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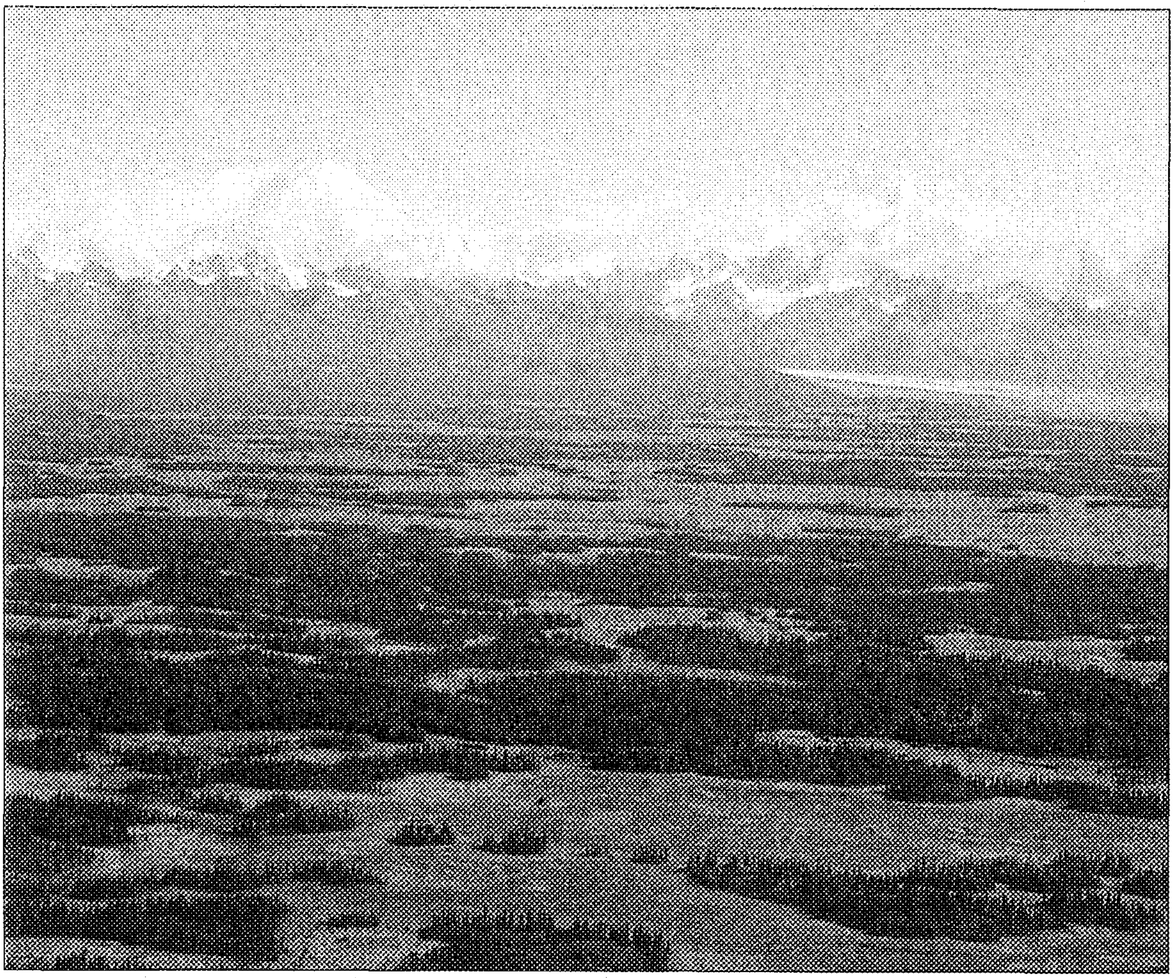
U.S. Department of the Air Force

Ducks Unlimited, Inc.

Susitna 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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Earth Cover Classification

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Special thanks are extended to those who worked in the field. Two separate crews performed the field work. Crew 1, which covered the upland areas, included Jeff Denton (BLM), Jim Sisk (BLM), Beate Sterrenberg (DU), Dan Fehringer (DU), Ben Dorland (DU), Ron Stromstad (DU), and Dick Kempka (DU). Crew 2, which covered the lowland areas, included Greg Balen (BLM), Tim Miner (Alaska Department of Fish and Game - volunteer), Dan Fehringer (DU), and Ruth Spell (DU). Thanks to Dayle Warren of Air Logistics, and Bob Mendenhall of TransAlaska Helicopters for safe air service. Thanks also to: Bob McAlpin from Alaska Fire Service for assistance in coordinating helicopter contracting; Jeff Campbell (Spatial Solutions), Dan Fehringer, and Ruth Spell for imaging processing; Mark Pearson (GeoNorth, Inc.) for programming the Ducks Unlimited Field Form (DUFF) database; and Jing Huang (DU) for programming the accuracy assessment program.

