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U.S. Department of the Air Force

Ducks Unlimited, Inc.

Stony River 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.

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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 Stony River Military Operations Area (MOA) and associated uplands. Portions of four Landsat TM satellite scenes (Path 72, Row 16-17 acquired 6/13/86 and Path 74, Row 16-17 acquired 8/14/89) were used to classify the 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. A helicopter was utilized to gain access to field sites throughout the project area. Global positioning system (GPS) technology was used both to navigate to pre-selected sites and record locations of new sites selected in the field. The Stony River MOA Project area is approximately 14.5 million acres. Due to the large size of the project area, the project was divided into an eastern and western project area. Field work, classification, and accuracy assessment was split between two field crews and two image processors. The Eastern Stony Project area is approximately 8.8 million acres and data were collected on 536 field sites during a 16 day field season from July 14, 1999 through July 29,1999. Approximately 25% (149) of these field sites were set aside for accuracy assessment. The Western Stony Project is approximately 5.7 million acres and data were collected on 338 field sites during a 13 day field season from July 29 to August 10 1999. Approximately 25% (83) 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 mapping categories was 91% at the +/-5% level of variation for the Eastern Stony Project and 90% at the +/-5% level of variation for Western Stony Project.

Introduction

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 geographic information system (GIS) technologies in 1988 (Ritter *et al.* 1989). Early mapping projects focused exclusively on wetlands (Ritter *et al.* 1989) but it was apparent that mapping the entire landscape was more cost effective and ultimately more useful to land managers. The BLM is creating a satellite-based, earth cover inventory of all BLM managed lands in Alaska. Many other agencies in Alaska (e.g., U.S. Air Force, 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, and cooperating on these mapping projects.

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; 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. 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 Stony River Military Operations Area (MOA) Earth Cover Classification Project area contains highly diverse landscapes and is deemed important for its wildlife and recreational values. The project area extends from the North Fork of the Kuskokwim River and Limestone Mountain in the north, to the Sparrevohn Air Force Station, Stony, and Hoholitna Rivers in the south, to the headwaters of the South Fork of the Kuskokwim and Stony Rivers in the east, and west to the Kuskokwim mountain range and the Russian Mountains in the southwest. Two other earth cover mapping projects are adjacent, the Innoko-Aniak project (to be completed in June 2000) to the west and the Susitna MOA to the east (to be completed in September 2001). The project area is essentially unroaded and supports limited recreational use with the exception of extensive hunting activity for moose, black and brown bear, caribou, and sheep. The earth cover data will aid in the critical process of resource planning in this valuable and diverse area.

Project Objective

The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Stony River MOA 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 Participants

The Eastern Stony Project

The project was administered by John Payne (BLM State Office) Jacqueline Frair (DU), Robb Macleod (DU), and Beate Sterrenberg (DU). The field work was accomplished by Jeff Campbell (Spatial Solutions, Inc./DU), Jacqui Frair (DU), Scott Guyer (BLM), and Chris Noyles (USAF). The pilot for the project was Dale Warren from AirLogistics, Fairbanks, Alaska. Jacqui Frair and Scott Guyer coordinated field logistics. Jeff Campbell performed the image processing. Mark Pearson (GeoNorth, Inc.) programmed the Ducks Unlimited Field Form (DUFF) database, and Jing Huang (DU) developed the accuracy assessment program.

The Western Stony Project

The project was administered by John Payne (BLM State Office), Jacqueline Frair (DU), Robb Macleod (DU), and Beate Sterrenberg (DU). The field work was accomplished by Ben Dorland (DU), Brendan O'Hara (DU), Terry Hobbs (BLM), and Jeff Denton (BLM). The pilot for the project was Bob Mendenhall from Trans-Alaska. Jacqueline Frair coordinated field logistics. Ben Dorland performed the image processing. Mark Pearson (GeoNorth, Inc.) programmed the DUFF database, and Jing Huang (DU) developed the accuracy assessment program.

Project Area

The Eastern Stony Project

The Eastern Stony Project consisted of 8.8 million acres centered roughly on the headwaters of the Windy River in the center of the McGrath 1:250,000 scale quadrangle. The North and South Fork of the Kuskokwim River run through the northern half of the project, with the main branch of the Kuskokwim running nearly the full length of the western boundary of the project area. It included portions of the following USGS 1:250 scale quadrangles: Medfra, McGrath, Talkeetna, and Lime Hills. The town of McGrath fell just inside the northwestern boundary of the project.

This project area encompassed a wide variety of environments ranging from glaciated mountains to lowland black spruce muskeg. Non-forested uplands form important caribou habitat, the higher elevations were home to Dall sheep, while moose and bear abounded throughout most of the project area. Innumerable small lakes and ponds supported the pond lilies and other aquatic vegetation that make up an important summer food source for breeding tundra swans. In addition, several herds of bison are found throughout a relatively confined region just north and west of Farewell Lake. Since the imagery acquisition date of June 1986, numerous wildfires have burned over a significant portion of the study that are not indicated on the 1986 satellite imagery.

The Western Stony Project

The Western Stony Project consisted of 5.7 million acres containing a large part of the Kuskokwim river. The Russian Mountains are the prominent features in the southwestern portion of the project, while the confluence of the Holitna, Stony, and Swift Rivers with the Kuskokwim are in the eastern part of the project area. The town of McGrath rests on the Northeastern boundary and the center portion of the image is dominated by the Kuskokwim Mountains.

The Kuskokwim River is a main thoroughfare via water into interior Alaska. It included portions of the following USGS 1:250 scale quadrangles: Iditarod, McGrath, Sleetmute, and Lime Hills. The town of Aniak fell just outside the southwestern boundary of the project.

This project area encompassed mainly upland environments ranging from lowland black spruce to Non-forested uplands. This land cover type is important caribou habitat, while moose and bear abounded throughout most of the project area. Since the imagery acquisition date of August 1989, numerous wildfires have burned over a significant portion of the study that are not indicated on the 1989 satellite imagery.

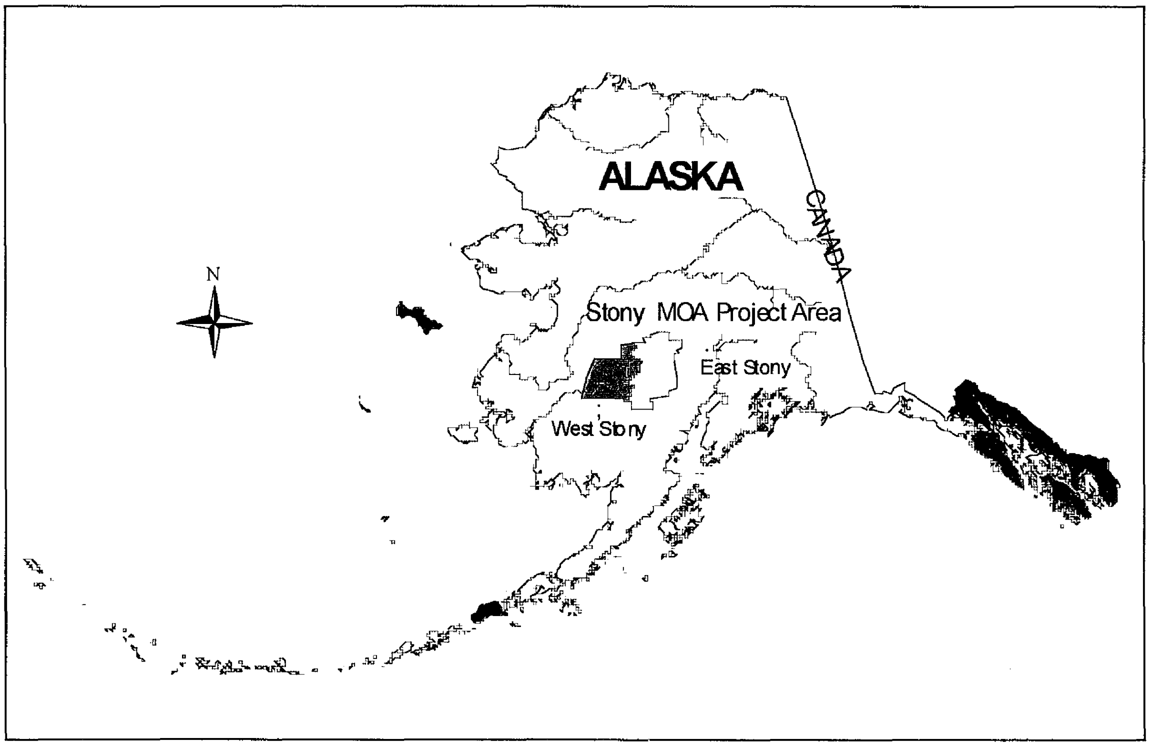


Figure 1. The Eastern and Western Stony project locations.

Data Acquisition

The Eastern Stony Project

Two Landsat TM scenes were purchased to cover this project area. Due to the scarcity of available cloud free images covering the study area, imagery from June 1986 (Path 72 Row 16 and 17) were acquired. Due to the relatively early summer season date of the imagery, an unusually large amount of snow was present in the imagery. The scenes were purchased from EROS Data Center in Albers Equal Area projection and were terrain corrected by EROS (Figure 2).

Field data were collected on 536 field sites during a 16-day field season from July 14, 1999 through July 29, 1999. The ancillary data used in this project included: 1:60,000 aerial photographs (color infrared transparencies from 1980-82, 1984, and 1986-87 and USGS1:250,000 scale Digital Elevation Models (DEM).

Figure 2. Satellite imagery used for the Eastern Stony project.

The Western Stony Project

Two Landsat TM scenes were purchased to cover this project area. The scenes were purchased from EROS Data Center in UTM Zone 4 projection and were terrain corrected by EROS. The scenes were: Path 74, Rows 16 and 17 acquired on August 14, 1989 (Figure 3).

Field data were collected over a 13-day period from July 29 to August 10 1999. The ancillary data used in this project included: 1:60,000 aerial photographs (color infrared transparencies from 1978, 1980, 1981, 1982, and 1984) on loan from BLM State Office and USGS1:250,000 scale Digital Elevation Models (DEM).

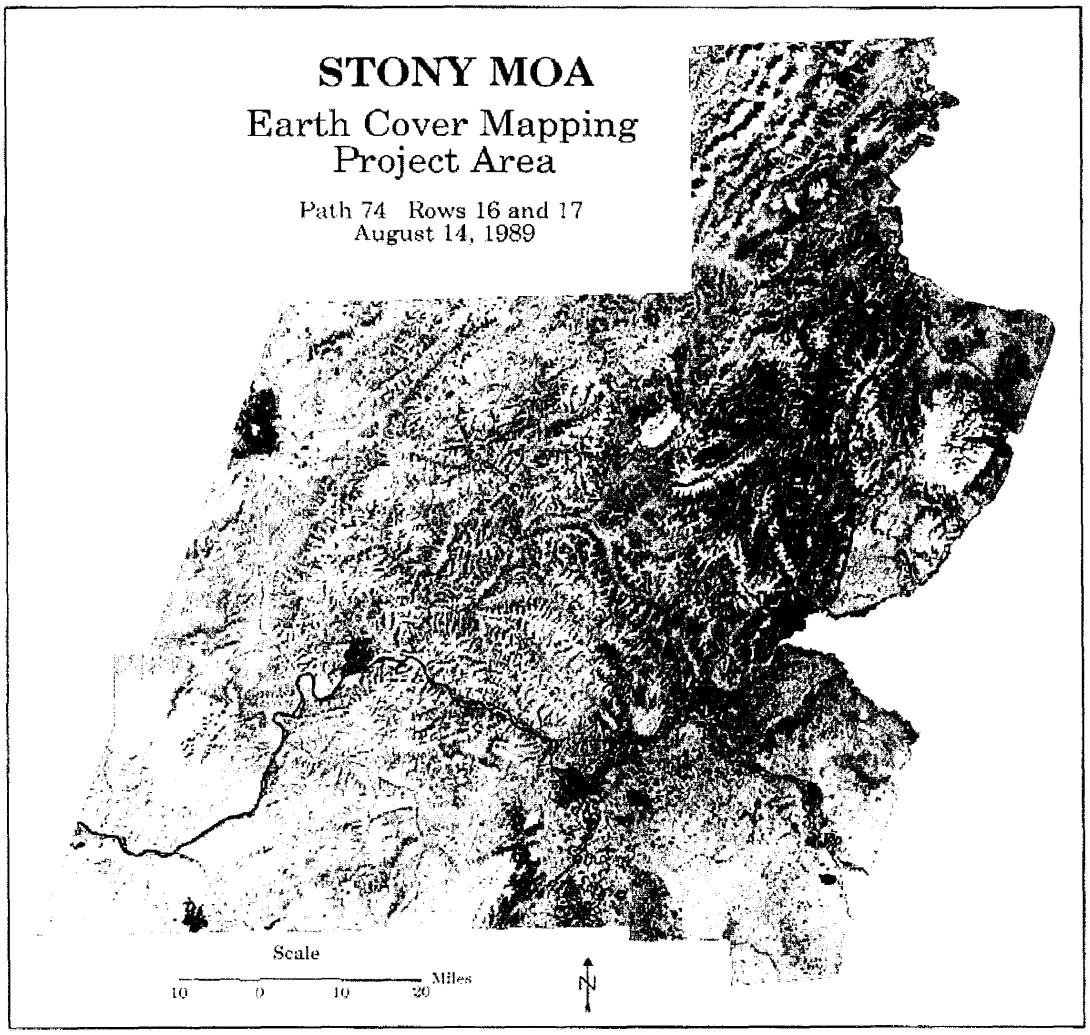


Figure 3. Satellite imagery used for the Western Stony project.

Methods

Classification Scheme

The classification system 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, 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). 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) (Table 1) 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 27 subcategories. A classification decision tree and written description (Appendices A and B) was developed in order 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 had to be 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, low shrub tussock tundra and low shrub willow/alder.

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 haze. Positional accuracy was checked by comparing the image to available ancillary data such as adjacent imagery, hydrography, and digital elevation models (DEMs).

Table 1. 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		

In order 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.

