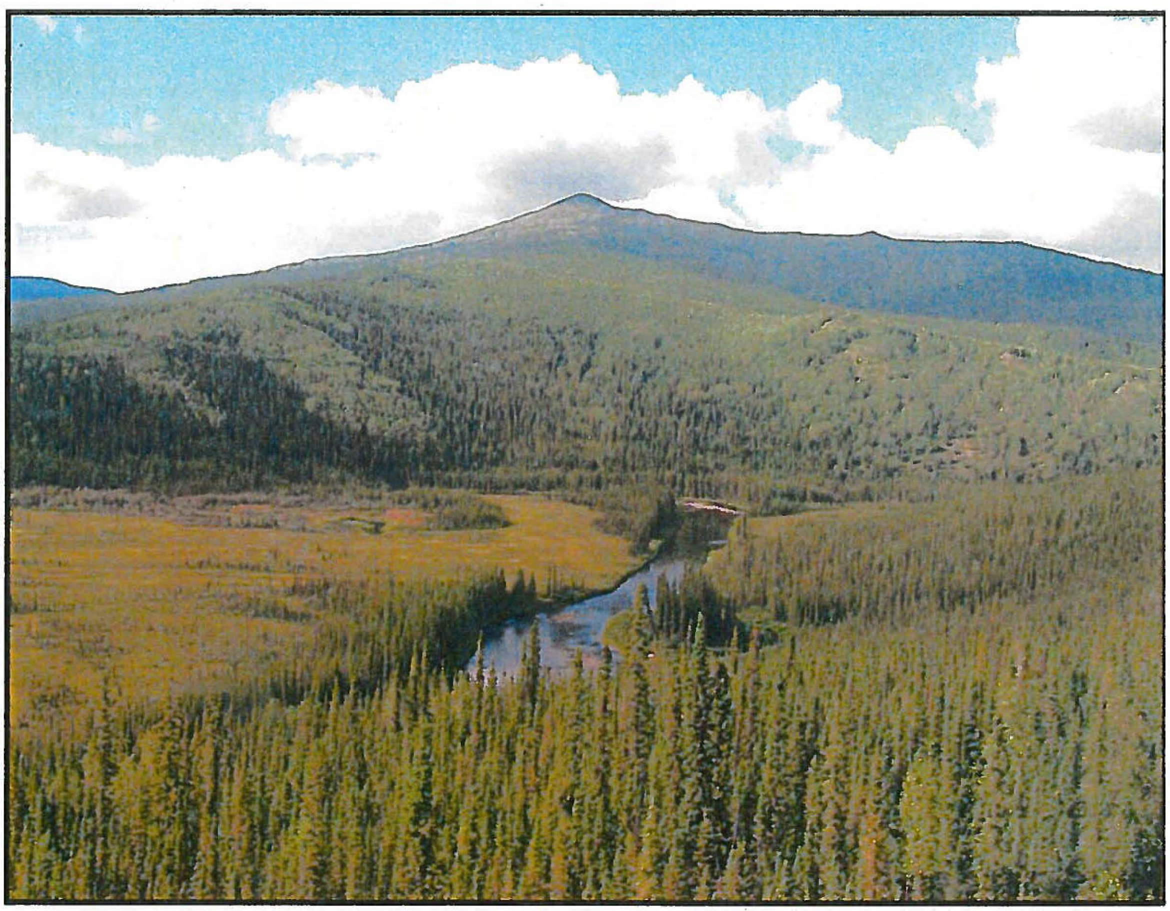
U.S. Department of the Interior
Bureau of Land Management

BLM-Alaska Technical Report 49
BLM/AK/ST-02/022+6500+931
October 2002

U.S. Department of the Air Force

Ducks Unlimited, Inc.

Northern and Southern Yukon MOA Earth Cover Classification



Mission Statement

The Bureau of Land Management (BLM) sustains the health, diversity and productivity of the public lands for the use and enjoyment of present and future generations.

Partners

The Department of the Interior, Bureau of Land Management, and Ducks Unlimited, Inc. completed this project under a cooperative agreement.

Cover

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

Technical Reports

Technical Reports issued by the Bureau of Land Management-Alaska present the results of research, studies, investigations, literature searches, testing, or similar endeavors on a variety of scientific and technical subjects. The results presented are final, or are a summation and analysis of data at an intermediate point in a long-term research project, and have received objective review by peers in the author's field.

The reports are available while supplies last from BLM External Affairs, 222 West 7th Avenue, #13, Anchorage, Alaska 99513 (907) 271-3318 and from the Juneau Minerals Information Center, 100 Savikko Road, Mayflower Island, Douglas, AK 99824, (907) 364-1553. Copies are also available for inspection at the Alaska Resource Library and Information Service (Anchorage), the United States Department of the Interior Resources Library in Washington, D. C., various libraries of the University of Alaska, the BLM National Business Center Library (Denver) and other selected locations.

A complete bibliography of all BLM-Alaska scientific reports can be found on the Internet at: http://www.ak.blm.gov/affairs/sci_rpts.html.

Related publications are also listed at
http://juneau.ak.blm.gov.

Northern and Southern Yukon MOA Earth Cover Classification

Technical Report 49
October 2002

U.S. Department of the Interior
Bureau of Land Management
Alaska State Office
222 West 7th Ave., No. 13
Anchorage, AK 99513

U. S. Department of the Air Force

Ducks Unlimited, Inc.
3074 Gold Canal Drive
Rancho Cordova, CA 95670

Acknowledgements

This project was funded under a cooperative agreement between the United States Department of the Interior's Fish and Wildlife Service (FWS) and Bureau of Land Management (BLM), and Ducks Unlimited, Inc (DU). John Payne (BLM), and Beate Sterrenberg (DU) administered this project.

Special thanks are extended to those who worked in the field. Three separate field crews performed the fieldwork, over two consecutive field seasons for the Northern and Southern Yukon MOA. The 1999 field crew included Alex Morton (formerly DU), Scott Guyer (BLM), Jim Herriges (BLM), and Roxie Anderson (DU). The 2000 field crew for Northern Yukon included Roxie Anderson (DU), Dan Fehringer (DU), Ruth Spell (DU), and Eric Lawton (BLM). The 2000 field crew for Southern Yukon included Roxie Anderson (DU), Lisa Saperstein (USFWS), Eric Lawton (BLM), and Lindsay Weight (BLM). Thanks to Ken Deyoe and Drew McCauly from Evergreen Helicopters, for safe air service. Thanks also to Bob McAlpin from Alaska Fire Service for help coordinating helicopter contracting; Jeff Campbell (Spatial Solutions, Inc./DU), Charlie Schrader-Patton (Spatial Solutions, Inc.), and Roxie Anderson (DU) for image processing; and Mark Pearson (GeoNorth, Inc.) for programming the Ducks Unlimited Field Form (DUFF) database.

Table of Contents

List of Figures

List of Tables

Abstract

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. The goal of this project was to continue the mapping effort by mapping the Northern and Southern portions of the Yukon Military Operations Areas (MOA). A Portion of one Landsat TM satellite scene (Path 67 Row 13 acquired 24 June 2000 shifted 35% North) was used to classify the Northern Yukon MOA project area into 34 earth cover categories. Portions of two Landsat TM satellite scenes (Path 66, Row 15 acquired 16 September 1995 and Path 68, Row 15 acquired 31 July 1999) were used to classify the Southern Yukon MOA project area into 31 earth cover categories. The path 66 and path 68 images were classified separately because of the large difference in image dates and season. The path 66 and path 68 earth cover classifications were mosaiced and edge-matched post-classification to produce a continuous earth cover map for the entire project area. An unsupervised clustering technique was used to determine the location of field sites and a custom field data collection form and digital database were used to record field information. Helicopters were 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 to record the locations of new sites selected in the field. The Northern Yukon MOA project area is approximately 3.6 million acres and the Southern Yukon MOA project area is approximately 3.8 million acres. For the Northern Yukon MOA project area, a total of 396 sites were visited during a 2-day field season in 1999 and a 6-day field season in 2000. For the Southern Yukon MOA project area, a total of 320 field sites were visited during a 3-day field season in 1999 and a 5-day field season in 2000. Approximately 30% of these field sites were set aside for accuracy assessment. A modified supervised/unsupervised classification technique was performed to classify the satellite imagery. The classification scheme for the earth cover inventory was based on Viereck *et al.* (1992) and revised through a series of meetings coordinated by the BLM – Alaska and DU. The overall accuracy of the Northern Yukon mapping categories was 85.4% at the +/-5% level of variation. The overall accuracy of the Southern Yukon mapping categories was 90.9% at the +/-5% level of variation for the path 66 classification and 89.8% at the +/-5% level of variation for the path 68 classification.

Introduction

In Alaska, most ground-based inventories of vegetation have been limited by accessibility to the area, or logistically restricted to a single large or several smaller watersheds. Aerial photography is available for much of Alaska, but is highly variable in scale and typically outdated which generally limits its usefulness for determining earth cover over large regional areas. In the last two decades, space-borne remote sensors (Landsat, SPOT, ERS-1, and others) have emerged as the best platforms for developing regional earth cover databases. Access to these large databases allow researchers, biologists, and managers to define and map crucial areas for wildlife, analyze related habitats, plot movement patterns for large ungulates, generate risk assessments for proposed projects, and provide baseline data to which wildlife and sociological data can be related.

A satellite inventory of earth cover serves many purposes. It provides baseline acreage statistics and corresponding maps for areas that currently lack or have outdated information for decision making. It is very useful for planning Environmental Impact Statements (EIS), Comprehensive Management Plans (CMP), and other regional studies that are mandated by the Federal Government. It can be integrated with other digital data sets into a GIS to produce maps, overlays, and further analysis. It also helps researchers identify areas most important to specific species of interest and can guide biologically driven decisions on land use practices (Kempka *et al.* 1993). Knowledge of the size, shape, distribution and extent of earth cover types, when linked to species habitat and human activities vastly improves our decision-making capabilities. The greater the area encompassed by earth cover information, in association with other digital base layers, the more regional, landscape-level assessment can be made and the more reliable our land management decisions will become.

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) began cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies in 1988 (Ritter *et al.* 1989). The initial mapping projects that were undertaken focused on mapping only the wetland types such as deep marsh, shallow marsh, and aquatic classes (Ritter *et al.* 1989). It soon became apparent that mapping the entire landscape was more cost effective and useful to both managers and habitat studies. Over the years, many refinements have been made to both the techniques of collecting field information and classifying the imagery. The BLM is currently in the process of mapping all of their lands in Alaska using this methodology. Many other agencies in Alaska (i.e. National Park Service, U.S. Fish and Wildlife Service, U.S. Forest Service, Alaska Department of Natural Resources, Alaska Department of Fish and Game) are also using similar techniques for mapping and wildlife analysis. This project represents a cooperative effort between the Bureau of Land Management, U.S. Air Force, and Ducks Unlimited, Inc. This earth cover mapping effort provides an inventory of Alaska's land base that can be used for regional management of land and wildlife. Earth cover databases allow researchers, biologists, and managers to define and map crucial areas for wildlife; perform analysis of related habitats; detect changes in the landscape; plot movement patterns for large ungulates; generate risk assessments for proposed projects; estimate fire fuel loadings; and provide baseline data to which wildlife and sociological data can be related.

Landsat Thematic Mapper (TM) satellite imagery was chosen as the primary source for the BLM/DU earth cover mapping effort and was the only imagery used for this project area. Satellite imagery offers a number of advantages for region-wide projects. TM data is cost effective, processed using automated mapping techniques, and collected on a cyclical basis, providing a standardized data source for future database updates or change detection studies (Kempka *et al.* 1993). In addition, TM imagery includes a mid-infrared band, which is sensitive to both vegetation and soil moisture content and is useful in identifying earth cover types. When combined with other GIS data sets, (e.g., elevation, slope, aspect, shaded relief, and hydrology), Landsat TM data produces highly accurate classifications with a moderately detailed classification scheme.

The Northern and Southern Yukon MOA Earth Cover Mapping project areas contain diverse landscapes and are deemed important for its wildlife and recreational values. The Northern Yukon MOA project area extends north approximately from Circle past the Artic Circle to the Black River. The western boundary lies just east of Fort Yukon and the confluence of the Yukon and Porcupine Rivers and extends to the eastern boundary along the Alaska/Canada border. The Southern Yukon MOA project area extends approximately from the Chena Hot Springs area in the northwest to Warbelow Mountain and Jake Wade in the northeast to the Tanana River near the confluence with the Johnson River and Sand Creek in the south. The western boundary extends to the region just north of Fairbanks, including the Chena Dome. The eastern boundary extends to the Alaska/Canada border.

Project Objective

The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the northern and southern regions of the Yukon MOA lands and associated areas. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project was an integrated GIS database that can be used for improved natural resources planning.

Project Area – Northern Yukon MOA

The project area (Figure 1) consisted of approximately 3.6 million acres and included lands owned or managed by several Federal and State agencies, and native corporations (Figure 2). The Yukon Flats NWR (1.6 million acres) formed the bulk of the western and central portions of the project area, with BLM lands (0.6 million acres) in the northeastern and southeastern portions. Approximately 0.7 million acres of State Selected and State Patent land (Table 1) and 0.7 million acres of Native Selected and Native Patent land within and around the BLM and FWS lands were mapped to provide a continuous data set for the entire area. The Alaska/Canada border defines the eastern boundary of the project area. The northern and eastern boundaries are defined by the Yukon MOA boundaries, the northern boundary lying north of and running parallel to the Arctic Circle. The southern boundary is defined along the boundaries of two previous projects completed in this area. The project area contains portions of the following United States Geological Survey (USGS) 1:250,000 scale quadrangles: Black River, Fort Yukon, Circle, and Charley River.

The project area was nearly roadless. The Steese Highway ending at Circle, in the southernmost portion of the project, was the only access afforded by the statewide road system. All other roads were limited to minor road systems associated with bush communities and Native villages scattered throughout the project area.

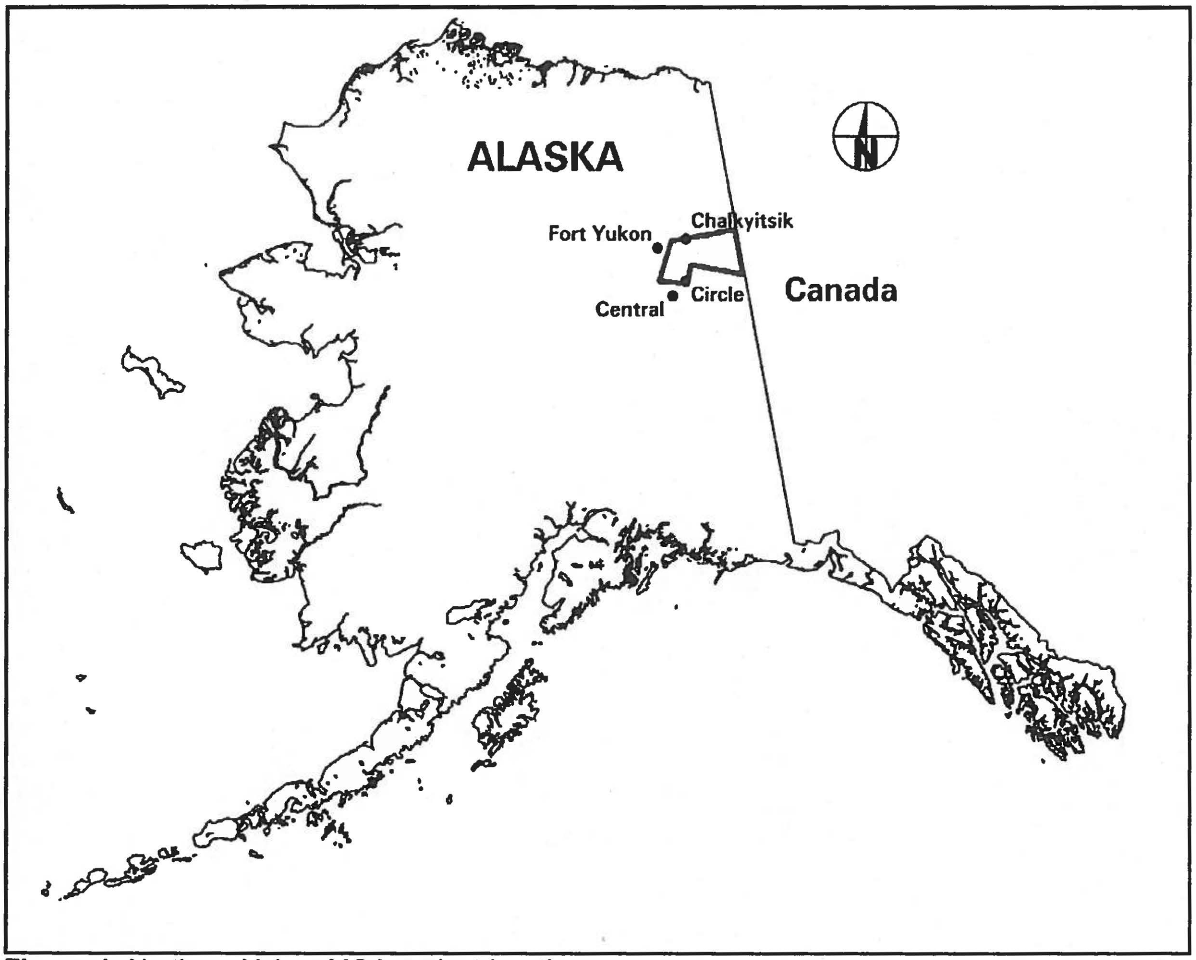


Figure 1. Northern Yukon MOA project location.

Table 1. Acreage of Northern Yukon MOA project area summed by land status.

Land Status	Acres
Bureau of Land Management	595,758
U.S. Fish and Wildlife Service	1,572,778
State Selected	398,872
State Patent or TA	300,817
Native Selected	240,073
Native Patent or IC	498,202
Total	3,606,500

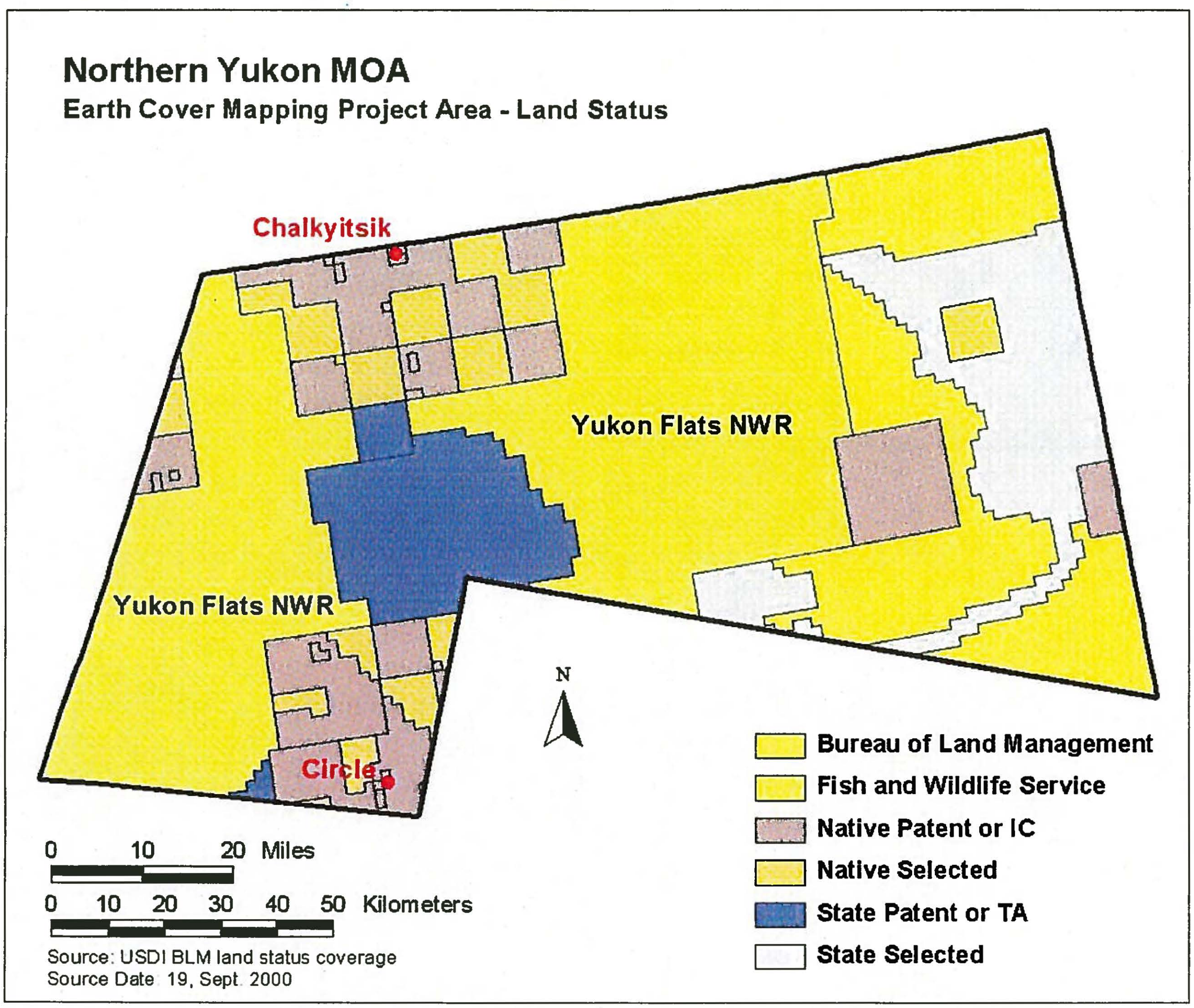


Figure 2. Land status within the project area.

The project area encompassed a wide variety of environments ranging from the broad pediment slopes of the Ogilvie Mountains to the relatively flat marshy basin floor of the Yukon Flats. The innumerable small lakes and ponds in the Yukon Flats NWR as well as in surrounding areas supported pond lilies and other aquatic vegetation that make up an important food source for waterfowl. Extensive forested uplands and lowlands were also present within the study area. The area was heavily influenced by fire as indicated by the numerous fire scars visible on the satellite imagery.

Project Area – Southern Yukon MOA

The project area (Figure 3) consisted of approximately 3.4 million acres and included lands owned or managed by several Federal and State agencies, and native corporations (Figure 4). State Selected and Patent lands (2.6 million acres) formed the bulk of the project area, with small parcels of BLM lands (56,000 acres) scattered throughout the project area. Approximately 0.7 million acres of Native Selected and Native Patent land and 94,000 acres of Military land (Table 2) around the State lands were mapped to provide a continuous data set for the entire area The Southern Yukon MOA project area is bordered by three projects that have previously been completed. The northern boundary extends approximately from the Chena Hot Springs area in the northwest to Warbelow Mountain and Jake Wade in the northeast. The southern boundary actually extends to the boundary of a Buffalo MOA. The western boundary extends to the region just north of Fairbanks, including the Chena Dome. The eastern boundary extends to the Alaska/Canada border. The project area contains portions of the following USGS 1:250,000 scale quadrangles: Eagle, Circle, Big Delta, Mt. Hayes, and Tanacross.

The project area was mostly roadless. Chena Hot Springs road leaving from Fairbanks ending at Chena Hot Springs traverses about 30 miles of the western portion of the project area. The Alaska Highway traverses about 25 miles through the southernmost portion of the project. Taylor Highway traverses about 30 miles across the easternmost portion of the project area. These highways were the only access afforded by the statewide road system. All other roads were limited to minor road systems associated with bush communities and Native villages scattered throughout the project area.

The entire area was within the interior highlands ecoregion of Alaska, with mountains rising to at least 1200 meters and slopes ranging from 5% to 15%. Dwarf shrub and low shrub were widespread on slopes exposed to wind. These Non-forested uplands form important caribou habitat. The lower elevations housed open needleleaf and woodland needleleaf communities. The area was heavily influenced by terrain shadow as indicated by the satellite imagery.

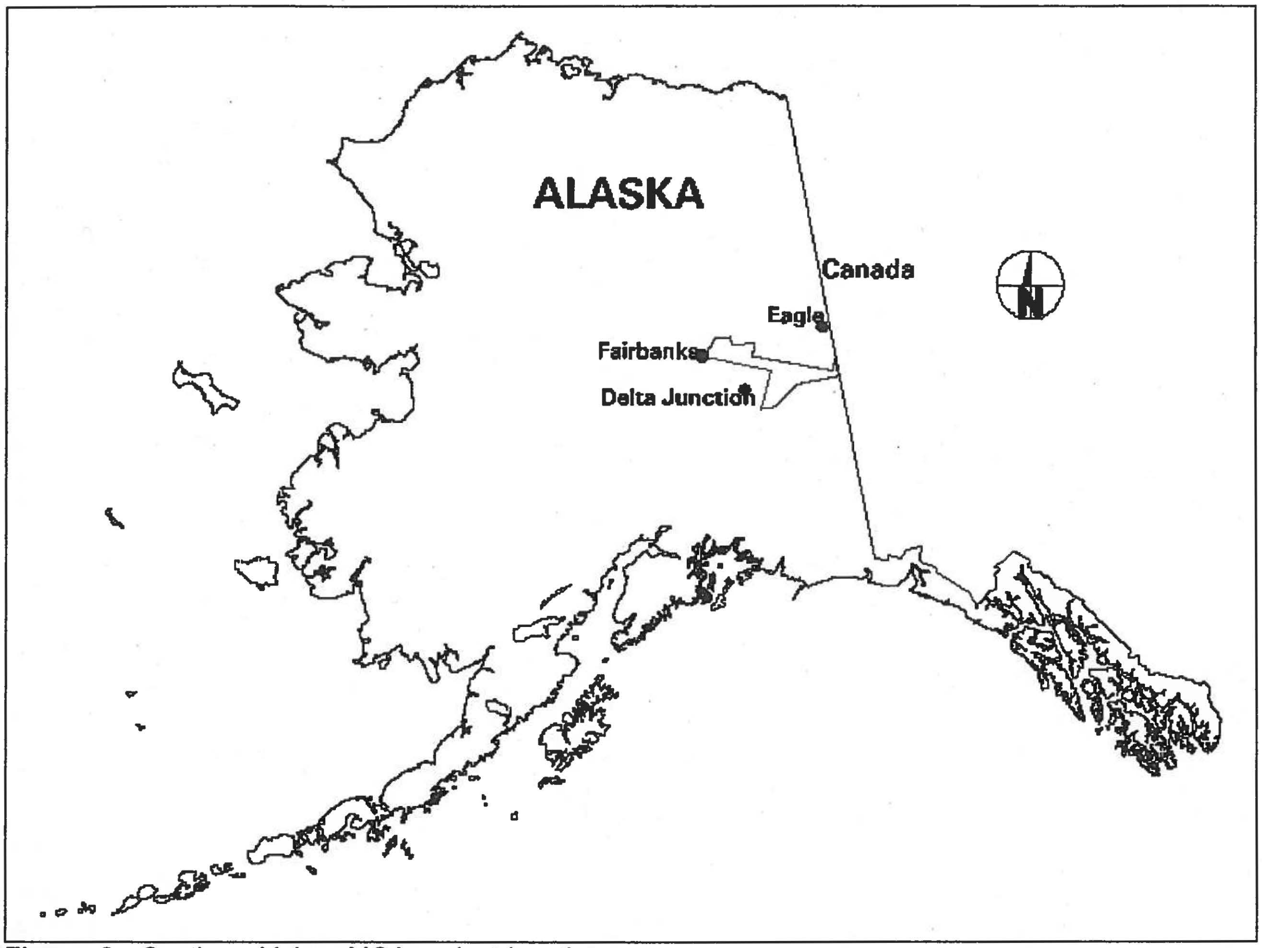


Figure 3. Southern Yukon MOA project location.

Table 2. Acreage of Southern Yukon MOA project area summed by land status.

Land Status	Acres
Bureau of Land Management	56,079
State Patent or TA	2,393,653
State Selected	164,710
Native Patent or IC	139,954
Native Selected	550,916
Military	94,177
Total	3,399,489

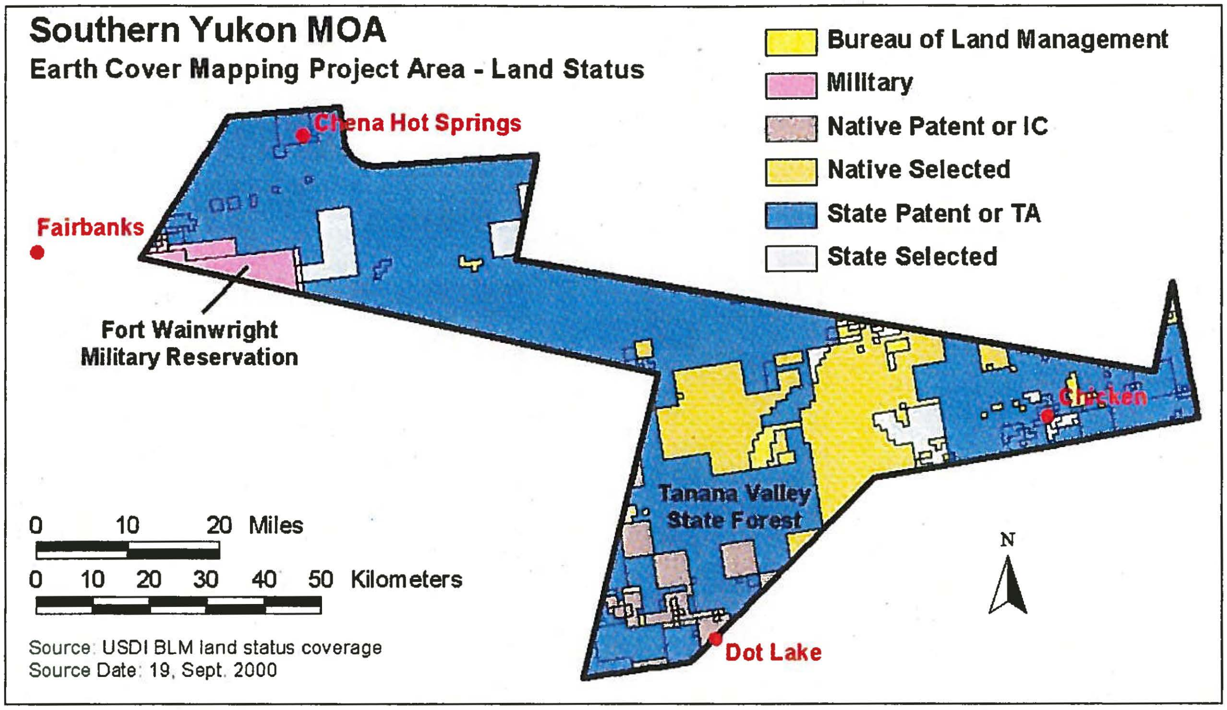


Figure 4. Land status within the project area.