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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 Susitna Military Operations Area (MOA) and associated uplands. Portions of three Landsat TM satellite scenes (Path 70, Rows 16 and 17 acquired 08/16/00 and Path 69, Row 17 acquired 07/10/89) were used to classify the project area into 44 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. Data were collected on 343 field sites during a 12-day field season from 7/15/99 through 7/26/99 and 421 field sites during an 11-day field season from 8/01/99 through 8/11/99. Of the total sites visited, only 679 sites were actually utilized as either image classification training sites or accuracy assessment sites. A total of 514 sites were used as training sites while approximately 25% (165) 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 87.6% at the +/-5% level of variation in interpretation of the accuracy assessment reference sites.

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., 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 Enhanced Thematic Mapper (ETM) 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 Susitna Military Operations Area (MOA) Earth Cover Mapping project area contained diverse landscapes and was deemed important for its wildlife and recreational values. The project area extended from the Alaska Range in the north including the headwaters of the Yentna and Susitna Rivers to Cook Inlet in the south, to the headwaters of the Skwentna and Happy Rivers in the west, and east to Talkeetna and the region just east of the Susitna River. A small lobe of the project area extended along the Knik Arm past the mouth of the Matanuska River and including the mouth of the Knik River. The major portion of the project area was essentially roadless. However, significant development was present along the Susitna River to the Talkeetna area as well as north of Cook Inlet and the Knik arm including the towns of Tyonek, Wasilla, and Palmer. The earth cover data aids 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 Susitna 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 Area

The Susitna MOA mapping project consisted of 7.7 million acres centered roughly on the Yentna and Susitna River drainage areas from the region of their headwaters in the Alaska Range in the northern portion of the study area to their confluence, and eventually to the mouth of the Susitna River in Cook Inlet in the south (Figure 1). The project area fell primarily in the Talkeetna and Tyonek 1:250,000 scale quadrangles. The entire course of the Yentna and Skewentna Rivers as well as the southern-most reaches of the Susitna River ran through the heart of the project. It included portions of the following USGS 1:250 scale quadrangles: Talkeetna, Tyonek, and Anchorage. The villages of Tyonek, Talkeetna, Wasilla, and Palmer fell inside the boundary of the project.

This project area encompassed a wide variety of environments ranging from glaciated mountains to lowland black spruce muskeg, and from 6,000+ ft. peaks of the Alaska Range to the salt water at sea level of Cook Inlet. Extensive non-forested uplands and associated habitats were present within the study area and varied from the foothills of the Alaska Range to the higher glacier canvassed peaks and alpine valleys. These regions form important caribou, goat, and sheep habitat. While moose abounded throughout most of the project area, evidence of frequent bear and wolf use was also present throughout the study 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. With the majority of the study area covered by satellite imagery acquired in August 2000, most all wildfires that had burned over the study area were indicated on the 2000 imagery. However, the eastern-most portion of the study area was mapped from an image that was captured in July 1989. This image did contain the area of at least one substantial region impacted by wildfire subsequent to image acquisition. Unfortunately, this fire-scar was bisected by the overlapping scene boundaries from the 1989 and 2000 satellite imagery. Therefore, an obvious earthcover classification "seam" boundary is evident in the region just west of Goose Bay and extending toward the northeast.

Data Acquisition

Due to the spatial configuration of the study area, two dates of Landsat Thematic Mapper (TM) imagery were required to cover the project area (Figure 2). Imagery from July 1989 and July 1986 were acquired: Path 69 Row 17 and Path 70 Rows 17 and 18. The scenes were purchased from EROS Data Center in Universal Transverse Mercator(UTM) projection and were terrain corrected by ImageLinks, Inc., Melbourne, FL. Both image dates contained substantial cloud cover throughout the southern and western regions of the study area. In addition, due to the relatively early summer date of the Path 70 imagery (July 1, 1986) containing most of the higher mountains of the Alaska Range, a substantial amount of snow cover was present in the higher elevations of the study area.