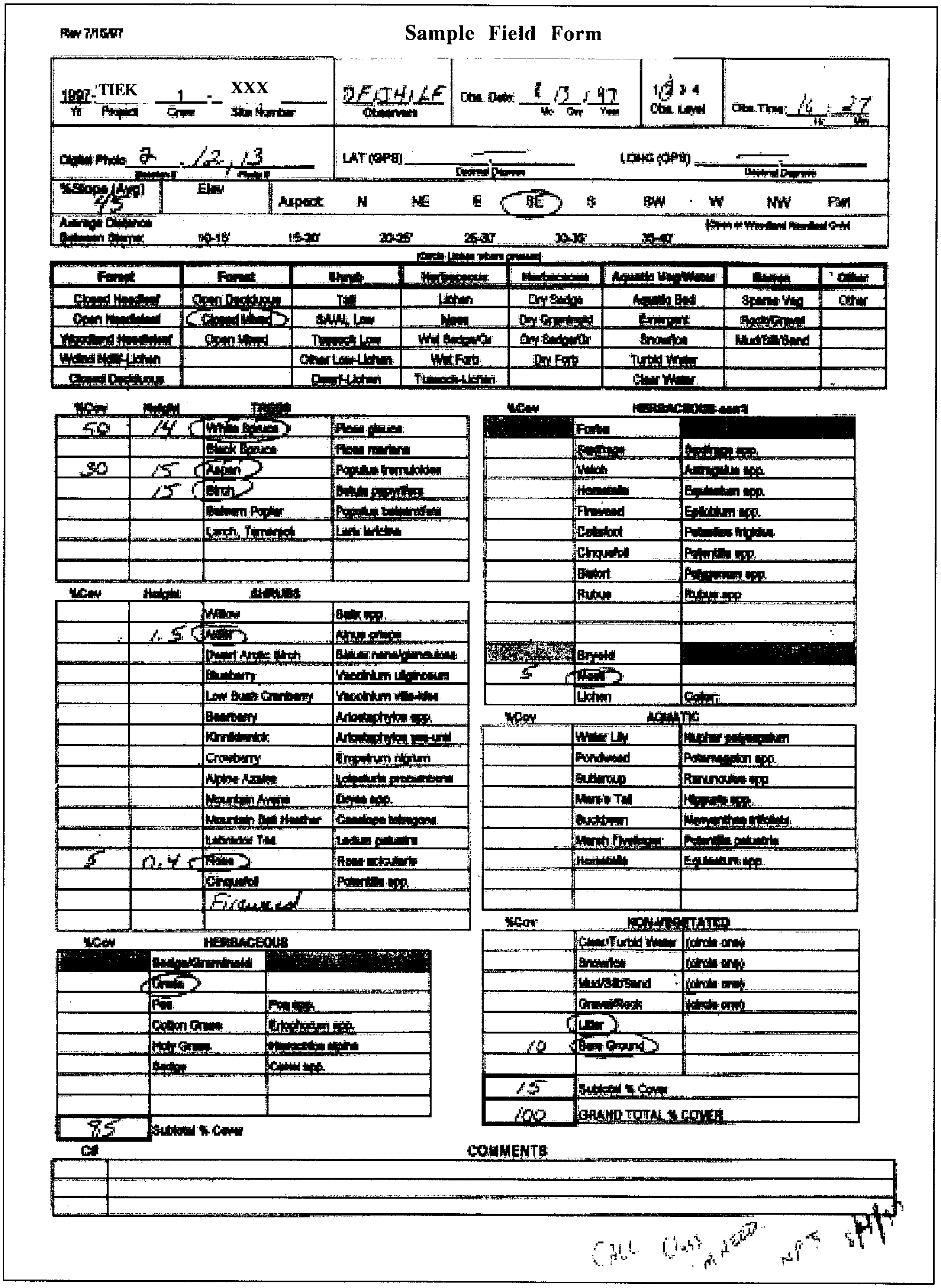
An unsupervised classification was used to identify spectrally unique areas within the study area. Training sites were individually selected from these spectrally unique areas by the image analyst. Whenever possible, training sites were grouped in clusters to reduce the amount of travel time between sites. The image analyst also to placed training sites near landmarks that were easily recognizable in the field, such as lakes or streams. 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 Global Positioning System 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 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 often the only alternative in Alaska due to the large amount of roadless areas.

In order 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 4). 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.



Rev 7/15/97

Sample Field Form

1997 - TIEK 1 - XXX (Yr, Project, Crew, Site Number) | OEJTHILF (Observers) | Obs. Date: 8/13/97 (Mo, Day, Year) | 1/2 3 4 Obs. Level | Obs. Time: 16:27 (Hr, Min)

Digital Photo 2 / 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' (Circle Unless where present)

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

TREES

%Cov	Height		
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

SHRUBS

%Cov	Height		
		Willow	Salix spp.
	1.5	(Alder)	Alnus crispa
		Dwarf Arctic Birch	Betula nana/glandulosa
		Blueberry	Vaccinium uliginosum
		Low Bush Cranberry	Vaccinium vitis-idaea
		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	

HERBACEOUS

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

HERBACEOUS-cont

%Cov		
	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:

AQUATIC

%Cov		
	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.

NON-VEGETATED

%Cov		
	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

Figure 4. Custom field data collection form.

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 5-10 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. The relational database was powered by SQL Anywhere while the user interface was programmed in Visual Basic. The user interface was organized similarly to the field form to facilitate data entry (Figure 5). 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 its cover percentage. 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

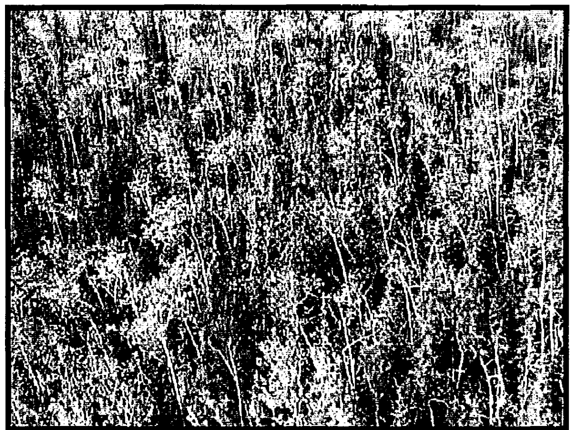
Every image is unique and presents special problems in the classification process. The approach used in this project (Figure 6) has been proven successful over many years. The image processor was actively involved in the field data collection and had first hand knowledge of every training site. The image 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. 8.3.1) 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 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). The NDVI had been correlated with various forest and crop canopy characteristics such as bio mass

Sample Field Site – Closed Mixed Needleleaf/Deciduous

High site photo



Low site photo

DUFF INTERFACE

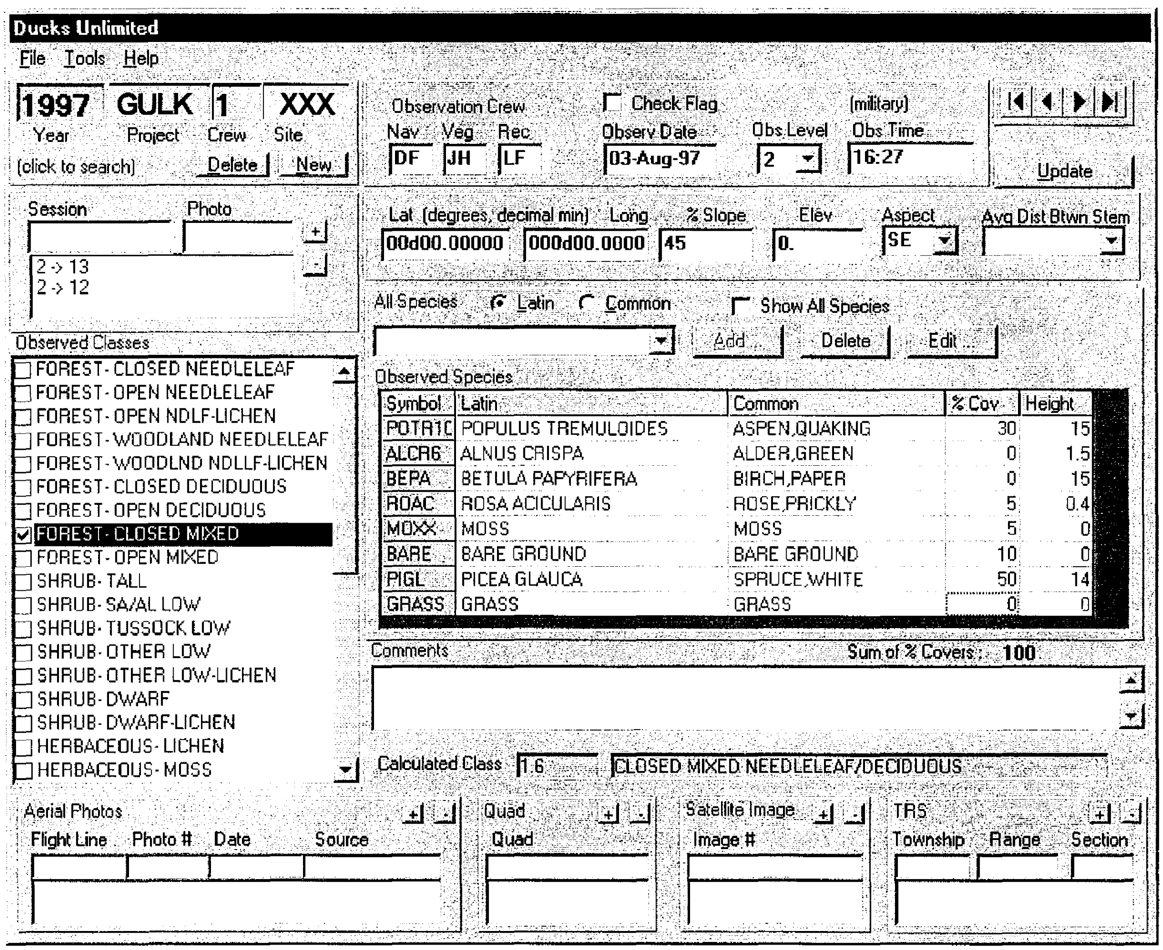


Figure 5. The customized database and user interface for field data entry (DUFF).

and leaf area index. This NDVI band replaced thermal band (band 6) to retain a 7-band image for classification.

Removal of Clouds and Shadows

Very few clouds and their associated shadows existed in the June 1986 TM imagery used on the Eastern Stony project. There were clouds present in the northern portion of the August, 1989 imagery. The clouds and cloud shadows that were present were removed from the image before field sites were selected. This process eliminated any confusion between clouds, cloud shadows, and other vegetation types. They were removed using an unsupervised classification and manual on-screen editing. Clouds were separated from shadows and classes were recoded to their respective class number. The cloud/shadow layer is then combined with the rest of the classified image during the last step in the classification process.

Seeding Process

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 were evaluated for inclusion in each training site using a threshold value based on a spectral Euclidean distance. The standard deviations of the seeded areas were kept close to or below 3 and all seeded areas were required to be over 15 pixels (approximately 3.75 acres) in size. Along with the field training areas, additional "seeds" were generated for clear water, turbid water, and snow classes. These classes were easily recognizable on the imagery and aerial photography. 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 was 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 one iteration and the next.

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 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 areal extent will have only a few samples that may severely hamper future analysis. The other extreme is to force a given number of samples from each category. Depending on the extent of each category, this approach can significantly bias the results. Finally, a sampling scheme must be selected. A purely random approach has excellent statistical properties, but is practically difficult and expensive to apply. A purely systematic approach is easy to apply, but could result in 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 the preprocessing stage and in the field to make sure adequate samples were obtained. However, funding limitations did not allow for the number of samples suggested for each class (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 25-30% of the collected field sites were set aside for use in the assessment of map accuracy while the remainder were 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) were required before any attempt was made to assess the accuracy of that class. Classes with less than 15 field sites were still classified. However, much fewer, if any, field sites were utilized for accuracy assessment for these classes. Accuracy assessment sites were selected randomly across the project area to reduce bias.

Some Considerations

While the accuracy assessment performed in this project was not a 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 this project, the imagery was from 1986 and 1989; the aerial photographs spanned a nine year period from 1978 through 1987, and the field data was collected in July/August 1999. Differences due to environmental changes from the different sources may have had a major impact on the accuracy assessment. In addition, several major ecological changes have occurred throughout the study area during the past 13+ years since the acquisition date of the satellite imagery. Primarily, tremendous land cover change has occurred throughout the project area as a result of the natural process of flooding, river/stream channel meandering, re-vegetation of formerly sparsely or barren areas, and fire activity. This on-going phenomenon has had a remarkable impact on the density and composition of forest and other vegetative species within the study area. The objective of this mapping project was to classify and map earth cover conditions as the existed in 1986. Capturing field data for accuracy assessment in 1999 for 1986 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 data.

A major assumption of quantitative accuracy assessments is that the label from the reference information represents the "true" label of the site and that all differences between the remotely sensed map classification and the reference data are due to classification and/or delineation 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.

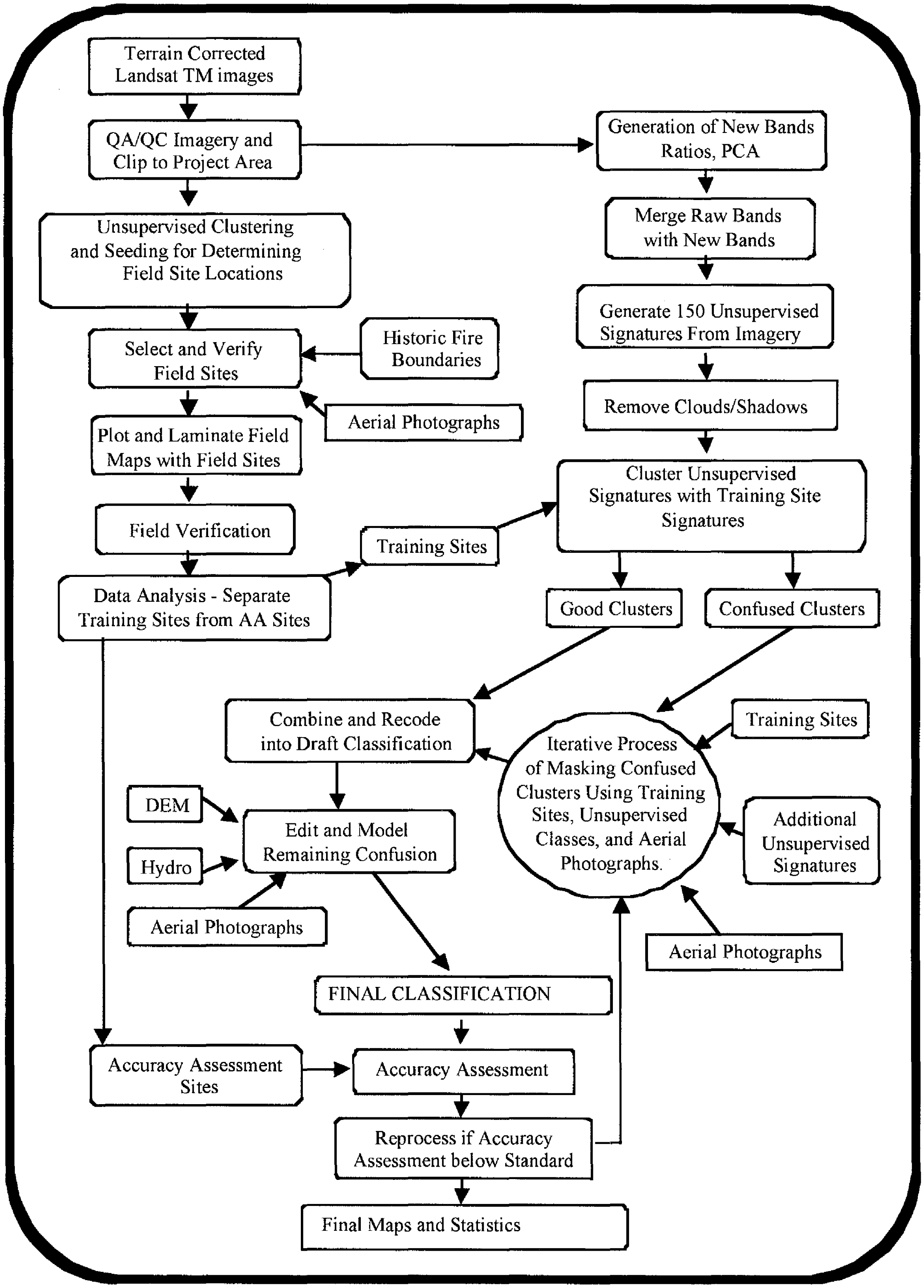


Figure 6. The image processing flow diagram.