Data Acquisition – Northern Yukon MOA

The Bureau of Land Management purchased all the imagery for the project in Albers or UTM projection from EROS Data Center. Acquisition of cloud-free imagery from midsummer dates is difficult in this portion of Alaska. Originally four Landsat TM scenes were mosaiced together to cover the project area with as little cloud cover as possible. Two of the four scenes used were scenes purchased for previous projects.

Landsat TM scene path 66 row 14 acquired August 20, 1991 was used to cover the southeastern portion of the project area. Landsat TM scene path 67 row 13 acquired September 10, 1999 was used to cover the northeastern portion of the project areas.

The two scenes purchased for the pre-processing of this particular project were Landsat TM scenes path 67 rows 13 and 14 acquired July 31, 1999. These two scenes covered the western portion of the project area. A composite of the four scenes was used for pre-processing and fieldwork (Figure 5).

Field data were collected during a 5-day field season from July 31 through August 4, 1999 and a 6-day field season from July 28 through August 2, 2000. Ancillary data sets used in this project included: 1:60,000 scale aerial photographs (color infrared transparencies from 1980-82, 1984, and 1986-87), and USGS 1:250,000 scale Digital Elevation Models (DEM). The aerial photographs and DEM's were provided by the BLM.

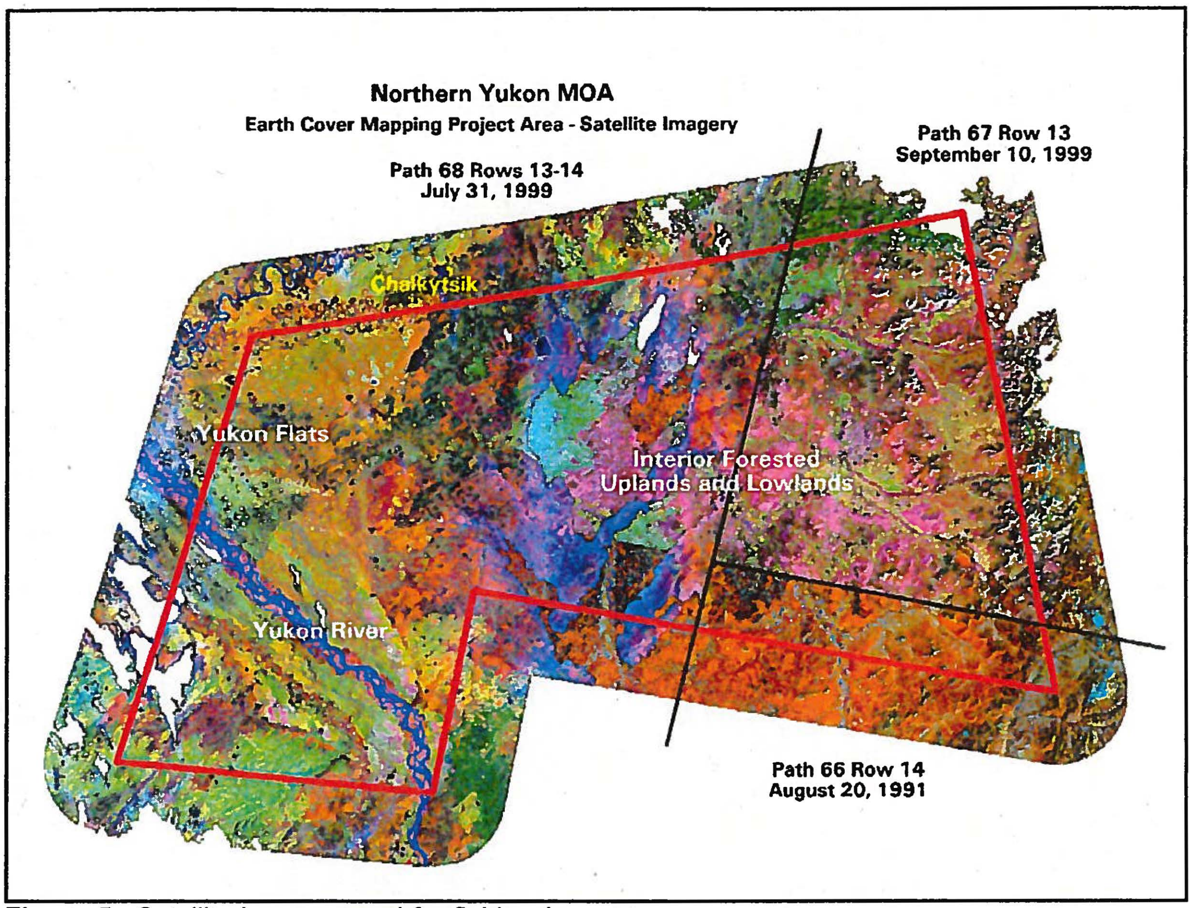


Figure 5. Satellite imagery used for fieldwork.

After the 2000 field season, Landsat TM scene path 67 Row 14 (shifted approximately 35% north) acquired June 24, 2000 was purchased for image processing. This Landsat TM scene covered the project area except for approximately 27,500 acres of the southeast corner. The scene purchased was essentially cloud-free. The earlier acquisition date resulted in a higher presence of water- a couple of sparse vegetation sites visited along the Yukon river in late July, showed up as flooded areas in the June 24, 2000 imagery (Figure 6).

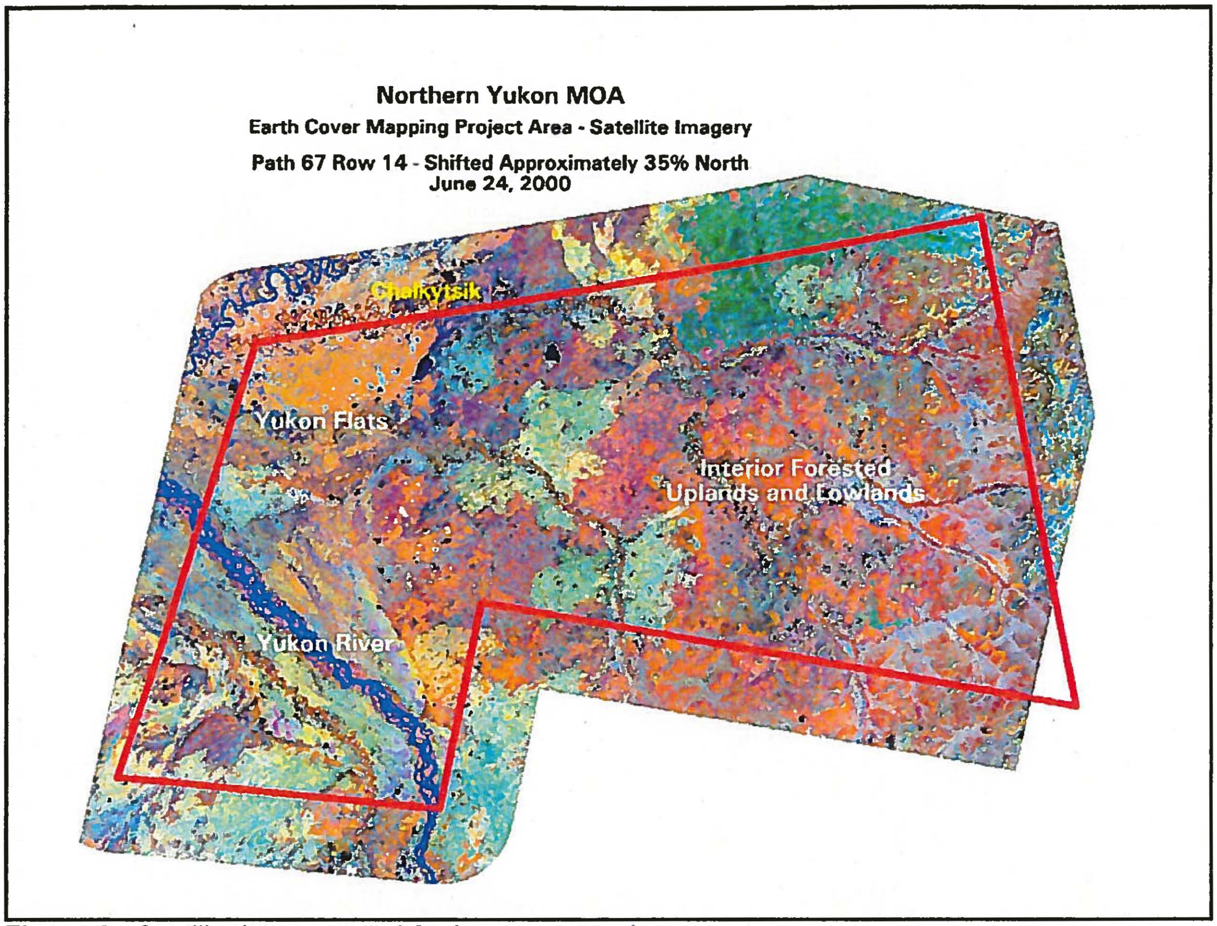


Figure 6. Satellite imagery used for image processing.

Data Acquisition – Southern Yukon MOA

The Bureau of Land Management purchased all imagery for the project in Albers projection from EROS Data Center. Two Landsat TM scenes were originally purchased to cover the project area. One scene (Path 68 Row 15) acquired on July 31, 1999 covered the western portion of the project area. The remaining scene (Path 66, Row 15) acquired on September 16, 1995 covered the eastern portion of the project area except for approximately 127,400 acres.

Acquisition of cloud- free imagery from midsummer dates is difficult in this portion of Alaska and the relatively late summer to early autumn date of the eastern image resulted in the presence of leaf senescence in many stands of deciduous trees in the images, particularly at higher elevations. In addition, the images covering the eastern portion of the study area contained significant cloud cover and terrain shadowing on the north and northwest facing slopes. A composite of these two scenes was used for the fieldwork and image classification phases of the project (Figure 7).

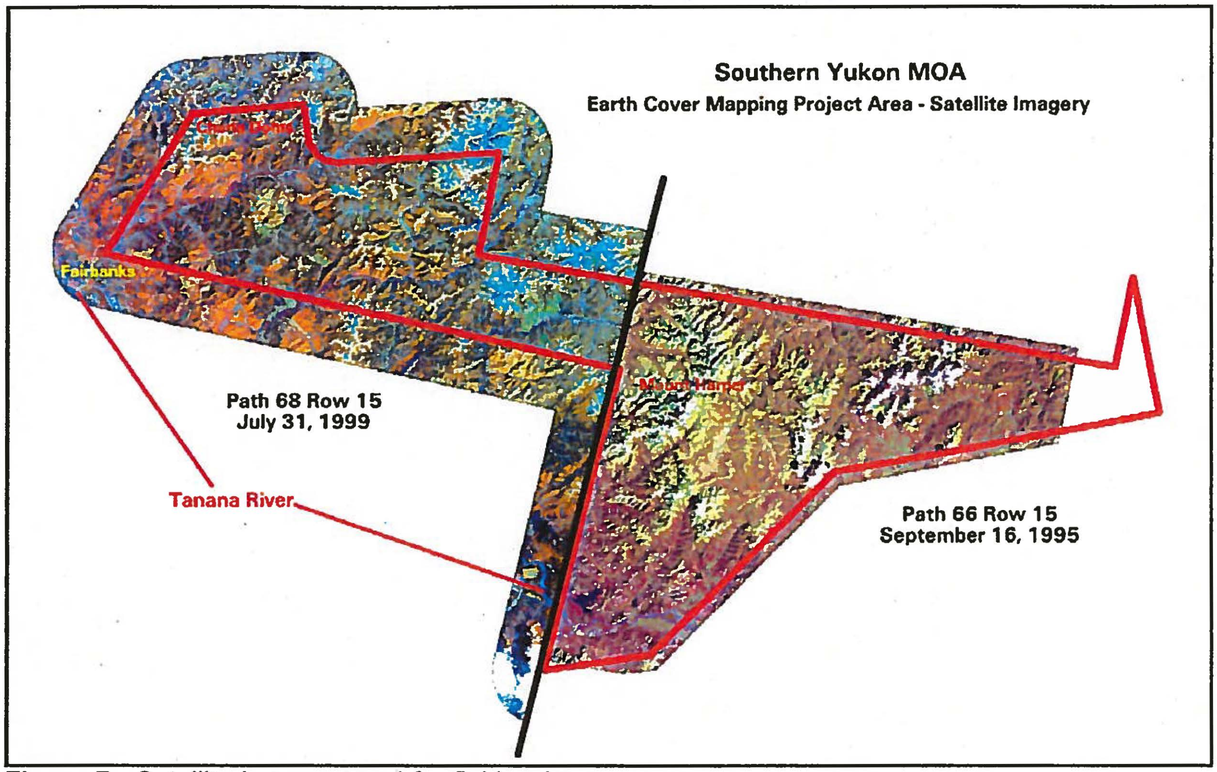


Figure 7. Satellite imagery used for fieldwork.

Field data were collected during a 5-day field season from July 31 through August 4, 1999 and a 7-day field season from August 4through August 10, 2000. Ancillary data sets used in this project included: 1:60,000 scale aerial photographs (color infrared transparencies from 1980-82, 1984, and 1986-87), and USGS 1:250,000 scale Digital Elevation Models (DEM). The aerial photographs and DEM's were provided by the BLM.

Methods

Classification Scheme

The classification system (Table 3) categorized the features to be mapped. The system was derived from the anticipated uses of the map information and the features of the earth that could be discerned by TM data. The classification system had two critical components: (1) a set of labels (e.g., forest, shrub, and water); and (2) a set of rules, or a system for assigning labels. The set of rules for assigning labels was mutually exclusive and totally exhaustive (Congalton 1991). That is, any given area fell into only one category and every area was to be included in the classification.

Until recently, the BLM/DU classification systems were project-specific. As projects expanded in size and as other cooperators began mapping and sharing data across Alaska, the necessity for a standardized classification system became apparent. At the BLM Earth Cover Workshop in Anchorage on 3-6 March 1997, a classification system based on the existing Alaska Vegetation Classification (Viereck *et al.*, 1992) was designed to address this need. The goal of this meeting was to (1) develop an earth cover classification system for the state of Alaska that can be used in large regional mapping efforts, and (2) build consensus for the system among multiple land management agencies. The classification system has been slightly improved since this meeting.

The classification scheme consisted of 10 major categories and 24 subcategories. A classification decision tree and written description (Appendices A and B) was developed to clarify the classification. Though based largely on Level III of the Viereck *et al.* (1992) classification, some classes have been modified, added or omitted for the earth cover mapping projects: e.g., rock, water, ice, cloud and shadow classes were added. Other classes that could not reliably be discerned from satellite imagery were collapsed, such as open and closed low shrub classes, or dryas, ericaceous, willow, and dwarf shrub classes. Because of the importance of lichen for site characterization and wildlife, and because the presence of lichen can be detected by satellite imagery, shrub and forested classes with and without a component of lichen were distinguished. A few classes from Level IV of the Viereck *et al.* (1992) classification were also mapped because of their identifiable satellite signature and their importance for wildlife management. These Level IV classes included tussock tundra and low shrub tussock tundra.

Image Preprocessing

Each image was examined for quality and consistency. Each band was examined visually and statistically by reviewing histograms. Combinations of bands were displayed to check for band-to-band registration and for clouds, shadows, and

Table 3. Classification scheme developed at the BLM Earth Cover Workshop.

Level II	Level III	Level IV
1.0 Forest	1.1 Closed Needleleaf	
	1.2 Open Needleleaf	1.21Open Needleleaf Lichen
	1.3 Woodland Needleleaf	1.31 Woodland Needleleaf Lichen
	1.4 Closed Deciduous	1.41 Closed Paper Birch
		1.42 Closed Aspen
		1.43 Closed Balsam Poplar/Cottonwood
		1.44 Closed Mixed Deciduous
	1.5 Open Deciduous	1.51 Open Paper Birch
		1.52 Open Aspen
		1.53 Open Balsam Poplar/Cottonwood
		1.54 Open Mixed Deciduous
	1.6 Closed Mixed Needleleaf/Deciduous	
	1.7 Open Mixed Needleleaf/Deciduous	
2.0 Shrub	2.1 Tall Shrub	
	2.2 Low Shrub	2.21 Low Shrub Willow/Alder
		2.22 Low Shrub Tussock Tundra
		2.23 Low Shrub Lichen
		2.24 Low Shrub Other
	2.3 Dwarf Shrub	2.31 Dwarf Shrub Lichen
		2.32 Dwarf Shrub Other
3.0 Herbaceous	3.1 Bryoid	3.11 Lichen
		3.12 Moss
	3.2 Wet Herbaceous	3.21Wet Graminoid
		3.22 Wet Forb
	3.3 Mesic/Dry Herbaceous	3.31 Tussock Tundra
		3.32 Mesic/Dry Sedge Meadow
		3.33 Mesic/Dry Grass Meadow
		3.34 Mesic/Dry Graminoid
		3.35 Mesic/Dry Forb
4.0 Aquatic Vegetation	4.1 Aquatic Bed	
	4.2 Emergent Vegetation	
5.0 Water	5.1 Snow	
	5.2 Ice	
	5.3 Clear Water	
	5.4 Turbid Water	
6.0 Barren	6.1 Sparsely Vegetated	
	6.2 Rock/Gravel	
	6.3 Mud/Silt/Sand	
7.0 Urban		
8.0 Agriculture		
9.0 Cloud/Shadow	9.1 Cloud	
	9.2 Shadow	
10.0 Other		

haze. This review did reveal several clusters of pixel anomalies in the Path 66, Row 15 imagery. The anomalies were generally in the form of erroneous bright pixels in the red-visible band (band 3) and the first mid-infrared band (band 5). Comparing the image to available ancillary data such as hydrography, adjacent imagery, and DEM's checked positional accuracy.

To optimize helicopter efficiency, field sites were identified and plotted on field maps before fieldwork began. Sufficient samples for each mapped class were selected to span the variation of spectral responses within that class throughout the entire image. For example, a shrub class in the southern part of an image may have a different spectral response than the same shrub class in the northern part of that image. Many factors contribute to such variation, including aspect, terrain shadow, or small differences in soil moisture. In addition, each earth cover type encompassed a variety of subtypes; e.g., the open needleleaf class included forested areas with 25%-60% crown closure, trees of varying height, and a diverse understory composition.

An unsupervised classification was used to identify spectrally unique areas within the study area. The image analyst individually selected training sites from these spectrally unique areas. Whenever possible, training sites were grouped in clusters to reduce the amount of travel time between sites. The image analyst also tried to place training sites near landmarks that were easily recognizable in the field, such as lakes, streams, or abrupt changes in cover type. A tally of the estimated number of field sites per class was kept until all of the target map classes were adequately sampled throughout the project area. The coordinates of the center points of the field sites were then uploaded into a Y-code Rockwell Precision Lightweight GPS receiver (PLGR) for navigational purposes. Training sites were overlain with the satellite imagery and plotted at 1 inch = 1 mile scale. These field maps were used for recording field notes, placing additional field sample sites, and navigating to field sites.

Field Verification

The purpose of field data collection was to assess, measure, and document the on-the-ground vegetation variation within the project area. This variation was correlated with the spectral variation in the satellite imagery during the image classification process. Low-level helicopter surveys were used as a very effective method of field data collection since a much broader area was covered with an orthogonal view from above, similar to a satellite sensor. In addition, aerial surveys were the most efficient alternative due to the large area and the lack of roads throughout the majority of the project area.

To obtain a reliable and consistent field sample, a custom field data collection form (Kempka *et al.*, 1994) was developed and used to record field information (Figure 8). A five-person helicopter crew performed the field assessment. Each crew consisted of a pilot, biologist, recorder, navigator, and alternate. The navigator operated the GPS equipment and interpreted the satellite image derived field maps to guide the biologist to the pre-defined field site. It was valuable for the image processor to gain first-hand knowledge of the project area; therefore the image processor also fulfilled the role of the navigator. The biologist identified plant species, estimated the percent cover of each cover type, determined the overall earth cover class, and photographed the site. The recorder wrote species percentages and other data on the field form and generally assisted the biologist. The alternate was responsible for crew flight following, data entry, and substitution in case of sickness. The majority of sites were observed without landing the helicopter. Ground verification was performed when identification of dominant vegetation was uncertain.

These DU/BLM procedures for collecting field data have evolved into a very efficient and effective means of data collection. The navigator used a GPS to locate the site and verified the location on the field map. As the helicopter approached the site at about 300 meters above ground level the navigator described the site and the biologist took a picture with a digital camera. The pilot then descended to approximately 2-5 meters above the vegetation and laterally moved across the site while the biologist called out the vegetation to the recorder. The biologist took another picture with the digital camera for a close-up view of the site. The pilot then ascended to approximately 100 meters so that the biologist could estimate the percentages of each species to the recorder. The navigator then directed the pilot to the next site. On average, it took approximately 5-8 minutes to collect all of the information for one site.

Field Data Analysis

The collected field information was entered into a digital database using the Ducks Unlimited Field Form (DUFF) custom data entry application, designed jointly by the BLM and DU and programmed by GeoNorth. SQL Anywhere powered the relational database, while the user interface was programmed in Visual Basic. The user interface was organized similarly to the field form to facilitate data entry (Figure 9). The application utilized pull down menus to minimize keystrokes and checked for data integrity to minimize data entry errors. The database program also calculated an overall class name for each site based on the recorded species and their cover percentages. Digital images from each site were stored in the database and accessible from within the user interface. The number of field sites per earth cover class was tracked daily to ensure that adequate samples were being obtained within each class.

Classification

Every image is unique and presents special problems in the classification process. The approach used in this project (Figure 10) has been proven successful over many years. The image processor was actively involved in the field data collection. The image processor's site-specific experience and knowledge in combination with high quality ancillary data overcame image problems and produced a high quality, useful product.

Erdas Imagine (vers. 8.4) was used to perform the classification. Arc Info (vers. 7.2.1) was utilized to manage the field site polygons. Various word processing and data analysis software were also used during the image classification including Microsoft Word, Excel, and Access.

Generation of New Bands

The Landsat TM imagery contained 7 bands of data: 3 visible bands, 1 near-infrared band, 2 mid-infrared bands, and 1 thermal band.

One new band, the Normalized Difference Vegetation Index (NDVI), was generated for this project. The NDVI was highly correlated with the 4/3 ratio, a band ratio that typically reduces the effect of shadows in the image and enhances the differences between vegetation types (Kempka *et al.* 1995, Congalton *et al.*, 1993). In addition, the NDVI has been correlated with various forest and crop canopy characteristics such as biomass and leaf area index. This NDVI band replaced the thermal band (band 6) to retain a 7-band image for classification.

Removal of Clouds and Shadows

Clouds and cloud shadows in the path 66 and path 68 images (Southern Yukon project area) were removed using an unsupervised classification and manual on-screen digitizing prior to the selection of field sites. The image for Northern Yukon (path 67 row 14) was essentially cloud free.

Terrain shadows were identified with models using unsupervised classifications and shaded relief images as inputs. The shaded relief images were produced in Erdas Imagine using USGS 1:63,360 scale Digital Elevation Models (DEMs). Sun azimuth and sun angle values for use in the shaded relief algorithm were obtained from the header file of the path 73 Landsat TM images. This allowed the shaded relief image to most closely mimic the terrain shadows present at the time of the Landsat TM image acquisition. The terrain shadow image contains values ranging from 0.0 to 1.0 with the most shaded areas equal to 0.0 and the brightest or least shaded areas equal to 1.0.

Terrain shadows were most often spectrally confused with earth cover classes that appeared very dark on the image, e.g. water, closed needleleaf, closed mixed needleleaf deciduous, and open needleleaf. An unsupervised classification was used to identify four spectral classes that confused terrain shadowed areas with these spectrally "dark" classes. The model then compared the pixels from these four spectral classes to the most shaded areas in the shaded relief image. If a pixel fell within one of these four classes and had a value less than .5 in the shaded relief image, it was labeled as a terrain shadow. Some additional on-screen digitizing was used to identify terrain shadowed pixels that were not identified by the modeling procedure. All the remaining "non-shadow" pixels were put back into the image for further iterations of unsupervised classifications that were used to identify earth cover classes.

Seeding Process

Spectral signatures for the field sites to be used as training areas were extracted from the imagery using a "seeding" process in Erdas Imagine. A pixel within each training area was chosen as a "seed" and adjoining pixels in the training site were evaluated for inclusion using a threshold value based on a spectral Euclidean distance. The standard deviations of the seeded areas were kept close to or below 2.5 and all seeded areas were required to be over 15 pixels (approximately 3.75 acres) in size. The output of the seeding process in Imagine was a signature file that contained all of the statistics for the training areas. The signature file was then used in the modified supervised/unsupervised classification.

Generation of Unsupervised Signatures

An unsupervised classification was generated using the six raw bands and the NDVI ratio. One hundred and fifty signatures were derived from the unsupervised classification using the ISODATA program in Imagine. The output of this process was a signature file similar to that of the seeding process but containing the 150 unsupervised signatures. A maximum likelihood classification of the 150 unsupervised signatures was generated using the supervised classification program in Imagine.

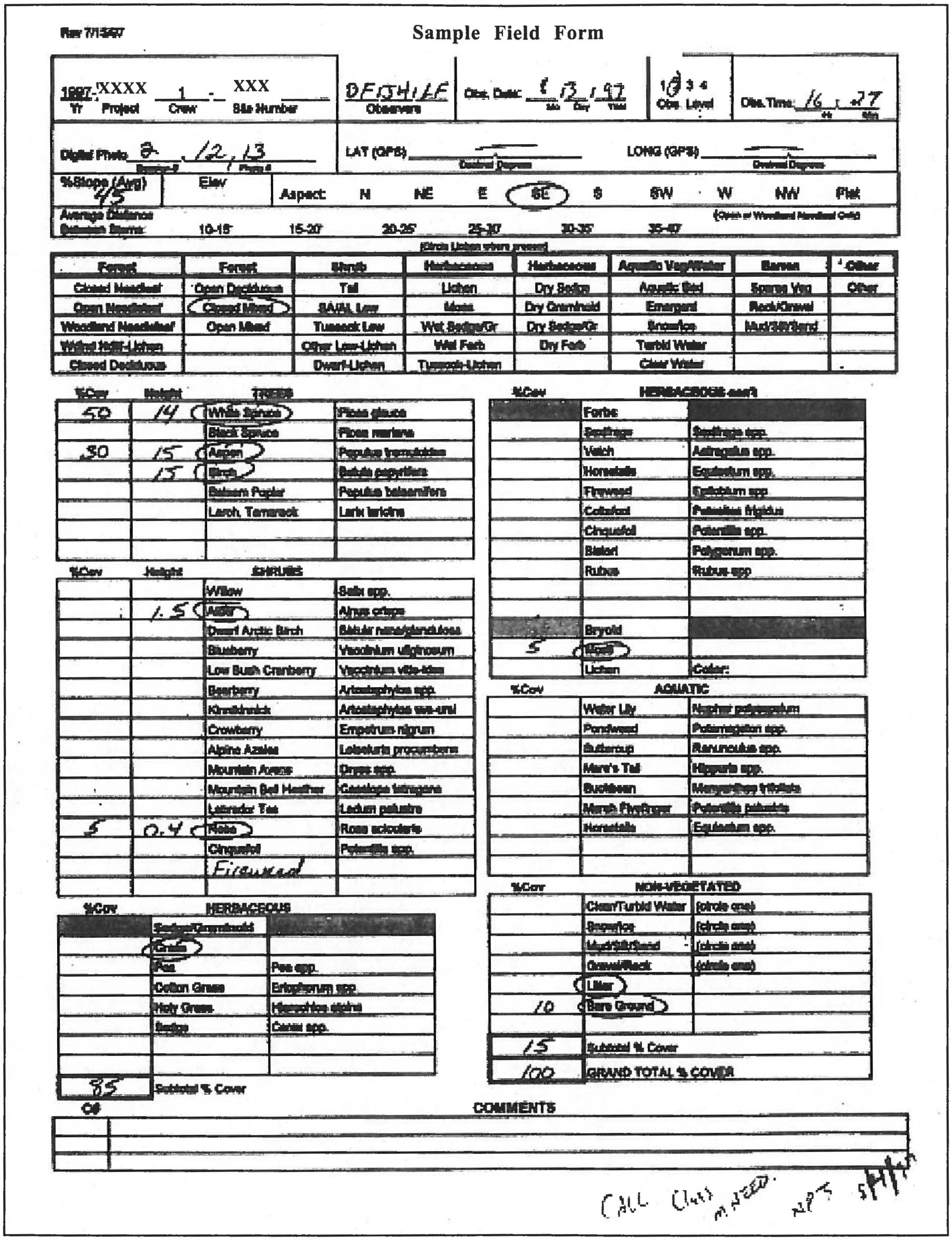
Modified Supervised/Unsupervised Classification

A modified supervised/unsupervised classification approach (Chuvieco and Congalton, 1988) was used for the classification. 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 classification approach provided three major benefits: (1) it aided in the labeling of the unsupervised classes by grouping them with known supervised training sites; (2) it helped to identify classes that possessed no spectral uniqueness (i.e., training sites that were spectrally inseparable); and (3) it identified areas of spectral reflectance present in the imagery that had not been represented by a training site. This approach was an iterative process because all of the supervised signatures do not cluster perfectly with the unsupervised signatures the first time. The unsupervised signatures that matched well with the supervised signatures were inspected, labeled with the appropriate class label, and removed from the classification process. The remaining confused clusters were grouped into general categories (e.g., forest, shrub, non-vegetation) and the process was repeated. This process continued until all of the spectral classes were adequately matched and labeled, or until the remaining confused classes were spectrally inseparable. Throughout this iterative process, interim checks of classification accuracy were performed by intersecting the classified image with a coverage of the training sites to determine if the training sites were being accurately labeled by the classification. Areas with incorrectly classified training sites were run through further iterations of the supervised/unsupervised classification and further refined. The iterative process of interim accuracy assessments and refining classifications was terminated when the accuracy assessments indicated no improvements between iterations.

Editing and Modeling

Models that incorporated ancillary data sets such as elevation, slope, aspect, shaded relief, or hydrography helped to separate confused classes. For instance, terrain shadow/water confusion was easily corrected by creating a model using a shaded relief layer derived from DEMs.