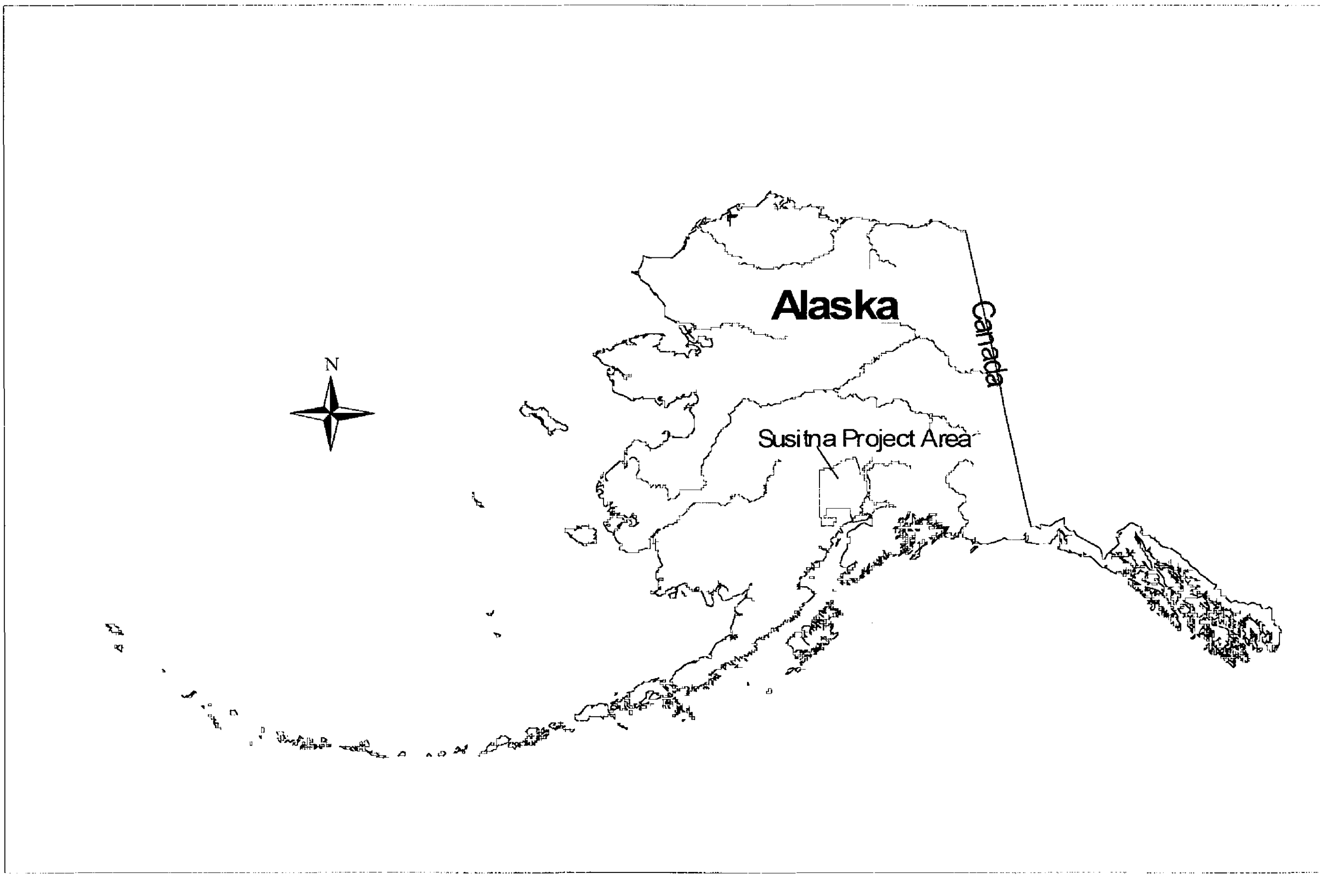


Figure 1. Susitna MOA project location.

Fortunately, however, a new image was identified and purchased that was acquired on August 16, 2000. This image was essentially cloud-free and contained much less snow cover than that of the July 1, 1986 image. Due to the high quality and recent date of this image, the 2000 Landsat TM imagery was utilized for the maximum amount of study area coverage possible. This left only a very small portion of the eastern most region of the study area to be covered by the much older (1989) satellite imagery. This imagery accounted for just over 300,000 acres of the more than 7 million-acre Susitna MOA study area.

Field data were collected on 343 field sites during a 12-day field season from 7/15/99 through 7/26/99 and 421 field sites during an 11-day field season from 8/01/99 through 8/11/99. Of the total sites visited, only 679 sites were actually utilized as either image classification training sites or accuracy assessment sites. 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 (DEMs).