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 or photo interpreted 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, especially when the reference data was derived from aerial photographs.

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

Field Verification

The Eastern Stony Project

Data were collected on 536 field sites during a 16-day field season from July 14, 1999 through July 29, 1999. Approximately 25% (149) of these field sites were set aside for accuracy assessment. Daily flight time did not exceed 6 hours. The proportions of sites per class (Table 2) largely reflected the proportion 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.

A Bell Long Ranger helicopter was used to gain access to the field sites. Field camps were located at Farewell Lake Lodge, Sparrevohn Air Force Military Radar Installation, and Stony River Lodge. Main fuel depots were based at Farewell Station (FAA airstrip), Big River Lodge Airstrip, McGrath (commercial fuel), Sparrevohn Airstrip, and Stony River Lodge Airstrip. Flight following was carried out by the alternate via satellite phone and radio.

The Western Stony Project

Field data were collected on a total of 338 field sites (Table 4) during the 13-day field season from July 29 to August 10, 1999. An average of 35 sites per day were collected, with one weather day and two pilot days off. Daily flight time did not exceed 6 hours. Approximately 25% (n=83) of these sites were reserved for accuracy assessment. The proportions of sites per class (Table 4) largely reflected the proportion of corresponding earth cover types within the project area. All plant species recorded during the field data collection and their overall percentages of cover are listed in Appendix C.

A Bell 206B Long Ranger helicopter was used to gain access to the field sites. The field camp and main fuel depot were based out of two privately owned lodges. The first three days in the field were based out of the Tukusko House in McGrath and the rest of the fieldwork was based out of the Red Devil Lodge in Red Devil. There were four fuel caches for this project; McGrath airport, the Red Devil landing, and two remote fuel depots. Flight following was carried out by the alternate via Iridium satellite phones. Contact was made every 30 minutes as specified by the Office of Aircraft Services.

Classification

The Eastern Stony Project

The four most extensive vegetated classes within the final classification were: open needleleaf (2,678,010 acres or 30% of total area), woodland needleleaf (1,278,536 acres or 14.5% or total area), low shrub (927,686 acres or 10.5% of total area) and dwarf shrub (389,187 acres or 4.5% of total area). Large expanses of open/woodland spruce interspersed with low shrub/wet graminoid muskegs were typical of the project area.

Class Name	Total Field Sites per Class	Sites Witheld for Accuracy Assesement
CLOSED NEEDLELEAF	11	3
OPEN NEEDLELEAF	126	33
OPEN NEEDLELEAF – LICHEN	9	2
WOODLAND NEEDLELEAF	67	22
WOODLAND NEEDLELEAF – LICHEN	3	0
CLOSED DECIDUOUS	23	6
OPEN DECIDUOUS	7	2
CLOSED MIXED NEEDLELEAF / DECIDUOUS	14	5
OPEN MIXED NEEDLELEAF / DECIDUOUS	11	2
TALL SHRUB	34	11
LOW SHRUB – OTHER	74	21
LOW SHRUB – LICHEN	2	0
LOW SHRUB – TUSSOCK TUNDRA	16	4
LOW SHRUB – WILLOW/ALDER	7	1
DWARF SHRUB – OTHER	38	14
DWARF SHRUB – LICHEN	12	3
WET GRAMINOID	9	3
WET FORB	4	1
MESIC / DRY GRAMINOID	1	0
MESIC / DRY FORB	2	0
TUSSOCK TUNDRA	7	2
TUSSOCK TUNDRA – LICHEN	3	0
EMERGENT VEGETATION	5	2
SPARSE VEGETATION	12	3
ROCK GRAVEL	28	29
NON-VEGETATED SOIL	1	0
OTHER	3	0
TOTAL	**536**	**149**

Table 2. Field sites per mapped class for the Eastern Stony project.

Participant	Role	Agency
Scott Guyer	Biologist/Vegetation Expert	BLM State Office
Chris Noyles	Recorder/Alternate	US Air Force
Jacqui Frair	Recorder/Alternate	DU – BLM State Office
Jeff Campbell	Navigator/Image Processor	DU – Spatial Solutions, Inc.

Table 3. List of field data collection participants for the Eastern Stony project.

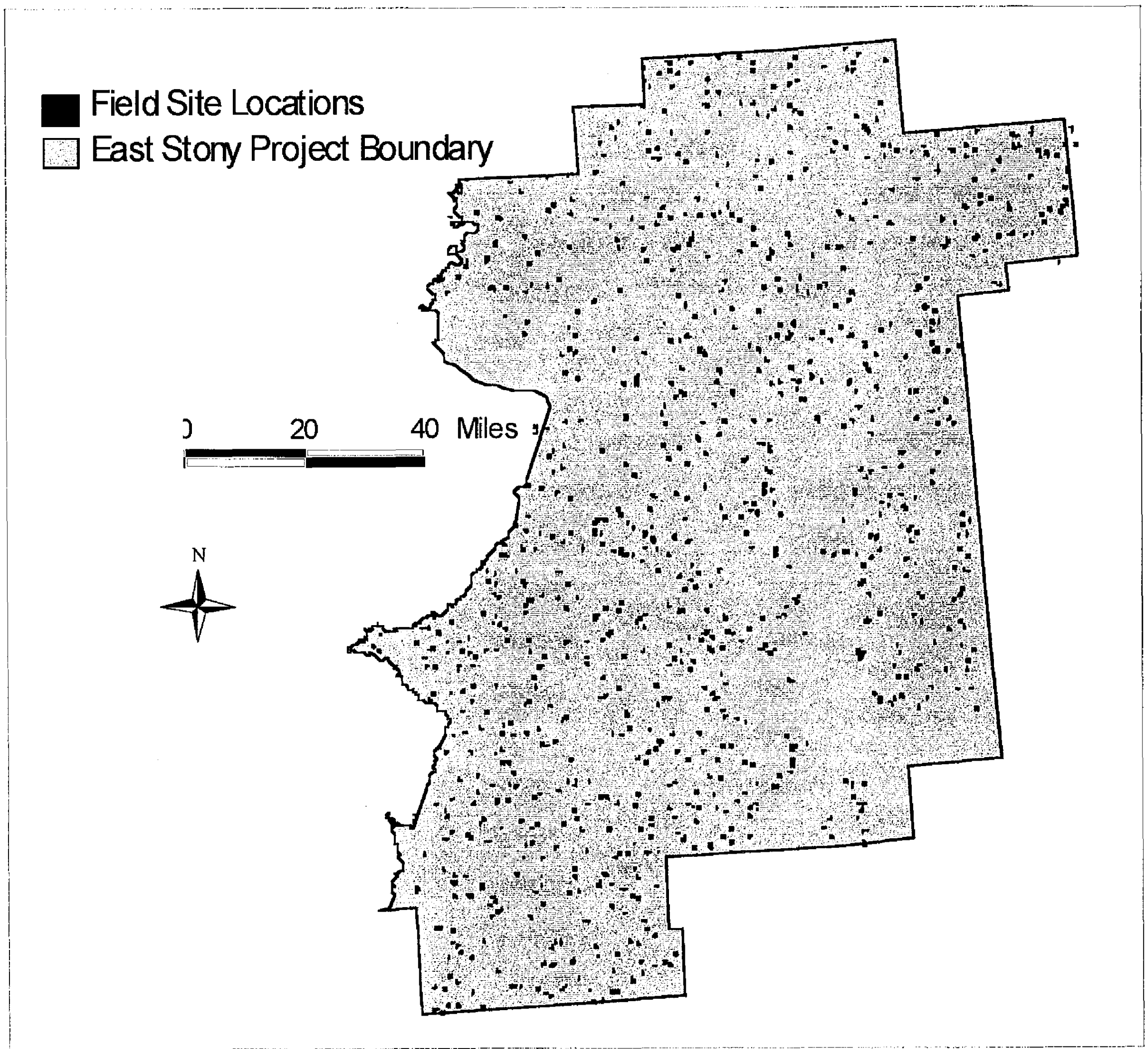


Figure 7. Distribution of field sites for the Eastern Stony project.

Class Name	Total Field Sites Per Class	Sites Witheld for Accuracy Assessment
OPEN NEEDLELEAF	40	11
OPEN NEEDLELEAF LICHEN	22	7
WOODLAND NEEDLELEAF	25	8
WOODLAND NEEDLELEAF LICHEN	19	6
CLOSED DECIDUOUS	40	10
*CLOSED POPLAR**	*(1)*	*(0)*
*CLOSED BIRCH**	*(28)*	*(9)*
*CLOSED ASPEN**	*(1)*	*(0)*
*CLOSED MIXED DECIDUOUS**	*(10)*	*(4)*
OPEN DECIDUOUS	12	0
*OPEN BIRCH**	*(4)*	*(0)*
*OPEN MIXED DECIDUOUS**	*(8)*	*(0)*
CLOSED MIXED NEEDLELEAF/DECIDUOUS	15	8
OPEN MIXED NEEDLELEAF/DECIDUOUS	32	5
TALL SHRUB	27	9
LOW SHRUB – LICHEN	2	0
LOW SHRUB – OTHER	22	7
DWARF SHRUB – LICHEN	17	5
DWARF SHRUB – OTHER	27	4
WET GRAMINOID	5	8
MESIC/DRY GRASS MEADOW	4	0
AQUATIC BED	1	0
EMERGENT VEGETATION	2	0
SPARSE VEGETATION	4	0
ROCK/GRAVEL	4	0
MOSS	10	0
LICHEN	5	0
CLEAR WATER	1	0
NON-VEGETATED SOIL	1	0
TUSSOCK TUNDRA	1	0
TOTAL	**338**	**83**

Table 4. Field sites per mapped class for the Western Stony project.

Participant	Role	Agency
Jeff Denton	Biologist/Vegetation Expert	BLM District Office
Terry Hobbs	Recorder/Alternate	BLM District Office
Ben Dorland	Recorder/Image Processor	DU Western Reg. Office
Brendan O'Hara	Navigator	DU Western Reg. Office

Table 5. List of field data collection participants for the Western Stony project.

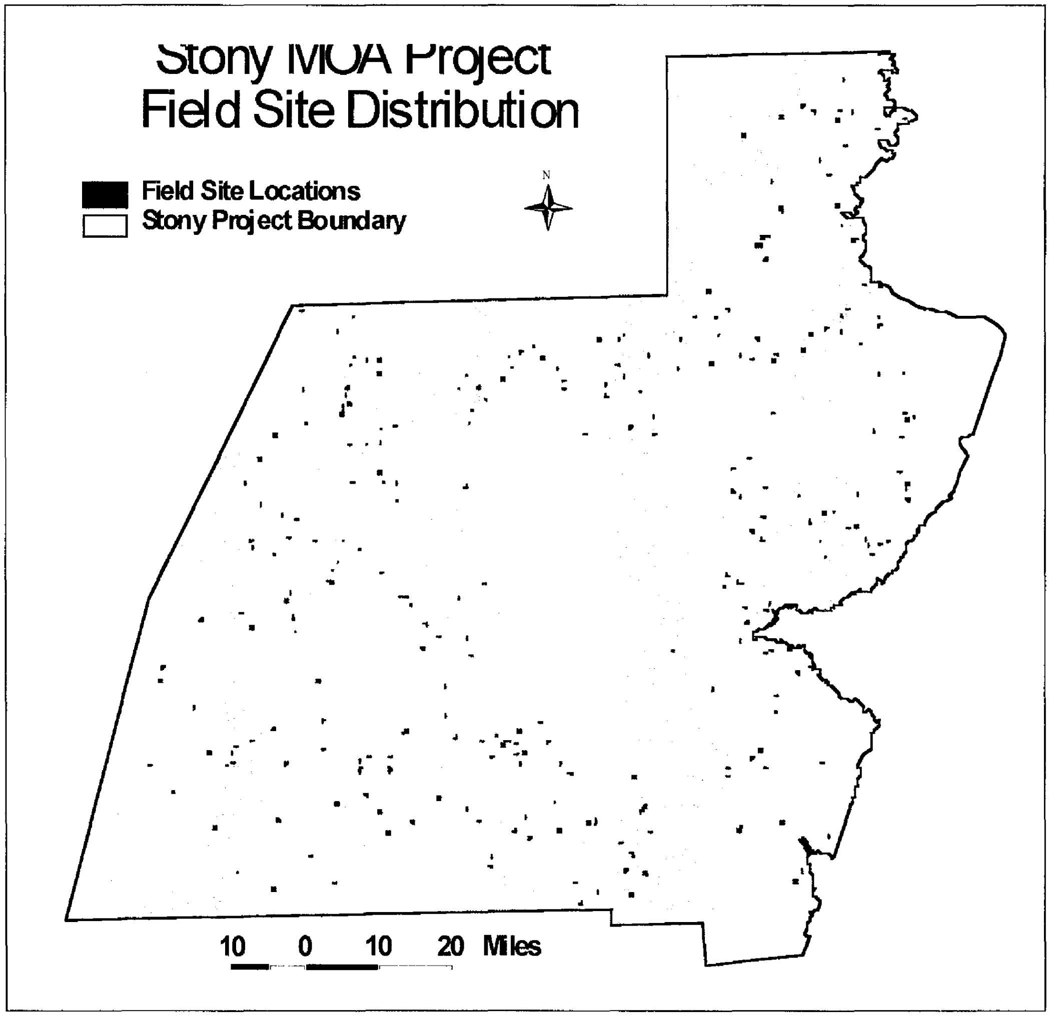


Figure 8. Distribution of sites for the Western Stony project.