For this project, the final steps of the classification process were to model the confused classes remaining after the iterative supervised/unsupervised classification process and to make final edits in areas that still had classification errors. Editing of classification errors was a process of comparing the classified image to the raw



Rev 7/15/97

Sample Field Form

1997-XXXX 1 - XXX (Yr, Project, Crew, Site Number)	DEFJSHILF (Observers)	Obs. Date: 8/13/97 (Mo, Day, Year)	1 2 3 4 Obs. Level	Obs. Time: 16 : 27 (Hr, Min)
Digital Photo 8, 12, 13 (Session #, Photo #)	LAT (GPS) ____ Decimal Degrees	LONG (GPS) ____ Decimal Degrees		

%Slope (Avg) 4/5 | Elev | Aspect: N NE E (SE) S SW W NW Flat

Average Distance Between Stems: 10-15' 15-20' 20-25' 25-30' 30-35' 35-40' (Open or Woodland Needleaf Only)

(Circle Lichen where present)

Forest	Forest	Shrub	Herbaceous	Herbaceous	Aquatic Veg/Water	Barren	Other
Closed Needleaf	Open Deciduous	Tall	Lichen	Dry Sedge	Aquatic Bed	Sparse Veg	Other
Open Needleleaf	(Closed Mixed)	SA/AL Low	Moss	Dry Graminoid	Emergent	Rock/Gravel	
Woodland Needleleaf	Open Mixed	Tussock Low	Wet Sedge/Gr	Dry Sedge/Gr	Snow/Ice	Mud/Silt/Sand	
Wdlnd Ndlf-Lichen		Other Low-Lichen	Wet Forb	Dry Forb	Turbid Water		
Closed Deciduous		Dwarf-Lichen	Tussock-Lichen		Clear Water		

%Cov	Height	TREES	
50	14	(White Spruce)	Picea glauca
		Black Spruce	Picea mariana
30	15	(Aspen)	Populus tremuloides
	15	(Birch)	Betula papyrifera
		Balsam Poplar	Populus balsamifera
		Larch, Tamarack	Larix laricina

%Cov	Height	SHRUBS	
		Willow	Salix spp.
	1.5	(Alder)	Alnus crispa
		Dwarf Arctic Birch	Betula nana/glandulosa
		Blueberry	Vaccinium uliginosum
		Low Bush Cranberry	Vaccinium vitis-idea
		Bearberry	Arctostaphylos spp.
		Kinnikinnick	Arctostaphylos uva-ursi
		Crowberry	Empetrum nigrum
		Alpine Azalea	Loiseleuria procumbens
		Mountain Avens	Dryas spp.
		Mountain Bell Heather	Cassiope tetragona
		Labrador Tea	Ledum palustre
5	0.4	(Rose)	Rosa acicularis
		Cinquefoil	Potentilla spp.
		Fireweed	

%Cov	HERBACEOUS	
	Sedge/Graminoid	
	(Grass)	
	Poa	Poa spp.
	Cotton Grass	Eriophorum spp.
	Holy Grass	Hierochloe alpina
	Sedge	Carex spp.
85	Subtotal % Cover	

%Cov	HERBACEOUS cont'd	
	Forbs	
	Saxifrage	Saxifraga spp.
	Vetch	Astragalus spp.
	Horsetails	Equisetum spp.
	Fireweed	Epilobium spp.
	Coltsfoot	Petasites frigidus
	Cinquefoil	Potentilla spp.
	Bistort	Polygonum spp.
	Rubus	Rubus spp.
	Bryoid	
5	(Moss)	
	Lichen	Color:

%Cov	AQUATIC	
	Water Lily	Nuphar polysepalum
	Pondweed	Potamogeton spp.
	Buttercup	Ranunculus spp.
	Mare's Tail	Hippuris spp.
	Buckbean	Menyanthes trifoliata
	Marsh Fivefinger	Potentilla palustris
	Horsetails	Equisetum spp.

%Cov	NON-VEGETATED	
	Clear/Turbid Water	(circle one)
	Snow/Ice	(circle one)
	Mud/Silt/Sand	(circle one)
	Gravel/Rock	(circle one)
	(Litter)	
10	(Bare Ground)	
15	Subtotal % Cover	
100	GRAND TOTAL % COVER	

C# | COMMENTS

CALL Class mixed. NPS sh/fm

Figure 8. Example custom field data collection form.

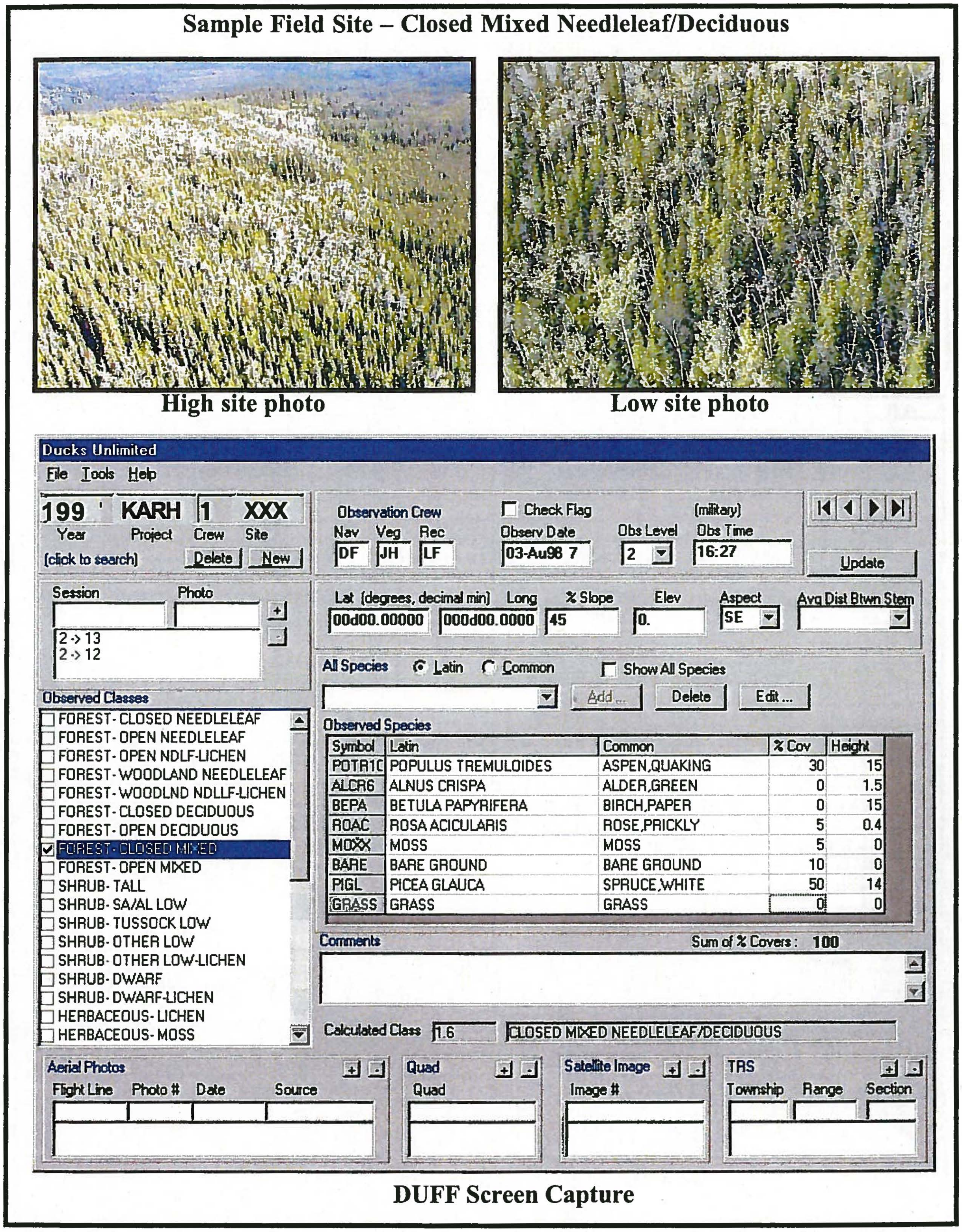


Figure 9. Ducks Unlimited Field Form (DUFF) Software, the customized database and user interface for field data entry.

satellite image, aerial photography, and notes on field maps to identify errors remaining in the classification. These errors were then corrected by manually changing the class value for the pixels that were classified in error to their correct class value.

Accuracy Assessment

There were two primary motivations for accuracy assessment: (1) to understand the errors in the map (so they can be corrected), and (2) to provide an overall assessment of the reliability of the map (Gopal and Woodcock, 1992). Factors affecting accuracy included the number and location of test samples and the sampling scheme employed. Congalton (1991) suggested that 50 samples be selected for each map category as a rule of thumb. This value has been empirically derived over many projects. A second method of determining sample size includes using the multinomial distribution and specifying a given confidence in the estimate (Tortora 1978). The results of this calculation tend to favorably agree with Congalton's rule of thumb. Once a sample size is determined, it must be allocated among the categories in the map. A strictly proportional allocation is possible. However, the smaller categories in area 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 sampling from only limited areas of the map.

Alaska Perspective

Obtaining adequate reference data for performing an accuracy assessment can be extremely expensive in remote areas. Aircraft is the only means of transportation throughout most of Alaska. Aerial photographs are available for most of Alaska, but most are at a scale that makes it difficult if not impossible to distinguish some vegetation classes. Ideally, fieldwork 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 in Alaska.

In this project, the fieldwork 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 preprocessing 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 (n=50) for the accuracy assessment. Some earth cover classes were naturally limited in size and distribution so that a statistically valid accuracy assessment sample could not be obtained without additional field time. For classes with low sample sizes few, if any, field sites were withheld for the accuracy assessment. This does not indicate that the classification for these types is inaccurate but rather that no statistically valid conclusions can be made about the accuracy of these classes. However, withholding even a small percentage of sites for the accuracy assessment provided some confidence in the classification and guided the image processor and end user in identifying areas of confusion in the classification.

Selection of Accuracy Assessment Sites

Approximately 30% of the collected field sites were set aside for use in the assessment of map accuracy while the remainder was utilized in the classification process. Unfortunately, given time and budget constraints it was not always possible to obtain enough sites per class to perform both the classification and a statistically valid accuracy assessment. A minimum of 15 sites in an individual class (5 for accuracy assessment, 10 for image processing training sites) was required before any attempt was made to assess the accuracy of that class. Classes with less than 15 field sites were still classified, but all field sites were utilized during the classification process and none were withheld for later use in accuracy assessment. Accuracy assessment sites were selected randomly across the project area to reduce bias. Although the study area for Southern Yukon MOA was processed as two individual pieces (path 66 and path 68), accuracy assessment sites were extracted from the total pool of field-visited sites from data collected in both the 1999 and 2000 field seasons. This resulted in some instances where less than 15 field sites for a particular mapping class were available for image classification but at least one or more accuracy assessment sites were selected for use with that particular image. An example from the path 66 image involves the inclusion of one "Open Aspen" accuracy assessment site while a total of only three "Open Aspen" field sites were available for use as image classification training sites.

Qualification of Accuracy Assessment Standards

While the accuracy assessment performed in this project was not a statistically robust test of the classification, it gives 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 the Northern Yukon project, the imagery was from 2000, the aerial photographs spanned a seventeen-year period from 1965 through 1982, and two different field crews in July/August 1999 and July/August 2000 collected the field data. For the Southern Yukon project, the imagery was from 1995 and 1999, the aerial photographs spanned a seven-year period from 1980 through 1987, and two different field crews in July/August 1999 and August 2000 collected the field data. Differences due to environmental changes from the different sources may impact the accuracy assessment. Primarily this affects the path 66 classification where several earth cover changes occurred throughout the study area during the 5 years between the acquisition date of the satellite imagery and the date of field data collection. These changes are most noticeable in areas of past fire activity, where the image shows the predominance of snags and litter that resulted from the fire, but the field data shows the presence of naturally occurring post-fire re-vegetation. Other changes result from river/stream channel meandering, and re-vegetation of formerly sparse or barren areas

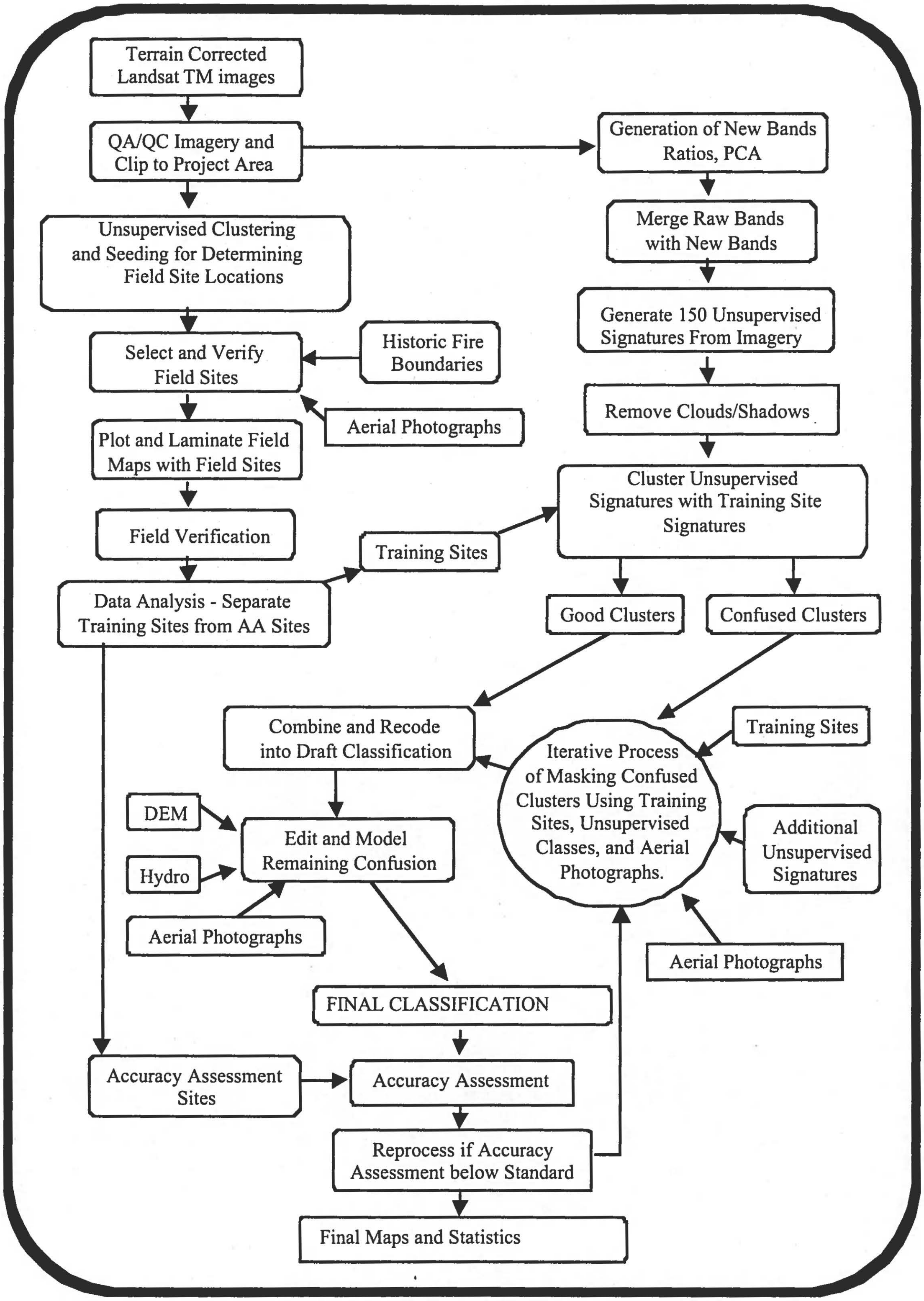


Figure 10. The image processing flow diagram.

such as gravel bars. The objective of this mapping project was to classify and map earth cover conditions as they existed at the dates of the satellite images: 1995 for the areas mapped with the path 66 imagery, and 1999 for the areas mapped with the path 68 imagery. Capturing field data in 2000 for training and accuracy assessment of 1995 imagery obviously results in the potential introduction of error and/or variation in human interpretation of land cover composition that may impact the reliability and consistency of the reference accuracy assessment and training site data.

A major assumption of quantitative accuracy assessment 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 errors (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.

In an effort to account for some of the variation in human interpretation in the accuracy assessment process, overall classification accuracies were also generated assuming a +/- 5% variation in estimation of vegetation compositions for each of the accuracy assessment sites. In other words, if a variation in interpretation of +/- 5% would have resulted in the generation of a different reference site label, this new label was also considered an acceptable mapping label for the reference site.

Error Matrix

The standard method for assessing the accuracy of a map was to build an error matrix, also known as a confusion matrix, or contingency table. The error matrix compares the reference data (field site) with the classification. The matrix was designed as a square array of numbers set out in rows and columns that expressed 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 represented the reference data while the rows indicated the classification (Lillesand and Kiefer, 1994). An error matrix was an effective way to represent accuracy in that the individual accuracy of each category was plainly described along with both the errors of inclusion (commission errors) and errors of exclusion (omission errors) present in the classification. A commission error occurred when an area was included in a category it did not belong. An omission error was excluding that area from the category in which it did belong. Every error was an omission from the correct category and a commission to a wrong category. Note that the error matrix and accuracy assessment was based on the assumption that the reference data was 100% correct. This assumption was not always true.

In addition to clearly showing errors of omission and commission, the error matrix was used to compute overall accuracy, producer's accuracy, and user's accuracy (Story and Congalton, 1986). Overall accuracy was allocated as the sum of 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.

Results – Northern Yukon

Field Verification

Data were collected on 364 field sites during 2-day field season in July/August 1999 and a 6-day field season in August 2000 (Figure 11). Daily flight time did not exceed 6 hours. The proportions of sites per class (Table 4) largely reflected the proportions of corresponding earth cover types within the project area, though proportionally more sites were collected for classes that exhibited greater variation in growth form and/or spectral response on the satellite imagery. Approximately 30% (103) of the total field sites were set aside for accuracy assessment and not used as training data in the image classification process.

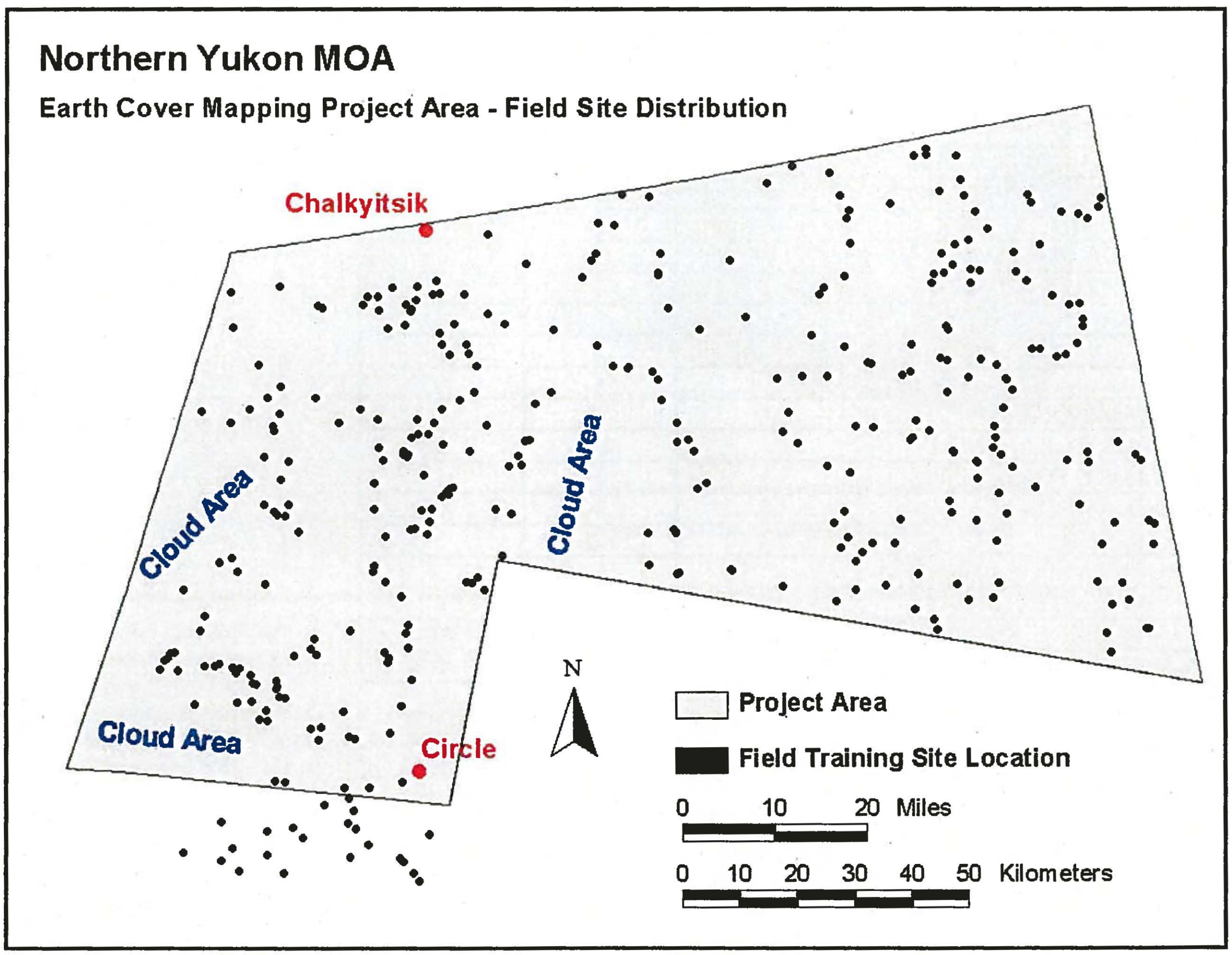


Figure 11. Distribution of field sites for Northern Yukon MOA project.

Table 4. Field sites and accuracy assessment sites per class for Northern Yukon MOA.

Class Name	Path 67 Total Field Sites per Class	Path 67 Sites Withheld for Accuracy Assessment
CLOSED NEEDLELEAF	18	5
OPEN NEEDLELEAF	66	21
OPEN NEEDLELEAF – LICHEN	3	0
WOODLAND NEEDLELEAF	33	11
WOODLAND NEEDLELEAF – LICHEN	19	5
CLOSED DECIDUOUS	23	7
CLOSED BIRCH	10	3
CLOSED ASPEN	18	6
OPEN DECIDUOUS	5	1
OPEN BIRCH	2	0
OPEN ASPEN	5	1
CLOSED MIXED NEEDLELEAF / DECIDUOUS	11	3
OPEN MIXED NEEDLELEAF / DECIDUOUS	10	3
TALL SHRUB	19	6
LOW SHRUB – OTHER	24	7
LOW SHRUB – LICHEN	0	0
LOW SHRUB – TUSSOCK TUNDRA	24	9
LOW SHRUB – WILLOW/ALDER	0	0
DWARF SHRUB – OTHER	4	0
DWARF SHRUB – LICHEN	0	0
LICHEN	1	0
MOSS	4	0
WET GRAMINOID	15	1
MESIC / DRY GRAMINOID	11	3
MESIC / DRY FORB	6	1
TUSSOCK TUNDRA	0	0
AQUATIC BED	10	3
EMERGENT VEGETATION	6	3
SPARSE VEGETATION	11	3
CLEAR WATER	0	0
NON-VEGETATED SOIL	5	0
ROCK GRAVEL	0	0
OTHER	1	1
TOTAL	**364**	**103**

A-Star helicopters were used to gain access to the field sites. For the field crew, during the 1999 field season, the field camp was located at a BLM bunkhouse in Central, from which barrel fuel was also available.

For the field crew, during the 2000 field season, the schoolhouse at Chalkyitsik was the field camp. A fuel bladder was available at Chalkyitsik and barrel fuel was stored at Circle and a remote fuel cache located in the southeastern portion of the project area.

Classification

34 earth cover classes were mapped in the final earth cover map (Figure 12). Table 5 presents the total acreage per class. Class acreage by ownership is presented in Appendix C, tables C1-C4. The three most extensive vegetative classes within the final classification were open needleleaf (25.15% of total area), closed mix needleleaf / deciduous (15.40% of total area), and woodland needleleaf (13.76% of total area).

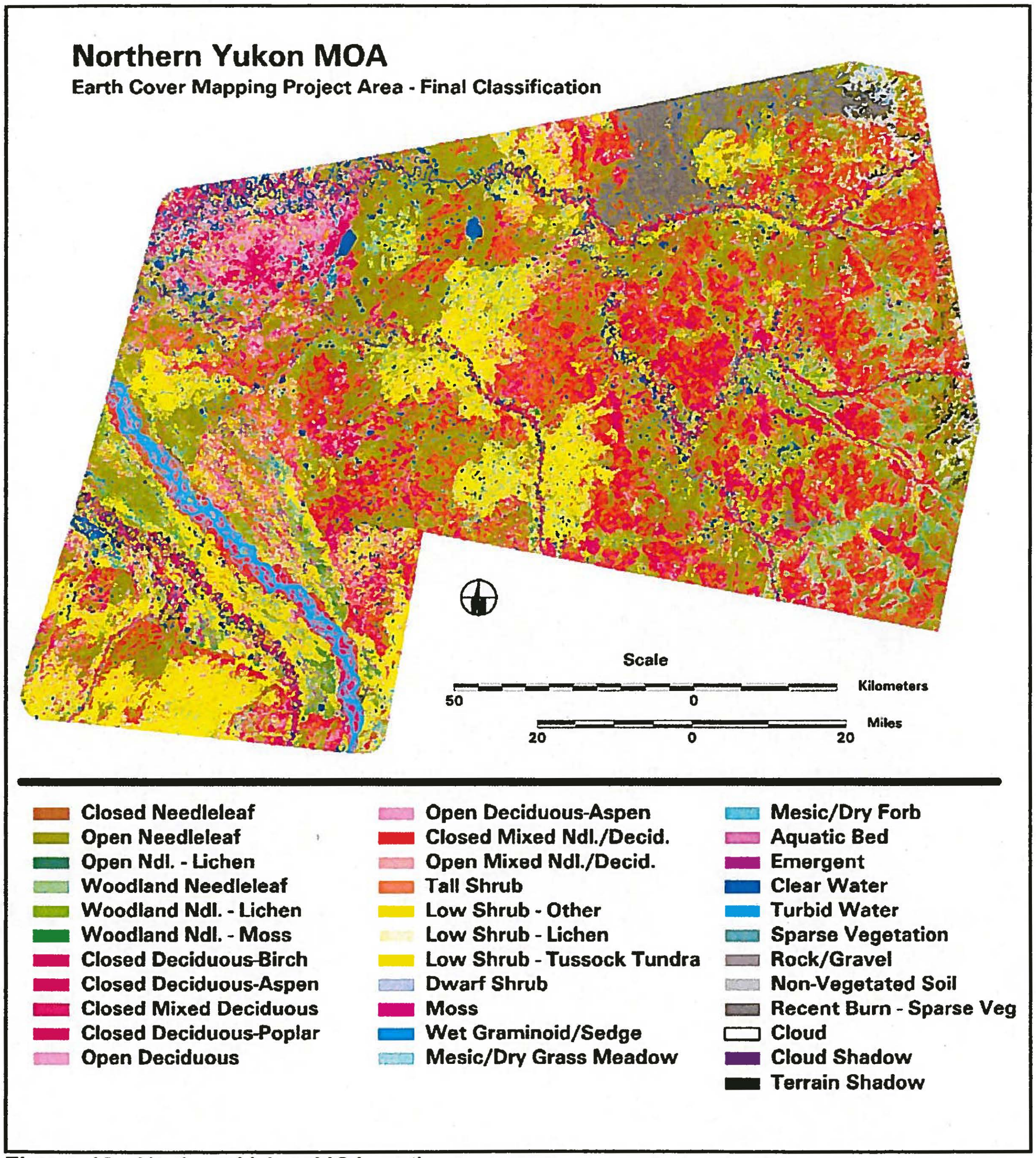


Figure 12. Northern Yukon MOA earth cover map.

Table 5. Acreage of earth cover classes within the project area.

CLASS NAME	ACRES	PERCENT COVER
Closed Needleleaf	179,084	4.21
Open Needleleaf	1,070,247	25.15
Open Ndl. – Lichen	9,636	0.23
Woodland Needleleaf	585,647	13.76
Woodland Ndl. – Lichen	26,126	0.61
Woodland Ndl. - Moss	16,178	0.38
Closed Birch	41,031	0.96
Closed Aspen	163,493	3.84
Closed Poplar	1,578	0.04
Closed Deciduous	160,390	3.77
Open Aspen	112,938	2.65
Open Deciduous	69,951	1.64
Closed Mixed Ndl./Decid.	655,169	15.40
Open Mixed Ndl./Decid.	136,940	3.22
Tall Shrub	123,802	2.91
Low Shrub – Other	392,449	9.22
Low Shrub - Tussock Tundra	117,591	2.76
Low Shrub – Lichen	924	0.02
Dwarf Shrub	20,850	0.49
Moss	3,305	0.08
Wet Graminoid / Sedge	21,049	0.49
Mesic / Dry Grass Meadow	12,655	0.30
Mesic / Dry Forb	11,862	0.28
Aquatic Bed	739	0.02
Emergent	12,823	0.30
Clear Water	105,500	2.48
Turbid Water	60,416	1.42
Sparse Vegetation	1,857	0.04
Rock/Gravel	1,046	0.02
Non-Vegetated Soil	1,718	0.04
Recent Burn – Sparse Vegetation	128,192	3.01
Cloud	103	0.00
Cloud Shadow	149	0.00
Terrain Shadow	10,019	0.24
Total	**4,255,457**	**100%**

This agrees with observations made during field data collection. Large expanses of open spruce interspersed with closed mix needleleaf / deciduous stands were typical of the project area, especially in the uplands. Open/woodland spruce and low shrub cover types were also found in the lowlands, along river corridors, and composed the regeneration vegetation of the fire scars throughout the project area.

Open and closed deciduous cover types were typically found on well-drained slopes, and on the broad alluvial plains of large rivers.

Open deciduous stands were also common in areas regenerating from fire disturbance. Aspen (*Populus tremuloides*) was by far the dominant deciduous tree on the broad alluvial plain just south of the Black River. In addition to aspen, paper birch (*Betula papyrifera*) stands were found on the well-drained slopes of the forested uplands and especially prevalent in the open deciduous stands of burn areas. Most of the mixed deciduous regions of the study area also contained a significant component of paper birch. Balsam poplar (*Populus balsamifera*) stands were less common and found exclusively along river flood plains and drainages.

Closed canopy needleleaf stands were primarily stands of large white spruce (*Picea glauca*) found along major river drainages. Occasionally white spruce stands on hillsides attained a closed canopy also. These were quite rare, however, and these typically exhibited canopy closures in the 60 to 65% range. Closed mixed needleleaf/deciduous stands also were found along river drainages and were common on the well-drained hillsides of the heavily forested uplands.

Closed mixed needleleaf / deciduous was the second most extensive class of this project area. There were three different growth forms of the open mixed needleleaf/deciduous class. The first included mature stands of large, openly spaced mixed spruce and deciduous trees typically found on well-drained, productive sites. The second was typically found in successional areas and consisted of openly spaced, smaller, sapling-sized spruce and deciduous trees. The third was similar in appearance to the second growth form, but was found on poorer sites. These appeared to be open needleleaf sites of marginal productivity with an encroachment of stunted birch and aspen scattered in with the more dominant spruce. The first growth form was the most common of the three and served as transition boundaries between purer stands of needleleaf and deciduous stands.

