass |
| Deschampsia caespitosa | Tufted hairgrass |
| Diapensia lapponica | Diapensia |
| Dryas spp | Mountain Avens |
| Dupontia fischeri | Dupontia |
| Elymus spp | Lyme grass |
| Empetrum nigrum | Black crowberry |

| Latin-Name | Common-Name |
|---|---|
| Epilobium latifolia | River beauty |
| Equisetum spp | Horsetail |
| Eriophorum angustifolium | Tall cotton-grass |
| Eriophorum russeolum | Russet cotton-grass |
| Eriophorum spp | Cotton-grass |
| Eriophorum vaginatum | Tussock cotton-grass |
| Geum spp | Geum |
| Grass | Grass |
| Hedysarum spp | Sweet-vetch |
| Hippuris spp | Marestail |
| Juncus spp | Rush |
| Ledum palustre | Labrador tea |
| Lichen | Lichen |
| Lupinus arcticus | Arctic lupine |
| Luzula spp | Woodrush |
| Moss | Moss |
| Oxytropis spp | Locoweed |
| Papaver spp | Arctic poppy |
| Pedicularis spp | Sudetan lousewort |
| Petasites figidus | Arctic sweet coltsfoot |
| Poa lanata | Wool bluegrass |
| Poa spp | Arctic bluegrass |
| Polygonum spp | Buckwheat |
| Potentilla fruticosa | Shrubby cinquefoil |
| Potentilla palustris | Marsh cinquefoil |
| Puccinellia | Alkali grass |
| Puccinellia phryganoides | Creeping alkali grass |

| Latin-Name | Common-Name |
|---|---|
| Pyrola spp | Wintergreen |
| Ranunculus spp | Buttercup |
| Rhododendron spp | Rhododendron |
| Rubus chamaemorus | Cloudberry |
| Salix spp | Willow |
| Saxifraga spp | Saxifrage |
| Senecio congestus | Marsh groundsel |
| Silene acaulis | Moss campion |
| Sphagnum spp | Sphagnum moss |
| Stellaria spp | Low starwort |
| Vaccinium uliginosum | Bog blueberry |
| Vaccinium vitis-idaea | Mountain cranberry |

**Total number of plant species or species groups = 63**

# APPENDIX F

All species observed sorted by class during field data collection from 1994-1996

## Arctophila fulva — Number of Sites = 43

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Arctophila fulva | Pendant grass | 31.88 |
| Caltha palustris | Common marsh marigodl | 0.81 |
| Carex aquatilis | Water sedge | 2.53 |
| Cassiope tetragona | Arctic bell heather | 0.05 |
| Clear water | Clear water | 60.14 |
| Eriophorum spp | Cottongrass | 0.02 |
| Hippuris spp | Marsetail | 0.47 |
| Lichen | Lichen | 0.00 |
| Moss | Moss | 0.26 |
| Mud | Mud | 2.09 |
| Potentia palustris | Marsh cinquefoil | 0.12 |
| Ranunculus spp | Buttercup | 0.23 |
| Turbid water | Turbid water | 1.40 |

**Total Cover Types = (13)**

## Barren Ground/Other — Number of Sites = 69

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Arctostaphylos spp | Bearberry | 0.01 |
| Betula glandulosa | Tundra dwarf birch | 0.06 |
| Carex aquatilis | Water sedge | 0.00 |
| Carex spp | Sedge-Other | 0.01 |
| Cassiope tetragona | Arctic bell-heather | 0.01 |
| Clear water | Clear water | 0.96 |
| Draba spp | Mustard | 0.00 |
| Dryas spp | Mountain avens | 0.42 |
| Epilobium latifolia | River beauty | 0.01 |
| Geum spp | Geum | 0.03 |
| Grass | Grass | 0.09 |
| Gravel | Gravel | 21.70 |
| Ledum palustre | Labrador tea | 0.01 |

| | | |
|---|---|---|
| Lichen | Lichen | 1.46 |
| Moss | Moss | 0.28 |
| Mud | Mud | 14.04 |
| Plant debris | Plant debris | 0.22 |
| Poa spp | Arctic bluegrass | 0.04 |
| Puccinellia phryganoides | Creeping alkali grass | 0.14 |
| Rock | Rock | 46.48 |
| Salix spp | Willow | 0.51 |
| Salt burn veg | Salt burn veg | 3.70 |
| Sand | Sand | 7.64 |
| Saxifraga spp | Saxifrage | 0.06 |
| Silene acaulis | Moss campion | 0.01 |
| Silt | Silt | 0.65 |
| Turbid water | Turbid water | 1.45 |

**Total Cover Types = (27)**

## Barren Ground/Other — Number of Sites = 69

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Alopecurus alpina | Foxtail | 0.23 |
| Andromeda polifolia | Bog rosemary | 0.02 |
| Arctophila fulva | Pendant grass | 0.23 |
| Arctostaphylos spp | Bearberry | 0.01 |
| Betula glandulosa | Tundra dwarf birch | 0.28 |
| Caltha palustris | Common marsh marigold | 0.02 |
| Carex aquatilis | Water sedge | 28.08 |
| Carex spp | Sedge other | 1.78 |
| Cassiope tetragona | Arctic bell-heather | 0.23 |
| Clear water | Clear water | 59.53 |
| Dryas spp | Mountain avens | 0.01 |
| Eriophorum angustifolium | Tall cotton-grass | 0.04 |
| Eriophorum risseolum | Russet cotton-grass | 0.16 |
| Eriophorum spp | Cotton-grass | 2.65 |
| Eriophorum vaginatum | Tussock cotton-grass | 0.09 |
| Grass | Grass | 0.27 |
| Ledum palustre | Labrador tea | 0.09 |
| Lichen | Lichen | 0.09 |
| Moss | Moss | 3.23 |

| | | |
|---|---|---|
| Mud | Mud | 1.68 |
| Pedicularis spp | Sudetan lousewort | 0.01 |
| Polygonum spp | Buckwheat | 0.00 |
| Potentilla palustris | Marsh cinquefoil | 0.12 |
| Ranunculus spp | Buttercup | 0.02 |
| Rubus chamaemorus | Cloudberry | 0.04 |
| Salix spp | Willow | 0.83 |
| Sand | Sand | 0.04 |
| Saxifraga spp | Saxifrage | 0.00 |
| Vaccinium vitis-idaea | Mountain cranberry | 0.07 |

**Total Cover Types = (29)**

## Barren Ground/Other — Number of Sites = 69

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Arctophila fulva | Pendant grass | 2.79 |
| Caltha palustris | Common marsh marigold | 0.01 |
| Carex aquatilis | Water sedge | 3.17 |
| Carex spp | Sedge other | 0.35 |
| Clear water | Clear water | 93.07 |
| Eriophorum spp | Cotton-grass | 0.07 |
| Lichen | Lichen | 0.00 |
| Moss | Moss | 0.38 |
| Mud | Mud | 0.11 |
| Potentilla palustris | Common marsh cinquefoil | 0.01 |
| Ranunculus spp | Buttercup | 0.03 |
| Salix spp | Willow | 0.03 |