Uplands were characterized by dwarf shrub, low shrub, sparse vegetation and some dry graminoid cover types. Other large classes include closed mixed needleleaf/deciduous forest, commonly found in broad riparian corridors of the major river drainages as well as on steep west- and northwest-facing slopes. Stands of closed canopy deciduous trees were found on steep, well drained south-facing slopes in the northern quarter of the study area, or on alluvial deposits near major rivers. These stands were composed primarily of Birch. Closed canopy needleleaf as well as the closed canopy mixed needleleaf/deciduous stands also appeared to be constrained by soil conditions and were found only near major river drainages. Open deciduous stands were rare, occurring mainly in areas that had been recently burned or otherwise disturbed. However, due to the great discrepancy between the acquisition date of the satellite imagery (1986) and the date of the field data collection (1999) many of these highly transitional post-burn regions of open deciduous appeared spectrally more similar to areas of low shrub on the 1986 imagery and were classified as such. The aquatic bed cover type, composed primarily of floating pond lilies, was relatively non-existent in this project area. Differentiating between wet and dry graminoid/forb proved to be futile as the moisture and water level conditions visible on the 1986 satellite imagery and those observed in the field in 1999 in many of the forb/graminoid types appeared highly variable. For instance, an area on the satellite imagery that appeared to be strongly influenced by the presence of standing water was found to be completely dry during the 1999 field data collection season. As a result, there was initial confusion between forb/graminoid regions being classified as dry when there was obvious presence of standing water visible in the satellite imagery. To compensate for this effect, areas of forb/graminoid were classified as a complete strata based on the reliance of supervised training site data. Subsequently, the spectral reflectance information present in the satellite imagery was primarily used to differentiate areas of wet vs. dry forb/ graminoid. Rock and sparse vegetation cover types were found mostly at the highest elevations, along ridgetops and in glaciated areas. Rock also appeared as gravel beds in riparian corridors along with non-vegetated soil, or mud. Here again, the consistent discrimination between areas truly devoid of significant vegetation along stream and river channels and those older, more established gravel bars that exhibit a significant stand of early successional vegetation was difficult. Many of these areas appeared completely unvegetated on the 1986 satellite imagery while 1999 field-based data described many of these sites as often containing substantial vegetation which resulted in a classification as either low shrub, tall shrub, or open deciduous. In order to maintain consistency throughout the mapping process as well as to meet the charge of mapping the region to reflect conditions present in the 1986 satellite imagery, these highly transitional riparian corridor gravel bars were characterized as rock/gravel or sparsely vegetated vs. their current condition of supporting well established vegetative communities. Most of the snow and ice was found in the mountains of the Alaska Range in the east-southeast region of the study area. Due to the relatively early summer capture date of the satellite imagery (June 13), the spatial extent of the snow in visible in the satellite imagery was significant. As a result, many high elevation areas that would have typically been characterized as dwarf shrub or sparsely vegetated were covered with remnant seasonal snow fields and were therefore classified as such. The only clouds present in the imagery for the Eastern Stony project were found in the extreme southwest corner of the study area. The area classified as clouds accounted for only 932 acres over the entire 8.8 million acres of the study area.

The Western Stony Project

The four most extensive classes within the final classification were: open needleleaf, woodland needleleaf, mixed needleleaf\deciduous, and closed deciduous. Large expanses of black spruce interspersed with low shrub, lichen, and moss were typical of the project area. Other large classes include tall and low shrub, commonly found on steep slopes and in riparian corridors. Dwarf shrub and dwarf shrub lichen were located on hilltops and in rolling hills near the Russian Mountains. Stands of closed canopy deciduous trees were found on well drained slopes, or on alluvial deposits near major rivers. Extensive stands of mixed needleleaf\deciduous forests were also found in river drainages especially near the confluences of the Holitna and Swift Rivers with the Kuskokwim River. Large stands of low and tall shrub along with some smaller stands of open deciduous were commonly found in older burn areas. Rock and sparse vegetation cover types were found mostly at the highest elevations along ridgetops. Rock also appeared as gravel beds in riparian corridors along with non-vegetated soil. The Western Stony project contained a few areas where clouds were present especially in the northern part of the imagery over the Kuskokwim mountain range.

The Western Stony project has two unique earth cover classes that were added to the classification for this project. The first class added was woodland needleleaf-moss (Figure 9) and the second was low shrub-wet (Figure 10). Low shrub-wet was added because the composition of these areas were the same as low shrub other sites but they had a high enough percentage of water that the signatures are much different than any of the other low shrub sites. The woodland needleleaf-moss class was included in this classification because there were a number of instances where a site would have a very different signature as compared to other woodland needleleaf sites due to the dominance of moss. It is important to note that for accuracy assessment purposes both of these classes were grouped as low shrub or woodland needleleaf respectively. Because of the lack of field sites both of these classes were completely hand edited into the classification.

Modeling

Modeling was performed using a shaded relief image and an elevation zone image derived from USGS DEM at 1:250,000 scale. The shaded relief image was created in Erdas Imagine using the solar azimuth and solar elevation listed in the header file for the TM image. The DEM was often used to help separate spectrally confused classes like terrain shadow and deep water. Elevation images were also used to model cover types that were limited by slope, aspect or elevation.

Modeling was primarily used to identify misclassified areas. Since water, wet graminoid, closed canopy forest and shadow have similar spectral signatures these classes were often confused. Water obviously does

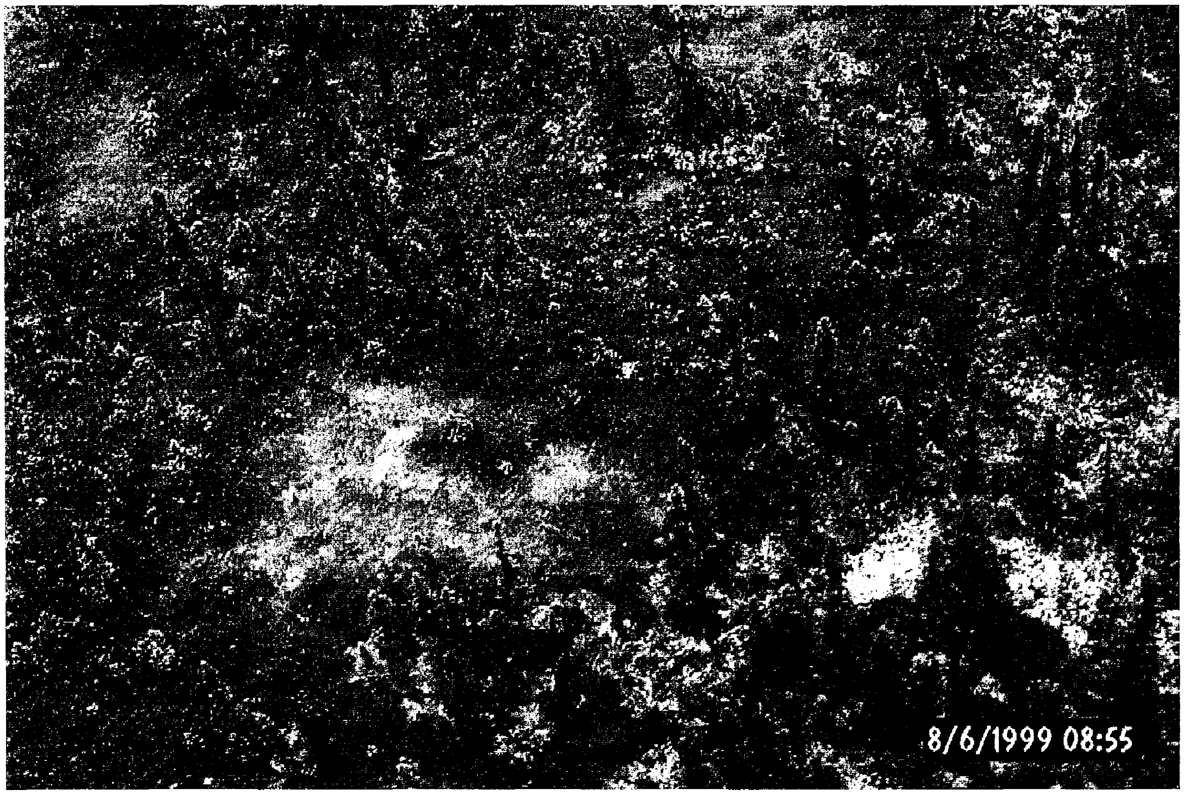


Figure 9. Woodland needleleaf-moss field site (Western Stony site 453).

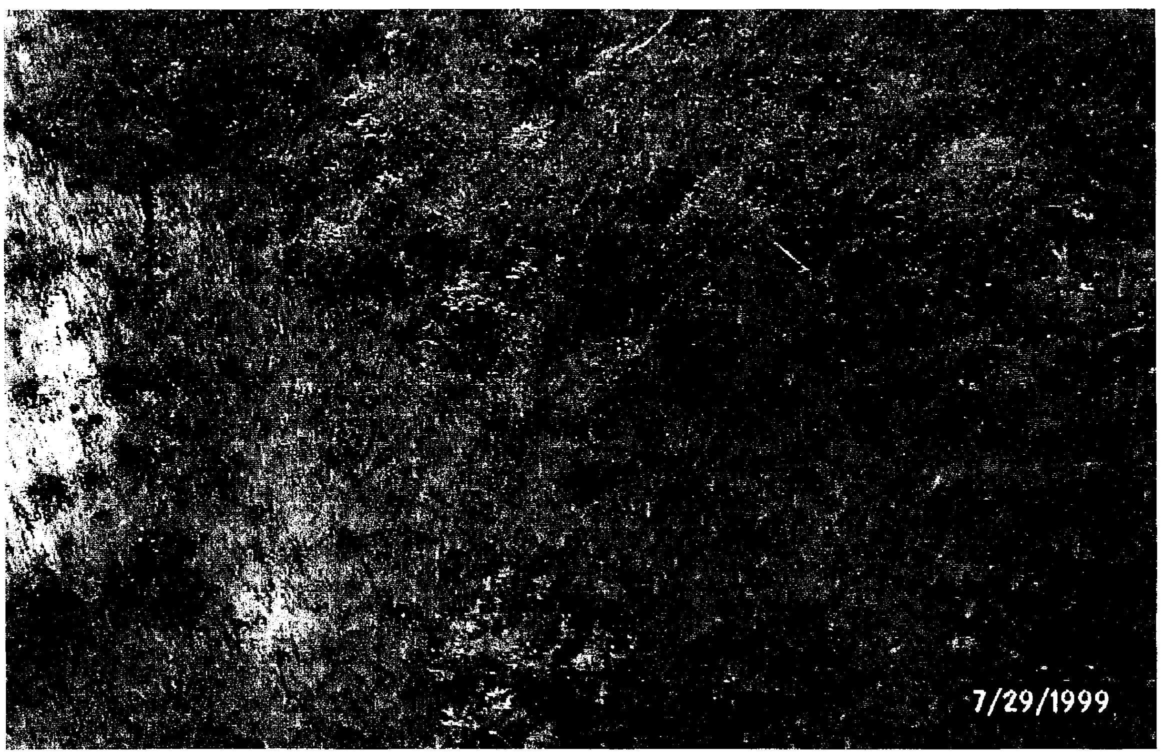


Figure 10. Low shrub-wet field site (Western Stony Site 62).

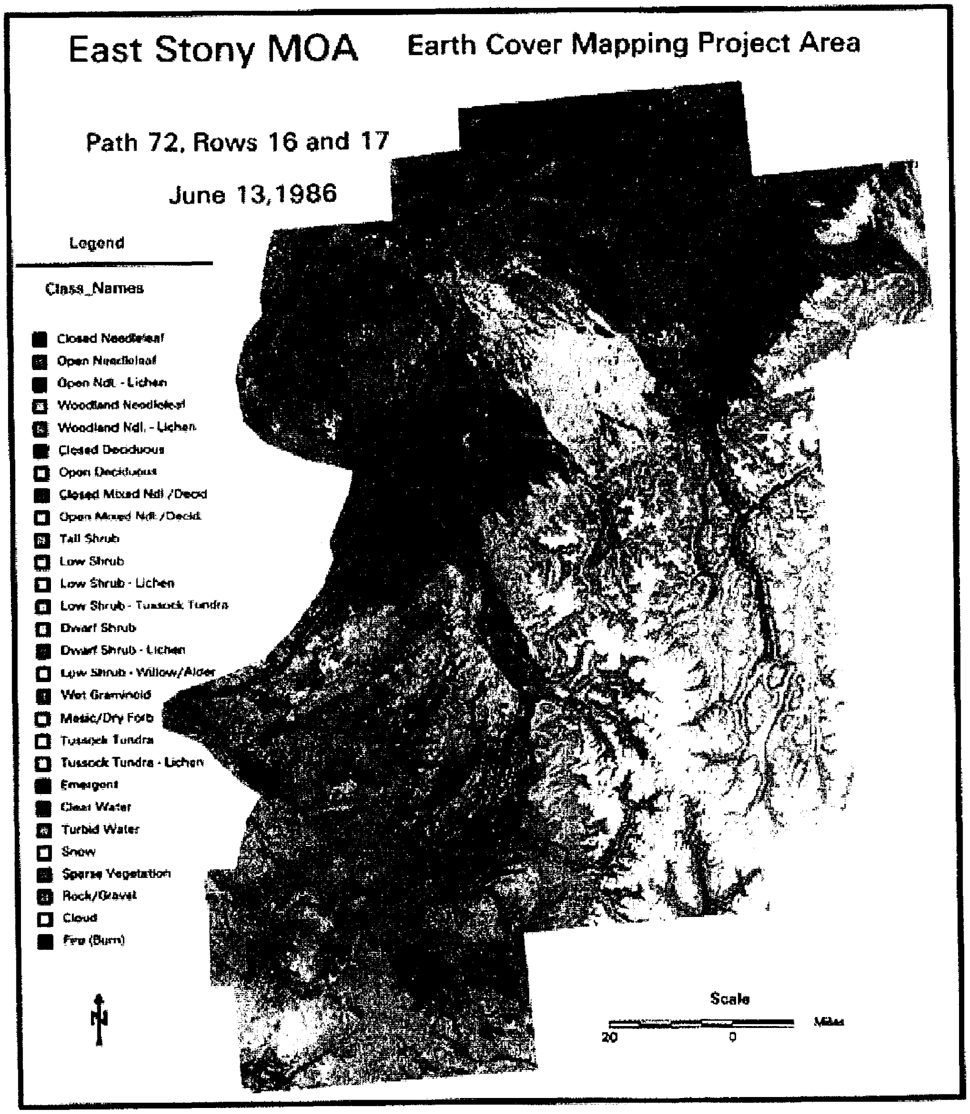


Figure 11. The Eastern Stony project final classified map.

not occur on a slope, but terrain shadows do, therefore a slope based model was used to search out shadowed areas that had been misclassified as water or wet graminoid. Tussock tundra signatures were confused with dwarf shrub, but unlike dwarf shrub, tussock tundra will not occur at higher elevations or on steep slopes. Closed and open canopy needleleaf was found only atlower elevations within the project area, and modeling was also used to check for terrain shadow that had been misclassified as forest. 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.