One of the more interesting earth cover categories to attempt to classify from the training site data provided was the Open needleleaf – lichen class. The challenges in consistently and accurately classifying this cover type originated from two sources. First, the spectral variation associated with the open needleleaf – lichen training sites was significant. Between the wide range of lichen composition in these forested stands and the varying slopes and aspects on which the stands were found to occur, spectral signatures characterizing this class were found to be confused with other cover types such as, but not limited to, dwarf shrub, open needleleaf, low shrub – other, sparse vegetation, and dry graminoid. Significant manual editing and multiple reclassifications using iterative unsupervised classification stratifications were utilized in an attempt to more accurately identify and represent this cover type in the final classification map. These efforts did narrow the majority of the spectral confusion to exist primarily between the open needleleaf, woodland needleleaf – lichen, and open needleleaf – lichen classes.

The aquatic bed, emergent vegetation, and wet graminoid classes were most commonly found in and around the innumerable ponds and lakes within the Yukon Flats NWR. They were also common around the lakes and ponds throughout flat lowlands in the remainder of the project area. There was wide variation in the spectral signatures of all three of these cover classes depending on the percentage of water present. When a high percentage of water was present, there was spectral confusion not only between these three classes, but also with the closed needleleaf, open needleleaf, and terrain shadow classes. The image was run through several iterations of unsupervised classifications to separate the aquatic classes from the needleleaf classes. This was somewhat successful in limited portions of the image, but a great deal of on-screen digitizing, using aerial photos as reference, was still needed to separate these classes across the rest of the image.

Wildland fire plays a significant role in the ecology of the project area and has significant impact on the vegetative regimes within the project area. The effect of fire on the landscape was evident in the spectral signatures detected by the Landsat TM imagery even many years after a fire burned through the area. The presence of post-fire snags and litter as well as patches of bare soil are the most likely cause of changes in spectral reflectance in these areas. The ability to collect suitable spectral data for vegetative regeneration in these areas is severely limited by several factors. First, snags and litter do not absorb any infrared wavelengths. In areas with significant percentages of snags and litter, the high reflectance in these wavelengths seems to overshadow the signatures of vegetation in the area. Second, vegetative succession occurs rapidly in many burned areas. Field data must be collected in very close proximity to the date of image acquisition, or significant discrepancies can occur between the vegetation represented by the field data and the vegetation represented by the spectral signatures within the image. Third, fires of many ages result in vegetative succession in many stages and with a variety of spectral reflectance. The ability to collect a suitable number of field sites to fully represent this wide range of spectral reflectance is not possible in the limited time allotted for field data collection without seriously reducing the number of field sites visited in the non-burned portions of the project area. However, as the processing of the field training site data and satellite imagery proceeded for this project, it became evident that achieving a consistent and reliable land cover classification within most of these recent burn areas was possible, except for the most recent burn area in the northeastern portion of the project area. The entire burn area of the most recent burn was classified as sparse vegetation. Field observations of this area had revealed that bare soil was still present and vegetation regeneration had just begun (Figure 13). No attempt was made to separate out the other burn areas into a specific category of their own. Instead, the land cover within the burned regions was classified directly into the existing earth cover mapping classes. These classes consisted primarily of four primary classes: low shrub – other, low shrub – tussock tundra, open mixed deciduous, and tall shrub. The age and severity of the burn tended to dictate which earth cover class was present at the time of the image acquisition. For instance, the younger burns were characterized primarily as a low shrub – other type while older burns generally contained a greater birch component that was best characterized as an open mixed deciduous type.

By far, the most complicating factor in the derivation of this earth cover type map was presence of recent wildfire activity. Approximately 500,000 acres had evidence

Figure 13. Example of recent burn area classified as sparse vegetation.

of a burn. of the 500,000 acres, about 128,000 acres were classified as a burn class, and the remaining acres were classified directly into the existing earth cover mapping classes. Spectral confusion between nearly every land cover class was found to exist at some point within these burn areas.

Modeling

Modeling was performed using shaded relief, slope and elevation images derived from USGS DEMs at 1:63,360 scale. The shaded relief image was created in Erdas Imagine using the solar azimuth and solar elevation listed in the header file for the path 67 TM image. Grouping the DEM into 250 ft. elevation zones created the elevation layer. The slope image was created using the "Slope" function in Erdas Imagine. The slope unit was defined as percent slope rather than degree of slope. This allowed for ease of comparison with the field site data sets in which slope was also estimated as percent slope. It is important to note that the modeling process was used primarily to identify *potentially* misclassified cover types throughout the study area. In order to maximize the reliability and classification accuracy in this mapping effort, manual review and editing techniques were utilized to correct the misclassified pixels to their appropriate mapping classification.

Approximately 10,000 acres or approximately 0.24% (Table 5) of the project area was modeled and edited to the terrain shadow class. Other portions of the image were affected by shadows, but not completely blackened by those shadows. The majority of these areas were labeled with an earth cover class, but some areas were too dark to discriminate. Attempts were made to classify any areas that showed even a small degree of spectral reflectance, but it was left up to the image processor's judgement whether or not to edit the shadowed area into the terrain shadow class. Due to the small area of mountainous uplands, an elevation model was not needed to determine the treeline.

The slope image was also used in the modeling process. Several unsupervised signatures exhibited spectral confusion between the low shrub and low shrub – tussock tundra earth cover classes. Tussock tundra is typically found only on poorly drained soils over permafrost on flats and gentle slopes of less than 10% gradient (Viereck *et al*, 1992). A model that utilized the slope image labeled pixels that were classified by these spectrally confused unsupervised signatures. Pixels that had a slope of less than 10% were labeled either low shrub – tussock tundra or tussock tundra, while pixels with slope greater than or equal to 10% were labeled low shrub.

Editing

Due to the relatively smaller size of the study areas of the Northern Yukon MOA, manual editing techniques were employed to a greater degree than spatial modeling in this project. Although spatial modeling is very effective at identifying and "flagging" potential erroneously classified pixels throughout the image very quickly, specific visual inspection and manual editing of these "flagged" pixels is generally the most effective and accurate method for achieving the final desired mapped results. Editing was performed on all classes to various extents depending on how well the iterative classification and modeling processes worked for each. The edits were verified with field sites, aerial photography and field notes wherever possible. Some editing centered on ecological differences across the project area. For example, a single signature classified low shrub in the lower lying areas and dwarf shrub in the higher elevation regions of the study area. Editing in this case consisted of correctly labeling and separating classes along ecological boundaries. Because the project area was relatively diverse, this kind of editing was often necessary.

Editing was also required to classify areas that fell in the middle of the gradient between one class and another, e.g., between woodland needleleaf and shrub. A woodland area of 10-15% trees was easily confused with a shrub area of 5-9% trees. The most prevalent example of the confusion within the gradient between classes was found between woodland needleleaf and low shrub - other. As evidenced by the field training sites, a large number of the open and woodland needleleaf classes exhibited a tree crown cover between 5% and 15%. Similarly, as discussed earlier, low shrub areas at a height of 0.3 meters were confused with dwarf shrub areas with a height of 0.2 meters. These transitional areas and signatures had to be examined and a classification decision made based on the available data.

In some cases, a single pixel fell across two cover types, for example, between a lake and the land surrounding it. These half-water, half-land signatures were often confused with emergent and open needleleaf signatures. Many of the small lakes and ponds had a 1 pixel wide ring of open needleleaf surrounding them in the classified map after the combined supervised/ unsupervised classification was completed. Editing was done to separate legitimate emergent, and open needleleaf pixels based on aerial photography, field notes and topography. While great effort was put forth to rectify this phenomenon, undoubtedly, some lakes and ponds in the final classification may contain an erroneous scattering of open needleleaf pixels surrounding their shores. The wet graminoid and emergent classes were also heavily edited based on aerial photography and field notes. These cover types commonly required extra editing because they were generally both limited in extent and highly variable. Emergent vegetation typically occurred in narrow strips, often only a few pixels wide, making it very difficult to obtain reliable ground samples. Wet graminoid sites were more extensive and common, but they were highly variable with respect to spectral reflectance. Small differences in soil moisture content, density of vegetation, and the proportion of senescent plants drastically affected the reflectance values. Standing water created a very dark signature, while senescent plants created a very bright signature. Wet graminoid signatures were confused with a wide variety of other cover types including open needleleaf, open and closed mixed needleleaf/deciduous, low shrub, emergent, moss, dwarf shrub, and even open and closed deciduous. Each of these conditions was edited manually to ensure consistency and reliability in the final representation of each affected class.

A final case of spectral classification confusion involved the misclassification of open mixed needleleaf/deciduous pixels in areas of woodland needleleaf that exhibited a dense low and tall shrub understory. The mix of the sparse needleleaf trees and the deciduous shrubs mimicked the spectral signatures of the open mixed needleleaf/deciduous training sites. This confusion was widespread, but within relatively small areas was consistent. That is, the signature would class mostly woodland needleleaf areas in one section of the image, but would class mostly open mixed needleleaf/deciduous areas in another section of the image. This confusion was corrected via manual editing utilizing photo-interpretation and review of specific field notes and photos.

Accuracy Assessment

Some earth cover classes were not adequately represented in the field data available for training and accuracy assessment, primarily because of their scarcity within the project area, e.g., low shrub-lichen, open needleleaf – lichen, open deciduous, open mixed needleleaf / deciduous, moss, wet/dry graminoid, lichen, aquatic bed, and emergent. In the past, classes with an inadequate sample size were collapsed into the next hierarchical cover type for accuracy assessment of the classification. This grouping often resulted in only 8-10 accuracy assessment classes vs. the 30+ classes present in the classification. In addition, this approach grouped classes based solely on their specific mapping class labels versus grouping individual sites based on their ecological composition or function. By grouping classes in this manner, one loses all ability to evaluate and measure the relationship between regions of the map that classify nicely into the "heart" of a mapping class and those regions that occur on the classification and ecological boundaries between the discrete mapping classes. For example, at field site #533 the vegetation caller interpreted the site to contain 60% total tree (black spruce) cover, and 40% various shrub and herbaceous understory species). This interpretation results in a closed needleleaf label for the site. The final classified map labeled the majority of this as open needleleaf. The error matrix would tally this label as an incorrect label. Since the literature generally accepts that even the most experienced visual estimates of earth cover consider a range of variation in interpretation of +/-10% to be acceptable, this particular accuracy assessment site containing 60% needleleaf tree cover would also be considered acceptably classified as open needleleaf if only a 5% variation in the amount of black spruce tree cover was considered. Evaluating the earth cover classification in this manner provides the end user with a more realistic measure of reliability of the classified map as it relates to the actual continuum of vegetation composition as compared to simply lumping mapping classes for evaluation based on their discrete class name.

The error matrix provided in Appendix E represents the reliability/accuracy of the earth cover classification. The error matrix presents values for user's accuracy, producer's accuracy, and the overall accuracy for 0% and +/-5% variation in the vegetation caller's interpretation of the reference data. In the error matrix, numbers along the main diagonal of the matrices indicate exact matches between the reference labels and map labels of the accuracy assessment sites. A tally of these numbers divided by the total number of sites indicates the overall accuracy of the map at the 0% variation in interpretation level. If two numbers occupy a non-diagonal cell, the left number indicates an acceptable match between the reference data site and the map assuming a +/- 5% variation in reference data interpretation. The number on the right indicates the number of sites that are not acceptable matches. A tally of the numbers within the diagonal along with the acceptable numbers in the off-diagonal cells (left number(s)) indicates the overall accuracy of the map at the +/- 5% variation in interpretation level.

A number of important analyses can be made regarding the relationship of the mapped data with the actual vegetation distributions throughout the study area using this method of accuracy assessment. Since the off-diagonal acceptable matches are presented, an indication of the number of field sites that represent vegetation compositions on the boundary of two or more mapping classes is given. The acceptance or non-acceptance of each accuracy assessment site with an off-diagonal map class provides insight into the vegetation composition of that reference site. For instance, in Appendix E, of the five accuracy assessment sites with a reference label of closed needleleaf, one site was an acceptable match with open needleleaf – lichen and one was a non-acceptable match with open needleleaf - lichen. The remainder of the sites (4) was diagonal matches with closed needleleaf. The off-diagonal matches indicate that at least one of those sites was on the border between closed needleleaf and open needleleaf. Similarly, since the number of misclassified sites is still indicated in the matrix, a user can determine in which classes the map is least reliable and with which mapping classes the unreliable classes are confused.

Path 67 Accuracy Assessment

The difference in classification accuracy between the 0% variation in interpretation level, 77.67% (Appendix E), and the +/- 5% variation in interpretation level, 85.44%, indicates that a number of the reference data sites were characterized as being on the boundary of two or more mapping classes. As stated earlier, it is generally accepted that variation in interpretation of +/- 10% is common and accepted for human interpreters estimating vegetative crown cover, either from aerial photography or on the ground. When this natural and accepted variation is measured and accounted for (as in the case of the error matrix in Appendix E), a more reliable and informative measure of accuracy and reliability is presented.

At the +/- 5% level of variation the accuracy of all needleleaf classes was 71% - 94%. Producer's accuracy of the open needleleaf class was 71%. The lower accuracy for open needleleaf was due to the different growth stages of black and white spruce (*Picea glauca and Picea mariana)*. This project area had stands of open white spruce over 20 meters tall. Figure 14 displays the shadows that taller, more robust needleleaf stands can create. Taller, open needleleaf stands can become confused with closed needleleaf due to a darker signature resulting from shadowing. Open needleleaf was also similar to woodland needleleaf class in its confusion with a variety of other cover classes. This is a result of very mixed spectral signatures that were dominated by understory species, such as moss, lichen, and tall shrub.

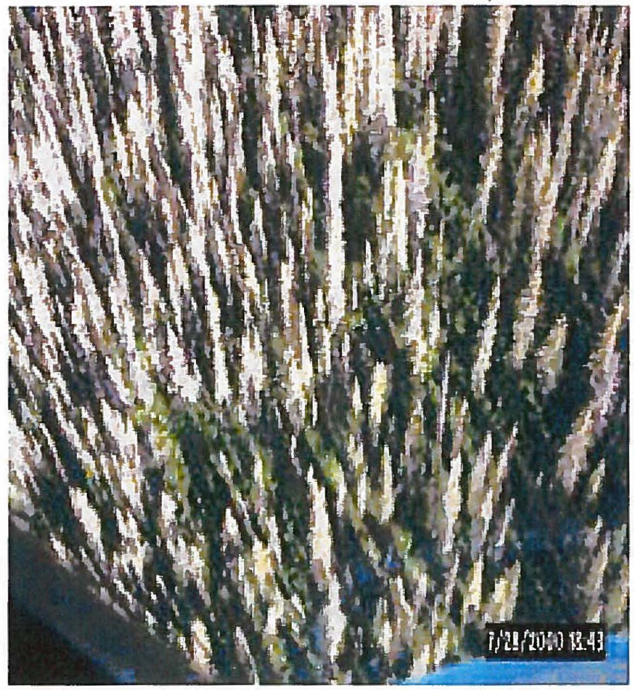


Figure 14. Example of shadowing within open needleleaf stand.

The open and closed deciduous classes had somewhat lower accuracy than the needleleaf classes in general. This is consistent with past earth cover mapping projects in other parts of Alaska and results from confusion within the deciduous earth cover classes. Only two accuracy assessment sites were available for the open deciduous class, of which, one site was confused with closed deciduous class because of its tall shrub under story. If these two mapping classes were combined into one general deciduous class, the accuracy would be 72% (13/18) at the 0% level of variation and 88% (16/18) at the +/- 5% level of variation. Most of the confusion with non-deciduous classes occurred with mixed needleleaf/deciduous classes and with the tall shrub class.

Closed mixed needleleaf/deciduous was the second most extensive vegetative class in the final classification (see Table 5), but because of the small sample size for this class the figures may be unreliable. A producer's accuracy of 100% and user's accuracy of 75% for closed mixed needleleaf/deciduous may indicate that too much area is being labeled as closed mix on the map. In general, there appears to be too much closed mixed needleleaf/deciduous and too little open mixed needleleaf/deciduous in the final map. As with the pure deciduous classes, much of the confusion in these classes can occur between the open and closed mixed classes, and not with other cover types. In addition to the confusion within the closed mixed needleleaf/deciduous class there is also some confusion with the open and closed needleleaf classes.

Although each of the shrub classes had very acceptable accuracy assessment results, it is observed from the number of off-diagonal elements along the map data row for low shrub – other that some tendency for potential over-classification of low shrub exists in the map data. The low shrub – other and low shrub – tussock classes were difficult to map because of the wide variability of the project area and regenerating fire scars. The producer's accuracy for both low shrub – other and low shrub – tussock exceeded 85% at the 0% variation. But the user's accuracy dropped to 67% for low shrub – other. This confusion could stem from the spectral variation of the regenerating vegetation of the fire scars in the project area. Figure 15 demonstrates a circumstance where an accuracy assessment site is characterized as closed aspen but is mapped as low shrub - other. In this example, 65% of the ground cover is characterized as aspen with an average height of 3 meters, but 10% of the cover is dead aspen snags left standing from a previous fire. The presence of post-fire snags and litter are the most likely cause of changes in the spectral reflectance of this site as throughout the image. This example again, reinforces the significant role that wildfires play in the ecology of the project area and its significant impact on the vegetative regimes within the project area.

Field sites were limited for several cover types and few or no accuracy assessment sites were reserved for the following classes: wet graminoid, moss, mesic/dry herbaceous, aquatic bed, emergent vegetation, and sparsely vegetated.

Figure 15. Example of regenerating aspen stand with post-fire snags.

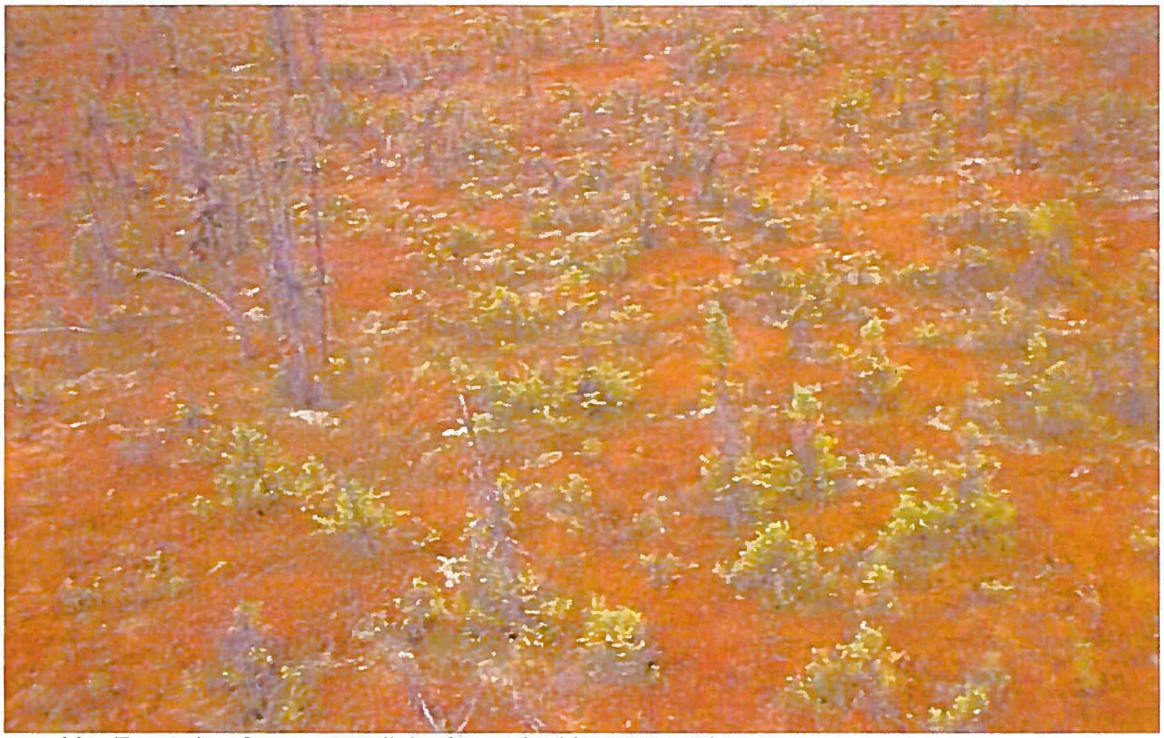


Figure 16. Example of open needleleaf stand with moss understory.

The bryoid class has a distinct signature that can be accurately classified. The most difficult aspect of identifying moss areas is their limited size. Moss sites were typically dominated by sphagnum mosses and were found the spruce bogs of the lowlands and in the small, drained lakebeds and ponds. The small size of the moss areas resulted in many of the pixels containing mixed signatures of moss and whatever earth cover type happened to be surrounding the moss, typically low shrub or woodland needleleaf. These "mixed" pixels would sometimes classify as moss and sometimes woodland needleleaf or open needleleaf. One open needleleaf accuracy assessment site (site 1826) had such a strong moss component (45% of cover) the moss signature dominated the signature of the developing 1 meter high black spruce which covered 35% of the site (Figure 16). Sites with high water content can be confused with emergent or wet graminoid sites. It should be noted that no field sites, and therefore no accuracy assessment sites, were captured representing the clear water or turbid water classes. These classes are among the most straightforward to discriminate and map from Landsat TM satellite imagery. Therefore, the limited field data collection time was focused on capturing data to assist in the discrimination and mapping of the more spectrally and ecologically complex vegetation communities throughout the study area. These two mapping classes accounted for less than 5% of the earth cover within the project area. Due to their spectral distinctiveness, it is certain that both the user's and producer's accuracy for these classes would be at or very near 100%, thus only acting to improve the overall accuracy calculations for the final earth cover map.

Results – Southern Yukon

Field Verification

Data were collected on 320 field sites during 5-day field season in July/August 1999 and a 7-day field season in August 2000 (Figure 17). 176 sites were in the area covered by the path 66 image. 187 sites were on the path 68 image. Approximately 44 sites were covered on both the path 66 and the path 68 imagery. Daily flight time did not exceed 6 hours. The proportions of sites per class (Table 6) largely reflected the proportions of corresponding earth cover types within the project area, though proportionally more sites were collected for classes that exhibited greater variation in growth form and/or spectral response on the satellite imagery. It is important to note that approximately 20 – 25 field sites that were located within the area of overlap of the path 66 and path 68 satellite images were utilized as classification training sites on *both* the path 66 and path 68 images. The dual use of these sites is reflected in the total number of training sites presented in Table 6. Approximately 30% (94) of the total field sites were set aside for accuracy assessment and not used as training data in the image classification process.

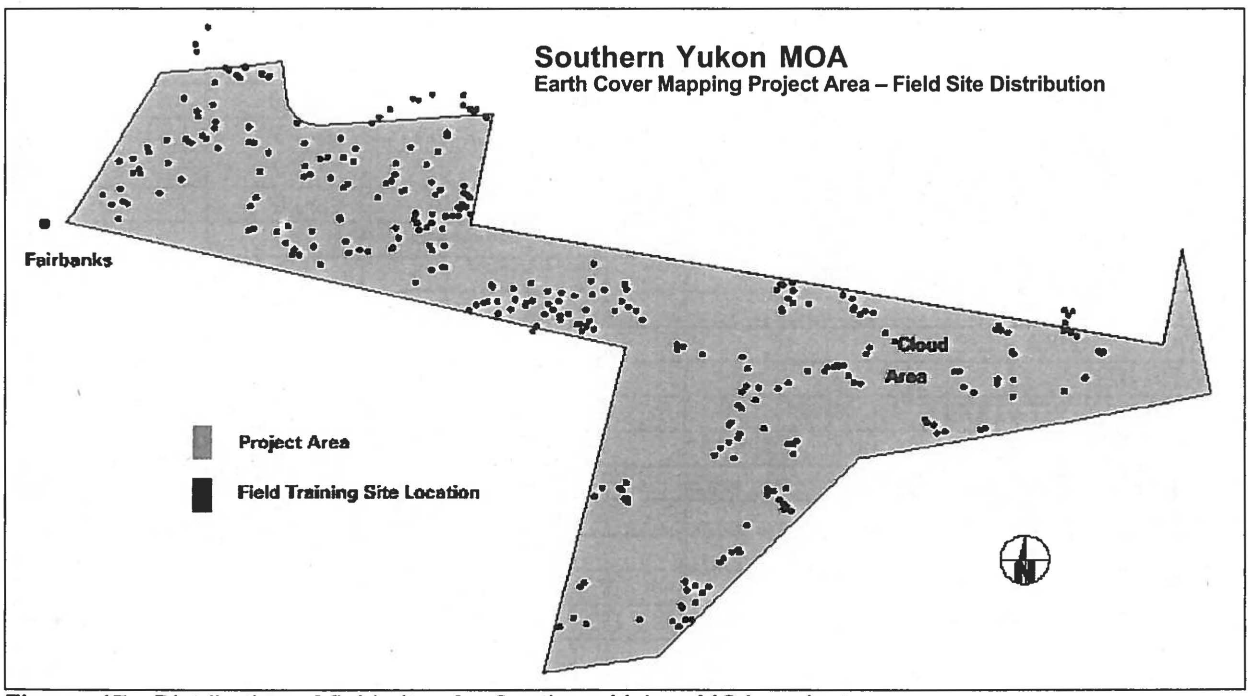


Figure 17. Distribution of field sites for Southern Yukon MOA project.

Table 6. Field sites and accuracy assessment sites per class for Southern Yukon MOA.

Class Name	Path 66 Total Field Sites per Class	Path 66 Sites Withheld for Accuracy Assessment	Path 68 Total Field Sites per Class	Path 68 Sites Used for Accuracy Assessment
CLOSED NEEDLELEAF	1	0	5	0
OPEN NEEDLELEAF	40	10	22	8
OPEN NEEDLELEAF – LICHEN	3	1	11	4
WOODLAND NEEDLELEAF	13	1	27	10
WOODLAND NEEDLELEAF – LICHEN	1	0	4	0
CLOSED DECIDUOUS	3	1	8	3
CLOSED BIRCH	6	3	16	5
OPEN DECIDUOUS	5	2	2	1
OPEN BIRCH	2	0	3	0
CLOSED ASPEN	1	0	1	0
OPEN ASPEN	4	1	1	0
CLOSED MIXED NEEDLELEAF / DECIDUOUS	1	0	7	2
OPEN MIXED NEEDLELEAF / DECIDUOUS	6	1	11	3
TALL SHRUB	5	1	11	3
LOW SHRUB – OTHER	40	13	14	4
LOW SHRUB – LICHEN	0	0	2	0
LOW SHRUB – TUSSOCK TUNDRA	11	3	0	0
LOW SHRUB – WILLOW/ALDER	0	0	1	0
DWARF SHRUB – OTHER	15	5	10	5
DWARF SHRUB – LICHEN	0	0	3	0
LICHEN	0	0	0	0
MOSS	1	0	0	0
WET GRAMINOID	1	0	0	0
MESIC / DRY GRAMINOID	1	0	1	0
TUSSOCK TUNDRA	2	0	1	0
TUSSOCK TUNDRA – LICHEN	0	0	0	0
AQUATIC BED	0	0	0	0
EMERGENT VEGETATION	1	0	0	0
SPARSE VEGETATION	4	0	2	0
CLEAR WATER	0	0	0	0
NON-VEGETATED SOIL	1	0	1	0
ROCK GRAVEL	7	2	5	1
OTHER	0	0	0	0
TOTAL	**175**	**44**	**169**	**49**

A-Star helicopters were used to gain access to the field sites. For the field crew, during the 1999 field season, the field camp was located at Chena Hot Springs Lodge, from which commercial fuel was also available.

For the field crew, during the 2000 field season, field camps were located at the BLM bunkhouse in Chicken and Kelly's Country Inn in Delta Junction. A fuel truck was with the crew throughout the project.

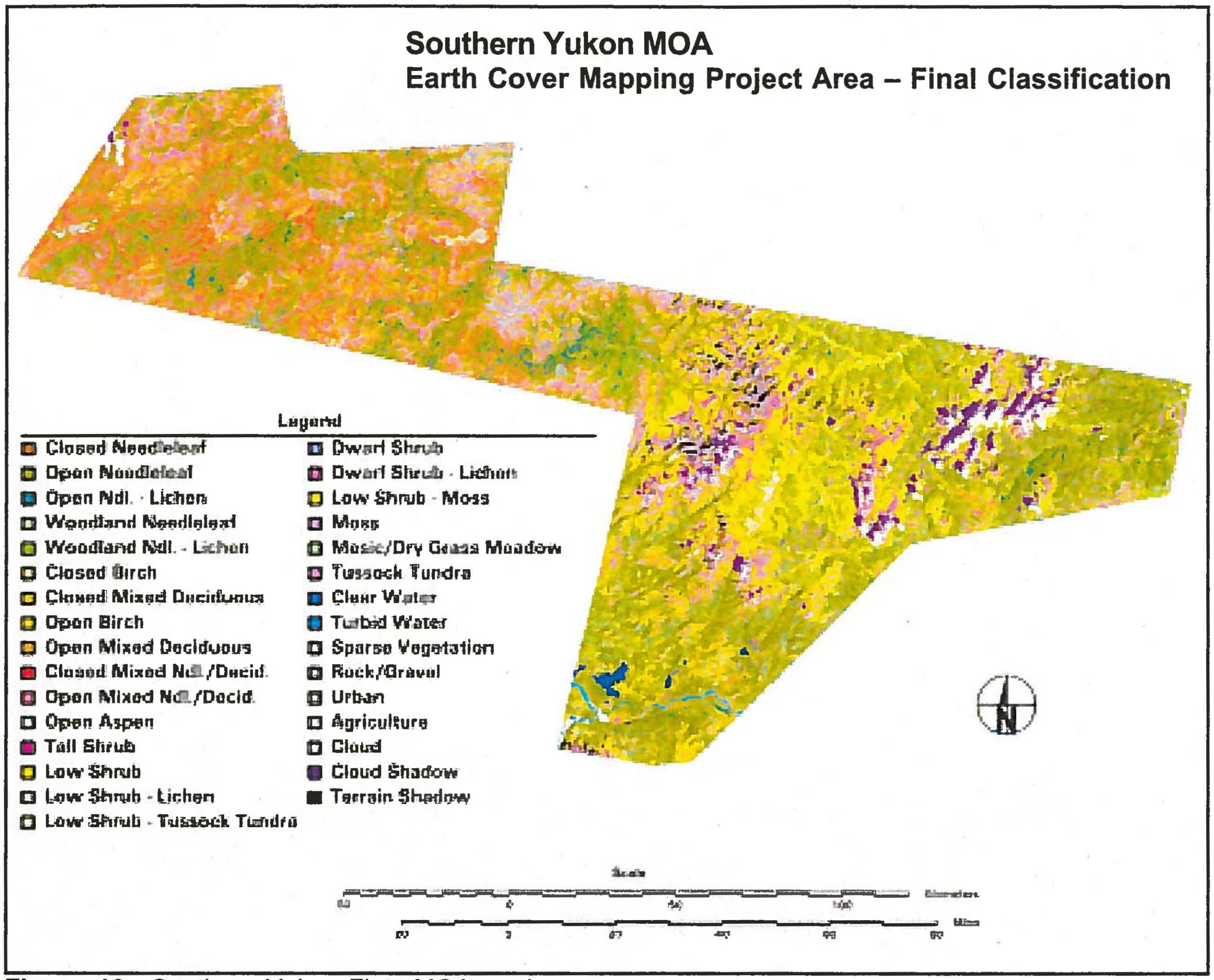


Figure 18. Southern Yukon Flats MOA earth cover map.