**Total Cover Types = (12)**

## Dunes/Dry Sand — Number of Sites = 37

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Arctagrostis latifolia | Broadleaf arctic bentgrass | 0.03 |
| Arctophila fulva | Pendant grass | 0.03 |
| Arctostaphylos spp | Bearberry | 0.05 |
| Astragalus spp | Milk vetch | 0.05 |
| Betula glandulosa | Tundra dwarf birch | 0.00 |
| Carex aquatilis | Water sedge | 0.03 |

| | | |
|---|---|---|
| Cassiope tetragona | Arctic bell-heather | 0.03 |
| Clear water | Clear water | 0.11 |
| Cochlearia officinalis | Scurvy grass | 0.00 |
| Dryas spp | Mountain avens | 0.08 |
| Epilobium latifolia | River beauty | 0.03 |
| Eriophorum spp | Cotton-grass | 0.08 |
| Grass | Grass | 0.30 |
| Gravel | Gravel | 0.14 |
| Juncus spp | Rush | 0.03 |
| Lichen | Lichen | 0.54 |
| Moss | Moss | 0.05 |
| Mud | Mud | 0.54 |
| Other | Other | 0.05 |
| Plant debris | Plant debris | 0.05 |
| Poa spp | Arctic bluegrass | 0.27 |
| Puccinellia phryganoides | Creeping alkali grass | 0.03 |
| Rock | Rock | 0.14 |
| Salix spp | Willow | 2.30 |
| Sand | Sand | 92.49 |
| Silt | Silt | 2.57 |

**Total Cover Types = (26)**

**Total Cover Types = (12)**

## Dwarf Shrub — Number of Sites = 219

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Alnus spp | Alder | 0.26 |
| Andromeda polifolia | Bog rosemary | 0.03 |
| Arctagrostis latifolia | Broadleaf arctic bentgrass | 0.18 |
| Arctophila fulva | Pendant grass | 0.00 |
| Arctostaphylos spp | Bearberry | 2.13 |
| Arenaria spp | Sandwort | 0.07 |
| Astragalus spp | Milk vetch | 0.06 |
| Betula glandulosa | Tundra dwarf birch | 8.64 |
| Boykinia Richardsonii | Boykinia | 0.07 |
| Carex aquatilis | Water sedge | 1.95 |

| | | |
|---|---|---|
| Carex spp | Sedge other | 4.25 |
| Cassiope tetragona | Arctic bell-heather | 3.07 |
| Clear water | Clear water | 0.60 |
| Deschampsia ceaspitosa | Tufted hairgrass | 0.05 |
| Diapensia lapponica | Diapensia | 0.32 |
| Dryas spp | Mountain avens | 15.42 |
| Empetrum nigrum | Black crowberry | 0.65 |
| Equisetum spp | Horsetail | 0.05 |
| Equisetum spp | Water horsetail | 0.02 |
| Eriophorum angustifolium | Tall cotton-grass | 0.02 |
| Eriophorum russeolum | Russet cotton-grass | 0.23 |
| Eriophorum spp | Cotton-grass | 1.33 |
| Eriophorum vaginatum | Tussock cotton-grass | 10.51 |
| Geum spp | Geum | 0.21 |
| Grass | Grass | 0.43 |
| Gravel | Gravel | 0.02 |
| Hedysarum spp | Sweet-vetch | 0.01 |
| Ledum palustre | Labrador tea | 3.29 |
| Lichen | Lichen | 4.81 |
| Lipinus arcticus | Arctic lupine | 0.68 |
| Luzula spp | Woodrush | 0.02 |
| Moss | Moss | 7.54 |
| Mud | Mud | 3.82 |
| Other | Other | 0.07 |
| Oxytropis spp | Locoweed | 0.03 |
| Papaver spp | Arctic poppy | 0.00 |
| Pedicularis spp | Sudetan lousewort | 0.02 |
| Petasites figidus | Arctic sweet coltsfoot | 0.04 |
| Plant debris | Plant debris | 0.64 |
| Poa spp | Arctic bluegrass | 0.11 |
| Polygonum spp | Buckwheat | 0.15 |
| Potentilla fruticosa | Shrubby cinquefoil | 0.02 |
| Pyrola spp | Wintergreen | 0.01 |
| Ranunculus spp | Buttercup | 0.00 |
| Rock | Rock | 8.37 |
| Rubus chamaemorus | Cloudberry | 0.38 |
| Salix spp | Willow | 14.40 |

| | | |
|---|---|---|
| Sand | Sand | 1.67 |
| Saxifraga spp | Saxifrage | 0.32 |
| Silene acaulis | Moss campion | 0.11 |
| Vaccinium uliginosum | Bog blueberry | 0.96 |
| Vaccinium vitis-idaea | Mountain cranberry | 2.23 |

**Total Cover Types = (52)**

## Ice — Number of Sites = 2

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Ice | Ice | 100.00 |

**Total Cover Types = (1 detail record)**

## Low Centered Polygon — Number of Sites = 87

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Alnus spp | Alder | 0.06 |
| Andromeda polifolia | Bog rosemarry | 0.08 |
| Arctophila fulva | Pendant grass | 6.07 |
| Arctostaphylos spp | Bearberry | 0.23 |
| Betula glandulosa | Tundra dwarf birch | 3.61 |
| Caltha palustris | Common marsh marigold | 0.06 |
| Carex aquatilis | Water sedge | 26.38 |
| Carex spp | Sedge other | 1.86 |
| Cassiope tetragona | Arctic bell-heather | 0.74 |
| Clear water | Clear water | 32.99 |
| Cochlearia officinalis | Scurvy grass | 0.00 |
| Deschampsia ceaspitosa | Tufted hairgrass | 0.11 |
| Dryas spp | Mountain avens | 0.36 |
| Empetrum nigrum | Black crowberry | 0.05 |
| Eriophorum angustifolium | Tall cotton-grass | 0.29 |
| Eriophorum russeolum | Russet cotton-grass | 1.57 |
| Eriophorum spp | Cotton-grass | 5.71 |
| Eriophorum vaginatum | Tussock cotton-grass | 0.98 |
| Grass | Grass | 0.02 |
| Juncus spp | Rush | 0.00 |
| Ledum palustre | Labrador tea | 0.66 |

| | | |
|---|---|---|
| Lichen | Lichen | 1.22 |
| Lupinus artcicus | Arctic lupine | 0.11 |
| Moss | Moss | 8.61 |
| Mud | Mud | 1.74 |
| Pedicularis spp | Sudetan lousewort | 0.02 |
| Plant debris | Plant debris | 0.06 |
| Poa spp | Arctic bluegrass | 0.38 |
| Potentilla palustris | Marsh cinquefoil | 0.63 |
| Pyrola spp | Wintergreen | 0.01 |
| Ranunculus spp | Buttercup | 0.00 |
| Rubus chamaemorus | Cloudberry | 0.32 |
| Salix spp | Willow | 4.43 |
| Sand | Sand | 0.23 |
| Senecio congestus | Marsh groundsel | 0.00 |
| Vaccinium uliginosum | Bog blueberry | 0.06 |
| Vaccinium vitis-idaea | Mountain cranberry | 0.07 |