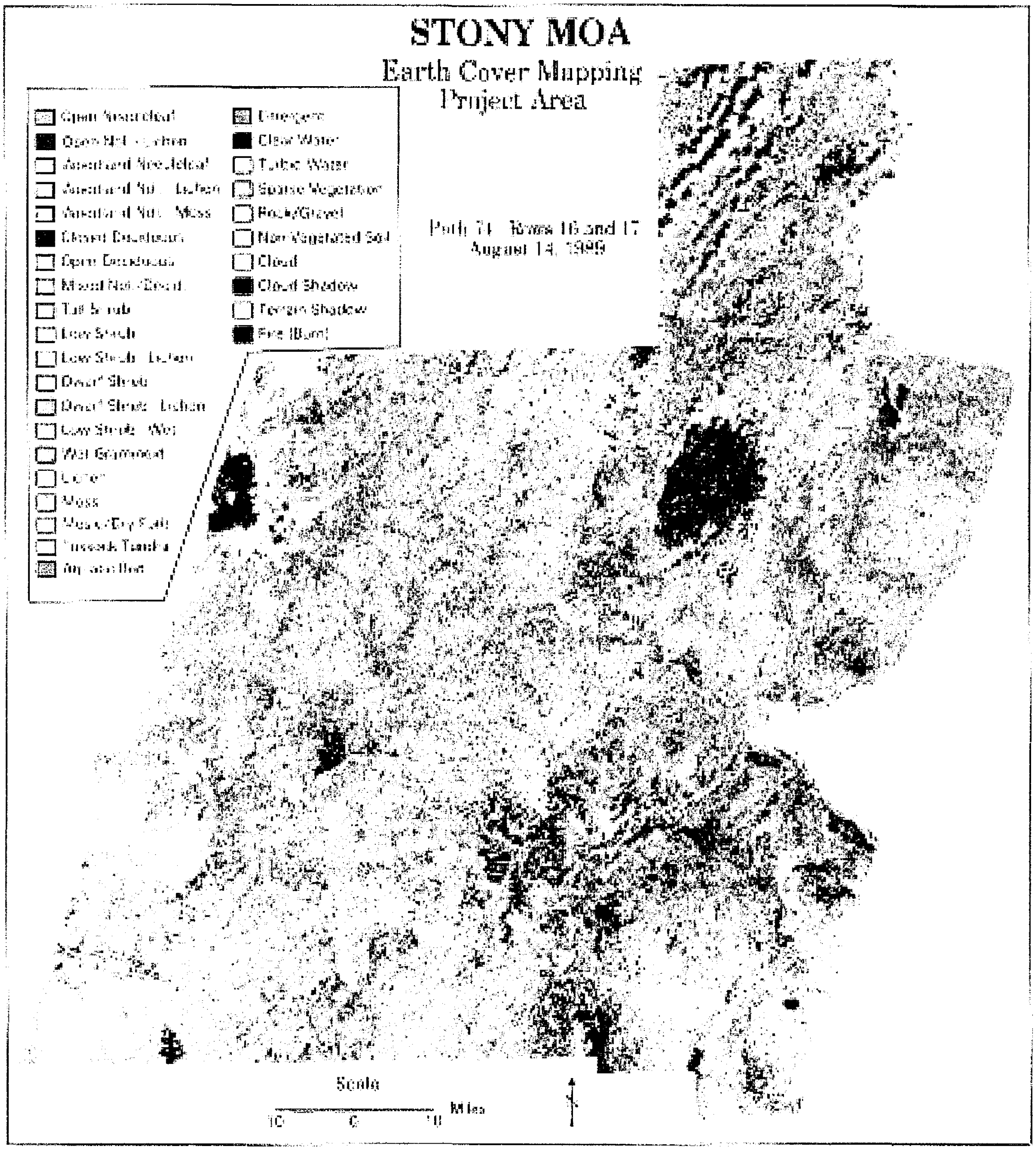


Figure 12. The Western Stony project final classified map.

Table 6. Acreage of earth cover classes within the project area.

CLASS NUMBER	CLASS NAME	ACRES	PERCENT COVER
1	Closed Needleleaf	67,686	0.48%
2	Open Needleleaf	3,778,095	26.59%
3	Open Ndl. - Lichen	516,249	3.63%
4	Woodland Needleleaf	1,917,540	13.50%
5	Woodland Ndl. - Lichen	385,260	2.71%
6	Woodland Ndl. – Moss	6505	0.05%
10	Closed Deciduous	578,167	4.07%
13	Open Deciduous	142,422	1.00%
16	Closed Mixed Ndl./Decid.	395,642	2.78%
17	Open Mixed Ndl./Decid.	601,275	4.23%
20	Tall Shrub	458,628	3.23%
21	Low Shrub	1,241,901	8.74%
22	Low Shrub - Lichen	14,704	0.10%
23	Low Shrub - Tussock Tundra	124,327	0.87%
24	Low Shrub – Alder/Willow	39,348	0.28%
25	Dwarf Shrub	578,177	4.07%
26	Dwarf Shrub - Lichen	451,526	3.18%
27	Low Shrub – Wet	19,796	0.14%
28	Burn regrowth – Low Shrub	19,697	0.14%
29	Burn regrowth – Tall Shrub	3,470	0.02%
32	Wet Graminoid	172,642	1.22%
36	Lichen	6,155	0.04%
37	Moss	97,181	0.68%
43	Mesic/Dry Graminoid	44,670	0.31%
44	Mesic/Dry Forb	6,318	0.04%
50	Tussock Tundra	37,068	0.26%
51	Tussock Tundra – Lichen	20,697	0.15%
60	Aquatic Bed	178	0.00%
61	Emergent Vegetation	21,227	0.15%
70	Clear Water	74,994	0.53%
71	Turbid Water	110,239	0.78%
72	Snow/Ice	940,890	6.62%
80	Sparse Vegetation	357,658	2.52%
81	Rock/Gravel	653,385	4.60%
92	Cloud	61,759	0.43%
93	Cloud Shadow	65,761	0.46%
94	Terrain Shadow	28,612	0.20%
96	Recent Burn	163,078	1.15%
Total		**14,209,246**	**100%**

Editing

Editing was performed on all classes to various extents depending on how well the iterative classification process worked for each. The edits were verified with field sites, aerial photography and field notes wherever possible. Some editing centered around ecological differences across the project area. For example, a single signature classified low shrub near Farewell Lake and dwarf shrub on the foothills of the Alaska Range near Big River. 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 dwarf shrub/sparse vegetation zones.

Most of the landscape involved in the Stony River MOA project area is based on successional stages of fire regimes. Many of the field sites were in old burn areas that were spectrally similar but very different on the ground. The older burn areas were dominated by standing dead and litter which would cause much of the confusion between the different field sites. Most of the confusion in the old burn areas were between tall shrub, low shrub, and woodland needleleaf. The majority of these old burn areas were classified solely on field site verification.

Areas that had been burned within a close timeframe of the image date left a very bright and homogenous signature because of the abundance of standing dead, litter, and burned vegetation. The standing dead, litter and burned vegetation gives a very high reflection value because the features do not absorb any IR. The actual live vegetation within the area was not be represented in the signature. Therefore, it is impossible to collect any variation in signatures for classification of these areas. Rather than mis-classifying vegetation in the recently burned areas, they were grouped into the fire (burn) class.

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 5-10% trees. This case was evident throughout the study area as occurrence of wetter low shrub/wet graminoid areas were surrounded by woodland needleleaf. The most prevalent example of the confusion within the gradient between classes was found between open- and woodland needleleaf. As evidenced by the field training sites, the majority of the open and woodland needleleaf classes exhibited a tree crown cover between 20% and 30%. Similarly, low shrub areas at a height of .3 meters were confused with dwarf shrub areas with a height of .2 meters. Also, low shrub areas at a height of 1 meter were confused with tall shrub areas of only 1.5 meters in height. 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 forested land surrounding it. These half-water, half-land signatures were often confused with emergent and closed deciduous signatures. Editing was done to separate legitimate emergent, deciduous or mixed forest pixels based on aerial photography, field notes and topography. 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. As discussed earlier, tremendous variation in standing water level from the time of satellite image acquisition (June 1986) to the time of field data collection (July 1999) was evident. Therefore, the editing associated with this type of confusion focused on best representing conditions as they were at the time of satellite image capture. Each of these conditions was edited manually to insure 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 two open mixed needleleaf/deciduous field training sites. This confusion was corrected via manual editing utilizing photo-interpretation and review of specific field notes and photos.

In some cases, a single pixel fell across the edge of a patch of tall shrub and the dwarf or low shrub surrounding it (Figure 13). These half-tall shrub, half-dwarf shrub signatures were often confused. Editing was done to separate legitimate tall shrub, dwarf shrub and deciduous pixels based on aerial photography, field notes and photographs. The higher elevation areas for this project had many patchy areas mixed with tall shrub, low shrub and dwarf shrub. The pixels were classified on what signature dominated the site, however, a mix of these three classes remained due to the variable landscape. The remaining mixed pixels were blended into surrounding areas with a limited majority scan algorithm.

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 deciduous, aquatic bed. 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, a vegetation caller may have interpreted a site to contain 10% tree cover

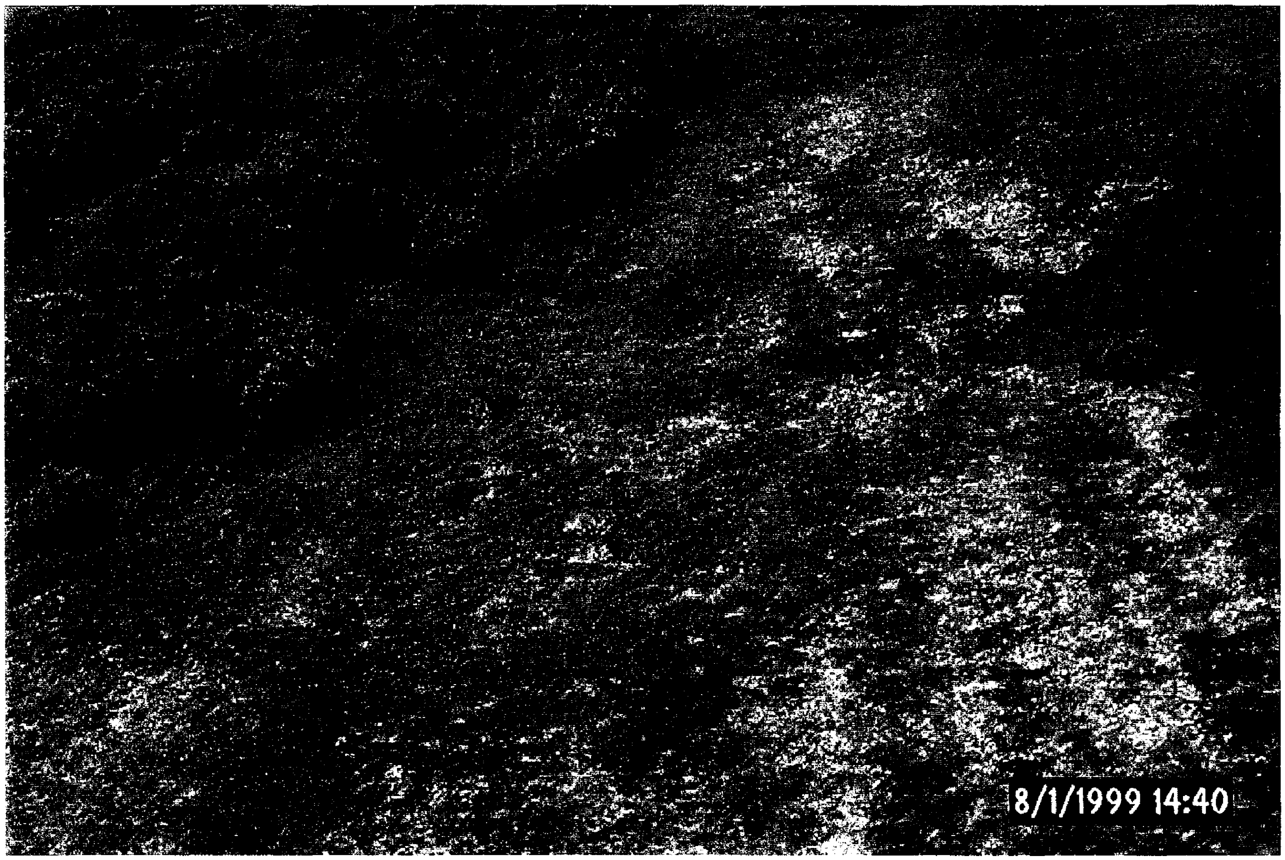


Figure 13. Dwarf shrub site with tall shrub patches (Western Stony site 585).

and 90% low shrubs. This site would be classified as a woodland conifer site. If this site is used to evaluate a site classified with a group of pixels indicating a presence of 5% tree cover and 95% low shrubs, the site would have been evaluated as incorrectly classified. Since the literature generally accepts the fact 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 10% tree cover should also be considered acceptably classified as low shrub and tallied as such. 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.

A more appropriate and informative representation of the reliability/accuracy of the earth cover classification is found in the error matrix provided in Appendix D. In this matrix, 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 map. The error matrix presents values for user's accuracy, producer's accuracy, and the overall accuracy for +/- 0% and +/-5% variation in interpretation within the reference data. In the error matrix, numbers along the main diagonal of the matrix indicate an exact match between the reference data site and the map. A tally of these numbers 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 unacceptance of each accuracy assessment site with an off-diagonal map class provides insight into the vegetation composition of that reference site. For instance, in the matrix in Appendix D, of the twenty-two reference sites characterized as woodland needleleaf, one site was an acceptable match with open needleleaf, one was an acceptable match with woodland needleleaf – lichen, one was an acceptable match with low shrub – other, and one was an unacceptable match with dry graminoid. The remainder of the sites (18) were diagonal matches with woodland needleleaf. The off-diagonal matches indicate that at least one of those sites was just on the border between woodland and open needleleaf (20-25% tree canopy cover), at least one was just on the border of having enough lichen present to be an acceptable match with woodland needleleaf – lichen (15-20% lichen), and at least one site had a significant low shrub component and just enough tree canopy cover to be considered forested (10-15% tree canopy cover). Similarly, since the number of misclassified sites are 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. If lumping of classes is still desired, this can easily be accomplished through application of the techniques utilized in previous projects. Although the matrix of lumped classes is not presented in this report, the classification accuracy of the grouped classes of Open Needleleaf, Woodland Needleleaf, Deciduous, Mixed Needleleaf/Deciduous, Tall Shrub, Low Shrub, Dwarf Shrub, Forb/Graminoid, and Barren was computed to be 82.3%.