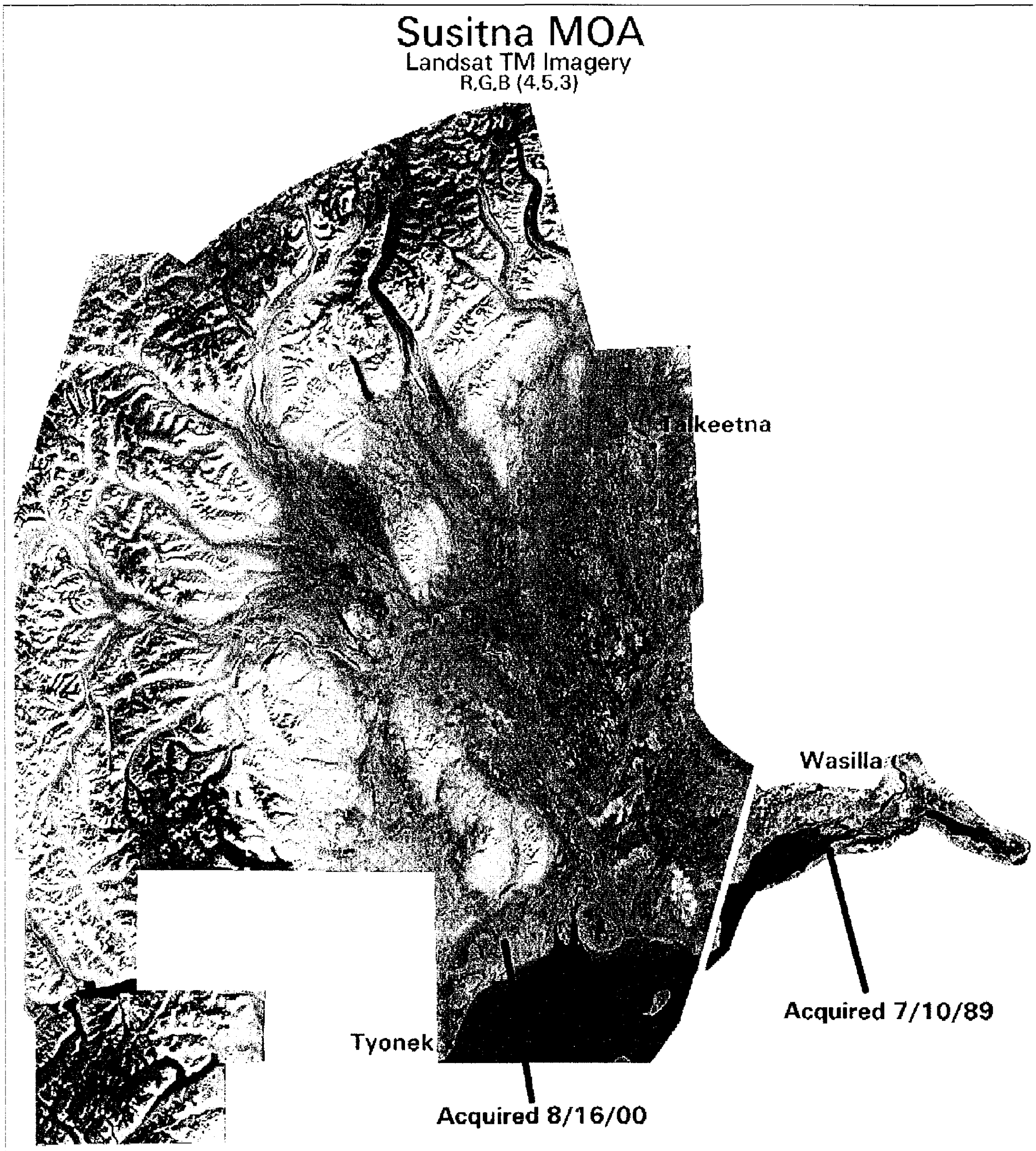


Figure 2. Landsat TM satellite imagery used for the Susitna MOA earth cover mapping project.

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 the last meeting.
The classification scheme consisted of 10 major categories and 24 subcategories. A classification decision tree and written description (Appendices A and B) was developed 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 these 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).

In order to optimize helicopter efficiency, field sites were identified and plotted on field maps before fieldwork began. Sufficient samples for each mapped class

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/Roads		
8.0 Agriculture		
9.0 Cloud/Shadow	9.1 Cloud	
	9.2 Shadow	
10.0 Other		

Table 1. Classification scheme developed at the BLM Earth Cover Workshop

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

An unsupervised classification was used to identify spectrally unique areas within the study area. The image analyst individually selected training sites from these spectrally unique areas. Whenever possible, training sites were grouped in clusters to reduce the amount of travel time between sites. The image analyst also 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 3). 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, so therefore the image processor had the navigator role. The biologist identified plant species, estimated the percent cover of each cover type, determines 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 check-ins, data entry, and substitution in case of sickness. The majority of sites were observed without landing the helicopter. Ground verification 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 was performed when identification of

Rev 7/15/97

Sample Field Form

1997-TIEK 1 - XXX Yr Project Crew Site Number	DFIJHILF 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) 45 — Elev — Aspect: N NE E (SE) S SW W NW Flat

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

(Circle Lichen where present)

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

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-idea
		Bearberry	Artostaphylos spp.
		Kinnikinnick	Artostaphylos uva-ursi
		Crowberry	Empetrum nigrum
		Alpine Azalea	Loiseluria 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 con't

%Cov		
	Forbs	
	Saxifrage	Saxifrage 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

CALL Class MNEED. NPS 8/1/17

Figure 3. Custom field data collection form.

dominant vegetation was uncertain. These 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 4-6 minutes to collect all of the information for one site.

Field Data Analysis

The collected field information was entered into a digital database using a custom data entry application (DUFF), 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 4). 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 5) 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 to produce a high quality, useful product. Erdas Imagine (vers. 8.4) was used to perform the classification as well as to manage the field site polygons. Various word processing and data analysis software packages were also used during the image classification including Microsoft Word, Excel, and Access.

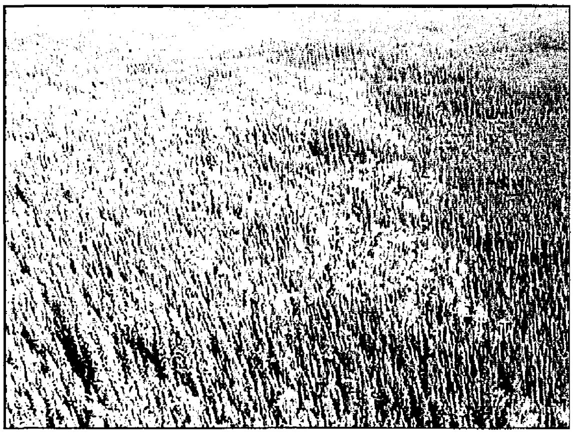
Generation of New Bands

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 was generated for this project. This new band was created using a band-4/band-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). This 4/3 ratio band replaced thermal band (band 6) to retain a 7-band image for classification.