**Total Cover Types = (37)**

## Low Shrub — Number of Sites = 169

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Alus spp | Alder | 3.24 |
| Arctogrostis latifolia | Broadleaf arctic bentgrass | 0.15 |
| Arctophila fulva | Pendant grass | 0.79 |
| Arctostaphylos spp | Bearberry | 2.91 |
| Astragalus spp | Milk vetch | 0.25 |
| Betula glandulosa | Tundra dwarf birch | 5.33 |
| Carex aquatilis | Water sedge | 2.93 |
| Carex spp | Sedge other | 1.67 |
| Cassiope tetragona | Arctic bell-heather | 1.29 |
| Clear water | Clear water | 1.53 |
| Dirt-bare | Dirt-bare | 0.03 |
| Dryas spp | Mountain avens | 0.46 |
| Empetrum nigrum | Black crowberry | 0.05 |
| Epilobium latifolia | River Beauty | 0.09 |
| Equisetum spp | Horsetail | 0.57 |
| Equisetum spp | Water horsetail | 0.11 |

| | | |
|---|---|---|
| Eriophorum russeolum | Russet cotton-grass | 0.30 |
| Eriophorum spp | Cotton-grass | 2.99 |
| Eriophorum vaginatum | Tussock cotton-grass | 1.67 |
| Grass | Grass | 0.59 |
| Hedysarum spp | Sweet-vetch | 0.80 |
| Ledum palustre | Labrador tea | 1.74 |
| Lichen | Lichen | 1.26 |
| Lupinus arcticus | Arctic lupine | 1.33 |
| Luzula spp | Woodrush | 0.00 |
| Moss | Moss | 6.54 |
| Mud | Mud | 1.80 |
| Papaver spp | Arctic poppy | 0.00 |
| Pedicularis spp | Sudetan lousewort | 0.01 |
| Petasites frigidus | Arctic sweet coltsfoot | 0.14 |
| Plant debris | Plant debris | 0.30 |
| Poa spp | Arctic bluegrass | 1.00 |
| Polygonum spp | Buckwheat | 0.00 |
| Potentilla fruticosa | Shrubby cinquefoil | 0.03 |
| Potentilla palustris | Marsh cinquefoil | 0.13 |
| Pyrola spp | Wintergreen | 0.06 |
| Ranunculus spp | Buttercup | 0.00 |
| Rock | Rock | 0.18 |
| Rubus chamaemorous | Cloudberry | 0.24 |
| Salix spp | Willow | 54.38 |
| Sand | Sand | 1.07 |
| Saxifraga spp | Saxifrage | 0.03 |
| Senecio congestus | Marsh groundsel | 0.01 |
| Stellaria spp | Low starwort | 0.00 |
| Unknown | Unknown | 0.01 |
| Vaccinium uliginosum | Bog blueberry | 1.54 |
| Vaccinium vitis-idaea | Mountain cranberry | 0.47 |

**Total Cover Types = (47)**

## Moss/Lichen — Number of Sites = 15

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Arctostaphylos spp | Bearberry | 0.67 |

| | | |
|---|---|---|
| Betula glandulosa | Tundra dwarf birch | 0.67 |
| Boykinia Richardsonii | Biykinia | 1.67 |
| Carex aquatilis | Water sedge | 3.67 |
| Carex spp | Sedge other | 1.67 |
| Cassiope tetragona | Arctic bell-heather | 1.67 |
| Clear water | Clear water | 1.00 |
| Dryas spp | Mountain avens | 10.00 |
| Empetrum nigrum | Black crowberry | 0.67 |
| Eriophorum spp | Cotton-grass | 1.13 |
| Ledum palustre | Labrador tea | 0.13 |
| Lichen | Lichen | 12.87 |
| Lupinus arcticus | Arctic lupine | 1.00 |
| Moss | Moss | 20.60 |
| Mud | Mud | 0.67 |
| Peat | Peat | 12.33 |
| Plant debris | Plant debris | 3.00 |
| Puccinellia phryganoides | Creeping alkali grass | 0.67 |
| Rock | Rock | 2.00 |
| Salix spp | Willow | 5.53 |
| Sand | Sand | 11.40 |
| Saxifraga spp | Saxifrage | 0.33 |

**Total Cover Types = (22)**

## Non-Patterned — Number of Sites = 115

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Alopecurus alpina | Foxtail | 0.04 |
| Arctophilla fulva | Pendant grass | 6.90 |
| Arctostaphylos spp | Bearberry | 0.02 |
| Betula glandulosa | Tundra dwarf birch | 0.30 |
| Carex aquatilis | Water sedge | 42.77 |
| Carex spp | Sedge other | 1.54 |
| Cassiope tetragona | Arctic bell-heather | 0.11 |
| Clear water | Clear water | 35.02 |
| Dryas spp | Mountain avens | 0.04 |
| Dupontia fischeri | Dupontia | 1.17 |
| Eriophorum angustifolium | Tall cotton-grass | 0.04 |

| | | |
|---|---|---|
| Eriophorum russeolum | Russet cotton-grass | 0.08 |
| Eriophorum spp | Cotton-grass | 1.77 |
| Ledum palustre | Labrabor tea | 0.06 |
| Lichen | Lichen | 0.20 |
| Moss | Moss | 5.36 |
| Mud | Mud | 1.65 |
| Poa spp | Arctic bluegrass | 0.01 |
| Potentilla palustris | Marsh cinquefoil | 0.09 |
| Ranunculus spp | Buttercup | 0.05 |
| Rubus chamaemorous | Cloudberry | 0.00 |
| Salix spp | Willow | 2.01 |
| Salt burn veg | Salt burn veg | 0.07 |
| Sphagnum spp | Sphagnum moss | 0.26 |
| Vaccinium vitis-idaea | Mountain cranberry | 0.01 |