The Eastern Stony Project Overall Accuracy Assessment

The difference in classification accuracy between the +/- 0% variation in interpretation level (74%) and the +/- 5% variation in interpretation level (90%) indicated that a great 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, 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 D), a more reliable and informative measure of accuracy and reliability is presented.

The accuracy measures of the needleleaf forested classes were acceptable with absolutely no lumping or variation of interpretation allowed (closed needleleaf = 67%, open needleleaf = 85%, and woodland needleleaf = 82%). Allowing +/- 5% variation in interpretation in the reference data, much greater accuracies were demonstrated (100%, 94%, and 95%). The User's Accuracy for the same classes were even greater. These measures were extremely encouraging since over 50% of the study area was mapped as one of these forested needleleaf classes. When an area was classified as one of the forested needleleaf classes, the user can have extreme confidence in the accuracy of that classification. Of the thirteen off-diagonal needleleaf reference sites, eight were considered acceptable matches at the +/- 5% variation in interpretation level. This indicates that the vast majority of the reference sites that were not direct matches with the map sites were on the boundary between two different mapping classes; one of which the map presented for the site.

The open and woodland needleleaf classes were the most difficult class to map due to their high diversity of possible components. For example, a woodland site could include 40% graminoid cover and just 10% trees, or it could contain 20% trees and 50% shrubs. In some cases, cover types other than trees dominated the signature of woodland sites, whereas in other cases, spruce trees dominated. A great deal of effort was expended in separating these two classes from one another as well as from other similar non-forested sites. The error matrix indicates that only three of the 60 needleleaf reference sites were mapped incorrectly when allowing for only +/- 5% variation in interpretation of the reference data.

Similar results were found throughout the error matrix. When accounting for those reference sites that characterized vegetation communities at the boundary of two or more mapping classes, consistently high accuracy measures were found for both the user's and producer's accuracy. Every measure of both the user's and producer's accuracy at the +/- 5% level of variation of interpretation in the reference data for classes containing at least three reference sites exceeded 82%, with the vast majority of these sites exceeding 90% accuracy. Despite the strong correlation between the reference data and the classified map data, one trend of potential interest to an end user is evidenced in the error matrix. From a user's perspective, the low shrub - other class presented a slight tendency toward being over classified. While 17 out of the 19 low shrub – other reference sites were found to be classified correctly (89.5% producer's accuracy at the +/- 5% variation level), only 16 out of 22 reference sites that were mapped as low shrub – other were found to be classified correctly (72.7% user's accuracy at the +/- 5% variation level). This indicated that several vegetation types were being incorrectly mapped disproportionately as low shrub – other. Fortunately, or unfortunately, no one specific vegetation type was found to be confused with the low shrub – other class more than another.

In summary, based on the quantitative accuracy assessment, the earth cover classification map produced for the Eastern Stony project is very reliable. Nearly 75% of the accuracy assessment sites matched the full detailed 32 mapping classes directly; even when taking no variation in interpretation into account. When as little as +/- 5% variation in interpretation was accounted for, more than nine out of ten (90.97%) of the reference sites were found to correspond correctly with the classified map.

The Western Stony Project Overall Accuracy Assessment

The difference in classification accuracy between the +/- 0% variation in interpretation level (77%) and the +/- 5% variation in interpretation level (90%) indicated that a great 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, 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 D), a more reliable and informative measure of accuracy and reliability is presented.

The accuracy measures of the needleleaf forested classes were acceptable with absolutely no lumping or variation of interpretation allowed (open needleleaf = 82%, open needleleaf lichen = 57%, woodland needleleaf = 88% and woodland needleleaf lichen = 50%). Allowing +/- 5% variation in interpretation in the reference data, much greater accuracies were demonstrated (82%, 71%, 100%, and 83% respectively). The User's Accuracy for the same classes were even greater. These measures were extremely encouraging since over 50% of the study area was mapped as one of these forested needleleaf classes. When an area was classified as one of the forested needleleaf classes, the user can have extreme confidence in the accuracy of that classification. A majority of the 10 off-diagonal needleleaf reference sites were confused between other needleleaf classes. A majority of the confusion lied between needleleaf lichen classes and needleleaf classes. This indicated that at the +/- 5% variation many of these needleleaf classes were very similar.

The open and woodland needleleaf classes were the most difficult class to map due to their high diversity of possible components. For example, a woodland site could include 40% graminoid cover and just 10% trees, or it could contain 20% trees and 50% shrubs. In some cases, cover types other than trees dominated the signature of woodland sites, whereas in other cases, spruce trees dominated. Open needleleaf lichen and woodland needleaf lichen also had a very low accuracy overall. The lichen signatures for both woodland and open needleleaf sites were dificult to differentiate. Since both types of earth cover are very similiar in composition it could be expected that there was great confusion between woodland, woodland lichen, open needleleaf, and open needleleaf lichen. The producer's accuracy was particularly high for closed deciduous classes (100%). Generally, the closed deciduous classes had a distinctive signature and were rarely confused with classes other than tall shrub. Tall shrub (78%), low shrub (86%) and dwarf shrub (88%) accuracy was satisfactory, especially since the sites that were misclassified fell into other shrub categories. Rock and gravel classes tended to be confused with dwarf shrub and dwarf shrub lichen, most of the confusion occured on hilltops and it was difficult to distinguish between these cover types.

In summary, based on the quantitative accuracy assessment, the earth cover classification map produced for the Western Stony project is very reliable. Nearly 77% of the accuracy assessment sites matched the full detailed 32 mapping classes directly; even when taking no variation in interpretation into account. When as little as +/- 5% variation in interpretation was accounted for, more than nine out of ten (89.9%) of the reference sites were found to correspond correctly with the classified map.

Discussion

While the accuracy assessment performed in this project was not a robust test of the classification, it gives the user some confidence in using the classification. It provided enough detail for the end user to determine where discrepancies in the classification may cause a problem while using the data. It is also important to note the variations in the dates of the imagery, aerial photographs, and field data. For this project, the imagery was acquired on June 13, 1986 and August 14, 1989. The aerial photographs spanned a nine year period from 1978-87, and the field data was collected in July 1999. Differences due to environmental changes from the different sources may have affected the accuracy assessment. As discussed earlier, the significant differences in standing water in many older oxbows and other wetter sites between the image date of June 1986 and the field collection date of July 1999 contributed to inconsistencies in correctly identifying sites as wet or dry graminoid/forb or emergent. Depending on the standing water present at any given time, each of these class labels may have been appropriate. The other primary impact of the differing dates of base and ancillary data used in this project was the extent of snow in the 1986 satellite imagery. Due to the relatively early season capture of the satellite imagery, snow covered a significant portion of the higher elevation landscape that would have actually presented low shrub, dwarf shrub, and sparse vegetation communities later in the summer. No field data was collected in the areas covered with snow on the satellite imagery from 1986. Recently burned areas in the 1989 satellite imagery and fires that had occurred after the date the image was taken proved to be a have a large impact on the Western Stony projects field data collection. Many of the burnt areas visible in the imagery were not visited and no sampling was conducted in areas that were burnt after 1989. Depending on the dates for the various fires the areas could consist of vegetation types varying from dwarf shrub to open deciduous cover types.

It should also be noted that no field sites, and therefore no accuracy assessment sites, were captured representing the snow/ice, 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. In terms of quantitative accuracy assessment, no assessment was conducted for mapping classes that accounted for over 10% of the ground cover within the study 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.

A major assumption of quantitative accuracy assessments is that the label from the reference information represents the "true" label of the site and that all differences between the remotely sensed map classification and the reference data are due to classification and/or delineation error (Congalton and Green, 1993). Unfortunately, error matrices can be inadequate indicators of map error because they are often confused by non-map error differences. Some of the non-map errors that can cause confusion are: (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 matrix developed and presented in this report attempts 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 Stony River MOA.

Final Products

The final products included a digital classification, map, and database of 30 earth cover classes within the Stony River MOA area. The digital map was delivered in Arc Info Grid and Erdas Imagine format. The unclassified Landsat TM images used to create the cover map were also delivered. The field site database, a species list and earth cover acreage tables were stored as digital tables in Microsoft Excel and Access format. Digital photographs of the field sites are stored in jpeg format. Hardcopy maps of the entire project area at 1:250,000 scale, and selected 1:63,360 scale quadrangles were also produced. All of the delivered datasets were loaded into Arcview projects for display purposes.

Summary

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 effort for the Stony River MOA project using Landsat TM satellite scenes, Path 72, Row 16 and 17 acquired June 13, 1986 and Landsat TM Path 74, Row 16 and 17 acquired August 14, 1989. The project area was classified into 30 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

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Appendix A. Alaska Earth Cover Classification Class Description

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 papyrifera*), 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. 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, 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 1.45)

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 deciduous trees were paper birch (*Betula Papyrifera).* This class was very rare.

1.42 Closed Aspen
At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the deciduous 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 deciduous trees were cottonwood. Stands of pure cottonwood were occasionally found on riparian gravel bars.

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 deciduous 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 deciduous 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 deciduous 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 Shrub
The tall and low shrub classes were dominated by willow species, dwarf birch (*Betula nana* and *B. 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 include some rock.

2.1 Tall Shrub
Shrubs made up 40-100% of the cover and shrub height was ≥1.3 meters. 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 40-100% of the cover, shrub height was .25-1.3 meters, and ≥75% of the shrub cover was willow and/or alder.

2.22 Other Low Shrub/Tussock Tundra
Shrubs made up 40-100% of the cover, shrub height was .25-1.3 meters, and ≥35% of the cover was made up of tussock forming cotton grass *(Eriophorum vaginatum)*. 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 40-100% of the cover, shrub height was .25-1.3 meters, and ≥20% of the cover was made up of lichen. 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 40-100% of the cover, shrub height was .25-1.3 meters. 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 40-100% of the cover, shrub height was ≤.25 meters, and ≥20% of the cover was made up of lichen. 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.

2.31 Other Dwarf Shrub
Shrubs made up 40-100% of the cover, the shrub height is ≤.25 meters. 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 <u>Herbaceous</u>
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 ≥ 60% lichen species.

3.12 Moss
Composed of ≥40% herbaceous species, ≤25% water, and ≥60% moss species.

3.21 Wet Graminoid
Composed of ≥40% herbaceous species, ≤25% water, and where ≥60% of the herbaceous cover was graminoid, and ≥20% of the graminoid cover was made up of *Carex aquatilis*. This class represented wet or seasonally flooded sites. It was often present in stands too small to be mapped at the current scale.

3.31 Tussock Tundra
Composed of ≥40% herbaceous species, ≤25% water, where ≥50% of the herbaceous cover was graminoid, and ≥35% of the graminoid 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 graminoid 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.

3.34 Mesic/Dry Graminoid
Composed of ≥40% herbaceous species, ≤5% water, with ≥50% graminoids excluding tussock forming cotton grass and *Carex aquatilis*. This class was not common and was found generally only at high elevations.

3.35 Mesic/Dry Forb
Composed of ≥40% herbaceous species, ≤5% water, with <50% graminiods. 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 Aquatic Vegetation
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 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 vegetation was composed of plants other than pond lilies. Generally included freshwater herbs such as horsetails, marestail, or buckbean.

5.1 Clear Water
Composed of ≥80% clear water.

5.2 Turbid Water
Composed of ≥80% turbid water.

6.0 Barren
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 or sand, and vegetation made up less than 20% of the cover. This type was generally along shorelines or rivers.

7.0 Urban
At least 50% of the area was urban. This class was not found in the study area.

8.0 Agriculture
At least 50% of the area was agriculture. This class was not found in the study area.

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

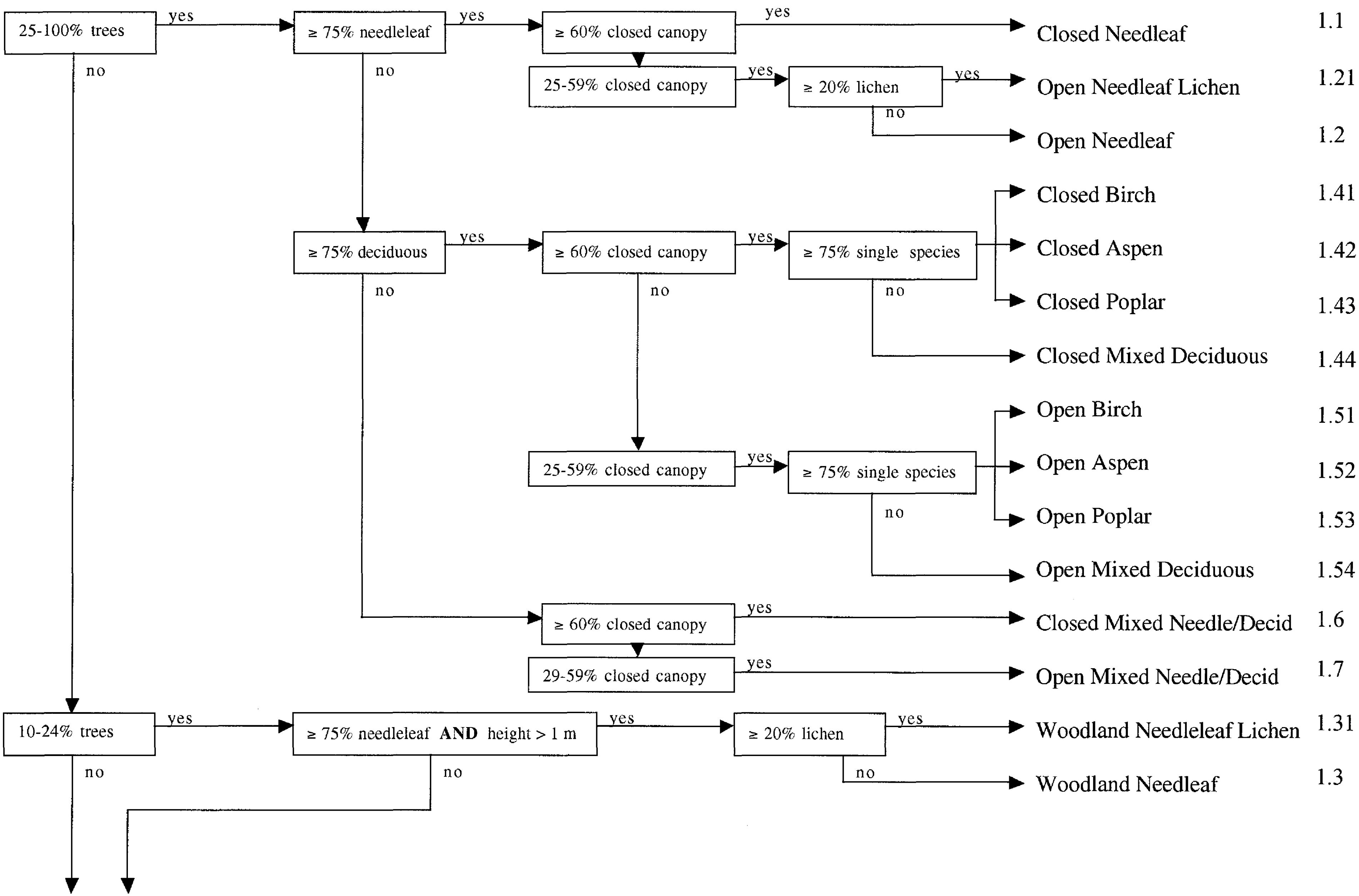
9.1 Cloud
At least 50% of the cover was made up of clouds.