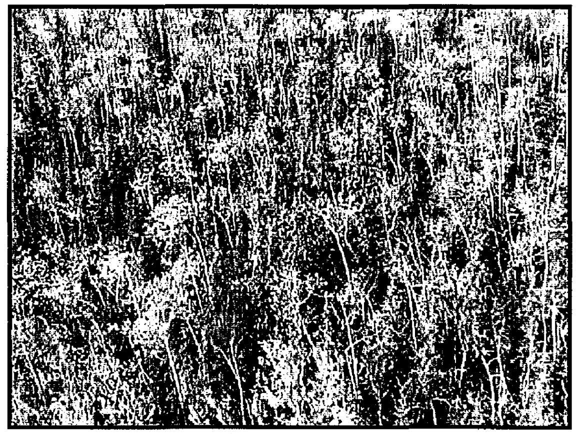
Removal of Clouds and Shadows

No discernable clouds existed in the August 2000 TM imagery that covered the majority of the Susitna MOA study area. However, the clouds and cloud shadows that were present in the July 1989 imagery covering 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.

Sample Field Site – Closed Mixed Needleleaf/Deciduous



High site photo



Low site photo

DUFF INTERFACE

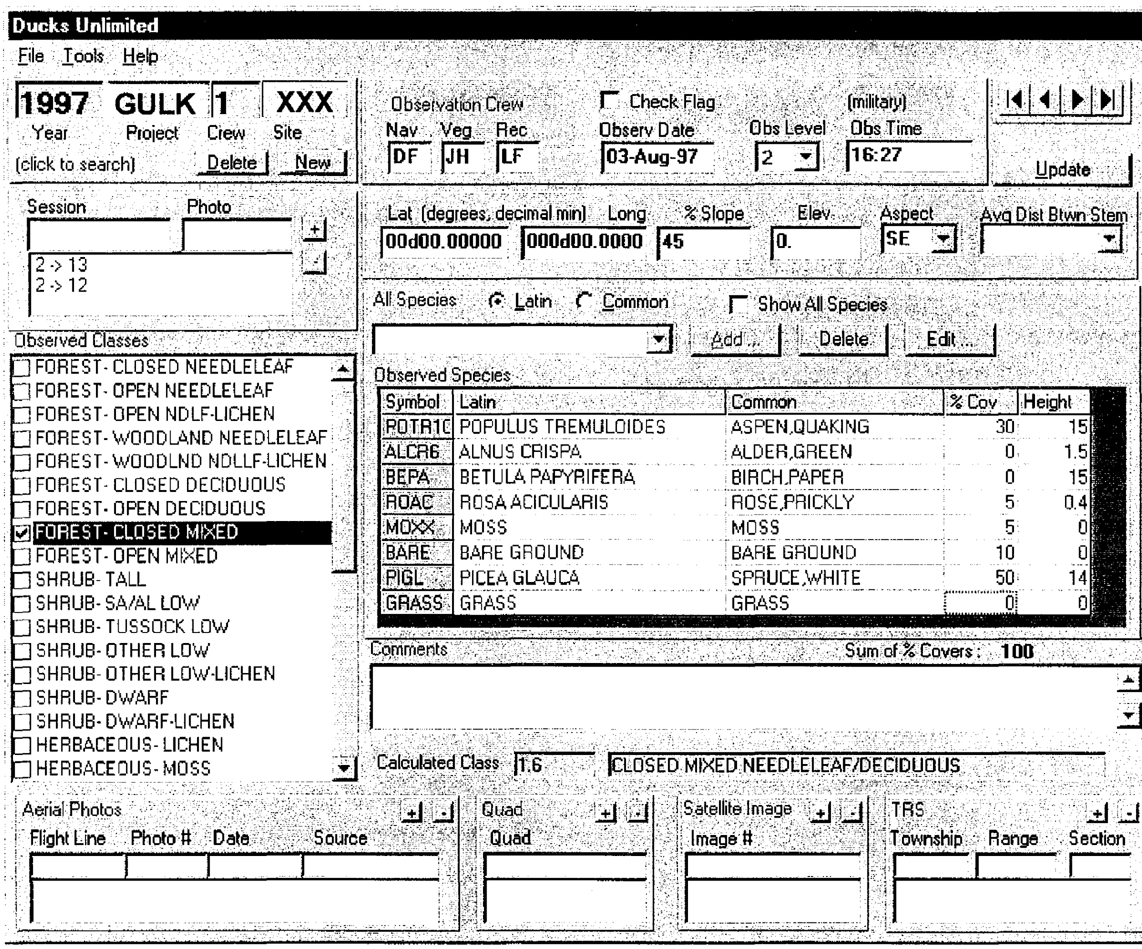


Figure 4. The customized database and user interface for field data entry (DUFF).