Classification

Thirty-one earth cover classes were mapped in the final earth cover map (Figure 18). Table 7 presents the total acreage per class. Class acreage by ownership is presented in Appendix C, tables C5-C8. The three most extensive vegetative classes within the final classification were open needleleaf (34.14% of total area), low shrub (15.54% of total area), and woodland needleleaf (11.02% of total area). This agrees with observations made during field data collection. Large expanses of open/woodland spruce interspersed with low shrub were typical of the project area, especially at lower elevations. Tussock tundra and low shrub tussock tundra cover types were also found on relatively flat areas and toe slopes at higher elevations where soil types appeared to be wetter.

Dwarf shrub, low shrub, tall shrub, sparse vegetation, rock/gravel, and dwarf shrub cover types characterized the mountainous uplands. There was difficulty in discriminating between dwarf shrub and dwarf shrub – lichen cover types as well as between low shrub and dwarf shrub. Most training sites for both dwarf shrub cover types included high percentages of rock, which dominated the signature and made it difficult to separate the two classes. In addition, several of the dwarf shrub lichen sites were on steep, shaded, north or west facing slopes which made it difficult to obtain signatures that were consistent with other portions of the image. Similarly, many of the training sites characterizing low shrub sites at higher elevations described shrubs generally between 0.2 and 0.3 meters in height. The propensity of shrub height directly on the boundary between dwarf and low shrubs often resulted in two sites that compositionally and spectrally appeared very similar but often contained differing mapping class labels (i.e. low shrub and dwarf shrub).

Open and closed deciduous cover types were typically found on well-drained slopes, and on the broad alluvial plains of large rivers. Open deciduous stands were also common in areas regenerating from fire disturbance. Paper birch (*Betula papyrifera*) was by far the most common deciduous tree. Even most of the mixed deciduous regions of the study area contained a significant component of Paper Birch. Because of the late season image acquisition of the path 66 imagery (September 17) the birch and mixed deciduous stands had at least reached their full senescence if not lost their leaves completely. This resulted in some consistent spectral confusion between hosts of other cover types depending on the aspect on which the deciduous stands were growing. In some cases, many of the closed birch stands spectrally resembled dwarf shrub sites found at alpine elevations. In addition to birch, aspen (*Populus tremuloides*) stands were found on the most well drained slopes, especially in recently burned areas. Closed canopy needleleaf stands were primarily stands of large white spruce (*Picea glauca*) found along major river drainages. Occasionally white spruce stands on hillsides attained a closed canopy also. These were quite rare, however, and these typically exhibited canopy closures in the 60 – 65% range. Closed mixed needleleaf/deciduous stands also were found along river drainages and were common on hill slopes.

One of the more interesting earth cover categories to attempt to classify from the training site data provided was the open needleleaf – lichen class. The challenges in consistently and accurately classifying this cover type originated from two sources. First, the spectral variation associated with the open needleleaf – lichen training sites was significant. Between the wide range of lichen composition in these forested stands and the varying slopes and aspects on which the stands were found to occur, spectral signatures characterizing this class were found to be confused with other cover types such as, but not limited to, dwarf shrub, open needleleaf, low shrub – other, sparse vegetation, and dry graminoid. Significant manual editing and multiple reclassifications using iterative unsupervised classification stratifications were utilized in an attempt to more accurately identify and represent this cover type in the final classification map. These efforts did act to at least narrow the majority of the spectral confusion to exist primarily between the open needleleaf, woodland needleleaf – lichen, and open needleleaf – lichen classes.

The second factor influencing the overall consistency of the open needleleaf – lichen class was the discrepancy between the number of field training sites labeled as open needleleaf – lichen for the path 66 and path 68 image data sets. As seen in Table 6, a total of 11 open needleleaf – lichen field sites were established in the path 68 imagery while only three such sites were established within the boundary of the path 66 imagery. This fact alone would account for some amount of inequality of the occurrence of this land cover class between the two dates of imagery that were, of course, processed separately using only the field training sites established within their respective boundaries. A great attempt was made to rectify this potentially artificial representation of this land cover class by extensive manual editing and localized reprocessing within both dates of imagery to assure that this land cover type was not inaccurately over- or under-represented in one scene or the other. The histograms from the two classifications from each image date seem to indicate that a reasonably consistent and reliable balance was achieved.

This same phenomenon can be seen with the training site distribution for several other land cover types including the open needleleaf, woodland needleleaf, closed birch, and low shrub – tussock tundra cover types. However, undoubtedly the most significant discrepancy in distribution of training sites for a particular cover type class is found in the low shrub – other class. As seen from Table 6, a total of 40 field sites were characterized as low shrub – other was available for the path 66 image as compared to 14 for the path 68 image. Judging from the fact that the opposite trend seems evident in the woodland class (i.e. more than twice as many woodland sites described in the path 68 image than the path 66 image), it appears that vegetation interpreters for the path 66 image tended to characterize sparsely forested areas as low shrub vs. interpreters completing field work for the path 68 image describing these areas as predominately forested (woodland). With a vast preponderance of the low shrub sites vs. woodland sites being established for the path 66 image, it is not unexpected to have such a phenomenon result in a significant increase in low shrub classification in the path 66 image vs. the path 68 image. This is borne out in the histograms for the individual image classifications: almost 21.5% of path 66 was classified as low shrub – other as compared to just over 7.5% of path 68 being classified as low shrub – other. However, along with the increase in total field sites in the cover type class comes a proportional increase in accuracy assessment sites for the class (13 for path 66 vs. 4 for path 68). The results of the accuracy assessment analysis (discussed below) indicate that the perceived "over-classification" of low shrub – other in the path 66 image is, according to the field-characterized accuracy assessment sites, legitimate.

The aquatic bed, emergent vegetation, and wet graminoid classes were essentially non-existent within this study area. Only one wet graminoid and one emergent vegetation training site was established throughout the entire study area. However, these two training sites were unable to closely identify spectrally with the spectral response on a per-pixel basis enough to confidently classify any areas as either of these two land cover classes. As a result, no pixels were classified as either wet graminoid or emergent vegetation within the project area.

Wildland fire plays a significant role in the ecology of the project area and has significant impact on the vegetative regimes within the project area. The effect of fire on the landscape was evident in the spectral signatures detected by the Landsat TM imagery even many years after a fire burned through the area. The presence of post-fire

Table 7. Acreage of earth cover classes within the project area.

CLASS NAME	ACRES	PERCENT COVER
Closed Needleleaf	32,445	0.86
Open Needleleaf	1,286,732	34.14
Open Ndl. – Lichen	130,650	3.47
Woodland Needleleaf	415,614	11.02
Woodland Ndl. – Lichen	16,898	0.45
Closed Birch	107,077	2.84
Closed Deciduous	69,864	1.85
Open Birch	1,028	0.03
Open Aspen	6,095	0.16
Open Deciduous	46,297	1.85
Closed Mixed Ndl./Decid.	135,508	3.60
Open Mixed Ndl./Decid.	281,293	7.46
Tall Shrub	120,787	3.20
Low Shrub	585,894	15.54
Low Shrub – Lichen	6,096	0.16
Low Shrub – Moss	4,234	0.11
Low Shrub - Tussock Tundra	11,004	0.29
Dwarf Shrub	108,045	2.87
Dwarf Shrub – Lichen	46,233	1.23
Moss	520	0.01
Mesic/Dry Graminoid	2,818	0.07
Tussock Tundra	3,602	0.10
Clear Water	10,833	0.29
Turbid Water	7,196	0.19
Sparse Vegetation	24,797	0.66
Rock/Gravel	64,521	1.71
Non-Vegetated Soil	7,610	0.20
Urban	49,817	1.32
Agriculture	1,911	0.05
Cloud	56,500	1.50
Cloud Shadow	72,341	1.92
Terrain Shadow	54,907	1.46
Total	**3,769,018**	**100%**

snags and litter as well as patches of bare soil are the most likely cause of changes in spectral reflectance in these areas. The ability to collect suitable spectral data for vegetative regeneration in these areas is severely limited by several factors. First, snags and litter do not absorb any infrared wavelengths. In areas with significant percentages of snags and litter, the high reflectance in these wavelengths seems to overshadow the signatures of vegetation in the area. Second, vegetative succession occurs rapidly in many burned areas. Field data must be collected in very close proximity to the date of image acquisition, or significant discrepancies can occur between the vegetation represented by the field data and the vegetation represented by the spectral signatures within the image. Third, fires of many ages result in vegetative succession in many stages and with a variety of spectral reflectance. The ability to collect a suitable number of field sites to fully represent this wide range of spectral reflectance is not possible in the limited time allotted for field data collection without seriously reducing the number of field sites visited in the non-burned portions of the project area. However, as the processing of the field training site data and satellite imagery proceeded for this project, it became evident that achieving a consistent and reliable land cover classification within these recent burn areas was possible. Therefore, no attempt was made to separate out the recent burn areas into a specific category of their own. Instead, the land cover within the recently burned regions was classified directly into the existing earth cover mapping classes. These classes consisted primarily of three primary classes: low shrub – other, open mixed deciduous, and tall shrub. The age and severity of the burn tended to dictate which earth cover class was present at the time of the image acquisition. For instance, the younger burns tended to present primarily as a low shrub – other type while older burns generally contained a greater birch component that was best characterized as an open mixed deciduous type. For this project, equal success in consistently classifying these burn areas was realized from both the 1995 (path 66) and 1999 (path 68) Landsat imagery.

By far, the most complicating factor in the derivation of this earth cover type map was the presence of significant terrain shadowing in the path 66 imagery acquired on September 17, 1995. The intense shadowing resulting from the low sun incidence angle at the time of image acquisition masked any opportunity to resolve the spectral signatures of whatever land cover may have existed on many of the north- and northwest-facing slopes throughout the image. Attempts to focus on extracting even subtle signatures from these slopes proved fruitless. Spectral confusion between nearly every land cover class was found to exist at some point within these severely shadowed slopes. In the end, it was determined that labeling these areas as terrain shadows would provide the end-user a more consistently reliable map product that attempting some hap hazardous guess as to what may exist within these deep shadows. Nearly 1.5% of the study area was labeled as terrain shadows. Nearly all of this area was covered by the path 66 image captured in September 1995.

Modeling

Modeling was performed using shaded relief, slope and elevation images derived from USGS DEMs at 1:63,360 scale. The shaded relief image was created in Erdas Imagine using the solar azimuth and solar elevation listed in the header file for the path 66 and 68 TM images. Grouping the DEM into 250 ft. elevation zones created the elevation layer. The slope image was created using the "Slope" function in Erdas Imagine. The slope unit was defined as percent slope rather than degree of slope. This allowed for ease of comparison with the field site data sets in which slope was also estimated as percent slope. It is important to note that the modeling process was used primarily to identify *potentially* misclassified cover types throughout the study area. In order to maximize the reliability and classification accuracy in this mapping effort, manual review and editing techniques were utilized to correct the misclassified pixels to their appropriate mapping classification. Approximately 54,900 acres or approximately 1.5% (Table 7) of the project area was modeled and edited to the terrain shadow class. A much larger portion of the image was affected by shadows, but not completely blackened by those shadows. The majority of these areas were labeled with an earth cover class, but some areas were too dark to discriminate. Attempts were made to classify any areas that showed even a small degree of spectral reflectance, but it was left up to the image processor's judgment whether or not to edit the shadowed area into the terrain shadow class.

The elevation zone image was used to model cover types that were limited by elevation. Through examination of the field data, the DEM, the TM images, and aerial photography it was determined that "treeline" (the elevation above which no trees are found) ranged in elevation from approximately 2,000 feet up to a maximum of approximately 2,750 feet throughout the project area. In most cases, treeline was at 2,500 feet or lower. After the initial earth cover classification was produced using several iterations of combined supervised/unsupervised classifications, the elevation zone image was used to identify all pixels above 2,500 feet elevation that had been classed as a forested earth cover type. Specific visual inspection and manual corrections were then made to these pixels using both unsupervised classifications and on-screen editing. Most of these pixels were relabeled to non-forested classes, but some were left with forested labels after verification with aerial photos or further unsupervised classifications.

The slope image was also used in the modeling process. Several unsupervised signatures exhibited spectral confusion between the low shrub, low shrub – tussock tundra, and tussock tundra earth cover classes. Tussock tundra is typically found only on poorly drained soils over permafrost on flats and gentle slopes of less than 10% gradient (Viereck *et al*, 1992). A model that utilized the slope image labeled pixels that were classified by these spectrally confused unsupervised signatures. Pixels that had a slope of less than 10% were labeled either low shrub – tussock tundra or tussock tundra, while pixels with slope greater than or equal to 10% were labeled low shrub.

Editing

Due to the relatively smaller size of the study areas of the Southern Yukon MOA, manual-editing techniques were employed to a greater degree than spatial modeling in this project. Although spatial modeling is very effective at identifying and "flagging" potential erroneously classified pixels throughout the image very quickly, specific visual inspection and manual editing of these "flagged" pixels is generally the most effective and accurate method for achieving the final desired mapped results. Editing was performed on all classes to various extents depending on how well the iterative classification and modeling processes worked for each. The edits were verified with field sites, aerial photography and field notes wherever possible. Some editing centered on ecological differences across the project area. For example, a single signature classified low shrub in the lower lying areas and dwarf shrub in the higher elevation regions of the study area. Editing in this case consisted of correctly labeling and separating classes along ecological boundaries. Because the project area was relatively diverse, this kind of editing was often necessary, especially in the transitional areas from treeline into the low shrub/dwarf shrub/sparse vegetation zones.

Editing was also required to classify areas that fell in the middle of the gradient between one class and another, e.g., between woodland needleleaf and shrub. A woodland area of 10-15% trees was easily confused with a shrub area of 5-9% trees. The most prevalent example of the confusion within the gradient between classes was found between woodland needleleaf and low shrub - other. As evidenced by the field training sites, a large number of the open and woodland needleleaf classes exhibited a tree crown cover between 5% and 15%. Similarly, as discussed earlier, low shrub areas at a height of .3 meters were confused with dwarf shrub areas with a height of .2 meters. These transitional areas and signatures had to be examined and a classification decision made based on the available data.

In some cases, a single pixel fell across two cover types, for example, between a lake and the land surrounding it. These half-water, half-land signatures were often confused with emergent and open needleleaf signatures. Many of the small lakes and ponds had a 1 pixel wide ring of open needleleaf surrounding them in the classified map after the combined supervised/unsupervised classification was completed. Editing was done to separate legitimate emergent, and open needleleaf pixels based on aerial photography, field notes and topography. While great effort was put forth to rectify this phenomenon, undoubtedly, some lakes and ponds in the final classification may contain an erroneous scattering of open needleleaf pixels surrounding their shores.

A final case of spectral classification confusion involved the misclassification of pixels of numerous cover types in areas affected by cloud shadows. As demonstrated in Table 7, clouds and their resulting shadows significantly impacted nearly 130,000 acres. The regions of deep cloud shadow and solid cloud cover were relatively easily identifiable and mapped to their respective class. However, nearly every supervised training site has been adversely impacted in some way by the clouds or their shadows; most often along the border of the clouds/shadows themselves where complete obstruction of the underlying ground cover was not achieved. In these regions, areas of complete and consistent cover of open needleleaf forest was made to spectrally appear similar to a low shrub or even sparsely vegetated region because of the impact of a light, hazy cloud cover.

Similarly, non-forested/sparsely vegetated regions partially obscured by a filtered cloud shadow often resulted in a spectral reflectance resembling that of an open or even closed needleleaf canopy. This confusion was corrected via manual editing utilizing photo-interpretation and review of specific field notes and photos. In many instances, the cloud or cloud shadow cover was too great to allow for any reliable interpretation of cover type. In such cases, the affected pixels were manually edited to either cloud or cloud shadow.

Accuracy Assessment

Some earth cover classes were not adequately represented in the field data available for training and accuracy assessment, primarily because of their scarcity within the project area, e.g., low shrub-lichen, woodland needleleaf – lichen, moss, wet/dry graminoid, lichen, aquatic bed, emergent. In the past, classes with an inadequate sample size were collapsed into the next hierarchical cover type for accuracy assessment of the classification. This grouping often resulted in only 8-10 accuracy assessment classes vs. the 30+ classes present in the classification. In addition, this approach grouped classes based solely on their specific mapping class labels versus grouping individual sites based on their ecological composition or function. By grouping classes in this manner, one loses all ability to evaluate and measure the relationship between regions of the map that classify nicely into the "heart" of a mapping class and those regions that occur on the classification and ecological boundaries between the discrete mapping classes. For example, at field site #209 the vegetation caller interpreted the site to contain 55% total tree cover (40% black spruce, 10% paper birch, 5% aspen, and 45% various shrub and herbaceous understory species). This interpretation results in a open mixed needleleaf/deciduous label for the site. The final classified map labeled the majority of this as open needleleaf. The error matrix would tally this label as an incorrect label. Since the literature generally accepts that even the most experienced visual estimates of earth cover consider a range of variation in interpretation of +/-10% to be acceptable, this particular accuracy assessment site containing 72% needleleaf tree cover would also be considered acceptably classified as open needleleaf if only a 5% variation in the amount of deciduous tree cover was considered. Similarly, site #67 is characterized as containing 20% low shrub cover (0.4-meters in height) and 25% dwarf shrub cover (0.2-meters in height). Again, a 5% variation in cover of dwarf vs. low shrub cover (not to mention the potential variation in interpretation of vegetation height with a +/-0.1-meter precision) would result in an accuracy assessment label directly matching the final classified map data showing low shrub – other as the predominant class. Evaluating the earth cover classification in this manner provides the end user with a more realistic measure of reliability of the classified map as it relates to the actual continuum of vegetation composition as compared to simply lumping mapping classes for evaluation based on their discrete class name.

The error matrices provided in Appendix F - G represent the reliability/accuracy of the earth cover classification. Accuracy assessment data is presented for the path 66 sites separately from the path 68 sites. The error matrices should not be combined to produce one error matrix for the entire project area because the processing was done separately for these two images and then stitched together after the classification for each was completed. The accuracy of classes within the path 66 portion of the map is independent of the class accuracies in the path 68 portion of the map. In the matrices, no lumping of mapping classes has occurred. Therefore, the user can evaluate the performance and interrelationships of *all* mapping classes represented in the final earth cover. The error matrices present values for user's accuracy, producer's accuracy, and the overall accuracy for 0% and +/-5% variation in the vegetation caller's interpretation of the reference data. In the error matrices, numbers along the main diagonal of the matrices indicate exact matches between the reference labels and map labels of the accuracy assessment sites. A tally of these numbers divided by the total number of sites indicates the overall accuracy of the map at the 0% variation in interpretation level. If two numbers occupy a non-diagonal cell, the left number indicates an acceptable match between the reference data site and the map assuming a +/- 5% variation in reference data interpretation. The number on the right indicates the number of sites that are not acceptable matches. A tally of the numbers within the diagonal along with the acceptable numbers in the off-diagonal cells (left number(s)) indicates the overall accuracy of the map at the +/- 5% variation in interpretation level.

A number of important analyses can be made regarding the relationship of the mapped data with the actual vegetation distributions throughout the study area using this method of accuracy assessment. Since the off-diagonal acceptable matches are presented, an indication of the number of field sites that represent vegetation compositions on the boundary of two or more mapping classes is given. The acceptance or non-acceptance of each accuracy assessment site with an off-diagonal map class provides insight into the vegetation composition of that reference site. For instance, in Appendix F, of the ten accuracy assessment sites with a reference label of open needleleaf, one site was an acceptable match with open needleleaf – lichen and one was a non-acceptable match with open needleleaf - lichen. The remainder of the sites (8) was diagonal matches with open needleleaf. The off-diagonal matches indicate that at least one of those sites was on the border between open needleleaf and open needleleaf - lichen (15-20% lichen understory present). Similarly, since the number of misclassified sites is still indicated in the matrix, a user can determine in which classes the map is least reliable and with which mapping classes the unreliable classes are confused.

Path 66 Accuracy Assessment

The difference in classification accuracy between the 0% variation in interpretation level, 77% (Appendix F), and the +/- 5% variation in interpretation level, 91%, indicates that a number of the reference data sites were characterized as being on the boundary of two or more mapping classes. As stated earlier, it is generally accepted that variation in interpretation of +/- 10% is common and accepted for human interpreters estimating vegetative crown cover, either from aerial photography or on the ground. When this natural and accepted variation is measured and accounted for (as in the case of the error matrix in Appendix F), a more reliable and informative measure of accuracy and reliability is presented.

The most striking aspect of the accuracy assessment for the path 66 classified data is the fact that only 13 of the 25 earth cover mapping classes that were actually present in the final map had at least one accuracy assessment site associated with them. And of these 13 cover classes, only five classes had three or more accuracy assessment sites represented. This was due to the relatively small land area represented by the path 66 study area and the proportionally small number of total field sites that were established in this area. Obviously, very little in the way of statistically significant conclusions can be drawn from the individual class accuracy measures for those classes containing only a few accuracy assessment sites. Even though the vast majority of these classes present user's and producer's accuracy measures of 100%, it would be unwise to believe that each of these classes has been mapped completely without error. Likewise, the couple of classes that show accuracy measures of less than 60% from only one or two accuracy assessment sites do not adequately depict the actual level of confidence an end user may have in these particular cover type classes. However, some basic important trends can be observed in the final path 66 accuracy assessment matrix (Appendix F).

At the +/- 5% level of variation the accuracy of all needleleaf classes was 90% - 100%. Accuracy of the open needleleaf class was 90%. The lower accuracy for open needleleaf is not surprising when compared to the open needleleaf – lichen class. With tree crown cover between 25% and 60% in this earth cover class, attempting to distinguish between a lichen understory component of between 15% - 20% can be difficult. However, only one of the ten open needleleaf accuracy assessment sites was found to not match the map data. Only one open needleleaf – lichen accuracy assessment site was established in the path 66 image. This site was found to be a direct match with the map data.

The open and closed deciduous classes had somewhat lower accuracy than the needleleaf classes in general. This is consistent with past earth cover mapping projects in other parts of Alaska and results from confusion within the deciduous earth cover classes. 75% of the incorrectly classified open deciduous accuracy assessment sites were confused with the closed deciduous class. If these two mapping classes were combined into one general deciduous class, the accuracy would be 80% (16/20) at the 0% level of variation and 85% (17/20) at the +/- 5% level of variation. Most of the confusion with non-deciduous classes occurred with mixed needleleaf/deciduous classes and with the tall shrub class.

Only one accuracy assessment site was available for the mixed needleleaf/deciduous classes. As represented in Table 6, only one closed mixed field site and 6 open mixed field sites were established within the path 66 data. It appears that most of the sites that may have been approaching the mixed needleleaf/deciduous composition was characterized most often as a pure needleleaf or pure deciduous site. There is some indication for this being the case by the single open mixed needleleaf/deciduous accuracy assessment site being found to be an acceptable match with the open needleleaf class.

Although each of the shrub classes, with the exception of tall shrub (0% with only a single accuracy assessment site), had very acceptable accuracy assessment results, it is observed from the number of off-diagonal elements along the map data row for the low shrub – other class that some tendency for potential over-classification of low shrub exists in the map data. The low shrub – other class was the most difficult shrub class to map because of its wide variability. However, both the producer's and user's accuracy for low shrub – other exceeded 92%. Even at 0% variation in interpretation level, producer's accuracy of 92% and a user's accuracy of 75% is observed. Typically this confusion occurred with other shrub classes and not with the forested classes. Figure 19 demonstrates one of these circumstance where an accuracy assessment site is characterized as dwarf shrub – other but is mapped as a mixture of dwarf and low shrub. In this example, 20% of the ground cover is characterized as low shrubs with an average height of .4-meters and 24% of the ground cover is characterized as dwarf shrub with an average height of .2-meters.

Appendix F also indicates a similar phenomenon within the open needleleaf class. Although the user's and producer's accuracy are 90% and 80% and the +/-5% and +/-0% variation levels respectively, the fact that two of the ten accuracy assessment sites that were characterized as open needleleaf in the *map* data tends to indicate that some map bias may be present toward

Figure 19. Example of the frequent subtle difference between a dwarf and low shrub site.

classifying cover as open needleleaf. As discussed in an earlier section, this was primarily due to the fact that, like the low shrub – other class, a great preponderance of the field training sites for the path 66 image were focused on open needleleaf sites. As presented in Table 6, 80 of the 175 total field training sites for path 66 were characterized as either low shrub – other or open needleleaf.

It should be noted that no field sites, and therefore no accuracy assessment sites, were captured representing the clear water or turbid water classes. These classes are among the most straightforward to discriminate and map from Landsat TM satellite imagery. Therefore, the limited field data collection time was focused on capturing data to assist in the discrimination and mapping of the more spectrally and ecologically complex vegetation communities throughout the study area.

These two mapping classes accounted for less than 1% of the earth cover within the project area. Due to their spectral distinctiveness, it is certain that both the user's and producer's accuracy for these classes would be at or very near 100%, thus only acting to improve the overall accuracy calculations for the final earth cover map.

Path 68 Accuracy Assessment

As was the case with the path 66 assessment, a relatively small number of accuracy assessment sites (49) was available with which to assess the accuracy of the 20+ thematic classes contained in the path 68 data. Of the 26 earth cover mapping classes containing data in this study area, only 12 mapping classes had accuracy assessment sites associated with them, and only six of these possessed more than three sites. Nevertheless, the quantitative overall, user's, and producer's accuracy measures all depict a map of earth cover that is reliable and accurate.

Similar to the path 66 assessment, the difference between the accuracy assessment measure at +/- 0% variation in interpretation (75.5%) vs. the +/- 5% variation in interpretation level (89.8%) indicates that again many of the accuracy assessment sites characterize the vegetation as being on the border of two or more mapping classes. Examination of the accuracy assessment matrix for path 68 (Appendix G) reveals that the majority of the confusion between these borderline classes is represented in the producer's accuracy of the woodland needleleaf class and the user's accuracy of the open needleleaf class.

First examining the producer's accuracy of the woodland needleleaf class, it is observed that no less than four other cover type classes exhibit some type of confusion with the woodland needleleaf class. Out of the ten total woodland needleleaf accuracy assessment sites, half of these sites are dominated by other non-woodland needleleaf class pixels in the final map; although two of the five were found to be acceptable matches at the +/- 5% variation in interpretation level. The lower accuracy for woodland needleleaf is not surprising. With tree crown cover between 10% and 25% in this earth cover class, the majority (75% - 90%) of the signature for these areas was comprised of vegetative species other than spruce. This made the woodland needleleaf class one of the most difficult to map. While two of the off-diagonal sites were confused with open needleleaf sites, which are clearly a confusion in forest canopy density, the remaining three off-diagonal sites were confused with other non-forested mapping classes. For example, woodland sites with a significant tall shrub understory was spectrally confused with the tall shrub class, the open mixed needleleaf/deciduous class, and the sparse vegetation class. In addition, woodland needleleaf cover types could be found nearly anywhere throughout the project area. Other than elevation constraints, which limited the presence of woodland needleleaf at the highest elevations, there were no environmental attributes (e.g. – slope, aspect, distance to water, etc.) that could be used in models to differentiate between woodland needleleaf and other spectrally similar classes. By far, the woodland needleleaf class contributed more toward the small amount of classification error that was indicated by the matrix in Appendix G than any other class. Even so, a producer's accuracy of 70% was realized at the +/- 5% variation of interpretation level. And perhaps more importantly, when the map indicated that woodland needleleaf was present, a user could have great confidence that woodland needleleaf was present, as indicated by a user's accuracy of 100%.

In addition to the difficulty of classification of the woodland needleleaf class, the open needleleaf class also presented some challenges. The range of spectral variation of the open needleleaf training sites was astounding. Open needleleaf sites ranged from very low reflecting shadowed north slopes to very highly reflective 25-30% canopy cover stands with a variety of lichen, tall-, and low-shrub understories on a variety of slopes and aspects. This wide spectral variation made for often significant confusion between a variety of other earth cover classes including open needleleaf – lichen, woodland needleleaf, and open mixed needleleaf/deciduous. While the producer's accuracy demonstrates a 100% agreement with the open needleleaf accuracy assessment data in eight out of eight cases,
seven other non-open needleleaf accuracy assessment sites were characterized predominantly by open needleleaf pixels in the final earth cover map. This would tend to indicate a propensity toward open needleleaf being over-represented in the final map. However, in all but two of these cases, a +/- 5% variation of interpretation in the characterization of the accuracy assessment data resulted in an acceptable match with the open needleleaf class. This resulted in a user's accuracy of nearly 87% at the +/- 5% variation level. The primary classes of confusion with the open needleleaf class were open needleleaf – lichen and open mixed needleleaf/deciduous. In five of seven of these coincidences, four of the sites were found to be acceptable matches at the +/- 5% variation in interpretation level. A minor variation in the amount of lichen present in the accuracy assessment site (20% vs. 15% lichen) or in the amount of deciduous component in the stand (10% vs. 15% birch) would have resulted in a different mapping class label. In fact, in a couple of these instances, there was some disagreement between the calculated class label (used to describe and label the accuracy assessment site) and the observed class label in which the vegetation interpreter actually characterized the accuracy assessment site as being an open needleleaf site.

The final mapping class contributing some error to the accuracy assessment matrix in

Appendix G is the tall shrub class. Although the producer's accuracy indicates complete agreement between each of the tall shrub accuracy assessment sites, three other non-tall shrub accuracy assessment sites were characterized by tall shrub pixels. In two of these cases, a variation of +/- 5% would not have made for an acceptable match between the map data and the accuracy assessment site. As with the open needleleaf class discussed above, this would tend to indicate a potential over-estimation of tall shrub in the map data. In both cases, the misclassification was between other shrub-dominated sites, one with a dwarf/low shrub composition and the other with a low shrub/woodland needleleaf composition.

As with the path 66 accuracy analysis discussion above, it should again be noted that no field sites, and therefore no accuracy assessment sites, were captured representing the clear water or turbid water classes. In the path 68 data, these two mapping classes again accounted for less than 1% of the earth cover within the project area.

Even with the spectral and classification confusion circumstances discussed above for both the path 66 and path 68 data, the overall, user's, and producer's accuracy measures at the +/- 5% variation in interpretation level are among the highest produced in the on-going earth cover mapping effort in Alaska. When visually compared with the previously completed earth cover mapping projects adjacent to the Southern Yukon MOA study area, the final earth cover classification produced in this effort fits nearly seamlessly into these existing thematic coverages providing continuous, consistent earth cover data for the region.

Discussion

A major assumption of quantitative accuracy assessments is that the label from the reference data 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: (1) registration differences between the reference data and the remotely sensed map classification, (2) digitizing errors, (3) data entry errors, (4) changes in land cover between the date of the remotely sensed data and the date of the reference data, (5) mistakes in interpretation of reference data, and perhaps most significant (6) variation in classification and delineation of the reference data due to inconsistencies in human interpretation of vegetation. The error matrices developed and presented in this report attempt to capture, measure, and account for the most significant of these sources of inconsistency and error in the development of the reference data set: variation in human interpretation. The results presented and discussed in this report provide the end user with valuable information regarding the accuracy and reliability of the earth cover data mapped for the project area.