**Total Cover Types = (25)**

## Sedge/Grass Meadow — Number of Sites = 205

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Alopecurus alpina | Foxtail | 0.23 |
| Andromeda polifolia | Bog rosemary | 0.01 |
| Arctagrostis latifolia | Broadleaf arctic bentgrass | 0.41 |
| Arctophila fulva | Pendant grass | 1.18 |
| Arctostaphylos spp | Bearberry | 0.36 |
| Arenaria spp | Sandwort | 0.07 |
| Artemisia | Artemisia | 0.02 |
| Astragalus spp | Milk vetch | 0.01 |
| Betula glandulosa | Tundra dwarf birch | 2.15 |
| Caltha palustris | Common marsh marigold | 0.02 |
| Carex aquatilis | Water sedge | 34.23 |
| Carex spp | Sedge other | 4.23 |
| Cassiope tetragona | Arctic bell-heather | 6.78 |
| Clear water | Clear water | 2.00 |
| Cochlearia officinalis | Scurvy grass | 0.02 |
| Deschampsia ceaspitosa | Tufted hairgrass | 1.07 |
| Draba spp | Mustard | 0.00 |
| Dryas spp | Mountain avens | 1.35 |

| | | |
|---|---|---|
| Dupontia fischeri | Dupontia | 0.90 |
| Empetrum nigrum | Black crowberry | 0.00 |
| Equisetum spp | Horsetail | 0.07 |
| Equisetum spp | Water horsetail | 0.07 |
| Eriophorum angustifolium | Tall cotton-grass | 0.15 |
| Eriophorum russeolum | Russet cotton-grass | 1.39 |
| Eriophorum spp | Cotton-grass | 4.35 |
| Eriophorum vaginatum | Tussock cotton-grass | 4.86 |
| Grass | Grass | 0.20 |
| Juncus spp | Rush | 0.15 |
| Ledum palustre | Labrador tea | 0.88 |
| Lichen | Lichen | 3.58 |
| Lupinus arcticus | Arctic lupine | 0.10 |
| Lazula spp | Woodrush | 0.46 |
| Moss | Moss | 10.20 |
| Mud | Mud | 1.05 |
| Papaver spp | Arctic poppy | 0.01 |
| Peat | Peat | 0.07 |
| Pedicularis spp | Sudetan lousewort | 0.00 |
| Petasites frigidus | Arctic sweet coltsfoot | 0.04 |
| Plant debris | Plant debris | 0.29 |
| Poa lanata | Wool bluegrass | 1.61 |
| Poa spp | Arctic bluegrass | 2.99 |
| Polygonum spp | Buckwheat | 0.00 |
| Potentilla palustris | Marsh cinquefoil | 0.97 |
| Puccinellia | Alkali grass | 0.49 |
| Ranunculus spp | Buttercup | 0.02 |
| Rock | Rock | 0.10 |
| Rubus camaemorous | Cloudberry | 0.20 |
| Salix spp | Willow | 9.32 |
| Sand | Sand | 0.10 |
| Saxifraga spp | Saxifrage | 0.02 |
| Stellaria spp | Low starwort | 0.00 |
| Vaccinium uligilosum | Bog blueberry | 0.22 |
| Vaccinium vitis-idaea | Mountain cranberry | 0.65 |

**Total Cover Types = (53)**

## Sparsely Vegetated — Number of Sites = 72

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Agropyron spp | Wheatgrass | 0.21 |
| Alopecurus alpina | Faxtail | 0.07 |
| Arctophila fulva | Pendant grass | 0.40 |
| Arctostaphylos spp | Bearberry | 0.40 |
| Arenaria spp | Sandwort | 0.07 |
| Astragalus spp | Milk vetch | 0.10 |
| Betula glandulosa | Tundra dwarf birch | 0.14 |
| Boykinia Richardsonii | Boykinia | 0.07 |
| Carex aquatilis | Water sedge | 0.42 |
| Carex spp | Sedge other | 0.40 |
| Cassiope tetragona | Arctic bell-heather | 0.49 |
| Clear water | Clear water | 0.36 |
| Cochlearia officinalis | Scurvy grass | 0.07 |
| Deschampsia ceaspitosa | Tufted hairgrass | 0.14 |
| Dryas spp | Mountain avens | 4.67 |
| Dupontia fischeri | Dupontia | 0.14 |
| Elymus spp | Lyme grass | 0.35 |
| Empetrum nigrum | Black crowberry | 0.15 |
| Epilobium latifolia | River beauty | 0.24 |
| Equisetum spp | Horsetail | 0.07 |
| Eriophorum spp | Cotton-grass | 0.26 |
| Geum spp | Geum | 0.04 |
| Grass | Grass | 0.14 |
| Gravel | Gravel | 3.40 |
| Ledum palustre | Labrador tea | 0.01 |
| Lichen | Lichen | 1.63 |
| Lupinus arcticus | Arctic lupine | 0.13 |
| Moss | Moss | 1.69 |
| Mud | Mud | 9.65 |
| Papaver spp | Arctic poppy | 0.00 |
| Peat | Peat | 0.21 |
| Pedicularis spp | Sudetan lousewort | 0.00 |
| Plant debris | Plant debris | 1.28 |
| Poa lenata | Wool bluegrass | 0.01 |
| Poa spp | Arctic bluegrass | 0.26 |

| | | |
|---|---|---|
| Puccinellia phryganoides | Creeping alkali grass | 0.63 |
| Ranunculus spp | Buttercup | 0.00 |
| Rock | Rock | 21.56 |
| Salix spp | Willow | 7.11 |
| Salt burn veg | Salt burn veg | 2.01 |
| Sand | Sand | 39.15 |
| Saxifraga spp | Saxifrage | 0.38 |
| Senecio congestus | Marsh groundsel | 0.00 |
| Silene acaulis | Moss campion | 0.15 |
| Stellaria spp | Low starwort | 0.28 |

**Total Cover Types = (45)**

## Tall Shrub — Number of Sites = 38

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Alnus spp | Alder | 13.79 |
| Arctagrostis latifolia | Broadleaf arctic bentgrass | 0.63 |
| Arctostaphylos spp | Bearberry | 0.13 |
| Astragalus spp | Milk vetch | 0.53 |
| Carex aquatilis | Water sedge | 0.61 |
| Carex spp | Sedge other | 0.63 |
| Castilleja spp | Paintbrush | 0.39 |
| Clear water | Clear water | 0.29 |
| Dirt – bare | Dirt – bare | 0.32 |
| Dryas spp | Mountain avens | 0.79 |
| Epilobium latifolia | River beauty | 0.18 |
| Equisetum spp | Horsetail | 0.13 |
| Equisetum spp | Water horsetail | 0.18 |
| Eriophorum spp | Cotton-grass | 0.42 |
| Grass | Grass | 2.58 |
| Gravel | Gravel | 0.13 |
| Hedysarum spp | Sweet-vetch | 0.26 |
| Lichen | Lichen | 0.53 |
| Lupinus arcticus | Arctic lupine | 3.16 |
| Moss | Moss | 2.66 |
| Mud | Mud | 1.92 |
| Plant debris | Plant debris | 1.53 |

| | | |
|---|---|---|
| Potentilla palustris | Marsh cinquefoil | 0.13 |
| Rock | Rock | 0.26 |
| Salix spp | Willow | 65.42 |
| Sand | Sand | 2.32 |
| Saxifraga spp | Saxifrage | 0.08 |

**Total Cover Types = (27)**

## Turbid Water — Number of Sites = 11

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Turbid water | Turbid water | 100.00 |