Seeding Process

Spectral signatures for the field sites to be the extreme eastern portion of the study area were removed from the image before field sites were selected. This process eliminated any confusion between clouds, cloud 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 recognized on the imagery and aerial photography. The output of the seeding process in Imagine was a signature file that contains 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 4/3 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 used 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 re-run through the process. This process was repeated 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

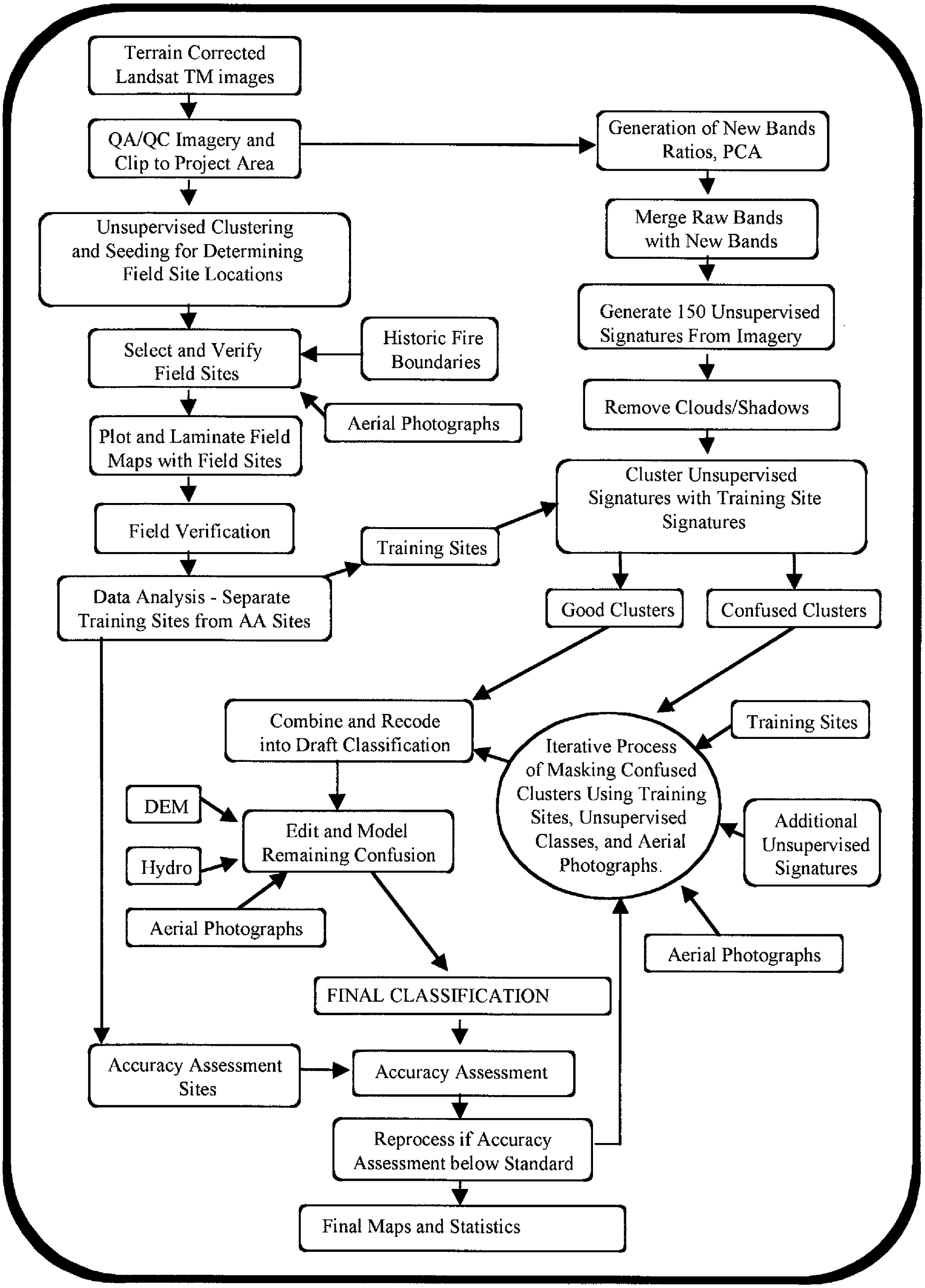


Figure 5. Image processing flow diagram.

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, etc. 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% of the collected field sites were set aside for use in the assessment of map accuracy while the remaining sites 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 is by no means a robust test of the classification, it does give the user some confidence in using the classification. It also provides enough detail for the end user to determine where discrepancies in the classification may cause a problem while using the data. It is also important to note the variations in the dates of the imagery, aerial photographs, and field data. For this project, the imagery was from July 1989 and August 2000; the aerial photographs spanned a seven-year period from 1980 through 1987, 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. A major assumption of quantitative accuracy assessments is that the label from the reference information represents the "true" label of the site and that all differences between the remotely sensed map classification and the reference data are due to classification and/or delineation error (Congalton and Green, 1993). Unfortunately, error matrices can be inadequate indicators of map error because they are often confused by non-map error differences. Some of the non-map errors that can cause confusion are: registration differences between the reference data and the remotely sensed map classification, digitizing errors, data entry errors, changes in land cover between the date of the remotely sensed data and the date of the reference data, mistakes in interpretation of reference data, and variation in classification and delineation of the reference data due to inconsistencies in human interpretation of vegetation.