Final Products

The final products included a digital earth cover classification, a hard-copy map of the entire project area, and three digital databases of field data collected for all of the field sites visited during the 1999 and 2000 field seasons of this project. The digital map was delivered in Arc/Info Grid and Erdas Imagine format. The field site databases, and vegetative species list were stored as digital tables in Dbase IV format. Digital photographs of the field sites are stored in .jpg format. Hardcopy maps of the entire project area at 1:250,000 scale were also produced as requested by cooperators. All of the delivered datasets were loaded into ArcView projects for display purposes.

Conclusions

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. This project continued with the mapping by completing the earth cover mapping of a region surrounded by previously completed mapping projects (Tanana, Steese-White Mountains, and Yukon-Charley study areas). The Northern and Southern Yukon MOA study areas mapped the remaining Yukon MOAs that had not been completed by the three other project areas mentioned above, to provide continuous, consistent earth cover data for the region. Northern Yukon MOA classification was performed using Landsat TM satellite scenes, Path 67, Row 14 (shifted approximately 35% north) acquired June 24, 2000. Southern Yukon MOA classification was performed using Landsat TM satellite scenes, Path 66, Row 15 acquired September 17, 1995 and Landsat TM Path 68, Row 15 acquired July 31, 1999. The Northern Yukon MOA project area was classified into 34 earth cover categories with an overall accuracy of 85% at the +/- 5% level of interpretation. The Southern Yukon MOA project area was classified into 31 earth cover categories with an overall accuracy of 90% at the +/- 5% level of variation in interpretation. The digital database and map of the classification were the primary products of this project along with hard copy maps of the classification, a complete field database including digital site photos, and an ArcView project.

Literature Cited

Chuvieco, E., and R. G. Congalton. 1988. Using cluster analysis to improve the selection for training statistics in classifying remotely sensed data. Photogrammetric Engineering and Remote Sensing 54:1275-1281.

Congalton, R., and K. Green. 1993. A practical look at the sources of confusion in error matrix generation. Photogrammetric Engineering & Remote Sensing 59:641-644.

Congalton, R. G., K. Green, and J. Teply. 1993. Mapping Old Growth Forest on National Forest and Park Lands in the Pacific Northwest from Remotely Sensed Data. Photogrammetric Engineering and Remote Sensing 59:529-535.

Congalton, R. G. 1991. A review of assessing the accuracy of classifications of remotely sensed data. Remote Sensing of Environment 37:35-46.

Ducks Unlimited Inc., 1998. Earth Cover Classification System –Draft. Unpublished Report. Rancho Cordova, California, USA.

Gopal, S., and C. Woodcock. 1992. Accuracy assessment of the Stanislaus vegetation map using fuzzy sets. Pages 378-394. Remote Sensing and Natural Resource Management: Proceedings of the Fourth Forest Service Remote Sensing Applications Conference. American Society for Photogrammetry and Remote Sensing, City, State, USA.

Jensen, J.R. 1986. Introductory Digital Image Processing. Prentice-Hall, Englewood Cliffs, New Jersey, USA.

Kempka, R. G., R. D. Macleod, J. Payne, F. A. Reid, D. A. Yokel, and G. R. Balogh. 1995. National Petroleum Reserve Alaska Landcover Inventory: Exploring Arctic Coastal Plain Using Remote Sensing. Pages 788-798 in Ninth Annual Symposium on Geographic Information Systems in Natural Resources Management, GIS World Inc., editor. GIS 95 Symposium Proceedings, Vancouver, British Columbia, Canada.

Kempka, R. G., B. S. Maurizi, F. A. Reid, R. C. Altop, and J.W. Denton. 1994. Standardizing reference data collection for satellite land cover mapping in Alaska. Pages 419-426 in Eighth Annual Symposium on Geographic Information Systems in Forestry, Environmental, and Natural Resources Management, GIS World Inc., editor. GIS 94 Symposium Proceedings Vancouver, British Columbia, Canada.

Kempka, R. G., F. A. Reid, and R. C. Altop. 1993. Developing large regional databases for waterfowl habitat in Alaska using satellite inventory techniques: a case study of the Black River. Pages 1-1 in Seventh Annual Symposium on Geographic Information

Systems in Forestry, Environment, and Natural Resources Management, GIS World Inc., editor. GIS 93 Symposium Proceedings Vancouver, British Columbia, Canada.

Lillesand, T., and R. Kiefer. 1994. Remote Sensing and Image Interpretation. Wiley and Sons, Inc., New York, USA.

Ritter, R. A., G. T. Koeln, and C. Altop. 1989. Use of Landsat Thematic Mapper Data for Waterfowl Habitat Inventory in Alaska.

Story, M., and R. G. Congalton. 1986. Accuracy Assessment: A User's Perspective. Photogrammetric Engineering and Remote Sensing 16:529-535.

Tortora, R. 1978. A note on sample size estimation for multinomial populations. The American Statistician 43:1135-1137.

Viereck, L. A., Dyrness, C. T., Batten, and A. R. Wenzlick. 1992. The Alaska Vegetation Classification. General Technical Report PNW-GTR-286. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon, USA.

Appendices

Appendix A. Alaska Earth Cover Classification Class Descriptions

1.0 Forest
Needleleaf and Deciduous Trees-
The needleleaf species generally found were white spruce (*Picea glauca*) and black spruce (*P. mariana*). White spruce tended to occur on warmer sites with better drainage, while black spruce dominated poorly drained sites, and was more common in the interior of Alaska. The needleleaf classes included both white and black spruce.

The deciduous tree species generally found were paper birch (*Betula papyfera*), aspen (*Populus tremuloides*) and cottonwood (*P. balsamifera* and *P. trichocarpa*). Black cottonwoods (*P. trichocarpa*) were generally found only in river valleys and on alluvial flats. Under some conditions willow (*Salix* spp.) and alder *(Alnus rubra)* formed a significant part of the tree canopy. Deciduous stands were found in major river valleys, on alluvial flats, surrounding lakes, or most commonly, on the steep slopes of small hills. Mixed deciduous/coniferous stands were present in the same areas as pure deciduous stands. While needleleaf stands were extremely extensive, deciduous and mixed deciduous/coniferous stands were generally limited in size. The only exception to this rule was near major rivers, where relatively extensive stands of pure deciduous trees occur on floodplains and in ancient oxbows.

1.1 Closed Needleleaf
At least 60% of the cover was trees, and ≥75% of the trees were needleleaf trees. Closed needleleaf sites were rare because even where stem densities were high, the crown closure remained low. Generally, closed needleleaf sites were found only along major rivers.

1.2 Open Needleleaf
From 25-59% of the cover was trees, and ≥75% of the trees were needleleaf with a height > 1 meter. This class was very common throughout the interior of Alaska. A wide variety of understory plant groups were present, including low and tall shrubs, forbs, grasses, sedges, horsetails, mosses and lichens.

1.21 Open Needleleaf Lichen
From 25-59% of the cover was trees, ≥75% of the trees were needleleaf with a height > 1 meter, and ≥ 20% of the understory was lichen.

1.3 Woodland Needleleaf
From 10-24% of the cover was trees, and ≥75% of the trees were needleleaf. Woodland understory was extremely varied and included most of the shrub, herbaceous, or graminoid types present in the study area.

1.31 Woodland Needleleaf Lichen
From 10-24% of the cover was trees, ≥75% of the trees were needleleaf, and ≥ 20% of the understory was lichen. The lichen often

occurred in small round patches between trees. Within the study area, this class was generally found along ridgetops or on riparian benches.

1.4 Closed Deciduous (Mixed Deciduous Species 1.44)
At least 60% of the cover was trees, and ≥75% of the trees were deciduous. Occurred in stands of limited size, generally on the floodplains of major rivers, but occasionally on hillsides, riparian gravel bars, or bordering small lakes. This class included Paper Birch, Aspen, or Cottonwood.

1.41 Closed Birch
At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were Paper Birch (*Betula Papyrifera).*

1.42 Closed Aspen
At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were Aspen. Stands of pure aspen occurred, but were generally no larger than a few acres. They were found on steep slopes, with particular soil conditions, and on river floodplains.

1.43 Closed Poplar
At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were Cottonwood.

1.5 Open Deciduous (Mixed Deciduous Species 1.54)
From 25-59% of the cover was trees, and ≥75% of the trees were deciduous. There was generally a needleleaf component to this class though it was less than 25%. This was a relatively uncommon class.

1.51 Open Birch
From 25-59% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were Paper Birch. This class was very rare. No examples of this class were found in the study area.

1.52 Open Aspen
From 25-59% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were Aspen.

1.53 Open Cottonwood
From 25-59% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were Cottonwood.

1.6 Closed Mixed Needleleaf/Deciduous
At least 60% of the cover was trees, but neither needleleaf nor deciduous trees made up ≥75% of the tree cover. This class was uncommon and found mainly along the meanders of major rivers.

1.7 Open Mixed Needleleaf/Deciduous
From 25-59% of the cover was trees, but neither needleleaf nor deciduous trees made up ≥75% of the tree cover. This class occurred in regenerating burns, on hill slopes, or bordering lakes.

2.0 <u>Shrub</u>
The tall and low shrub classes were dominated by willow species, dwarf birch (*Betula nana* and *Betula glandulosa*) and *Vaccinium* species, with alder being somewhat less common. However, the proportions of willow to birch and the relative heights of the shrub species varied widely, which created difficulties in determining whether a site was made up of tall or low shrub. As a result, the height of the shrub species making up the largest proportion of the site dictated whether the site was called a low or tall shrub. The shrub heights were averaged within a genus, as in the case of a site with both tall and low willow shrubs. Dwarf shrub was usually composed of dwarf ericaceous shrubs and

Dryas species, but often included a variety of forbs and graminoids. The species composition of this class varied widely from site to site and included rare plant species. It is nearly always found on hill tops or mountain plateaus, and may have included some rock.

2.1 Tall Shrub
Shrubs made up 25-100% of the cover and either ≥25% of the site consisted of shrubs ≥1.3 meters in height OR shrubs ≥1.3 meters were the most common shrubs. This class generally had a major willow component that was mixed with dwarf birch and/or alder, but could also have been dominated by nearly pure stands of alder. It was found most often in wet drainages, at the head of streams, or on slopes.

2.21 Willow/Alder Low Shrub
Shrubs made up 25-100% of the cover, ≥75% of the shrub cover was willow and/or alder, and either ≥25% of the site consisted of shrubs .25-1.3 meters OR shrubs .25-1.3 meters were the most common shrubs.

2.22 Other Low Shrub/Tussock Tundra
Shrubs made up 25-100% of the cover, ≥35% of the cover was made up of tussock forming cotton grass *(Eriophorum vaginatum*), and either ≥25% of the site consisted of shrubs .25-1.3 meters in height OR shrubs .25-1.3 meters were the most common shrubs. This class was found in extensive patches in flat, poorly drained areas. It was generally made up of cotton grass, ericaceous shrubs, willow and/or alder shrubs, other graminoids, and an occasional black spruce.

2.23 Other Low Shrub/Lichen
Shrubs made up 25-100% of the cover, ≥20% of the cover was made up of lichen, and either 25% of the site consisted of shrubs .25-1.3 meters in height OR shrubs .25-1.3 meters were the most common shrubs. This class was found at mid-high elevations. The shrub species in this class were nearly always dwarf birch.

2.24 Other Low Shrub
Shrubs made up 25-100% of the cover and either 25% of the site consisted of shrubs .25-1.3 meters in height OR shrubs .25-1.3 meters were the most common shrubs. This was the most common low shrub class. It was generally composed of dwarf birch, willow species, *Vaccinium* species, and *Ledum* species.

2.31 Dwarf Shrub/Lichen
Shrubs made up 25-100% of the cover, ≥20% of the cover was made up of lichen and either 25% of the site consisted of shrubs ≤ .25 meters in height OR shrubs ≤ .25 meters were the most common shrubs. This class was generally made up of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids. It was nearly always found at higher elevations on hilltops, mountain slopes and plateaus. This class may be more open than the Other Dwarf Shrub class.

2.32 Other Dwarf Shrub
Shrubs made up 40-100% of the cover and either 25% of the site consisted of shrubs ≤ .25% meters in height OR shrubs ≤ .25 meters were the most common shrubs. This class was generally made up of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids, and some rock. It was nearly always found at higher elevations on hilltops, mountain slopes, and plateaus.

3.0 Herbaceous

The classes in this category included bryoids, forbs, and graminoids. Bryoids and forbs were present as a component of most of the other classes but rarely appeared in pure stands. Graminoids such as *Carex* spp., *Eriophorum* spp., or bluejoint grass (*Calamagrostis canadensis*) may have dominated a community.

3.11 Lichen

Composed of ≥40% herbaceous species, ≤25% water, and ≥ 50% bryoid species of which ≥50% were lichen species.

3.12 Moss

Composed of ≥40% herbaceous species, ≤25% water, and ≥50% bryoid species of which ≥50% were moss species.

3.21 Wet Graminoid

Composed of ≥40% herbaceous species, 5-25% water or ≥20% *Carex aquatilis*, and where ≥50% of the herbaceous cover was graminoid. This class represented wet or seasonally flooded sites. It was often present in stands too small to be mapped at the current scale.

3.22 Web Forb

Composed of ≥40% herbaceous species, 5-25% water or ≥20% *Carex aquatilis*, and where <50% of the herbaceous cover was graminoid.

3.31 Tussock Tundra

Composed of ≥40% herbaceous species, ≤25% water, where ≥50% of the herbaceous cover was graminoid, and ≥35% of the cover was made up of tussock forming cotton grass. Tussock tundra often included ericaceous shrubs, willow and/or alder shrubs, forbs, bryoids, and other graminoids, and was usually found at lower elevations in flat, poorly drained areas.

3.311 Tussock Tundra/Lichen

Composed of ≥40% herbaceous species, ≤25% water, where ≥50% of the herbaceous cover was graminoid, and ≥20% of the cover was lichen, and ≥35% of the cover was made up of tussock forming cotton grass. Tussock tundra often included ericaceous shrubs, willow and/or alder shrubs, forbs and other graminoids, and was usually found at lower elevations in flat, poorly drained areas. This class included a major component of lichen.

3.32 Mesic/Dry Sedge Meadow

Composed of ≥40% herbaceous species, ≤5% water, and <35% tussock, with the non-bryoid herbaceous species being ≥50% graminoid (sedge, grass, tussock) and ≥50% sedge (ie dominated by sedge species).

3.33 Mesic/Dry Grass Meadow

Composed of ≥40% herbaceous species, ≤5% water, and <35% tussock, with the non-bryoid herbaceous species being ≥50% graminoid (sedge, grass, tussock) and ≥50% by grass (ie dominated by grass species).

3.34 Mesic/Dry Graminoid

Composed of ≥40% herbaceous species, ≤5% water, and <35% tussock, with the non-bryoid herbaceous species being ≥50% graminoid (sedge, grass, tussock) but <50% of either sedge or grass (ie neither sedge nor grass is clearly dominant). This was not common and was found generally only at high elevations.

3.35 Mesic/Dry Forb

Composed of ≥40% herbaceous species, ≤5% water, with the non-bryoid herbaceous species being <50% graminoid. Regenerating burn areas dominated by fireweed *(Epilobium angustifolium)* fell into the mesic/dry forb category. However, forb communities without significant graminoid or shrub components were generally rare in the interior of Alaska.

4.0 <u>Aquatic Vegetation</u>
The aquatic vegetation was divided into Aquatic Bed and Emergent classes. The Aquatic Bed class was dominated by plants with leaves that float on the water surface, generally pond lilies (*Nuphar polysepalum*). The Emergent Vegetation class was composed of species that were partially submerged in the water, and included freshwater herbs such as Horsetails (*Equisetum* spp.), Marestail (*Hippuris* spp.), and Buckbean (*Menyanthes trifoliata*).

4.1 Aquatic Bed
Aquatic vegetation made up ≥20% of the cover, and ≥20% of the aquatic vegetation was composed of plants with floating leaves. This class was generally dominated by pond lilies.

4.2 Emergent Vegetation
Aquatic vegetation made up ≥20% of the cover, and ≥20% of the aquatic vegetation was composed of plants other than pond lilies. Generally included freshwater herbs such as Horsetails, Marestail, or Buckbean.

4.3 Coastal Marsh
This class was added to the classification scheme for this particular project. Coastal marsh was found in the study area only along the tidal marshes surrounding the mouth of the Knik River as it empties into the Knik Arm. Wet sedge/graminoid communities and saturated ground with occasional standing water characterized these areas.

5.1 Snow
Composed of ≥50% snow.

5.2 Ice
Composed of ≥50% ice.

5.3 Clear Water
Composed of ≥80% clear water.

5.4 Turbid Water
Composed of ≥80% turbid water.

<u>6.0 Barren</u>
This class included sparsely vegetated sites, e.g., abandoned gravel pits or riparian gravel bars, along with non-vegetated sites, e.g., barren mountaintops or glacial till.

6.1 Sparse Vegetation
At least 50% of the area was barren, but vegetation made up ≥20% of the cover. This class was often found on riparian gravel bars, on rocky or very steep slopes and in abandoned gravel pits. The plant species were generally herbs, graminoids and bryoids.

6.2 Rock/Gravel
At least 50% of the area was barren, ≥50% of the cover was composed of rock and/or gravel, and vegetation made up less than 20% of the cover. This class was most often made up of mountaintops or glaciers.

6.3 Non-vegetated Soil
At least 50% of the area was barren, ≥50% of the cover was composed of mud, silt, sand or soil, and vegetation made up less than 20% of the cover. This type was generally along shorelines or rivers.

6.4 Tidal Mud Flats
This class was added to the classification scheme for this project to take into account the coastal influences of the area. These areas consist of mud flats exposed at times

of low tide. They are composed of predominantly non-vegetated mud/silt/sand.

7.0 Urban/Roads
At least 50% of the area was urban and/or roads. This class was found region north of Knik Arm around the developments of Talkeetna, Wasilla, and Palmer. The village of Tyonek also presented some urban/road class.

8.0 Agriculture
At least 50% of the area was agriculture. This class was found in the study area some 20 km east of the Susitna River and 5 km north of Cook Inlet as well as throughout the area around Wasilla and Palmer.

9.0 Cloud/Shadow
At least 50% of the cover was cloud or shadow.

9.1 Cloud
At least 50% of the cover was made up of clouds.

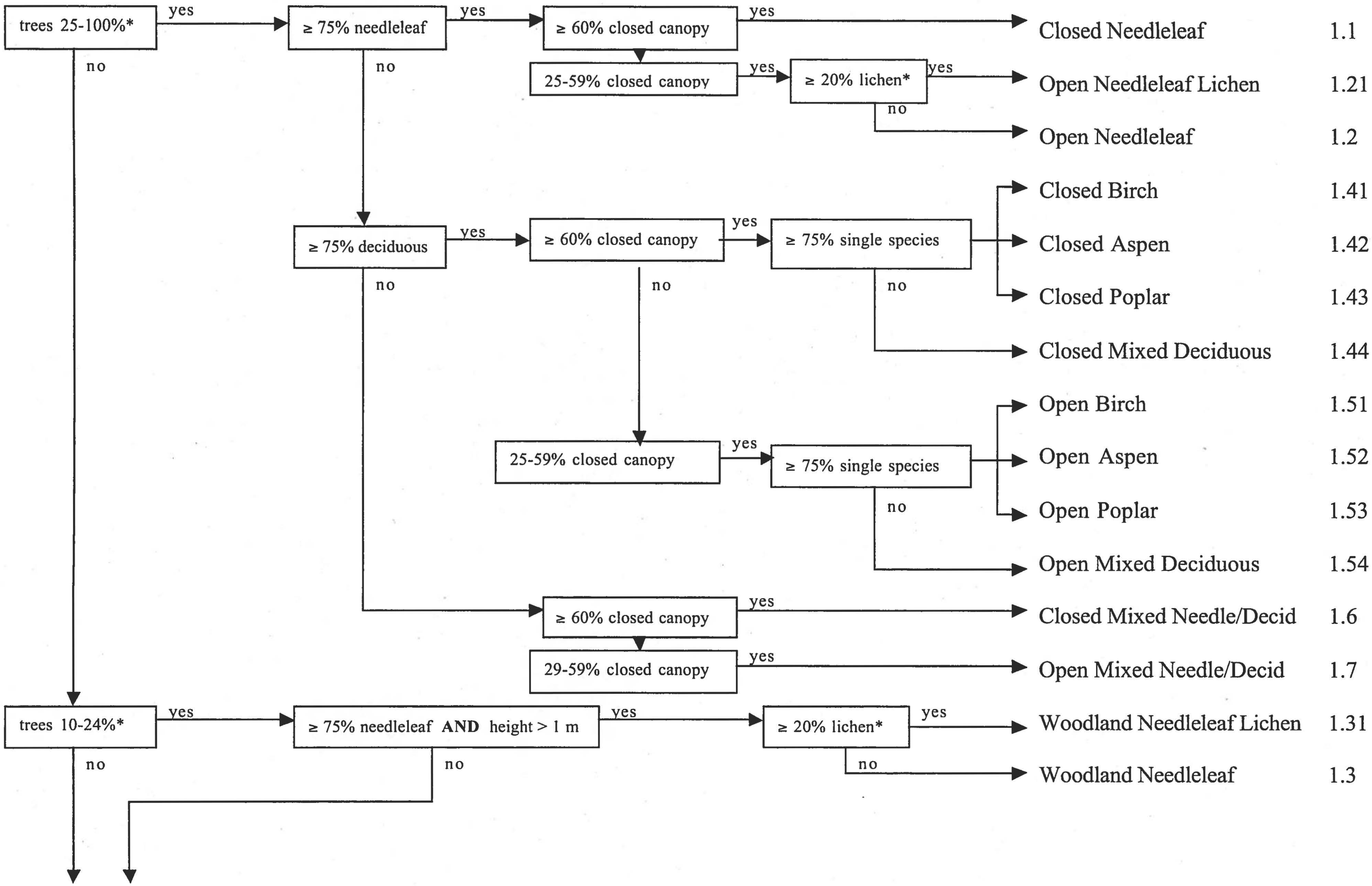
9.2 Cloud Shadow
At least 50% of the cover was made up of clouds shadows.

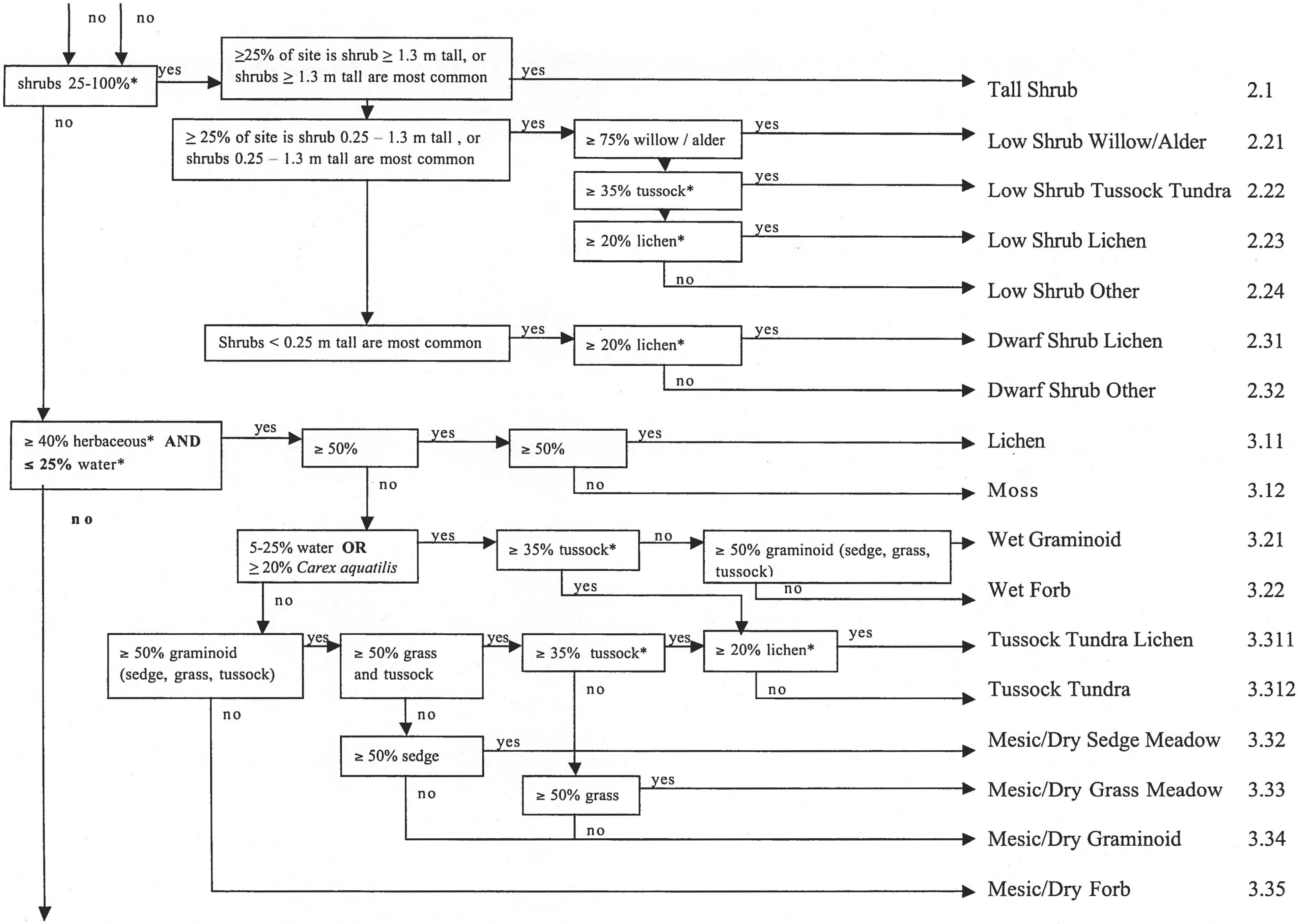
9.3 Terrain Shadow
At least 50% of the cover was made up of terrain shadows.

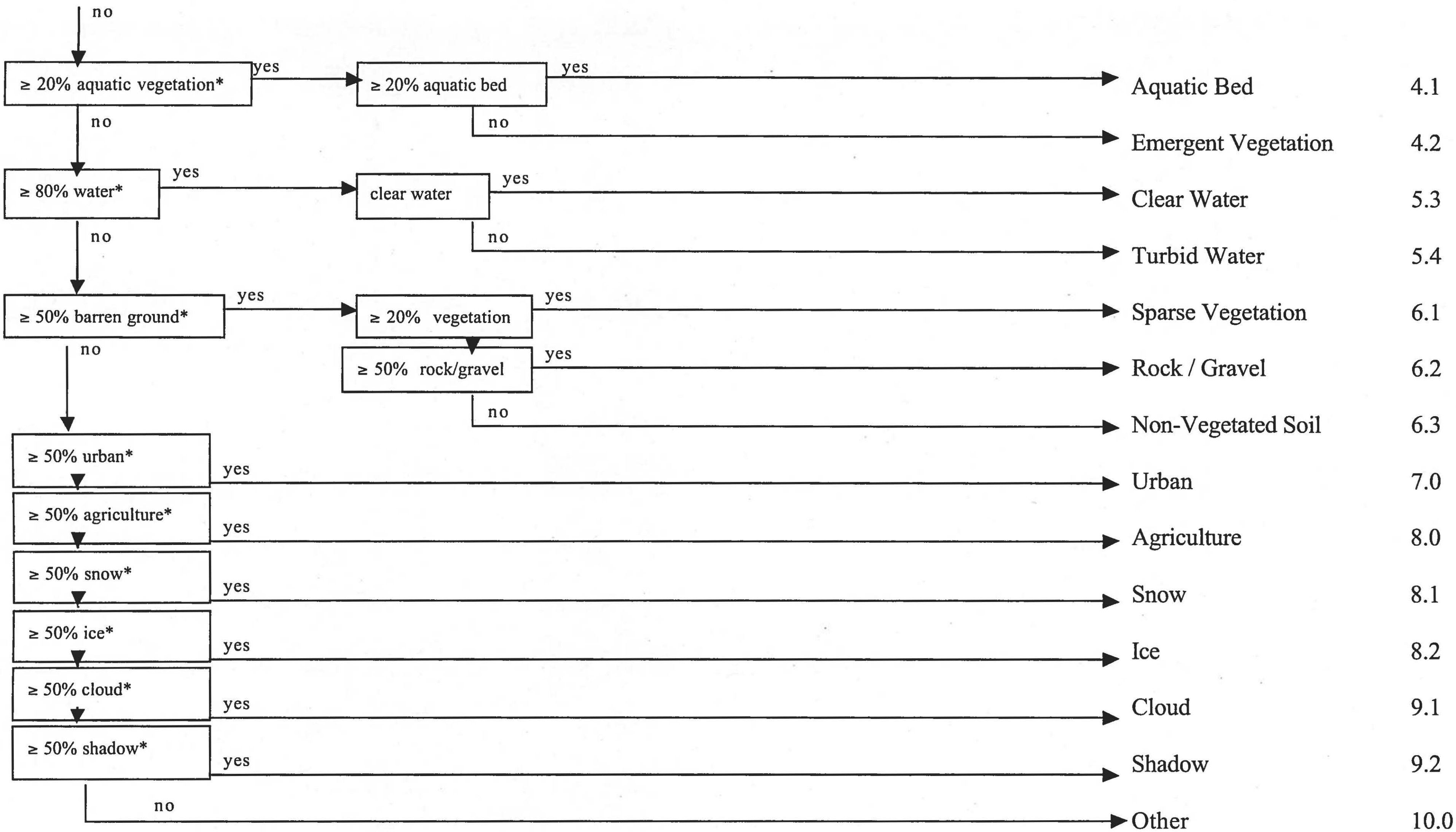
10.0 Other
Sites that did not fall into any other category were assigned to Other. For example, sites containing 25%-80% water, <25% shrub and <20% aquatic vegetation were classed as Other. Sites classed as Other may have also included extensive areas of vegetative litter, such as downed wood.