**Total Cover Types = (1 detailed record)**

## Tussock Tundra — Number of Sites = 169

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Andromeda polifolia | Bog rosemary | 0.07 |
| Arctophila fulva | Pendant grass | 0.03 |
| Arctostaphylos spp | Bearberry | 0.41 |
| Betula glandulosa | Tundra dwarf birch | 4.78 |
| Boykinia Richardsonii | Boykinia | 0.09 |
| Carex aquatilis | Water sedge | 2.79 |
| Carex spp | Sedge other | 1.61 |
| Cassiope tetragona | Arctic bell-heather | 2.10 |
| Clear water | Clear water | 1.22 |
| Dryas spp | Mountain avens | 0.75 |
| Empetrum nigrum | Black crowberry | 0.06 |
| Equisetum spp | Horsetail | 0.04 |
| Eriophorum russeolum | Russet cotton-grass | 0.82 |
| Eriophorum spp | Cotton-grass | 30.67 |
| Eriophorum vaginatum | Tussock cotton-grass | 26.34 |
| Grass | Grass | 0.03 |
| Ledum palustre | Labrador tea | 1.79 |
| Lichen | Lichen | 3.40 |
| Lupinus arcticus | Arctic lupine | 0.27 |
| Luzula spp | Woodrush | 0.09 |
| Moss | Moss | 8.47 |
| Mud | Mud | 0.74 |

| | | |
|---|---|---|
| Pedicularis spp | Sudetan lousewort | 0.00 |
| Petasites frigidus | Arctic sweet coltsfoot | 0.15 |
| Plant debris | Plant debris | 0.21 |
| Poa spp | Arctic bluegrass | 0.12 |
| Polygonum spp | Buckwheat | 0.00 |
| Ranunculus spp | Buttercup | 0.00 |
| Rock | Rock | 0.09 |
| Rubus chamaemorous | Cloudberry | 0.62 |
| Salix spp | Willow | 10.74 |
| Saxifraga spp | Saxifrage | 0.02 |
| Vaccinium uliginosum | Bog blueberry | 0.06 |
| Vaccinium vitis-idaea | Mountain cranberry | 1.17 |

**Total Cover Types = (34)**

## Wet Tundra — Number of Sites = 186

| LATIN-NAME | COMMON-NAME | AVERAGE PER CLASS |
|---|---|---|
| Andromeda polifolia | Bog Rosemary | 0.08 |
| Arctophila fulva | Pendant grass | 2.87 |
| Arctostaphylos spp | Bearberry | 0.15 |
| Astragalus spp | Milk vetch | 0.01 |
| Betula glandulosa | Tundra dwarf birch | 3.88 |
| Caltha palustris | Common marsh marigold | 0.05 |
| Carex aquatilis | Water sedge | 40.09 |
| Carex spp | Sedge other | 3.12 |
| Cassiope tetragona | Arctic bell-heather | 1.57 |
| Clear water | Clear water | 14.93 |
| Coal | Coal | 0.03 |
| Dryas spp | Mountain avens | 0.61 |
| Dupontia fischeri | Dupontia | 0.11 |
| Equisetum spp | Horsetail | 0.04 |
| Equisetum spp | Water horsetail | 0.11 |
| Eriophorum angustifolium | Tall cotton-grass | 0.12 |
| Eriophorum russeolum | Russet cotton-grass | 2.57 |
| Eriophorum spp | Cotton-grass | 6.05 |
| Eriophorum vaginatum | Tussock cotton-grass | 1.37 |
| Grass | Grass | 0.24 |

| | | |
|---|---|---|
| Hippuris spp | Marestail | 0.03 |
| Ledum palustre | Labrador tea | 0.85 |
| Lichen | Lichen | 1.65 |
| Lupinus arcticus | Arctic lupine | 0.05 |
| Moss | Moss | 7.50 |
| Mud | Mud | 0.98 |
| Pedicularis spp | Sudetan lousewort | 0.01 |
| Petisites frigidus | Arctic sweet coltsfoot | 0.00 |
| Plant debris | Plant debris | 0.13 |
| Poa spp | Arctic bluegrass | 0.50 |
| Potentilla fruticosa | Shrubby cinquefoil | 0.05 |
| Potentilla palustris | Marsh cinquefoil | 1.39 |
| Puccinellia phryganoides | Creeping alkali grass | 0.30 |
| Ranunculus spp | Buttercup | 0.03 |
| Rhododendron spp | Rhododendron | 0.03 |
| Rock | Rock | 0.08 |
| Rubus chamaemorous | Cloudberry | 0.17 |
| Salix spp | Willow | 7.42 |
| Sand | Sand | 0.22 |
| Saxifraga spp | Saxifrage | 0.03 |
| Senecio congestus | Marsh groundsel | 0.03 |
| Vaccinium uliginusum | Bog blueberry | 0.12 |
| Vaccinium vitis-idaea | Mountain cranberry | 0.32 |

**Total Cover Types = (43)**

# APPENDIX G

Error matrices for the NPR-A classification.

Error matrix for Phase 3 (Southern) of the NPR-A Earth Cover Classification

**CLASSIFICATION**

| | | Water | | Aquatic | | Flooded Tun. | | Wet T. | Moist Tundra | | | Shrub | | | Barren | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CW | ICE | CA | AF | LCP | NP | WT | SGM | TT | ML | DSH | LSH | TSH | DDS | SV | OTH | TOTAL | USERS |
| | CW | **29** | | | | | | | | | | | | | | | | 29 | 100% |
| | ICE | | | | | | | | | | | | | | | | | 0 | 100% |
| | CA | | | | | | | | | | | | | | | | | 0 | 100% |
| R | AF | 3 | | | **3** | | | | | | | | | | | | | 6 | 50% |
| E | LCP | | | | | **4** | 3 | | | 1 | | | | | | | | 8 | 50% |
| F | NP | | | | | | **13** | | | | | 1 | | | | | | 14 | 93% |
| E | WT | | | | | 1 | 2 | **30** | 1 | 3 | | 1 | | | | | | 38 | 79% |
| R | SGM | | | | | | | 2 | **10** | 6 | | 5 | 3 | | | | | 26 | 38% |
| E | TT | | | | | | | | | **19** | | 8 | 1 | | | | | 28 | 68% |
| N | ML | | | | | | | | | | | | | | | | | 0 | 100% |
| C | DSH | | | | | | | | 1 | 14 | | **55** | 2 | | | 4 | 2 | 78 | 71% |
| E | LSH | | | | | | | | | 1 | | 5 | **18** | | | | | 24 | 75% |
| | TSH | | | | | | | | | | | | 1 | **2** | | | | 3 | 67% |
| | DDS | | | | | | | | | | | | | | | | | 0 | 100% |
| | SV | | | | | | | | | | | 1 | | | | **9** | 4 | 14 | 64% |
| | OTH | | | | | | | | | | | | | | | 4 | **21** | 25 | 84% |
| | Total | 32 | 0 | 0 | 3 | 5 | 18 | 32 | 12 | 44 | 0 | 76 | 25 | 2 | 0 | 17 | 27 | **293** | |
| | PRODUCERS | 91% | 100% | 100% | 100% | 80% | 72% | 94% | 83% | 43% | 100% | 72% | 72% | 100% | 100% | 53% | 78% | | |

**OVERALL ACCURACY =**
**213/293 =**
**73%**

CW = water, ICE = ice, CA = carex aquatilis, AF = arctophila fulva, LCP = low centered polygons, NP = nonpattern, WT = wet tundra, SGM = sedge/grass meadow, TT = tussock tundra, ML = moss/lichen, DSH = dwarf shrub, LSH = low shrub, TSH = tall shrub, DDS = dunes/dry sand, SV = sparsely vegetated, OTH = other.