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

Error Matrix

The standard method for assessing the accuracy of a map was to build an error matrix, also known as a confusion matrix, or contingency table. The error matrix compares the reference data (field site 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. 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

Data were collected on 764 field sites during an 11-day and a 12-day field seasons from 7/15/99 through 8/11/99. Originally, more than 30% of the total field sites were set aside for accuracy assessment. These sites were originally delineated and visited in the field based on their spectral and thematic homogeneity in the original 1986 and 1989 satellite imagery planned for use in this project. However, upon purchase and utilization of the newer 2000 satellite imagery, a large number of these sites were found to be inappropriate for use as either image training sites or quantitative accuracy assessment sites. The spectral values of many of these sites had changed significantly so as to result in an often spectrally heterogeneous site that was difficult to relate to the field vegetation characterization established for that site. Since a positive correlation between the spectral reflectance on the 2000 imagery and the field vegetation characterizations originally established based on 1986 and 1989 satellite imagery, many of these sites were eliminated from further use as either training or accuracy assessment sites. Approximately 25% (165) of the remaining field sites were set aside for accuracy assessment. The proportions of sites per class (Table 2) largely reflects 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.

Bell Long Ranger helicopters were used to gain access to the field sites. Crew 1 field camps were located at Chelatna Lake Lodge, Winter Lake Lodge, and Tyonek Lodge. Fuel was accessed from barrels or bladders that were flown into Chelatna Lake, Tyonek, and Skwetna for use on the project. In addition, a remote fuel cache was located at the airstrip for Rainy Pass Lodge. Crew 2 field camps were located at Big Lake Lodge, Skwentna Roadhouse, and Anchorage. Fuel was accessed from the fuel bladder at the Skwetna airstrip and commercial fuel was obtained at the Big Lake airstrip, Palmer airfield and Merrill Field in Anchorage.

Classification

Other than the non-vegetated classes of snow and rock/gravel, the three most extensive vegetated classes within the final classification were: tall shrub (925,332 acres or 12.02% of total area), low shrub (615,320 acres or 7.99% or total area), and closed mixed deciduous (596,539 acres or 7.75% of total area). In addition, extensive areas of closed birch (408,090 acres or 5.30% of total area) and open mixed needleleaf/deciduous (433,662 acres or 5.63% of total area) were present throughout the study area. Large expanses of closed mixed deciduous/closed birch and mixed needleleaf/deciduous forestland interspersed with low shrub-other/wet sedge/wet graminoid were typical of the project area's lowland earthcover. Uplands were characterized by foothills and mountains of the Alaska Range covered with a transition from the lowland types to tall shrub, low

Table 2. Field sites per mapped class.

Class Name	Original Total Field Sites per Class	Sites Witheld for Accuracy Assessment
CLOSED NEEDLELEAF	2	0
OPEN NEEDLELEAF	39	10
OPEN NEEDLELEAF – LICHEN	1	0
WOODLAND NEEDLELEAF	37	4
WOODLAND NEEDLELEAF – LICHEN	3	0
CLOSED DECIDUOUS (includes CL Birch, Poplar, and Aspen)	76	18
OPEN DECIDUOUS (includes OP Birch, Poplar, and Aspen)	41	9
CLOSED MIXED NEEDLELEAF / DECIDUOUS	11	2
OPEN MIXED NEEDLELEAF / DECIDUOUS	41	7
TALL SHRUB	105	27
LOW SHRUB – OTHER	87	23
LOW SHRUB – LICHEN	1	0
LOW SHRUB – ALDER/WILLOW	10	3
DWARF SHRUB – OTHER	42	10
DWARF SHRUB – LICHEN	22	6
WET SEDGE / GRAMINOID	55	15
WET FORB	3	0
MESIC/DRY SEDGE MEADOW	2	0
MESIC/DRY GRASS MEADOW	14	1
MESIC / DRY GRAMINOID	4	1
MESIC / DRY FORB	14	1
EMERGENT VEGETATION	27	7
AQUATIC BED	15	3
CLEAR WATER	0	4
TURBID WATER	0	3
SPARSE VEGETATION	17	3
ROCK GRAVEL	7	0
NON-VEGETATED SOIL	11	0
LICHEN	12	3
MOSS	29	6
SNOW/ICE	0	3
OTHER	36	0
TOTAL	**764**	**169**

shrub to dwarf shrub communities, and finally to regions of sparse vegetation, bare rock/gravel and perennial snowfields and glaciers. The distribution of these types is characterized in Table 3 and Figure 6. Stands of closed canopy deciduous trees were found throughout the lowlands of the study area. Even in areas appearing to have a significant needleleaf component, a substantial deciduous canopy usually dominated. These stands were composed primarily of Birch; although occasional stands of Poplar, Aspen, and Alder were present. Unfortunately, no consistent, reliable spectral signature could be derived for these often scattered and smaller stands of Aspen. The training sites which attempted to capture an Aspen signature consistently showed significant spectral confusion with a variety of other vegetation types. These Aspen stands were therefore most often captured and characterized by the open- and closed-deciduous land cover classes. Pure closed and open canopy needleleaf stands also appeared to be constrained by soil and wetness conditions and were found primarily near major river drainages or in other low lying wet areas. While almost 350,000 acres of open or closed canopy needleleaf were present in the study area (~4.5%), most lowland forests in the study area had a significant component, if not completely dominated by Birch and other deciduous types. When needleleaf and deciduous forest types presented a mixed canopy, the canopy cover for the stands tended to be more open than closed; generally aggregating in the 45-60% canopy cover range. Open deciduous stands were rare, occurring mainly in areas that had been recently burned or otherwise disturbed. The aquatic bed cover type, composed primarily of floating pond lilies, was a relatively common type within the numerous small pond and lakes throughout the full extent of the project area's lowland region. In the non-forested lowland areas, vegetation cover varied from wet low shrub types to wet graminoid/sedge communities and emergent vegetation. Differentiating between these types proved to be difficult as the moisture and water level conditions visible on the 2000 satellite imagery and those observed in the field in 1999 in many of the forb/graminoid types appeared highly variable.