Appendix B. Alaska Earth Cover Classification Decision Tree

(*Indicates %of Total Land cover, otherwise % of Major Category)




no
no
shrubs 25-100%*
yes
≥25% of site is shrub ≥ 1.3 m tall, or shrubs ≥ 1.3 m tall are most common
yes
Tall Shrub
2.1
no
≥ 25% of site is shrub 0.25 – 1.3 m tall , or shrubs 0.25 – 1.3 m tall are most common
yes
≥ 75% willow / alder
yes
Low Shrub Willow/Alder
2.21
≥ 35% tussock*
yes
Low Shrub Tussock Tundra
2.22
≥ 20% lichen*
yes
Low Shrub Lichen
2.23
no
Low Shrub Other
2.24
Shrubs < 0.25 m tall are most common
yes
≥ 20% lichen*
yes
Dwarf Shrub Lichen
2.31
no
Dwarf Shrub Other
2.32
≥ 40% herbaceous* AND ≤ 25% water*
yes
≥ 50%
yes
≥ 50%
yes
Lichen
3.11
no
no
Moss
3.12
no
5-25% water OR ≥ 20% Carex aquatilis
yes
≥ 35% tussock*
no
≥ 50% graminoid (sedge, grass, tussock)
Wet Graminoid
3.21
yes
no
Wet Forb
3.22
no
≥ 50% graminoid (sedge, grass, tussock)
yes
≥ 50% grass and tussock
yes
≥ 35% tussock*
yes
≥ 20% lichen*
yes
Tussock Tundra Lichen
3.311
no
no
Tussock Tundra
3.312
no
no
≥ 50% sedge
yes
Mesic/Dry Sedge Meadow
3.32
≥ 50% grass
yes
Mesic/Dry Grass Meadow
3.33
no
no
Mesic/Dry Graminoid
3.34
Mesic/Dry Forb
3.35


no
≥ 20% aquatic vegetation*
yes
≥ 20% aquatic bed
yes
Aquatic Bed 4.1
no
no
Emergent Vegetation 4.2
≥ 80% water*
yes
clear water
yes
Clear Water 5.3
no
no
Turbid Water 5.4
≥ 50% barren ground*
yes
≥ 20% vegetation
yes
Sparse Vegetation 6.1
no
≥ 50% rock/gravel
yes
Rock / Gravel 6.2
no
Non-Vegetated Soil 6.3
≥ 50% urban*
yes
Urban 7.0
≥ 50% agriculture*
yes
Agriculture 8.0
≥ 50% snow*
yes
Snow 8.1
≥ 50% ice*
yes
Ice 8.2
≥ 50% cloud*
yes
Cloud 9.1
≥ 50% shadow*
yes
Shadow 9.2
no
Other 10.0

Appendix C. Earth Cover Class Acreage Summaries by General Land Status.

Northern Yukon MOA

Southern Yukon MOA

Land status based on the "GENSTAT" coverage produced by the Bureau of Land Management - Alaska State Office. GENSTAT coverage compiled September 19, 2000.

C1. Northern Yukon MOA earth cover class acreages for Bureau of Land Management lands.

CLASS NAME	ACRES	PERCENT COVER
Closed Needleleaf	21,126	3.70%
Open Needleleaf	158,881	27.83%
Open Ndl. - Lichen	2,907	0.51%
Woodland Needleleaf	92,155	16.14%
Woodland Ndl. - Lichen	6,094	1.07%
Woodland Ndl. - Moss	4,676	0.82%
Closed Deciduous	23,288	4.08%
Closed Deciduous-Birch	7,664	1.34%
Closed Deciduous-Aspen	12,753	2.23%
Closed Deciduous-Poplar	0	0.00%
Open Deciduous	7,733	1.35%
Open Deciduous-Aspen	5,540	0.97%
Closed Mixed Ndl./Decid.	115,315	20.20%
Open Mixed Ndl./Decid.	19,339	3.39%
Tall Shrub	9,662	1.69%
Low Shrub - Other	27,569	4.83%
Low Shrub - Lichen	86	0.01%
Low Shrub - Tussock Tundra	8,218	1.44%
Dwarf Shrub	9,278	1.63%
Moss	334	0.06%
Wet Graminoid/Sedge	376	0.07%
Mesic/Dry Grass Meadow	22	0.00%
Mesic/Dry Forb	404	0.07%
Aquatic Bed	0	0.00%
Emergent	163	0.03%
Clear Water	6,888	1.21%
Turbid Water	53	0.01%
Sparse Vegetation	655	0.11%
Rock/Gravel	42	0.01%
Non-Vegetated Soil	12	0.00%
Recent Burn - Sparse Veg	26,714	4.68%
Cloud	68	0.01%
Cloud Shadow	75	0.01%
Terrain Shadow	2,744	0.48%
Total	**570,835**	**100%**

C2. Northern Yukon MOA earth cover class acreages for State Patented and State Selected lands.

CLASS NAME	ACRES	PERCENT COVER
Closed Needleleaf	37,575	5.18%
Open Needleleaf	211,018	29.11%
Open Ndl. - Lichen	2,092	0.29%
Woodland Needleleaf	114,247	15.76%
Woodland Ndl. - Lichen	6,538	0.90%
Woodland Ndl. - Moss	4,137	0.57%
Closed Deciduous	30,089	4.15%
Closed Deciduous-Birch	4,982	0.69%
Closed Deciduous-Aspen	23,598	3.26%
Closed Deciduous-Poplar	0	0.00%
Open Deciduous	9,803	1.35%
Open Deciduous-Aspen	11,023	1.52%
Closed Mixed Ndl./Decid.	168,882	23.30%
Open Mixed Ndl./Decid.	22,430	3.09%
Tall Shrub	12,796	1.77%
Low Shrub - Other	37,471	5.17%
Low Shrub - Lichen	223	0.03%
Low Shrub - Tussock Tundra	11,151	1.54%
Dwarf Shrub	833	0.11%
Moss	180	0.02%
Wet Graminoid/Sedge	933	0.13%
Mesic/Dry Grass Meadow	714	0.10%
Mesic/Dry Forb	777	0.11%
Aquatic Bed	68	0.01%
Emergent	230	0.03%
Clear Water	9,830	1.36%
Turbid Water	340	0.05%
Sparse Vegetation	65	0.01%
Rock/Gravel	344	0.05%
Non-Vegetated Soil	93	0.01%
Recent Burn - Sparse Veg	1,646	0.23%
Cloud	0	0.00%
Cloud Shadow	28	0.00%
Terrain Shadow	699	0.10%
Total	**724,833**	**100%**

C3. Northern Yukon MOA earth cover class acreages for U.S. Fish and Wildlife Service lands.

CLASS NAME	ACRES	PERCENT COVER
Closed Needleleaf	69,547	4.42%
Open Needleleaf	363,440	23.07%
Open Ndl. - Lichen	1,011	0.06%
Woodland Needleleaf	210,931	13.39%
Woodland Ndl. - Lichen	2,194	0.14%
Woodland Ndl. - Moss	2,727	0.17%
Closed Deciduous	58,266	3.70%
Closed Deciduous-Birch	11,019	0.70%
Closed Deciduous-Aspen	55,468	3.52%
Closed Deciduous-Poplar	328	0.02%
Open Deciduous	26,074	1.66%
Open Deciduous-Aspen	44,910	2.85%
Closed Mixed Ndl./Decid.	220,003	13.97%
Open Mixed Ndl./Decid.	52,515	3.33%
Tall Shrub	49,586	3.15%
Low Shrub - Other	188,585	11.97%
Low Shrub - Lichen	205	0.01%
Low Shrub - Tussock Tundra	56,658	3.60%
Dwarf Shrub	419	0.03%
Moss	1,317	0.08%
Wet Graminoid/Sedge	11,003	0.70%
Mesic/Dry Grass Meadow	5,145	0.33%
Mesic/Dry Forb	4,857	0.31%
Aquatic Bed	454	0.03%
Emergent	7,432	0.47%
Clear Water	44,616	2.83%
Turbid Water	26,250	1.67%
Sparse Vegetation	402	0.03%
Rock/Gravel	446	0.03%
Non-Vegetated Soil	962	0.06%
Recent Burn - Sparse Veg	58,330	3.70%
Cloud	0	0.00%
Cloud Shadow	6	0.00%
Terrain Shadow	1	0.00%
Total	**1,575,104**	**100%**

C4. Northern Yukon MOA earth cover class acreages for Native Patented and Native Selected lands.

CLASS NAME	ACRES	PERCENT COVER
Closed Needleleaf	29,594	3.99%
Open Needleleaf	189,910	25.64%
Open Ndl. - Lichen	3,251	0.44%
Woodland Needleleaf	98,032	13.23%
Woodland Ndl. - Lichen	10,257	1.38%
Woodland Ndl. - Moss	3,646	0.49%
Closed Deciduous	23,571	3.18%
Closed Deciduous-Birch	9,404	1.27%
Closed Deciduous-Aspen	50,182	6.77%
Closed Deciduous-Poplar	1,205	0.16%
Open Deciduous	12,134	1.64%
Open Deciduous-Aspen	34,632	4.67%
Closed Mixed Ndl./Decid.	65,331	8.82%
Open Mixed Ndl./Decid.	20,585	2.78%
Tall Shrub	26,197	3.54%
Low Shrub - Other	67,147	9.06%
Low Shrub - Lichen	391	0.05%
Low Shrub - Tussock Tundra	22,398	3.02%
Dwarf Shrub	1,240	0.17%
Moss	1,067	0.14%
Wet Graminoid/Sedge	4,704	0.64%
Mesic/Dry Grass Meadow	4,785	0.65%
Mesic/Dry Forb	2,971	0.40%
Aquatic Bed	213	0.03%
Emergent	2,834	0.38%
Clear Water	25,406	3.43%
Turbid Water	26,735	3.61%
Sparse Vegetation	116	0.02%
Rock/Gravel	54	0.01%
Non-Vegetated Soil	261	0.04%
Recent Burn - Sparse Veg	702	0.09%
Cloud	0	0.00%
Cloud Shadow	25	0.00%
Terrain Shadow	1,823	0.25%
Total	**740,801**	**100%**

C5. Southern Yukon MOA earth cover class acreages for Bureau of Land Management lands.

CLASS NAME		ACRES	PERCENT COVER
Closed Needleleaf		44	0.08%
Open Needleleaf		18,507	33.94%
Open Ndl. - Lichen		1,903	3.49%
Woodland Needleleaf		6,409	11.75%
Woodland Ndl. - Lichen		43	0.08%
Closed Deciduous		479	0.88%
Closed Birch		681	1.25%
Open Birch		13	0.02%
Open Mixed Deciduous		1,309	2.40%
Closed Mixed Ndl./Decid.		354	0.65%
Open Mixed Ndl./Decid.		2,103	3.86%
Open Aspen		24	0.04%
Tall Shrub		681	1.25%
Low Shrub		13,994	25.67%
Low Shrub - Lichen		3	0.01%
Low Shrub - Tussock Tundra		3,426	6.28%
Dwarf Shrub		354	0.65%
Dwarf Shrub - Lichen		107	0.20%
Low Shrub - Moss		300	0.55%
Moss		28	0.05%
Mesic/Dry Grass Meadow		8	0.02%
Tussock Tundra		1,621	2.97%
Clear Water		142	0.26%
Turbid Water		46	0.08%
Sparse Vegetation		9	0.02%
Rock/Gravel		118	0.22%
Non-Vegetated Soil		65	0.12%
Urban		182	0.33%
Agriculture		0	0.00%
Cloud		62	0.11%
Cloud Shadow		436	0.80%
Terrain Shadow		1,067	1.96%
Total		**54,521**	**100%**

C6. Southern Yukon MOA earth cover class acreages for State Patented and State Selected lands.

CLASS NAME	ACRES	PERCENT COVER
Closed Needleleaf	21,221	0.85%
Open Needleleaf	888,482	35.70%
Open Ndl. - Lichen	92,989	3.74%
Woodland Needleleaf	269,317	10.82%
Woodland Ndl. - Lichen	14,378	0.58%
Closed Deciduous	51,429	2.07%
Closed Birch	74,978	3.01%
Open Birch	640	0.03%
Open Mixed Deciduous	26,827	1.08%
Closed Mixed Ndl./Decid.	106,663	4.29%
Open Mixed Ndl./Decid.	204,254	8.21%
Open Aspen	4,353	0.17%
Tall Shrub	82,089	3.30%
Low Shrub	341,412	13.72%
Low Shrub - Lichen	4,775	0.19%
Low Shrub - Tussock Tundra	5,313	0.21%
Dwarf Shrub	70,723	2.84%
Dwarf Shrub - Lichen	25,219	1.01%
Low Shrub - Moss	2,016	0.08%
Moss	310	0.01%
Mesic/Dry Grass Meadow	2,227	0.09%
Tussock Tundra	1,385	0.06%
Clear Water	3,084	0.12%
Turbid Water	2,983	0.12%
Sparse Vegetation	14,898	0.60%
Rock/Gravel	38,620	1.55%
Non-Vegetated Soil	4,102	0.16%
Urban	37,956	1.53%
Agriculture	1,658	0.07%
Cloud	29,413	1.18%
Cloud Shadow	31,986	1.29%
Terrain Shadow	33,158	1.33%
Total	**2,488,858**	**100%**

C7. Southern Yukon MOA earth cover class acreages for Military lands.

CLASS NAME	ACRES	PERCENT COVER
Closed Needleleaf	4,704	4.97%
Open Needleleaf	39,155	41.40%
Open Ndl. - Lichen	4,001	4.23%
Woodland Needleleaf	6,708	7.09%
Woodland Ndl. - Lichen	989	1.05%
Closed Deciduous	3,021	3.19%
Closed Birch	4,154	4.39%
Open Birch	27	0.03%
Open Mixed Deciduous	301	0.32%
Closed Mixed Ndl./Decid.	9,449	9.99%
Open Mixed Ndl./Decid.	12,556	13.28%
Open Aspen	206	0.22%
Tall Shrub	2,169	2.29%
Low Shrub	927	0.98%
Low Shrub - Lichen	57	0.06%
Low Shrub - Tussock Tundra	0	0.00%
Dwarf Shrub	381	0.40%
Dwarf Shrub - Lichen	66	0.07%
Low Shrub - Moss	0	0.00%
Moss	0	0.00%
Mesic/Dry Grass Meadow	142	0.15%
Tussock Tundra	0	0.00%
Clear Water	26	0.03%
Turbid Water	0	0.00%
Sparse Vegetation	11	0.01%
Rock/Gravel	134	0.14%
Non-Vegetated Soil	1	0.00%
Urban	5,390	5.70%
Agriculture	0	0.00%
Cloud	6	0.01%
Cloud Shadow	0	0.00%
Terrain Shadow	0	0.00%
Total	**94,583**	**100%**

C8. Southern Yukon MOA earth cover class acreages for Native Patented and Selected lands.

CLASS NAME	ACRES	PERCENT COVER
Closed Needleleaf	1,376	0.20%
Open Needleleaf	191,098	27.24%
Open Ndl. - Lichen	17,984	2.56%
Woodland Needleleaf	86,320	12.30%
Woodland Ndl. - Lichen	201	0.03%
Closed Deciduous	3,235	0.46%
Closed Birch	12,441	1.77%
Open Birch	113	0.02%
Open Mixed Deciduous	10,938	1.56%
Closed Mixed Ndl./Decid.	382	0.05%
Open Mixed Ndl./Decid.	26,953	3.84%
Open Aspen	661	0.09%
Tall Shrub	21,870	3.12%
Low Shrub	176,065	25.09%
Low Shrub - Lichen	18	0.00%
Low Shrub - Tussock Tundra	1,936	0.28%
Dwarf Shrub	24,933	3.55%
Dwarf Shrub - Lichen	15,313	2.18%
Low Shrub - Moss	1,553	0.22%
Moss	139	0.02%
Mesic/Dry Grass Meadow	20	0.00%
Tussock Tundra	566	0.08%
Clear Water	6,895	0.98%
Turbid Water	2,547	0.36%
Sparse Vegetation	6,161	0.88%
Rock/Gravel	13,805	1.97%
Non-Vegetated Soil	1,162	0.17%
Urban	63	0.01%
Agriculture	0	0.00%
Cloud	23,460	3.34%
Cloud Shadow	36,508	5.20%
Terrain Shadow	16,939	2.41%
Total	**701,656**	**100%**

Appendix D. Plant Species and Frequency for Northern and Southern Yukon MOAs.

Site_Tally	Symbol	Species	Common Name
597	LITT	LITTER	LITTER
494	MOXX	MOSS	MOSS
442	SAX_	SALIX SPP	WILLOW
401	LEPA11	LEDUM PALUSTRE	LABRADOR TEA
324	LIXX	LICHEN SPP	LICHEN
313	VAUL	VACCINIUM ULIGINOSUM	BLUEBERRY,BOG
256	PIGL	PICEA GLAUCA	SPRUCE,WHITE
256	PIMA	PICEA MARIANA	SPRUCE,BLACK
245	GRASS	GRASS	GRASS
240	VAVI	VACCINIUM VITIS-IDAEA	CRANBERRY,LOWBUSH
234	BEPA	BETULA PAPYRIFERA	BIRCH,PAPER
227	ALCR6	ALNUS CRISPA	ALDER,GREEN
192	BEGL	BETULA GLANDULOSA	BIRCH,RESIN
179	LITT2	LITTER STANDING	LITTER STANDING
171	RUCH	RUBUS CHAMAEMORUS	CLOUDBERRY
168	ERVA4	ERIOPHORUM VAGINATUM	COTTON-GRASS,TUSSOCK
156	ROAC	ROSA ACICULARIS	ROSE,PRICKLY
144	CAXX	CAREX SPP	SEDGE SPP
144	EMNI	EMPETRUM NIGRUM	CROWBERRY,BLACK
130	BENA	BETULA NANA	BIRCH,DWARF
119	EPAN2	EPILOBIUM ANGUSTIFOLIUM	FIREWEED
107	PEFR5	PETASITES FRIGIDUS	COLTSFOOT,ARCTIC SWEET
105	POTR10	POPULUS TREMULOIDES	ASPEN,QUAKING
93	CACA4	CALAMAGROSTIS CANADENSIS	REEDGRASS,BLUE-JOINT
92	ERXX	ERIOPHORUM SPP	COTTON-GRASS
88	SATRE	SALIX TREE	WILLOW TREE
85	ROCK	ROCK	ROCK
80	EQXX	EQUISETUM SPP	HORSETAILS SPP
79	CWATER	CLEAR WATER	CLEAR WATER
70	CHCA2	CHAMAEDAPHNE CALYCULATA	LEATHERLEAF
70	POFR4	POTENTILLA FRUTICOSA	CINQUEFOIL,SHRUBBY
67	BARE	BARE GROUND	BARE GROUND
51	CAAQ	CAREX AQUATILIS	SEDGE,WATER
44	DRXX	DRYAS SPP	MOUNTAIN-AVENS
40	ANPO	ANDROMEDA POLIFOLIA	ROSEMARY,BOG
38	GELI2	GEOCAULON LIVIDUM	TOADFLAX,NORTHERN RED-FRUIT
38	PICEA	PICEA SPP.	SPRUCE, MIXED WHITE AND BLACK
31	POBA2	POPULUS BALSAMIFERA	POPLAR,BALSAM
31	SADW	SALIX DW.	WILLOW, DWARF
30	ALTRE	ALNUS SPP TREE	ALDER, TREE
29	POAL5	POLYGONUM ALASKANUM	RHUBARB,ALASKA WILD
24	COCA13	CORNUS CANADENSIS	BUNCHBERRY,CANADA
24	POPA14	POTENTILLA PALUSTRIS	CINQUEFOIL,MARSH
24	ARCTO3	ARCTOSTAPHYLOS SPP	BEARBERRY

Site Tally	Symbol	Species	Common Name
21	LUPIN	LUPINUS SPP	LUPINE,SPP
20	RUMEX	RUMEX SPP	DOCK,SPP
18	ARRU	ARCTOSTAPHYLOS RUBRA	BEARBERRY,RED
18	GRAV	GRAVEL	GRAVEL
18	NODATA	NODATA FLYBY	NODATA,FLYBY
16	METR3	MENYANTHES TRIFOLIATA	BUCKBEAN
16	MEPA	MERTENSIA PANICULATA	BLUEBELLS,TALL
16	POBI5	POLYGONUM BISTORTA	BISTORT,MEADOW
15	ACDE2	ACONITUM DELPHINIFOLIUM	MONKSHOOD,LARKSPUR-LEAF
15	CABI5	CAREX BIGELOWII	SEDGE,BIGELOW'S
15	PEDIC	PEDICULARIS SPP	LOUSEWORT,SPP
13	SPBE	SPIREA BEAUVERDIANA	SPIREA
12	CATE11	CASSIOPE TETRAGONA	BELL-HEATHER,ARCTIC
12	MUDX	MUD	MUD
10	EQFL	EQUISETUM FLUVIATILE	HORSETAIL,WATER
10	DIAPE	DIAPENSIA SPP	DIAPENSIA,SPP
10	FEXX	FERN SPP	FERN SPP
9	CALA7	CAMPANULA LASIOCARPA	BELLFLOWER,COMMON ALASKA
9	LOPR	LOISELURIA PROCUMBENS	AZALEA, ALPINE
9	CATUSS	CAREX SPP - TUSSOCK	SEDGE,SPP-TUSSOCK
8	ARAL2	ARCTOSTAPHYLOS ALPINA	MANZANITA,ALPINE
8	MYGA	MYRICA GALE	SWEETGALE
8	SIAC	SILENE ACAULIS	CAMPION,MOSS
8	TYLA	TYPHA LATIFOLIA	CATTAIL,BROAD-LEAF
8	LYCOP2	LYCOPODIUM SPP	CLUBMOSS,SPP
8	NUPO	NUPHAR POLYSEPALUM	WATER LILY
7	ACMI2	ACHILLEA MILLEFOLIUM	YARROW,COMMON
7	SAXX	SAXIFRAGA SPP	SAXIFRAGE SPP
6	ARUV	ARCTOSTAPHYLOS UVA-URSI	KINNEKINNICK
6	LALA	LARIX LARICINA	LARCH,AMERICAN
6	SAAR13	SAXIFRAGA ARGUTA	SAXIFRAGE,BROOK
6	ARXX	ARNICA SPP	ARNICA SPP
6	MINUA	MINUARTIA SPP.	STITCHWORT,SPP
5	PESA5	PETASITES SAGITTATUS	COLTSFOOT,ARROW-LEAF SWEET
5	SHCA	SHEPHERDIA CANADENSIS	SOAPBERRY
4	ASXX	ASTRAGALUS SPP	VETCH
4	HOJU	HORDEUM JUBATUM	BARLEY,FOX-TAIL
4	PAPA8	PARNASSIA PALUSTRIS	GRASS-OF-PARNASSUS,NORTHERN
4	POTAM	POTAMEGETON SPP	PONDWEED
3	CAPA	CALLA PALUSTRIS	CALLA,WILD
3	CIMA	CICUTA MACKENZIANA	WATER-HEMLOCK,MACKENZIE
3	EPLA	EPILOBIUM LATIFOLIUM	BEAUTY,RIVER
3	EPXX	EPILOBIUM SPP	FIREWEED SPP
3	LEMI3	LEMNA MINOR	DUCKWEED,LESSER
3	NYTE	NYMPHAEA TETRAGONA	WATER-LILY,PYGMY
3	PALA9	PAPAVER LAPPONICUM	POPPY,ARCTIC
3	POTEN	POTENTILLA SPP.	CINQUEFOIL

Site_Tally	Symbol	Species	Common Name
3	SOLID	SOLIDAGO SPP.	GOLDENROD SPP.
3	POLYG4	POLYGONUM SPP.	BISTORT
2	CLAYT	CLAYTONIA SPP.	SPRINGBEAUTY,SPP
2	POAC	POLEMONIUM ACUTIFLORUM	JACOB'S-LADDER,STICKY TALL
2	RUBUS	RUBUS SPP.	RUBUS SPP.
2	SAND	SAND	SAND
2	TUWA	TURBID WATER	TURBID WATER
2	JUCO	JUNIPERUS COMMUNIS	JUNIPER, COMMON MOUNTAIN
2	OXNIN	OXYTROPIS NIGRESCENS	OXYTROPE,BLACKISH
2	CORNU	CORNUS SPP TREE	DOGWOOD SPP TREE
2	MIAR3	MINUARTIA ARCTICA	STITCHWORT, ARCTIC
2	ARTEM	ARTEMISIA SPP	SAGE, SPP
2	SAPU15	SALIX PULCHRA	WILLOW,COMMON
2	CIXX	CICUTA SPP	WATER-HEMLOCK
1	AGBO2	AGROSTIS BOREALIS	BENTGRASS,NORTHERN
1	ANMO9	ANTENNARIA MONOCEPHALA	PUSSYTOE
1	ALGE2	ALOPECURUS GENICULATUS	FOXTAIL,MEADOW
1	ARFU2	ARCTOPHILA FULVA	GRASS,PENDENT
1	CARO2	CAMPANULA ROTUNDIFOLIA	BELLFLOWER,SCOTCH
1	CARO6	CAREX ROSTRATA	SEDGE,BEAKED
1	COSU4	CORNUS SUECICA	DOGWOOD,SWEDISH DWARF
1	HIPPU	HIPPURIS SPP.	MARE'S TAIL
1	DEAR4	DENDRANTHEMA ARCTICUM	DAISY,ARCTIC
1	EQPA	EQUISETUM PALUSTRE	HORSETAIL,MARSH
1	ERAN6	ERIOPHORUM ANGUSTIFOLIUM	COTTON-GRASS,NARROW-LEAF
1	FOXX	FORB SPP	FORB SPP
1	GEAL2	GENTIANA ALGIDA	GENTIAN,WHITISH
1	GEAL3	GEUM ALEPPICUM	AVENS,YELLOW
1	GERO2	GEUM ROSSII	AVENS,ROSS'
1	GRXX	GRAMINOID SPP	GRAMINOID SPP
1	HAST3	HARRIMANELLA STELLERANA	HEATH,ALASKA MOSS
1	HIVU2	HIPPURIS VULGARIS	MARE'S-TAIL,COMMON
1	IRSE	IRIS SETOSA	IRIS,BEACH-HEAD
1	JUHO2	JUNIPERUS HORIZONTALIS	JUNIPER,CREEPING
1	LIBO3	LINNAEA BOREALIS	TWINFLOWER
1	POXX	POA SPP	POA SPP
1	RUAR	RUBUS ARCTICUS	RASPBERRY,ARCTIC
1	RUAR6	RUMEX ARCTICUS	DOCK,ARCTIC
1	BORI2	BOYKINIA RICHARSONI	BEARPLANT
1	SATR5	SAXIFRAGA TRICUSPIDATA	SAXIFRAGE,THREE-TOOTH
1	SCPA2	SCHEUCHZERIA PALUSTRIS	POD-GRASS
1	SERO2	SEDUM ROSEA	STONECROP,ROSEROOT
1	SILT	SILT	SILT
1	SISU2	SIUM SUAVE	WATER-PARSNIP,HEMLOCK
1	SOMU	SOLIDAGO MULTIRADIATA	GOLDEN-ROD,MOUNTAIN
1	SPAN2	SPARGANIUM ANGUSTIFOLIUM	BURREED,NARROWLEAF
1	VIED	VIBURNUM EDULE	CRANBERRY,HIGHBUSH
1	SENEC	SENECIO SPP	SENECIO,SPP

Site_Tally	Symbol	Species	Common Name
1	RIBES	RIBES SPP	CURRANT,SPP
1	OSHRB	OTHER SHRUB	OTHER SHRUB
1	ARAR9	ARTEMISIA ARCTICA	SAGEBRUSH, BOREAL
1	POTR15	POPULUS TRICHOCARPA	BLACK COTTONWOOD
1	DRFR	DRYOPTERIS FRAGRANS	FERN,FRAGRANT
1	ANNA	ANEMONE NARCISSIFLORA	ANEMONE,NARCISSUS

Appendix E. Error Matrix for Northern Yukon MOA Path 67 Image Classification – Accuracy Assessment

Reference Class (columns); **Majority (Map) Class** (rows)

AA Matrix	Closed Needleleaf	Open Needleleaf	Woodland Needleleaf	Closed Deciduous	Closed Birch	Closed Aspen	Open Deciduous	Open Aspen	Closed Mixed	Open Mixed	Tall Shrub	Low Shrub - Other	Low Shrub-Tussock	Moss	Wet Graminoid / Sedge	Mesic / Dry Herbaceous	Aquatic Bed	Emergent Vegetation	Clear Water	Turbid Water	Sparse Vegetation	Burn - Sparse Vegetation	Other	Total	User's Accuracy +/- 0%	User's Accuracy +/- 5%
Closed Needleleaf	**4**	0,2								0,1														7	57%	57%
Open Needleleaf	1,0	**15**																0,1						17	88%	94%
Woodland Needleleaf		0,2	**15**																					17	88%	88%
Closed Deciduous				**7**		1,0																		8	87%	100%
Closed Birch					**2**																			2	100%	100%
Closed Aspen					0,1	**3**		0,1																5	60%	60%
Open Decidiuous							**1**																	1	100%	100%
Open Aspen																								0	0%	0%
Closed Mixed		0,1							**3**															4	75%	75%
Open Mixed										**2**														2	100%	100%
Tall Shrub						0,1					**4**	1,0												6	67%	83%
Low Shrub - Other						0,1					0,1	**6**	1,0											9	67%	78%
Low Shrub - Tussock			1,0										**8**											9	89%	100%
Moss		0,1																						1	0%	0%
Wet Graminoid / Sedge															**1**									1	100%	100%
Mesic / Dry Herbaceous																**4**								4	100%	100%
Aquatic Bed																	**2**							2	100%	100%
Emergent Vegetation																		**2**					0,1	3	67%	67%
Clear Water											1,0						0,1							2	0%	50%
Turbid Water																					2,0			2	0%	100%
Sparse Vegetation																								0	0%	0%
Burn -Sparse Vegetation																						**1**		1	100%	100%
Other																								0		
Total	5	21	16	7	3	6	1	1	3	3	6	7	9	0	1	4	3	3	0	0	2	1	1	**103**		
Producer's Accuracy (+/-0%):	80%	71%	94%	100%	67%	50%	100%	0%	100%	67%	67%	86%	89%	0%	100%	100%	67%	67%	0%	0%	0%	100%	0%			
Producer's Accuracy (+/-5%):	100%	71%	100%	100%	67%	67%	100%	0%	100%	67%	83%	100%	100%	0%	100%	100%	67%	67%	0%	0%	100%	100%	0%			

Total # of Accuracy Assessment Sites = 103
Diagonal = 80
Off-Diagonal Total = 23
Off-Diagonal Acceptable = 8
Overall Accuracy (0% var) = 77.67%
Overall Accuracy (+/- 5% var) = 85.44%

Appendix F. Error Matrix for Southern Yukon MOA Path 66 Image Classification – Accuracy Assessment Sites.