Error matrix for Phase 3 (Southern) of the NPR-A Earth Cover Classification

**CLASSIFICATION**

| R | | Water | Aquatic | Flooded Tundra | Wet Tundra | Moist Tundra | Shrub | Barren Ground | TOTAL | USERS |
|---|---|---|---|---|---|---|---|---|---|---|
| E | **Water** | **29** | | | | | | | 29 | **98%** |
| F | **Aquatic** | **3** | **3** | | | | | | 6 | **73%** |
| E | **Flooded Tundra** | | | **20** | | 1 | 1 | | 22 | **91%** |
| F | **Wet Tundra** | | | 3 | **30** | 4 | 1 | | 38 | **41%** |
| E | **Moist Tundra** | | | | 2 | **35** | 17 | | 54 | **85%** |
| N | **Shrub** | | | | | 16 | **83** | 6 | 105 | **85%** |
| C | **Barren Ground** | | | | | | 1 | **38** | 39 | **96%** |
| E | **TOTAL** | 32 | 3 | 23 | 32 | 56 | 103 | 44 | **293** | |
| | **PRODUCERS** | **100%** | **85%** | **72%** | **67%** | **80%** | **82%** | **96%** | | |

**OVERALL ACCURACY =**
**238/293 =**
**81%**

Error matrix for all three phases of the NPR-A Earth Cover Classification

**CLASSIFICATION**

| | | Water | | Aquatic | | Flooded Tun. | | Wet T. | Moist Tundra | | | Shrub | | | Barren | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CW | ICE | CA | AF | LCP | NP | WT | SGM | TT | ML | DSH | LSH | TSH | DDS | SV | OTH | TOTAL | USERS |
| | CW | **29** | | | | | | | | | | | | | | | | 29 | 100% |
| | ICE | | | | | | | | | | | | | | | | | 0 | 100% |
| | CA | | | | | | | | | | | | | | | | | 0 | 100% |
| R | AF | 3 | | | **3** | | | | | | | | | | | | | 6 | 50% |
| E | LCP | | | | | **4** | 3 | | | 1 | | | | | | | | 8 | 50% |
| F | NP | | | | | | **13** | | | | | 1 | | | | | | 14 | 93% |
| E | WT | | | | | 1 | 2 | **30** | 1 | 3 | | 1 | | | | | | 38 | 79% |
| R | SGM | | | | | | | 2 | **10** | 6 | | 5 | 3 | | | | | 26 | 38% |
| E | TT | | | | | | | | | **19** | | 8 | 1 | | | | | 28 | 68% |
| N | ML | | | | | | | | | | | | | | | | | 0 | 100% |
| C | DSH | | | | | | | | 1 | 14 | | **55** | 2 | | | 4 | 2 | 78 | 71% |
| E | LSH | | | | | | | | | 1 | | 5 | **18** | | | | | 24 | 75% |
| | TSH | | | | | | | | | | | | 1 | **2** | | | | 3 | 67% |
| | DDS | | | | | | | | | | | | | | | | | 0 | 100% |
| | SV | | | | | | | | | | | 1 | | | | **9** | 4 | 14 | 64% |
| | OTH | | | | | | | | | | | | | | | 4 | **21** | 25 | 84% |
| | Total | 32 | 0 | 0 | 3 | 5 | 18 | 32 | 12 | 44 | 0 | 76 | 25 | 2 | 0 | 17 | 27 | **293** | |
| PRODUCERS | | 91% | 100% | 100% | 100% | 80% | 72% | 94% | 83% | 43% | 100% | 72% | 72% | 100% | 100% | 53% | 78% | | |

**OVERALL ACCURACY =**
**213/293 =**
**73%**

CW = water, ICE = ice, CA = carex aquatilis, AF = arctophila fulva, LCP = low centered polygons, NP = nonpattern, WT = wet tundra, SGM = sedge/grass meadow, TT = tussock tundra, ML = moss/lichen, DSH = dwarf shrub, LSH = low shrub, TSH = tall shrub, DDS = dunes/dry sand, SV = sparsely vegetated, OTH = other.

Error matrix for all three phases of the NPR-A Earth Cover Classification

**CLASSIFICATION**

| R | | Water | Aquatic | Flooded Tundra | Wet Tundra | Moist Tundra | Shrub | Barren Ground | TOTAL | USERS |
|---|---|---|---|---|---|---|---|---|---|---|
| E | **Water** | **119** | 2 | 1 | | | | | 122 | **98%** |
| F | **Aquatic** | 3 | **45** | 5 | 3 | | | | 56 | **73%** |
| E | **Flooded Tundra** | | 5 | **77** | 1 | 3 | 1 | | 87 | **91%** |
| F | **Wet Tundra** | | 1 | 12 | **51** | 10 | 1 | | 75 | **41%** |
| E | **Moist Tundra** | | | 2 | 4 | **110** | 20 | | 136 | **85%** |
| N | **Shrub** | | | 1 | | 28 | **154** | 7 | 190 | **85%** |
| C | **Barren Ground** | | | | | | 1 | **73** | 74 | **96%** |
| E | **TOTAL** | 122 | 53 | 98 | 59 | 151 | 177 | 80 | **740** | |
| | **PRODUCERS** | **100%** | **85%** | **72%** | **67%** | **80%** | **82%** | **96%** | | |

**OVERALL ACCURACY =**
**629/740 =**
**85%**

# APPENDIX H

Metadata for the NPR-A earth cover classification

**Metadata Information System (MIS):**
**NPR-A Earth Cover Classification**

**General Description:**

Coverage/Image Name: npra_classification.img

**Description:**

The objective of this project was to create an updated and detailed earth cover inventory in computer database format for the entire NPR-A. The purpose of the project was to develop a tool to aid in the management of the NPR-A and to develop baseline information that could be used in other studies. Due to the immense size of the project area, limited field access, and lack of aircraft support infrastructure, the NPR-A project was divided into three phases. These phases were completed in 1995, 1996, and 1998, respectively. Eight Landsat TM satellite scenes and three SPOT XS satellite scenes, were used to classify the NPR-A into earth cover categories. An unsupervised clustering or seeding technique was used to determine the location of field sites and a custom field data collection card was used to record field information. After initial on-the-ground sampling, a helicopter was utilized to gain access to field sites throughout the project area. Global positioning system (GPS) technology was used both to navigate to pre-selected sites and record locations of new sites selected in the field. Data were collected on 1,667 field sites during a three-year field season from 1994 through 1996. A portion (44%) of these field sites were set aside for accuracy assessment. A combined supervised/unsupervised classification technique was performed to classify the satellite imagery into seven major classes and seventeen minor classes. The classification scheme for the land cover inventory was developed through a series of meetings with biologists familiar with the vegetation and previous work (Markon and Derkson 1994). As each scene was completed it was mosaicked and edge matched with adjacent scenes to produce a seamless database of NPR-A earth cover types.