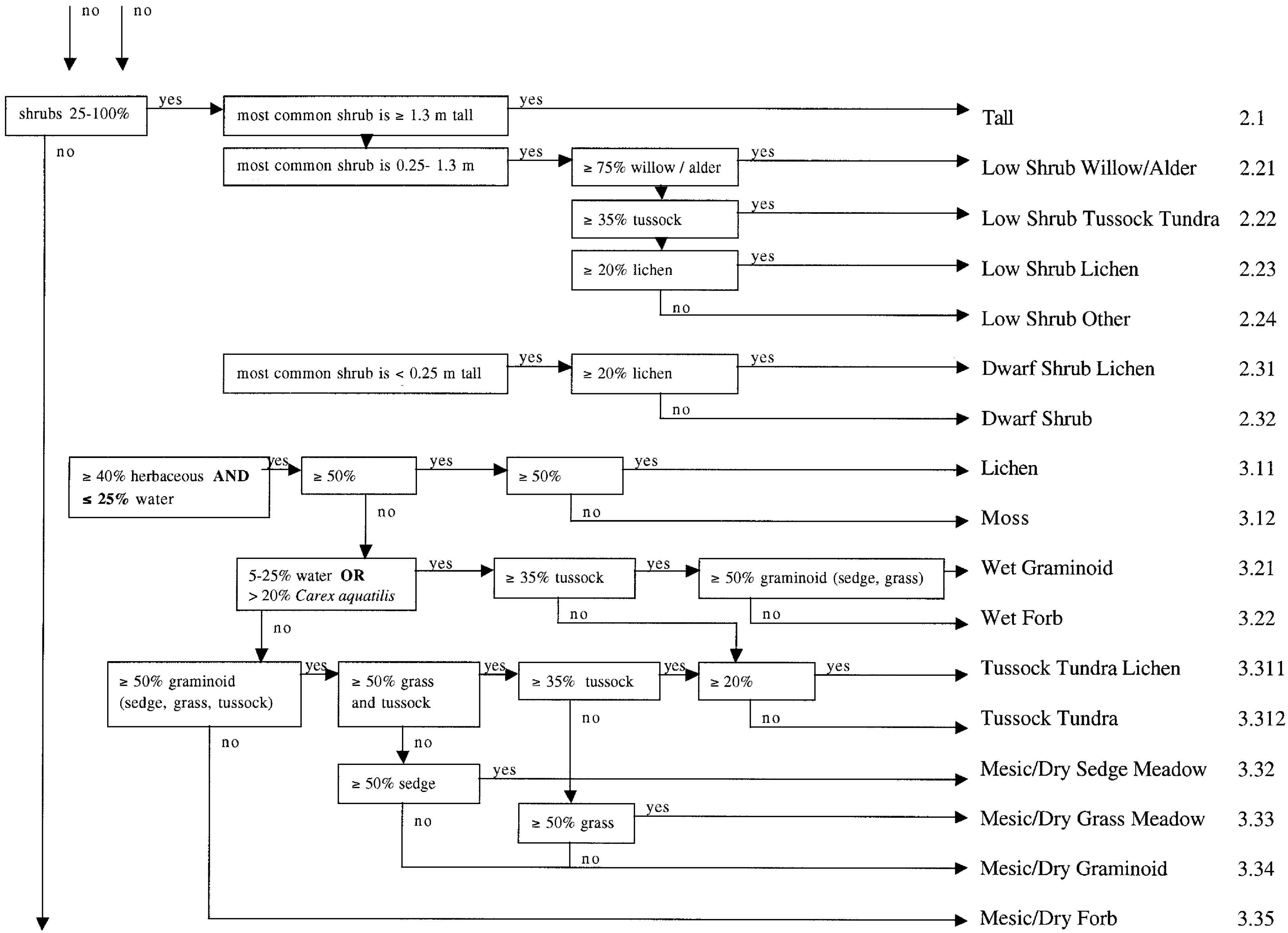
9.2 Cloud Shadow
At least 50% of the cover was made up of cloud shadows.

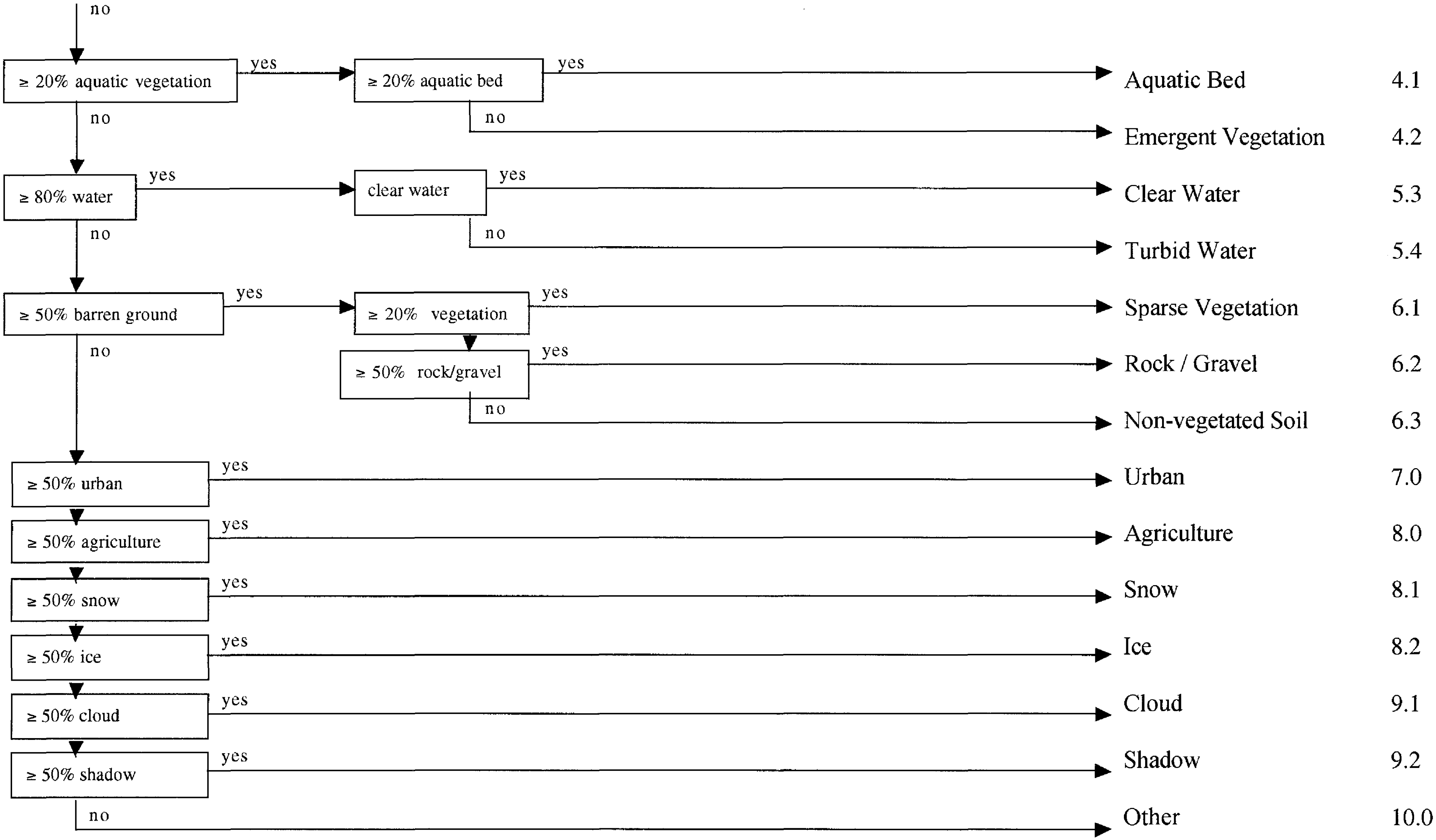
9.3 Terrain Shadow
At least 50% of the cover was made up of terrain shadows.

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. Earth Cover Classification Decision Tree.




no
no
shrubs 25-100%
yes
most common shrub is ≥ 1.3 m tall
yes
Tall
2.1
no
most common shrub is 0.25- 1.3 m
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
most common shrub is < 0.25 m tall
yes
≥ 20% lichen
yes
Dwarf Shrub Lichen
2.31
no
Dwarf Shrub
2.32
≥ 40% herbaceous AND ≤ 25% water
yes
≥ 50%
yes
≥ 50%
yes
Lichen
3.11
no
no
Moss
3.12
5-25% water OR > 20% Carex aquatilis
yes
≥ 35% tussock
yes
≥ 50% graminoid (sedge, grass)
Wet Graminoid
3.21
no
no
Wet Forb
3.22
no
≥ 50% graminoid (sedge, grass, tussock)
yes
≥ 50% grass and tussock
yes
≥ 35% tussock
yes
≥ 20%
yes
Tussock Tundra Lichen
3.311
no
no
Tussock Tundra
3.312
no
no
≥ 50% sedge
yes
Mesic/Dry Sedge Meadow
3.32
no
≥ 50% grass
yes
Mesic/Dry Grass Meadow
3.33
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. Plant Species and Cover Type List.

Site Tally	Symbol	Species	Common Name
665	MOXX	MOSS	MOSS
581	LITT	LITTER	LITTER
561	VAUL	VACCINIUM ULIGINOSUM	BLUEBERRY,BOG
552	LEPA	LEDUM PALUSTRE	LABRADOR TEA
541	LIXX	LICHEN	LICHEN
405	SAX_	SALIX SPP	WILLOW
321	BEGL	BETULA GLANDULOSA	BIRCH,DWARF ARCTIC
318	PIGL	PICEA GLAUCA	SPRUCE,WHITE
299	CACA4	CALAMAGROSTIS CANADENSIS	REEDGRASS,BLUEJOINT
270	BEPA	BETULA PAPYRIFERA	BIRCH,PAPER
266	BENA	BETULA NANA	BIRCH,SWAMP
252	CAXX	CAREX SPP	SEDGE SPP
235	EMNI	EMPETRUM NIGRUM	CROWBERRY,BLACK
229	PIMA	PICEA MARIANA	SPRUCE,BLACK
228	RUCH	RUBUS CHAMAEMORUS	CLOUDBERRY
220	EQXX	EQUISETUM SPP	HORSETAILS SPP
178	ALCR6	ALNUS CRISPA	ALDER,GREEN
174	STDE	STANDING DEAD	STANDING DEAD
160	VAVI	VACCINIUM VITIS-IDAEA	CRANBERRY,MOUNTAIN
146	SPBE	SPIRAEA BEAUVERDIANA	SPIRAEA,BEAUVERED
145	ERXX	ERIOPHORUM SPP	COTTON-GRASS
145	FERN	FERN SPP	FERN
134	LALA	LARIX LARICINA	LARCH,AMERICAN
129	PISP	PICEA SPP.	SPRUCE, MIXED WHITE AND BLACK
120	EPAN2	EPILOBIUM ANGUSTIFOLIUM	FIREWEED
112	CLWA	CLEAR WATER	CLEAR WATER
95	ROCK	ROCK	ROCK
92	DRXX	DRYAS SPP	MOUNTAIN-AVENS
83	GRASS	GRASS	GRASS
81	POTR10	POPULUS TREMULOIDES	ASPEN,QUAKING
78	COCA13	CORNUS CANADENSIS	BUNCHBERRY,CANADA
77	SADW	SALIX DW.	WILLOW, DWARF
64	ROAC	ROSA ACICULARIS	ROSE,PRICKLY
64	ALNS	ALNUS SPP	ALDER SPP
62	GRAV	GRAVEL	GRAVEL
56	POFR	POTENTILLA FRTICOSA	CINQUEFOIL, BUSH
55	POBA2	POPULUS BALSAMIFERA	POPLAR,BALSAM
45	CAAQ	CAREX AQUATILIS	SEDGE,WATER
42	VAMI	VACCINIUM MICROCARPUS	BLUEBERRY
40	ERVA4	ERIOPHORUM VAGINATUM	COTTON-GRASS,TUSSOCK
40	SATRE	SALIX TREE	WILLOW TREE
33	PEFR5	PETASITES FRIGIDUS	COLTSFOOT,ARCTIC SWEET
32	ALTRE	ALNUS SPP TREE	ALDER, TREE
30	CHCA2	CHAMAEDAPHNE CALYCULATA	LEATHERLEAF
27	MYGA	MYRICA GALE	SWEETGALE
25	METR3	MENYANTHES TRIFOLIATA	BUCKBEAN