	Reference Class																
Majority (Map) Class / AA Matrix	Open Needleleaf	Open Ndl.-Lichen	Woodland Needleleaf	Closed Deciduous	Closed Birch	Open Deciduous	Open Aspen	Open Mixed	Tall Shrub	Low Shrub - Other	Low Shrub-Tussock	Dwarf Shrub-Other	Sparse Vegetation	Rock/Gravel	Total	User's Accuracy +/- 0%	User's Accuracy +/- 5%
Open Needleleaf	**8**							1,0		0,1					10	80%	90%
Open Ndl. - Lichen	1,1	**1**													3	33%	66%
Woodland Needleleaf			**1**												1	100%	100%
Closed Deciduous				**1**											1	100%	100%
Closed Birch					**3**										3	100%	100%
Open Decidiuous						**2**									2	100%	100%
Open Aspen							**1**								1	100%	100%
Open Mixed															0	0%	0%
Tall Shrub											0,1				1	0%	0%
Low Shrub - Other									1,0	**12**	1,0	1,1			16	75%	94%
Low Shrub - Tussock											**1**				1	100%	100%
Dwarf Shrub - Other												**3**			3	100%	100%
Sparse Vegetation														1,0	1	0%	100%
Rock/Gravel														**1**	1	100%	100%
Total	10	1	1	1	3	2	1	1	1	13	3	5	0	2	**44**		
Producer's Accuracy (+/-0%):	80%	100%	100%	100%	100%	100%	100%	0%	0%	92%	33%	60%	0%	50%			
Producer's Accuracy (+/-5%):	90%	100%	100%	100%	100%	100%	100%	100%	100%	92%	66%	80%	0%	100%			

Total # of Accuracy Assessment Sites =	44
Diagonal =	34
Off-Diagonal Total =	10
Off-Diagonal Acceptable =	6
Overall Accuracy (0% var) =	**77.27%**
Overall Accuracy (+/- 5% var) =	**90.91%**

Appendix G. Error Matrix for Southern Yukon MOA Path 68 Image Classification – Accuracy Assessment Sites.

Reference Class

Majority (Map) Class

AA Matrix	Open Needleleaf	Open Ndl.- Lichen	Woodland Needleleaf	Closed Deciduous	Closed Birch	Open Deciduous	Open Aspen	Open Mixed	Tall Shrub	Low Shrub - Other	Low Shrub- Tussock	Dwarf Shrub- Other	Sparse Vegetation	Rock/Gravel	Total	User's Accuracy +/- 0%	User's Accuracy +/- 5%
Open Needleleaf	**8**	2,1	1,1					2,0							15	53%	87%
Open Ndl. - Lichen		**1**													1	100%	100%
Woodland Needleleaf			**5**												5	100%	100%
Closed Deciduous				**3**											3	100%	100%
Closed Birch					**5**										5	100%	100%
Open Decidiuous															0	0%	0%
Closed Mixed							**2**								2	100%	100%
Open Mixed			0,1					**1**							2	50%	50%
Tall Shrub			0,1			1,0			**3**			0,1			6	50%	67%
Low Shrub - Other										**4**					4	100%	100%
Low Shrub - Tussock															0	0%	0%
Dwarf Shrub - Other												**4**			4	100%	100%
Sparse Vegetation			1,0												1	0%	100%
Rock/Gravel														**1**	1	100%	100%
Total	8	4	10	3	5	1	2	3	3	4	0	5	0	1	**49**		
Producer's Accuracy (+/-0%):	100%	25%	50%	100%	100%	0%	100%	33%	100%	100%	0%	80%	0%	100%			
Producer's Accuracy (+/-5%):	100%	75%	70%	100%	100%	100%	100%	100%	100%	100%	0%	80%	0%	100%			

Total # of Accuracy Assessment Sites =	49
Diagonal =	37
Off-Diagonal Total =	12
Off-Diagonal Acceptable =	7
Overall Accuracy (0% var) =	**75.51%**
Overall Accuracy (+/- 5% var) =	**89.80%**

Appendix H. Northern Yukon MOA Earth Cover Mapping Classified Image Metadata

Filename: Nyuk_earthcov
Filetype:Arc/Info Grid

Metadata:
Identification_Information
  Data_Quality_Information
  Spatial_Reference_Information
  Entity_and_Attribute_Information
  Metadata_Reference_Information
Identification_Information:
  Citation:
    Citation_Information:
      Originator:Ducks Unlimited,Inc.
      Publication_Date: 102001
      Publication_Time:
      Title: nyuk_earthcov
      Edition:
      Geospatial_Data_Presentation_Form:map
  Description: Northern Yukon MOA Earth Cover Classification
    Abstract:
      The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. The goal of this project was to continue the mapping effort by mapping the Northern portion of the Yukon Military Operations Areas (MOA). A Portion of one Landsat TM satellite scene (Path 67 Row 13 acquired 24 June 2000 shifted 35% North) was used to classify the Northern Yukon MOA project area into 30 earth cover categories. An unsupervised clustering technique was used to determine the location of field sites and a custom field data collection form and digital database were used to record field information. Helicopters were 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 to record the locations of new sites selected in the field. The Northern Yukon MOA project area is approximately 3.6 million. For the Northern Yukon MOA project area, a total of 396 sites were visited during a 2-day field season in 1999 and a 6-day field season in 2000. Approximately 30% of these field sites were set aside for accuracy assessment. A modified supervised/unsupervised classification technique was performed to classify the satellite imagery. The classification scheme for the earth cover inventory was based on Viereck *et al.* (1992) and revised through a series of meetings coordinated by the BLM – Alaska and DU. The overall accuracy of the Northern Yukon mapping categories was 85.4% at the +/-5% level of variation.
    Purpose:
      The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Northern Yukon MOA area. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project was an integrated GIS database that can be used for improved natural resources planning.
  Time_Period_of_Content:
    Time_Period_Information:
      Multiple_Dates/Times:
      Single_Date/Time:
        Calendar_Date:06242000
    Currentness_Reference:102001
  Status:
    Progress:complete

    Maintenance_and_Update_Frequency:none
  Spatial_Domain:
    Bounding_Coordinates:
      West_Bounding_Coordinate: -145.157
      East_Bounding_Coordinate: -141.085
      North_Bounding_Coordinate: 66.981
      South_Bounding_Coordinate: 65.515
  Keywords:
    Theme:
      Theme_Keyword_Thesaurus:
      Theme_Keyword:Land Cover Classification
      Theme_Keyword:Earth Cover Classification
      Theme_Keyword:Landsat TM
    Place:
      Place_Keyword_Thesaurus:
      Place_Keyword:Northern Yukon MOA
      Place_Keyword:Yukon MOA
      Place_Keyword:Alaska
    Temporal:
      Temporal_Keyword_Thesaurus:
      Temporal_Keyword:1999
      Temporal_Keyword:2000
      Temporal_Keyword:2001
  Point_of_Contact:
    Contact_Information:
      Contact_Organization:Ducks Unlimited, Inc.
      Contact_Person:
      Contact_Position:GIS Manager
      Contact_Address:
        Address_Type:
        Address:3074 Gold Canal Drive
        City:Rancho Cordova
        State_or_Province:California
        Postal_Code:95670
        Country:U.S.A
      Contact_Voice_Telephone:(916)852-2000
Data_Quality_Information:
  Attribute_Accuracy:
    Attribute_Accuracy_Report:See Final Report
    Quantitative_Attribute_Accuracy_Assessment:
      Attribute_Accuracy_Value:
      Attribute_Accuracy_Explanation:
  Lineage:
    Source_Information:
    Source_Citation:
      Citation_Information:
        Originator:EROS Data Center
        Publication_Date:2000
        Publication_Time:
        Title:Landsat7 ETM Imagery From Path 67, Rows 14 shifted approximately 35% acquired 6/24/00
          Edition:
          Geospatial_Data_Presentation_Form:remote sensing image
      Source_Scale_Denominator:
      Type_of_Source_Media:

Source_Time_Period_of_Content:
Time_Period_Information:
Multiple_Dates/Times:
Single_Date/Time:
Calendar_Date:2000
Process_Step:
Process_Description:See "Northern and Southern Yukon MOA Earth Cover Classification" report
Source_Used_Citation_Abbreviation:
Process_Date:2000/2001
Process_Time:
Source_Produced_Citation_Abbreviation:
Spatial_Data_Organization_Information:
Indirect_Spatial_Reference:
Direct_Spatial_Reference_Method:Raster
Raster_Object_Information:
Raster_Object_Type:Pixel
Row_Count:4363
Column_Count:6924
Vertical_Count:
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution:
Longitude_Resolution:
Geographic_Coordinate_Units:
Planar:
Map_Projection:
Map_Projection_Name:
Albers_Conical_Equal_Area:
1st_Standard_Parallel:65
2nd_Standard_Parallel:55
Longitude_of_Central_Meridian:-154
Latitude_of_Projection_Origin:50
False_Easting:
False_Northing:
Geodetic_Model:
Horizontal_Datum_Name:NAD27 (Alaska)
Ellipsoid_Name:Clarke 1866
Semi-major_Axis:
Denominator_of_Flattening_Ratio:
Metadata_Reference_Information:
Metadata_Date:102001
Metadata_Review_Date:
Metadata_Future_Review_Date:
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:Ducks Unlimited
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:

Address_Type:
Address:3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province:California
Postal_Code:95670
Country:U.S.A
Contact_Voice_Telephone:(916)852-2000
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Metadata_Standard_Name:Northern and Southern Yukon MOA Earth Cover Classification Metadata
Metadata_Standard_Version:
Metadata_Time_Convention:
Metadata_Access_Constraints:
Metadata_Use_Constraints:
Metadata_Security_Information:
Metadata_Security_Classification_System:
Metadata_Security_Classification:
Metadata_Security_Handling_Description:
Metadata_Extensions:
Online_Linkage:
Profile_Name:

Appendix I. Southern Yukon MOA Earth Cover Mapping Classified Image Metadata

Filename: Syuk_earthcov
Filetype:Arc/Info Grid

Metadata:

- Identification_Information
- Data_Quality_Information
- Spatial_Reference_Information
- Entity_and_Attribute_Information
- Metadata_Reference_Information

Identification_Information:
  Citation:
    Citation_Information:
      Originator:Ducks Unlimited,Inc.
      Publication_Date: 102001
      Publication_Time:
      Title: syuk_earthcov
      Edition:
      Geospatial_Data_Presentation_Form:map
  Description: Southern Yukon MOA Earth Cover Classification
    Abstract:
      The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. The goal of this project was to continue the mapping effort by mapping the Southern portion of the Yukon Military Operations Areas (MOA). Portions of two Landsat TM satellite scenes (Path 66, Row 15 acquired 16 September 1995 and Path 68, Row 15 acquired 31 July 1999) were used to classify the Southern Yukon MOA project area into 30 earth cover categories. The path 66 and path 68 images were classified separately because of the large difference in image dates and season. The path 66 and path 68 earth cover classifications were mosaiced and edge-matched post-classification to produce a continuous earth cover map for the entire project area. An unsupervised clustering technique was used to determine the location of field sites and a custom field data collection form and digital database were used to record field information. Helicopters were 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 to record the locations of new sites selected in the field. The Southern Yukon MOA project area is approximately 3.8 million acres. For the Southern Yukon MOA project area, a total of 320 field sites were visited during a 3-day field season in 1999 and a 5-day field season in 2000. Approximately 30% of these field sites were set aside for accuracy assessment. A modified supervised/unsupervised classification technique was performed to classify the satellite imagery. The classification scheme for the earth cover inventory was based on Viereck *et al.* (1992) and revised through a series of meetings coordinated by the BLM – Alaska and DU. The overall accuracy of the Southern Yukon mapping categories was 90.9% at the +/-5% level of variation for the path 66 classification and 89.8% at the +/-5% level of variation for the path 68 classification.

    Purpose:
      The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Southern Yukon MOA area. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project was an integrated GIS database that can be used for improved natural resources planning.

```
Time_Period_of_Content:
      Time_Period_Information:
         Multiple_Dates/Times:
         Single_Date/Time:
            Calendar_Date:09161995
      Currentness_Reference:102001
   Status:
      Progress:complete
      Maintenance_and_Update_Frequency:none
   Spatial_Domain:
      Bounding_Coordinates:
         West_Bounding_Coordinate: -147.117
         East_Bounding_Coordinate: -141.827
         North_Bounding_Coordinate: 65.195
         South_Bounding_Coordinate: 63.386
   Keywords:
      Theme:
         Theme_Keyword_Thesaurus:
         Theme_Keyword:Land Cover Classification
         Theme_Keyword:Earth Cover Classification
         Theme_Keyword:Landsat TM
      Place:
         Place_Keyword_Thesaurus:
         Place_Keyword:Southern Yukon MOA
         Place_Keyword:Yukon MOA
         Place_Keyword:Alaska
      Temporal:
         Temporal_Keyword_Thesaurus:
         Temporal_Keyword:1995
         Temporal_Keyword:1999
         Temporal_Keyword:2001
   Point_of_Contact:
      Contact_Information:
         Contact_Organization:Ducks Unlimited, Inc.
         Contact_Person:
         Contact_Position:GIS Manager
         Contact_Address:
            Address_Type:
            Address:3074 Gold Canal Drive
            City:Rancho Cordova
            State_or_Province:California
            Postal_Code:95670
            Country:U.S.A
         Contact_Voice_Telephone:(916)852-2000
Data_Quality_Information:
   Attribute_Accuracy:
      Attribute_Accuracy_Report:See Final Report
      Quantitative_Attribute_Accuracy_Assessment:
         Attribute_Accuracy_Value:
         Attribute_Accuracy_Explanation:
   Lineage:
      Source_Information:
      Source_Citation:
         Citation_Information:
```

Originator:EROS Data Center
Publication_Date:1995 and 1999
Publication_Time:
Title:Landsat7 ETM Imagery From Path 66, Rows 15 acquired 9/16/95 and Path 68 Row 15 acquired 7/31/1999
Edition:
Geospatial_Data_Presentation_Form:remote sensing image
Source_Scale_Denominator:
Type_of_Source_Media:
Source_Time_Period_of_Content:
Time_Period_Information:
Multiple_Dates/Times:
Single_Date/Time:
Calendar_Date:1995
Single_Date/Time:
Calendar_Date:1999
Process_Step:
Process_Description:See "Northern and Southern Yukon MOA Earth Cover Classification" report
Source_Used_Citation_Abbreviation:
Process_Date:2000/2001
Process_Time:
Source_Produced_Citation_Abbreviation:
Spatial_Data_Organization_Information:
Indirect_Spatial_Reference:
Direct_Spatial_Reference_Method:Raster
Raster_Object_Information:
Raster_Object_Type:Pixel
Row_Count:5440
Column_Count:9403
Vertical_Count:
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution:
Longitude_Resolution:
Geographic_Coordinate_Units:
Planar:
Map_Projection:
Map_Projection_Name:
Albers_Conical_Equal_Area:
1st_Standard_Parallel:65
2nd_Standard_Parallel:55
Longitude_of_Central_Meridian:-154
Latitude_of_Projection_Origin:50
False_Easting:
False_Northing:
Geodetic_Model:
Horizontal_Datum_Name:NAD27 (Alaska)
Ellipsoid_Name:Clarke 1866
Semi-major_Axis:
Denominator_of_Flattening_Ratio:
Metadata_Reference_Information:
Metadata_Date:102001
Metadata_Review_Date:

Metadata_Future_Review_Date:
Metadata_Contact:
  Contact_Information:
    Contact_Person_Primary:
      Contact_Person:
      Contact_Organization:
    Contact_Organization_Primary:
      Contact_Organization:Ducks Unlimited
      Contact_Person:
    Contact_Position:GIS Manager
    Contact_Address:
      Address_Type:
      Address:3074 Gold Canal Drive
      City:Rancho Cordova
      State_or_Province:California
      Postal_Code:95670
      Country:U.S.A
    Contact_Voice_Telephone:(916)852-2000
    Contact_TDD/TTY_Telephone:
    Contact_Facsimile_Telephone:
    Contact_Electronic_Mail_Address:
    Hours_of_Service:
    Contact_Instructions:
Metadata_Standard_Name:Northern and Southern Yukon MOA Earth Cover Classification Metadata
Metadata_Standard_Version:
Metadata_Time_Convention:
Metadata_Access_Constraints:
Metadata_Use_Constraints:
Metadata_Security_Information:
  Metadata_Security_Classification_System:
  Metadata_Security_Classification:
  Metadata_Security_Handling_Description:
Metadata_Extensions:
  Online_Linkage:
      Profile_Name:

Appendix J. Northern Yukon MOA Earth Cover Mapping Field Sites Metadata

Filename:nyuk_fld_sts
Filetype:Arc/Info coverage

Metadata:

- Identification_Information
- Data_Quality_Information
- Spatial_Reference_Information
- Entity_and_Attribute_Information
- Metadata_Reference_Information

Identification_Information:
- Citation:
  - Citation_Information:
    - Originator:Ducks Unlimited, Inc.
    - Publication_Date:10/2001
    - Publication_Time:
    - Title: nyuk_fld_sts
    - Edition:
  - Geospatial_Data_Presentation_Form:map
- Description:
  - Abstract:
    - The field data collected for the Northern Yukon MOA Earth Cover Mapping Project is included on the final products CD's. Nyuk_fld_sts is an Arcinfo coverage of all sites that were visited in the field. Nyuk_fld_sts includes site information about each polygon. Three DBASE files (nyuk_photo.dbf, nyuk_site_species.dbf, and nyuk_species.dbf) are also included on the final products CD's. All three of these files can be linked to the ArcInfo polygon coverage to provide the complete database of information collected for each fieldsite. The links are made by the duff.avx ArcView extension included on the final products CD's.
  - Purpose:
    - The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Northern Yukon MOA area. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project was an integrated GIS database that can be used for improved natural resources planning.
- Time_Period_of_Content:
  - Time_Period_Information:
    - Single_Date/Time:
      - Calendar_Date:10/2001
  - Currentness_Reference:10/2001
- Status:
  - Progress:complete
  - Maintenance_and_Update_Frequency:none
- Spatial_Domain:
  - Bounding_Coordinates:
    - West_Bounding_Coordinate: -145.157
    - East_Bounding_Coordinate: -141.085
    - North_Bounding_Coordinate: 66.981
    - South_Bounding_Coordinate: 65.515
  - Keywords:

Theme:
Theme_Keyword_Thesaurus:
Theme_Keyword:Field Sites
Theme_Keyword:ArcInfo Coverages
Theme_Keyword:Land Cover Classification
Theme_Keyword:Earth Cover Classification
Place:
Place_Keyword_Thesaurus:
Place_Keyword:Northern Yukon MOA
Place_Keyword:Yukon MOA
Place_Keyword:Alaska
Stratum:
Stratum_Keyword_Thesaurus:
Stratum_Keyword:
Temporal:
Temporal_Keyword_Thesaurus:
Temporal_Keyword:2001
Access_Constraints:
Use_Constraints:
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:Ducks Unlimited, Inc.
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:
Address_Type:
Address:3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province:California
Postal_Code:95670
Country:U.S.A.
Contact_Voice_Telephone:916 852-2000
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:See Final Report
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:Ducks Unlimited, Inc.
Publication_Date:2001
Publication_Time:
Title:ArcInfo polygon coverage for Northern Yukon MOA field sites and associated Dbase files.
Edition:
Geospatial_Data_Presentation_Form:ArcInfo polygon coverage. DBASE files.

Process_Step:
Process_Description:See "Northern and Southern Yukon MOA Earth Cover Classification"
Source_Used_Citation_Abbreviation:
Process_Date:2001
Process_Time:
Source_Produced_Citation_Abbreviation:
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:Ducks Unlimited, Inc.
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:
Address_Type:
Address:3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province:California
Postal_Code:95670
Country:U.S.A
Contact_Voice_Telephone:916-852-2000
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Cloud_Cover:
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name:
Albers_Conical_Equal_Area:
1st_Standard_Parallel:65
2nd_Standard_Parallel:55
Longitude_of_Central_Meridian:-154
Latitude_of_Projection_Origin:50
False_Easting:
False_Northing:
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method:
Coordinate_Representation:
Abscissa_Resolution:
Ordinate_Resolution:
Geodetic_Model:
Horizontal_Datum_Name:NAD27 (Alaska)
Ellipsoid_Name:Clarke1866
Semi-major_Axis:
Denominator_of_Flattening_Ratio:
Entity_and_Attribute_Information:
Overview_Description:

Entity_and_Attribute_Overview:
See Appendix L in "Northern and Southern Yukon MOA Earth Cover Classification Final Report" or see Fielddata_documentation.doc on final deliverable CD.
Entity_and_Attribute_Detail_Citation:
Metadata_Reference_Information:
Metadata_Date:10/2001
Metadata_Review_Date:
Metadata_Future_Review_Date:
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:Bureau of Land Management Alaska
Contact_Organization_Primary:
Contact_Organization:
Contact_Person:
Contact_Position:
Contact_Address:
Address_Type:
Address:222 West 7th avenue
City:Anchorage
State_or_Province:Alaska
Postal_Code:99513
Country:U.S.A
Contact_Voice_Telephone:
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Metadata_Standard_Name:
Metadata_Standard_Version:
Metadata_Time_Convention:
Metadata_Access_Constraints:
Metadata_Use_Constraints:
Metadata_Security_Information:
Metadata_Security_Classification_System:
Metadata_Security_Classification:
Metadata_Security_Handling_Description:
Metadata_Extensions:
Online_Linkage:
Profile_Name:
City:Anchorage
State_or_Province:Alaska
Postal_Code:99513
Country:U.S.A
Contact_Voice_Telephone:
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:

Appendix K. Southern Yukon MOA Earth Cover Mapping Field Sites Metadata

Filename:syuk_fld_sts
Filetype:Arc/Info coverage

Metadata:

- Identification_Information
- Data_Quality_Information
- Spatial_Reference_Information
- Entity_and_Attribute_Information
- Metadata_Reference_Information

Identification_Information:
  Citation:
    Citation_Information:
      Originator:Ducks Unlimited, Inc.
      Publication_Date:10/2001
      Publication_Time:
      Title:syuk_fld_sts
      Edition:
    Geospatial_Data_Presentation_Form:map
  Description:
    Abstract:
      The field data collected for the Southern Yukon MOA Earth Cover Mapping Project is included on the final products CD's. Syuk_fld_sts is an Arcinfo coverage of all sites that were visited in the field. Syuk_fld_sts includes site information about each polygon. Three DBASE files (syuk_photo.dbf, syuk_site_species.dbf, and syuk_species.dbf) are also included on the final products CD's. All three of these files can be linked to the ArcInfo polygon coverage to provide the complete database of information collected for each fieldsite. The links are made by the duff.avx ArcView extension included on the final products CD's.
    Purpose:
      The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Southern Yukon MOA area. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project was an integrated GIS database that can be used for improved natural resources planning.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date:10/2001
    Currentness_Reference:10/2001
  Status:
    Progress:complete
    Maintenance_and_Update_Frequency:none
  Spatial_Domain:
    Bounding_Coordinates:
      West_Bounding_Coordinate: -147.117
      East_Bounding_Coordinate: -141.827
      North_Bounding_Coordinate: 65.195
      South_Bounding_Coordinate: 63.386
    Keywords:
      Theme:
        Theme_Keyword_Thesaurus:
        Theme_Keyword:Field Sites

Theme_Keyword:ArcInfo Coverages
Theme_Keyword:Land Cover Classification
Theme_Keyword:Earth Cover Classification
Place:
Place_Keyword_Thesaurus:
Place_Keyword:Southern Yukon MOA
Place_Keyword:Yukon MOA
Place_Keyword:Alaska
Stratum:
Stratum_Keyword_Thesaurus:
Stratum_Keyword:
Temporal:
Temporal_Keyword_Thesaurus:
Temporal_Keyword:2001
Access_Constraints:
Use_Constraints:
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:Ducks Unlimited, Inc.
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:
Address_Type:
Address:3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province:California
Postal_Code:95670
Country:U.S.A.
Contact_Voice_Telephone:916 852-2000
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:See Final Report
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:Ducks Unlimited, Inc.
Publication_Date:2001
Publication_Time:
Title:ArcInfo polygon coverage for Southern Yukon MOA field sites and associated Dbase files.
Edition:
Geospatial_Data_Presentation_Form:ArcInfo polygon coverage. DBASE files.
Process_Step:
Process_Description:See "Northern and Southern Yukon MOA Earth Cover Classification"
Source_Used_Citation_Abbreviation:

Process_Date:2001
Process_Time:
Source_Produced_Citation_Abbreviation:
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:Ducks Unlimited, Inc.
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:
Address_Type:
Address:3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province:California
Postal_Code:95670
Country:U.S.A
Contact_Voice_Telephone:916-852-2000
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Cloud_Cover:
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name:
Albers_Conical_Equal_Area:
1st_Standard_Parallel:65
2nd_Standard_Parallel:55
Longitude_of_Central_Meridian:-154
Latitude_of_Projection_Origin:50
False_Easting:
False_Northing:
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method:
Coordinate_Representation:
Abscissa_Resolution:
Ordinate_Resolution:
Geodetic_Model:
Horizontal_Datum_Name:NAD27 (Alaska)
Ellipsoid_Name:Clarke1866
Semi-major_Axis:
Denominator_of_Flattening_Ratio:
Entity_and_Attribute_Information:
Overview_Description:
Entity_and_Attribute_Overview:
See Appendix L in "Northern and Southern Yukon MOA Earth Cover Classification Final Report" or see Fielddata_documentation.doc on final deliverable CD.
Entity_and_Attribute_Detail_Citation:

Metadata_Reference_Information:
  Metadata_Date:10/2001
  Metadata_Review_Date:
  Metadata_Future_Review_Date:
  Metadata_Contact:
    Contact_Information:
      Contact_Person_Primary:
        Contact_Person:
        Contact_Organization:Bureau of Land Management Alaska
      Contact_Organization_Primary:
        Contact_Organization:
        Contact_Person:
      Contact_Position:
      Contact_Address:
        Address_Type:
        Address:222 West 7th avenue
        City:Anchorage
        State_or_Province:Alaska
        Postal_Code:99513
        Country:U.S.A
      Contact_Voice_Telephone:
      Contact_TDD/TTY_Telephone:
      Contact_Facsimile_Telephone:
      Contact_Electronic_Mail_Address:
      Hours_of_Service:
      Contact_Instructions:
  Metadata_Standard_Name:
  Metadata_Standard_Version:
  Metadata_Time_Convention:
  Metadata_Access_Constraints:
  Metadata_Use_Constraints:
  Metadata_Security_Information:
    Metadata_Security_Classification_System:
    Metadata_Security_Classification:
    Metadata_Security_Handling_Description:
  Metadata_Extensions:
    Online_Linkage:
    Profile_Name:
        City:Anchorage
        State_or_Province:Alaska
        Postal_Code:99513
        Country:U.S.A
      Contact_Voice_Telephone:
      Contact_TDD/TTY_Telephone:
      Contact_Facsimile_Telephone:
      Contact_Electronic_Mail_Address:
      Hours_of_Service:
      Contact_Instructions:

Appendix L. Attribute Descriptions for Field Site Coverage and Dbase Files.

Field Site Polygon Coverage Attribute Table - **nyuk_fld_sts.pat and syuk_fld_sts.pat**

Field	Width	Output	Type	#Decimals	Description
AREA	4	12	F	-	ArcInfo internal fields
PERIMETER	4	12	F	-	ArcInfo internal fields
coverage#	4	5	B	-	ArcInfo internal fields
coverage-ID	4	5	B	-	ArcInfo internal fields
SITE_NUM**	4	4	I	-	Field site number
YEAR	4	4	I	-	Year of field data collection.
AREA_NAME	10	10	C	-	Name of project area.
CREW_NUM	1	1	I	-	Id number of crew that collected data
OBS_NAV	2	2	C	-	Navigator for field data collection
OBS_VEG	2	2	C	-	Vegetation caller for field data collection
OBS_REC	2	2	C	-	Recorder for field data collection
OBS_DATE	8	8	D	-	Date of field data collection
PERCNT_SLP	3	3	I	-	Percent slope of site
ASPECT_DIR	2	2	C	-	Aspect of site (8 compass points – N,NE,E,etc., FL=Flat)
LATITUDE	10	10	N	5	Latitude of polygon labelpoint – Decimal Degrees
LONGITUDE	11	11	N	5	Longitude of polygon labelpoint – Decimal Degrees
OBS_LEVEL	1	1	I	-	Observation level, where: 1 = site visited on the ground, 2 = viewed from above (ie from helicopter), 3 = viewed from a distance, 4 = viewed on air photos.
STEM_DIST	2	2	I	-	Distance between tree stems(applies to Open or Woodland Needleaf only).
OBS_ID	2	2	I	-	Id of site class as observed by the vegetation caller.
MAJ_OBS	20	20	C	-	Level 1 class of classification hierarchy.
OBS_CLASS	25	25	C	-	Vegetation caller's observed class for site.
COMMENTS	200	200	C	-	Notes made by vegetation caller while at the site.

CALC_CLASS	50	50	C	-	Classification of site as calculated using the project decision tree
CALC_CL_ID	6	6	N	3	ID number of calculated class
AA_FLAG	1	1	I	-	Indicates if site was used as accuracy assessment or training data. 0 = site used for training. 1 = site used for accuracy assessment.

**NOTE: To avoid duplicate site confusion from field seasons 1999 and 2000, all sites from 1999 were renumbered (SITE_NUM + 1000). For example site 807 from 1999 field season would become site 1807 in arc coverage, but remains as site 807 in 1999 DUFF database.

Data exported from Ducks Unlimited Field Form Software.

NYUK_SITE_PHOTO.dbf and SYUK_SITE_PHOTO.dbf Dbase IV file containing site photo information.

YEAR	Year of field data collection
AREA_NAME	Name of project area
CREW_NUM	Id number of crew that collected data
SITE_NUM	Field site number; relates to SITE_NUM of field site polygon coverage in a one-to-many relationship (i.e. each site may have multiple photos).
SESS_NUM	Session number for field data collection. Photos are uniquely numbered within each session.
PHOTO_NUM	Photo number. Photos are numbered consecutively within each session.

NYUK_SITE_SPECIES.dbf. and SYUK_SITE_SPECIES.dbf Dbase IV file containing species composition information for each site. Each record describes an individual species observed at a site. Each site can have multiple records in this table, depending on how many different species were observed within the site.

YEAR	Year of field data collection
AREA_NAME	Name of project area
CREW_NUM	Id number of crew that collected data
SITE_NUM	Field site number; relates to SITE_NUM of field site polygon coverage in a one-to-many relationships. Each site may have multiple species records in this table.
PCT_COVER	Percent cover of the species at site observed by the vegetation caller.
HEIGHT	Height of tree or shrub species at site as observed by the vegetation caller.

NOTE: The data in site species Dbase IV file are based on the PLANTS National Database developed by the National Resource Conservation Service. Edits have been made to some species codes to facilitate use of the data with the DUFF data entry program. Also species have been added to the list as necessary when compiling field data. Non-vegetated identifiers (Rock, Sand, Litter, etc.) have also been added.

NYUK_SPECIES.dbf and SYUK_SPECIES.dbf

SYMBOL	Species code - usually a combination of the first two letters of the genus and first two letters of the species.
FAMILY	Plant family.
SPECIES	Plant genus and species.
AUTHOR	Author citation for species information.
COMMON	Common name.
ALT_NAME	Alternate name.
GENERAL	General plant type; used to pipe information correctly through the decision tree.
SPECIFIC	Specific plant type; used to pipe information correctly through the decision tree.