**Layer Scale:** 30 meter pixels (MMU = 10 acres)

**Date Developed:** October 20, 1998

**Data Type:** ERDAS Imagine 8.2

**Source Data:**

| PHASE # | SENSOR | PATH/ROW | % SHIFT | DATE |
|---|---|---|---|---|
| 1 | Landsat Thematic Mapper (TM) | 81/10 | 42% | 6-Jul-92 |
| 1 | Landsat Thematic Mapper (TM) | 79/10 | 21% | 8-Jul-92 |
| 2 | Landsat Thematic Mapper (TM) | 75/11 | 0% | 28-Jul-92 |
| 2 | SPOT XS | k425/j202 | 10% | 9-Aug-94 |
| 2 | SPOT XS | k425/j202 | 60% | 4-Aug-94 |
| 2 | SPOT XS | k425/j203 | 70% | 4-Aug-94 |
| 3 | Landsat Thematic Mapper (TM) | 77/11 | 0% | 28-Aug-95 |
| 3 | Landsat Thematic Mapper (TM) | 77/12 | 0% | 28-Aug-95 |
| 3 | Landsat Thematic Mapper (TM) | 80/11 | 0% | 31-Jul-92 |
| 3 | Landsat Thematic Mapper (TM) | 81/11 | 0% | 6-Jul-92 |
| 3 | Landsat Thematic Mapper (TM) | 79/11 | 0% | 22-Jun-92 |

**Projection Information:**

**Name of Projection:** UTM Zone 4

**Name of Spheroid:** Clarke 1866

**Name of Datum:** NAD 27

**Map Unit:** Meters

**Upper Left X** 249481.0

**Upper Left Y** 8011939.0

**Data Dictionary:**

| | |
|---|---|
| 1.0 Water | 5.0 Moist Tundra |
| 1.1 Clear | 5.1 Sedge/Grass |
| Meadow | |
| 1.2 Turbid | 5.2 Tussock Tundra |
| 1.3 Ice | 5.3 Moss/Peat/Lichen |
| | |
| 2.0 Aquatic | 6.0 Shrub |
| 2.1 Carex aquatilis | 6.1 Dwarf |
| 2.2 Arctophila fulva | 6.2 Low |
| | 6.3 Tall |
| 3.0 Flooded Tundra | |
| 3.1 Low-Centered Polygons | 7.0 Barren Ground |
| 3.2 Non-Patterned | 7.1 Dunes/Dry Sand |
| | 7.2 Sparsely Vegetated |
| 4.0 Wet Tundra | 7.3 Other |

1.1 Clear Water - Fresh or saline waters with little or no particulate matter. Clear water areas are typically deep (greater than one meter). The clear water class may contain small amounts of *Arctophila fulva* or *Carex aquatilis* but generally less than 15% surface coverage of these species.

1.2 Turbid Water - Waters that contain particulate matter or shallow (<1m), clear water bodies that are spectrally different from class 1.1. This class typically occurs in shallow lake shelves, deltaic plumes, and rivers and lakes with high sediment loads. The turbid water class may contain small amounts of *Arctophila fulva* or *Carex aquatilis* but generally less than 15% surface coverage of these species.

1.3 Ice - May last into late summer on lakes and larger ponds. Ice is present year round in many of the larger lakes.

2.1 Carex aquatilis - Associated with lake or pond shorelines and composed of 50 - 80% clear or turbid water that was greater than 10 centimeters deep. The dominant species was *Carex aquatilis*. A small percentage of *Arctophila fulva, Hippuris vulgaris, Potentilla palustris,* and *Caltha palustris* may be present.

2.2 Arctophila fulva - Associated with lake or pond shorelines and composed of 50 - 80% clear or turbid water that was greater then 10 centimeters deep. The dominant species was *Arctophila fulva*. A small percentage of *Carex aquatilis, Hippuris vulgaris, Potentilla palustris,* and *Caltha palustris* may also be present.

3.1 Flooded Tundra-Low Centered Polygons - Polygon features that retain water throughout the summer. This class is composed of 25 - 50% water; *Carex aquatilis* is the dominant species in the permanently flooded areas. The drier ridges of the polygons are composed mostly of *Eriophorum russeolum, Eriophorum vaginatum, Sphagnum* spp., *Salix* spp., *Betula nana, Arctostaphylos* spp., and *Ledum palustre*.

3.2 Flooded Tundra-Non-Pattern - Continuously flooded areas composed of 25-50% water. *Carex aquatilis* was the dominant species. Other species may include *Hippuris vulgaris, Potentilla palustris,* and *Caltha palustris*. Non-pattern is distinguished from low-centered polygons by the lack of polygon features and associated shrub species that grow on the dry ridges of low-centered polygons.

4.0 Wet Tundra - Associated with areas of super saturated soils and standing water. Wet tundra often floods in early summer and generally drains of excess water during dry periods but remains saturated throughout the summer. It is composed of 10-25% water; *Carex aquatilis* is the dominant species. Other species may include *Eriophorum angustifolium*, and other sedges, grasses, and forbs.

5.1 Sedge/Grass Meadow - Dominated by the sedge family. This class commonly consists of a continuous mat of sedges and grasses with a moss and lichen understory. The dominant species were *Carex aquatilis, Eriophorum angustifolium, Eriophorum russeolum, Arctagrostis latifolia* and *Poa arctica*. Associated genera include *Cassiope* spp., *Ledum* spp., and *Vaccinium* spp.

5.2 Tussock Tundra - Dominated by the tussock-forming sedge *Eriophorum vaginatum*. Tussock tundra is common throughout the Arctic Foothills and may be found on well-drained sites in all areas of the NPR-A. Cottongrass tussocks are the dominant landscape elements, while moss is the common understory. Lichen, forbs, and shrubs are also present in varying densities. Associated genera include *Salix* spp., *Betula nana, Ledum palustre*, and *Carex* spp.

5.3 Moss/Lichen - Associated with low-lying lakeshores and dry sandy ridges dominated by moss and lichen species. As this type grades into a sedge type, graminoids such as *Carex aquatilis* may increase in cover, forming an intermediate zone.