Site Tally	Symbol	Species	Common Name
24	FESP	FESTUCA SPP	FESCUE
24	ARSP	ARCTOSTAPHYLOS SPP.	BEARBERRY
23	SESP	SENECIO SPP	SENECIO
20	POPA14	POTENTILLA PALUSTRIS	CINQUEFOIL,MARSH
18	VEVI	VERATRUM VIRIDE	FALSE-HELLEBORE,AMERICAN
17	BARE	BARE GROUND	BARE GROUND
17	CATE11	CASSIOPE TETRAGONA	BELL-HEATHER,ARCTIC
16	SAXX	SAXIFRAGA SPP	SAXIFRAGE SPP
16	DIUN	DIAPENSIA	DIAPENSIA
15	LUPS	LUPINUS SPP.	LUPINE
14	GELI2	GEOCAULON LIVIDUM	TOADFLAX,NORTHERN RED-FRUIT
14	HELA4	HERACLEUM LANATUM	COW-PARSNIP
14	SACA14	SANGUISORBA CANADENSIS	BURNET,CANADA
13	ARTSP	ARTEMISIA SPP.	SAGE, SPP.
13	MUDX	MUD	MUD
13	ARNS	ARNICA SPP.	ARNICA
12	ANPO	ANDROMEDA POLIFOLIA	ROSEMARY,BOG
12	SERO2	SEDUM ROSEA	STONECROP,ROSEROOT
11	ASXX	ASTRAGALUS SPP	VETCH
11	GEPR4	GERANIUM PRATENSE	CRANE'S-BILL,MEADOW
11	ACDE2	ACONITUM DELPHINIFOLIUM	MONKSHOOD,LARKSPUR-LEAF
10	EQFL	EQUISETUM FLUVIATILE	HORSETAIL,WATER
8	SIAC	SILENE ACAULIS	CAMPION,MOSS
8	LYSP	LYCOPODIUM SPP.	CLUBMOSS
8	COST4	CORNUS STOLONIFERA	DOGWOOD,RED-OSIER
7	PESP	PEDICULARIS SPP	LOUSEWORT
7	VIED	VIBURNUM EDULE	SQUASHBERRY
6	POBI5	POLYGONUM BISTORTA	BISTORT,MEADOW
6	SHCA	SHEPHERDIA CANADENSIS	BUFFALO-BERRY,CANADA
6	CALA7	CAMPANULA LASIOCARPA	BELLFLOWER,COMMON ALASKA
5	JUCO	JUNIPERUS COMMUNIS	JUNIPER, COMMON MOUNTAIN
5	MEPA	MERTENSIA PANICULATA	BLUEBELLS,TALL
4	BORI	BOYKINIA RICHARSONI	BEARPLANT
4	POAL5	POLYGONUM ALASKANUM	RHUBARB,ALASKA WILD
4	SAND	SAND	SAND
4	AGBO2	AGROSTIS BOREALIS	BENTGRASS,NORTHERN
4	ANPO	ANDROMEDA POLIFOLIA	ROSEMARY,BOG
4	GRXX	GRAMINOID SPP	GRAMINOID SPP
4	SHRUB	SHRUB COMPLEX	SHRUB COMPLEX
3	ANMO	ANTENNARIA MONOCEPHALA	PUSSYTOE
3	CIDO	CICUTA DOUGLASII	WATER-HEMLOCK,WESTERN
3	COSP	CORNUS SPP.	DOGWOOD SPP.
3	GABO2	GALIUM BOREALE	BEDSTRAW,NORTHERN
3	LYAL3	LYCOPODIUM ALPINUM	CLUBMOSS,ALPINE
3	POAC	POLEMONIUM ACUTIFLORUM	JACOB'S-LADDER,STICKY TALL
3	RISP	RIBES SPP.	RASBERRY

Site Tally	Symbol	Species	Common Name
3	SAEX2	SAXIFRAGA EXILIS	SAXIFRAGE
3	FOXX	FORB SPP	FORB SPP
3	IRSE	IRIS SETOSA	IRIS,BEACH-HEAD
3	ARRU	ARCTOSTAPHYLOS RUBRA	BEARBERRY,RED
3	SAPU15	SALIX PULCHRA	WILLOW,COMMON
2	CAMS	CAMPANULA SPP.	CAMPANULA
2	CAPA5	CALTHA PALUSTRIS	MARSH-MARIGOLD,COMMON
2	CASP	CASTILLEJA	CASTILLEJA
2	DEGL3	DELPHINIUM GLAUCUM	LARKSPUR,TOWER
2	LOPR	LOISELURIA PROCUMBENS	AZALEA, ALPINE
2	MISP	MINUARTIA SPP.	MINUARTIA
2	PALA9	PAPAVER LAPPONICUM	POPPY,ARCTIC
2	RHLA2	RHODODENDRON LAPPONICUM	AZALEA,LAPLAND
2	RUAR6	RUMEX ARCTICUS	DOCK,ARCTIC
2	CARO2	CAMPANULA ROTUNDIFOLIA	BELLFLOWER,SCOTCH
2	EQSP	EPILIOLIUM SPP	FIREWEED
2	CORNU	CORNUS SPP TREE	DOGWOOD SPP TREE
2	LEDE5	LEDUM DECUMBENS	LABRADOR-TEA,NARROW-LEAF
2	MOLA6	MOEHRINGIA LATERIFLORA	SANDWORT,GROVE
2	NUPO	NUPHAR POLYSEPALUM	WATER LILY
2	OXNIN	OXYTROPIS NIGRESCENS	OXYTROPE,BLACKISH
1	ANPA	ANEMONE PARVIFLORA	THIMBLE-WEED,SMALL-FLOWER
1	ARUV	ARCTOSTAPHYLOS UVA-URSI	KINNEKINNICK
1	ASSP	ASTER SPP	ASTER
1	CAMI12	CASTILLEJA MINIATA	INDIAN-PAINTBRUSH,SCARLET
1	EPAN4	EPILOBIUM ANAGALLIDIFOLIUM	WILLOW-HERB,PIMPERNEL
1	HEAL	HEDYSARUM ALPINUM	SWEETVETCH,ALPINE
1	HESPP	HEDYSARUM SPP.	SWEETVETCH, SPECIES
1	LIBO3	LINNAEA BOREALIS	TWINFLOWER
1	MIAR	MINUARTIA ARCTICA	STITCHWORT, ARCTIC
1	POLS	POLYGONUM SPP.	BISTORT
1	POTS	POTENTILLA SPP.	CINQUEFOIL
1	RITR	RIBES TRISTE	CURRANT,SWAMP RED
1	RMSP	RUMEX SPP	DOCK
1	VAAL	VACCINIUM ALASKAENSE	BLUEBERRY,ALASKA
1	VISP	VIOLA SPP	VIOLET
1	ARAL2	ARCTOSTAPHYLOS ALPINA	MANZANITA,ALPINE
1	BEOC2	BETULA OCCIDENTALIS	BIRCH,SPRING
1	CHNO	CHAMAECYPARIS NOOTKATENSIS	CEDAR,ALASKA
1	CIMA	CICUTA MACKENZIANA	WATER-HEMLOCK,MACKENZIE
1	EQPA	EQUISETUM PALUSTRE	HORSETAIL,MARSH
1	POTAM	POTAMEGETON SPP	PONDWEED
1	RUAC	RUBUS ACAULIS	RASPBERRY,DWARF
1	SAST11	SANGUISORBA STIPULATA	BURNET
1	SPAN2	SPARGANIUM ANGUSTIFOLIUM	BURREED,NARROWLEAF

Appendix D. Eastern Stony Project Accuracy Assessment Error Matrix

REFERENCE

Class Name / No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29		User's +/-0	User's +/- 5%
1) Closed Needleleaf	2																													2	100%	100%
2) Open Needleleaf	1,0	28		1,0				1,0																						31	90%	100%
3) Open Needleleaf - Lichen			1																											1	100%	100%
4) Woodland Needleleaf		2,0		18							1,0																			21	86%	100%
5) Woodland Needleleaf - Lichen			1,0	1,0																										2	0%	100%
6) Closed Deciduous						3		1,0																						4	75%	100%
7) Open Decidiuous																														0	N/A	N/A
8) Closed Mixed						2,0		3	1,0																					6	50%	100%
9) Open Mixed		1,0				0,1																								2	0%	50%
10) Tall Shrub										9	0,1			0,1																11	82%	82%
11) Low Shrub - Other		0,2		1,0					0,1	1,1	14				0,1									0,1						22	64%	73%
12) Low Shrub - Lichen																														0	N/A	N/A
13) Low Shrub - Tussock Tundra													4		1,0						0,1									6	67%	83%
14) Low Shrub - Alder/Willow											0,1																			1	0%	0%
15) Dwarf Shrub - Other											2,0				11	1,0													1,0	15	73%	100%
16) Dwaft Shrub - Lichen																2														2	100%	100%
17) Wet Graminoid																	2													2	100%	100%
18) Wet Forb																														0	N/A	N/A
19) Dry Graminoid				0,1													1,0													2	0%	50%
20) Dry Forb																														0	N/A	N/A
21) Tussock Tundra																					1									1	100%	100%
22) Tussock Tundra - Lichen																														0	N/A	N/A
23) Aquatic Bed																														0	N/A	N/A
24) Emergent																		1,0						1						2	50%	100%
25) Clear Water																														0	N/A	N/A
26) Turbid Water																														0	N/A	N/A
27) Snow/Ice																														0	N/A	N/A
28) Sparse Vegetation																												1	1,0	2	50%	100%
29) Rock/Gravel															0,1													1,0	7	9	78%	89%
Reference Sites Total:	3	33	2	22	0	6	0	5	2	11	19	0	4	1	14	3	3	1	0	0	2	0	0	2	0	0	0	2	9	144		
Producer's (+/- 0%):	67%	85%	50%	82%	N/A	50%	N/A	60%	0%	82%	74%	N/A	100%	0%	79%	67%	67%	0%	N/A	N/A	50%	N/A	N/A	50%	N/A	N/A	N/A	50%	78%			
Producer's (+/- 5%):	100%	94%	100%	95%	N/A	83%	N/A	100%	50%	91%	89%	N/A	100%	0%	86%	100%	100%	100%	N/A	N/A	50%	N/A	N/A	50%	N/A	N/A	N/A	100%	100%			

Total Accuracy Assessment Sites = 144
Diagonal Total = 107
Off-Diagonal Total = 37
Off-Diagonal Acceptable Total = 24
Overall Accuracy (0% var) = 74.3%
Overall Accuracy (+/- 5% var) = 91.0%

Appendix E. Western Stony Project Accuracy Assessment Error Matrix

	Open Ndlf.	Open Ndlf. Lichen	Wdlnd Ndlf.	Wdlnd Ndlf. Lichen	Closed Decid.	Open Mixed Ndlf./ Decid.	Closed Mixed Ndlf./ Decid.	Tall Shrub	Low Shrub	Dwarf Shrub	Dwarf Shrub Lichen	Rock/ Gravel	**Total**	User's +/- 0%	User's +/- 5%
Open Ndlf.	**9**	0,1		0,1			1,0						**12**	75	83.33
Open Ndlf. Lichen	0,1	**4**		2,0									**7**	57.14	85.71
Wdlnd Ndlf.		0,1	**7**										**8**	87.5	87.5
Wdlnd Ndlf. Lichen		1,0		**3**									**4**	75	100
Closed Decid.					**10**	1,0		1,0					**12**	83.33	100
Open Mixed Ndlf./Decid.						**1**							**1**	100	100
Closed Mixed Ndlf./Decid.	0,1					2,1	**6**						**10**	60	80
Tall Shrub			1,0					**7**					**8**	87.5	100
Low Shrub							0,1	0,1	**6**				**8**	75	75
Dwarf Shrub									1,0	**7**			**8**	87.5	100
Dwarf Shrub Lichen											**3**		**3**	100	100
Rock/ Gravel										1,0	1,0		**2**	N/A	N/A
Total	**11**	7	**8**	**6**	**10**	**5**	**8**	**9**	7	**8**	**4**	**0**	**83**		
Producer's +/- 0%	81.82	57.14	87.5	50	100	20	75	77.78	85.71	87.5	75	-----		**76.61**	
Producer's +/- 5%	81.82	71.43	100	83.33	100	80	87.5	88.89	85.71	100	100	-----			**89.9**

Total Accuracy Assesment Sites	83
Diagonal Total	63
Off-Diagonal Total	20
Off-Diagonal Acceptable Total	12
Overall Accuracy (0% variance)	76.61%
Overall Accuracy (+/- 5% variance)	89.9%

Appendix F. Stony River MOA Metadata

Stony MOA Earth Cover Classification

Metadata also available as

Metadata:

- Identification_Information
- Data_Quality_Information
- Spatial_Data_Organization_Information
- Spatial_Reference_Information
- Metadata_Reference_Information

Identification_Information:
Citation:
Citation_Information:
Originator: Ducks Unlimited,Inc.
Publication_Date: 03/2000
Publication_Time:
Title: Stony MOA Earth Cover Classification
Edition:
Geospatial_Data_Presentation_Form: map
Description:
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 Stony River Military Operations Area (MOA) and associated uplands. Portions of four Landsat TM satellite scenes (Path 72, Row 16-17 acquired 6/13/86 and Path 74, Row 16-17 acquired 8/14/89) were used to classify the 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. A helicopter was utilized to gain access to field sites throughout the project area. Global positioning system (GPS) technology was used both to navigate to pre-selected sites and record locations of new sites selected in the field. The Stony MOA project area is approximately 14.5 million acres. Due to the large size of the project area, field work, classification, and accuracy assessment was split between two field crews and two image processors. The Stony MOA project divided into an eastern and western project area. The Eastern Stony MOA project area is approximately 8.8 million acres and data were collected on 536 field sites during a 16 day field season from July 14, 1999 through July 29,1999. Approximately 25% (149) of these field sites were set aside for accuracy assessment. Western Stony MOA is approximately 5.7 million acres and data were collected on 338 field sites during a 13 day field season from July 29 to August 10 1999. Approximately 25% (83) 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 mapping categories was 91% at the +/-5% level of variation for eastern Stony MOA and 90% at the +/-5% level of variation for western Stony MOA.

Purpose:

The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Stony River MOA 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.

Supplemental_Information:
Time_Period_of_Content:
Time_Period_Information:
Multiple_Dates/Times:
Single_Date/Time:
Calendar_Date: 06/13/1986
Calendar_Date: 08/14/1989
Currentness_Reference: 03/1999
Status:
Progress: complete
Maintenance_and_Update_Frequency: none
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -159.13
East_Bounding_Coordinate: -152.28
North_Bounding_Coordinate: 63.32
South_Bounding_Coordinate: 60.98
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: Stony MOA
Place_Keyword: Kuskokwim
Place_Keyword: MOA
Temporal:
Temporal_Keyword_Thesaurus:
Temporal_Keyword: 1986
Temporal_Keyword: 1989
Point_of_Contact:
Contact_Information:
Contact_Organization: Ducks Unlimited, Inc.
Contact_Person:
Contact_Position:
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 Main Report
Quantitative_Attribute_Accuracy_Assessment:
Attribute_Accuracy_Value:
Attribute_Accuracy_Explanation:

Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator: EROS
Publication_Date: 1986 and 1989
Publication_Time:
Title:
Landsat TM Imagery From Path 72, Rows 16-17 acquired 6/13/86 and Path 74, Rows 16-17 acquired 8/14/89
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: 1989
Calendar_Date: 1986
Time_of_Day:
Process_Step:
Process_Description: See "Stony River MOA Earth Cover Classification" report
Source_Used_Citation_Abbreviation:
Process_Date: 1999
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: 10502
Column_Count: 13163
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:
Standard_Parallel: 50
Longitude_of_Central_Meridian: -154
Latitude_of_Projection_Origin: 65
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: 03/2000
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:
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: Stony 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:

Appendix G. Contact Information

The following additional data is available:

ARC/INFO coverages
Final map classification in ERDAS Imagine format
Final map compositions in Imagine 8.2 format
Raw Landsat TM and DEM imagery
Field database files and FoxPro data entry program
ARC/INFO coverage of aerial photograph flight lines

For more information please contact:

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907-271-3431

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