6.1 Dwarf Shrub - Associated with ridges and well-drained soils and dominated by shrubs less than 30 centimeters in height. Because of the relative dryness of the sites on which this cover type occurs, it is the most species diverse. Major species included *Salix* spp., *Betula nana, Ledum palustre, Dryas* spp., *Vaccinium* spp., *Arctostaphylos* spp., *Eriophorum vaginatum, and Carex aquatilis.* This class frequently occurs over a substrate of tussocks.

6.2 Low Shrub - Associated with small streams and rivers, but also occurring on hillsides in the southern portion of the NPR-A. This class is dominated by shrubs between 30 centimeters and 1.5 meters in height. Major species included *Salix* spp., *Betula nana, Alnus crispa*, and *Ledum palustre.*

6.3 Tall Shrub - Found along the Colville River and some of its major tributaries, and dominated by *Salix* spp. over 1.5 meters in height. This class may also contain significant presence of *Alnus crispa* over 1.5 meters in height.

7.1 Dunes/Dry Sand - Associated with streams, rivers, lakes and coastal beaches. Dominated by dry sand with less than 10% vegetation. Plant species may include *Poa* spp., *Salix* spp., *Astragulus* spp., *Carex* spp., *Stellaria* spp., *Arctostaphylos* spp., and *Puccinellia phryganodes.*

7.2 Sparsely Vegetated - Occurred primarily along the coast in areas affected by high or storm tides, in recently drained lake or pond basins, and where there is bare mineral soil that is being re-colonized with vegetation. Dominated by non-vegetated material with 10-30% vegetation. The vegetation in these areas may include rare plants but some of the more commonly found species included *Stellaria* spp., *Poa* spp., *Salix* spp., *Astragulus* spp., *Carex* spp., *Stellaria* spp., *Arctostaphylos* spp., and *Puccinellia phryganodes.*

7.3 Barren Ground/Other - Associated with river and stream gravel bars, mountainous areas and urban areas. Includes less than 10% vegetation. May incorporate dead vegetation associated with salt burn from ocean water.

**Classification Decision Rules:**

1.0 WATER ( $\geq$ 80% water)
- 1.1 Clear Water - (depth $\geq$ 1 meter)
- 1.2 Turbid Water - (depth <1 meter)
- 1.3 Ice - (ice $\geq$ 60%)

2.0 AQUATIC ($\geq$50% water and <80% water and > 10cm in depth)
- 2.1 Carex aquatilis - (> 15% Carex aquatilis and < 15% Arctophila fulva)
- 2.2 Arctophila fulva - (>15% Arctophila fulva and < 15% Carex aquatilis)

3.0 FLOODED TUNDRA ( $\geq$25% water and <50% water and < 10cm in depth)
- 3.1 Low Centered Polygons ( $\geq$ 5% Sedge/Grass)
- 3.2 Non -pattern ( < 5% sedge/Grass)

4.0 WET TUNDRA ( $\geq$ 10% and < 25% water)

5.0 MOIST TUNDRA ( <10% water, < 40% shrub, composed mostly of sedges, grasses, rushes and moss/peat/lichen complex)
- 5.1 Sedge/Grass Meadow - ( $\geq$ 50% sedge/grass and <40% tussock cotton grass)
- 5.2 Tussock Tundra - ( $\geq$ 40% tussock cotton grass)
- 5.3 Moss/lichen - ( $\geq$ 50% moss and/or lichen)

6.0 SHRUB (< 5% water and $\geq$40% shrub)

6.1 Dwarf - ( ≤ 30cm in height)
6.2 Low - ( > 30cm and < 1.5 m in height)
6.3 Tall – (≥ 1.5 m in height)

7.0 BARREN GROUND (0-30% vegetated)
7.1 Dunes/dry sand - ( <10% vegetation and ≥ 50% dry sand)
7.2 Sparsely Vegetated - (10-30% vegetated)
7.3 Other - (< 10% vegetation and < 50% dry sand)

**Accuracy Assessment:**

The overall accuracy for the NPR-A was 85% for the seven major classes and 75% for the seventeen minor classes.

**CLASSIFICATION**

| | | Water | | Aquatic | | Flooded Tun. | | Wet T. | Moist Tundra | | | Shrub | | | Barren | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CW | ICE | CA | AF | LCP | NP | WT | SGM | TT | ML | DSH | LSH | TSH | DDS | SV | OTH | TOTAL | USERS |
| | CW | **98** | 1 | 1 | 1 | 1 | | | | | | | | | | | | 102 | 96% |
| | ICE | 1 | **19** | | | | | | | | | | | | | | | 20 | 95% |
| | CA | | | **22** | | 2 | 3 | 2 | | | | | | | | | | 29 | 76% |
| R | AF | 3 | | 7 | **16** | | | 1 | | | | | | | | | | 27 | 59% |
| E | LCP | | | 2 | | **29** | 10 | | | 2 | | | | | | | | 43 | 67% |
| F | NP | | | 3 | | 5 | **33** | 1 | 1 | | | 1 | | | | | | 44 | 75% |
| E | WT | | | 1 | | 10 | 2 | **51** | 5 | 5 | | 1 | | | | | | 75 | 68% |
| R | SGM | | | | | 1 | | 4 | **44** | 11 | 1 | 6 | 3 | | | | | 70 | 63% |
| E | TT | | | | | 1 | | | 3 | **50** | | 10 | 1 | | | | | 65 | 77% |
| N | ML | | | | | | | | | | **1** | | | | | | | 1 | 100% |
| C | DSH | | | | | | | | 3 | 20 | 1 | **78** | 7 | | 1 | 4 | 2 | 116 | 67% |
| E | LSH | | | | | 1 | | | | 4 | | 11 | **44** | | | | | 60 | 73% |
| | TSH | | | | | | | | | | | 1 | 1 | **12** | | | | 14 | 86% |
| | DDS | | | | | | | | | | | | | | **12** | 4 | | 16 | 75% |
| | SV | | | | | | | | | | | 1 | | | 3 | **20** | 4 | 28 | 71% |
| | OTH | | | | | | | | | | | | | | 1 | 4 | **25** | 30 | 83% |
| | Total | 102 | 20 | 36 | 17 | 50 | 48 | 59 | 56 | 92 | 3 | 109 | 56 | 12 | 17 | 32 | 31 | **740** | |
| | PRODUCERS | 96% | 95% | 61% | 94% | 58% | 69% | 86% | 79% | 54% | 33% | 72% | 79% | 100% | 71% | 63% | 81% | | |

**OVERALL ACCURACY =**
**554/740 =**
**75%**

**Contact Information:**


| | |
|---|---|
| **Contact Agency:** | Bureau of Land Management |
| **Contact Personnel:** | John Payne or Scott Guyer |
| **Contact Address** | 222 West 7th Avenue<br>Alaska State Office<br>Anchorage, AK 99513 |
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