Unfortunately, the class label for a given training site polygon is very sensitive to the presence of as little as 5% water. For instance, an area on the satellite imagery appeared to be completely free from the presence of standing water or any other forms of moisture. However, during the field data reconnaissance, many of these areas were found to contain 5-10% standing water that had not yet completely dried-up for the summer. This very small amount of water present on the training site often resulted in a "wet" label for the polygon when the satellite image clearly portrayed the area as being completely dry. Similarly, the amount of standing water present in the training site had a direct impact between the site's consideration as an emergent vegetation site vs. an otherwise wet graminoid/sedge site (when aquatic species may be present). In other cases, the site may have been characterized as having as much as 10-15% standing water with low shrub cover of more than 25%. These sites, while characterized as a low shrub site, often appeared spectrally very similar to sites containing now shrub cover but also possessing a substantial amount (10-25%) of standing water. Therefore, consistently distinguishing between very wet low shrub and wet graminoid/sedge sites was a challenge.

Rock and sparse vegetation cover types were found mostly at the highest elevations, along stream and riverbanks and sandbars. Substantial regions of snow and ice were found throughout the Alaska Range mountains in the study area. Numerous glaciers and perennial snowfields blanketed the higher regions of the Alaska Range. With the inclusion of the cloud-free August 2000 imagery, the only clouds present in the imagery for the Susitna MOA study area were found in the extreme southeast region of the study area just north of Knik Arm on the July 1989 imagery. While the area classified as clouds and cloud shadow accounted for just over 2,000 acres over the entire 7.7 million acres of the study area, the vast majority of the study area was completely cloud-free. Accounting for substantially more "unclassified" acreage were the regions characterized and mapped as terrain shadow. Although the "terrain shadow" class label is always used very sparingly, the substantial shadows cast by the formidable mountain peaks and terrain in the mid-to-late summer (August 16) made accurately and consistently distinguishing and characterizing the earthcover enveloped in the shadows essentially impossible. Nearly 1.5% of the study area (114,600 acres) was impacted by these terrain shadows.

Modeling

Modeling was performed using a variety of ancillary data tools. The purpose of utilizing modeling in the classification and mapping process is to improve the evolving earth cover map by incorporating information other than spectral data to further discriminate between various vegetation types when spectral reflectance values alone have proven ineffective for doing such. A shaded relief image and an elevation zone image derived from USGS DEM at 1:250,000 scale were used in this regard.

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 slope, aspect or elevation limited. While these slope, aspect, and/or elevation limitations did provide good consistent measures for correcting misclassifications throughout the study area, they are not always to be trusted to represent actual vegetation occurrence 100% of the time. Therefore, careful manual confirmation of model results were performed and anomalies corrected following the execution of each spatial model.

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 did not occur on a slope, but terrain shadows did, so a slope based model was used to search out shadowed areas that had been misclassified as water or wet graminoid. Closed and open canopy needleleaf was found only at lower elevations within the project area, so modeling was also used to check for terrain shadow at higher elevations that had been misclassified as forest.

In addition to the use of DEM data to support modeling efforts, know ecological relationships between vegetation types occurring throughout the study area were utilized to further refine the earth cover classification. For instance, a particular spectral signature for an aquatic bed type was found to possess a great amount of spectral confusion with open and closed canopy needleleaf types throughout the study area. Since this signature also very accurately captured and classified numerous areas of aquatic beds, simply deleting or re-labeling the signature would have adversely impacted the evolving earth cover map. Therefore, a spatial model was developed that utilized "neighborhood analysis" to find those instances where this aquatic bed signature was surrounded by open/closed needleleaf signatures and then re-labeled these specific occurances of the signature to the appropriate needleleaf class. This type of model was used in many different forms to augment the spectral data in the development of the earth cover map. 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.

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, field photographs, aerial photography and field notes wherever possible. Some editing centered on ecological differences across the project area. For example, a single signature classified moss in the lowlands surrounding the Susitna River and dwarf shrub on the higher elevation regions in the northwestern regions of the study area. Editing in this case consisted of correctly labeling and separating classes along ecological boundaries. Because the project area was relatively diverse, this kind of editing was often necessary; especially in the transitional areas from treeline into the dwarf shrub/sparse vegetation zones.

Another kind of editing was needed 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, as when a pixel fell across the edge 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.

By far, the most pervasive editing challenge for this project dealt with the development of the open/closed mixed deciduous and tall shrub labels on numerous sites. The confusion centered around the fact that, in general, any sites containing alder and/or willow shrubs that were greater 4-meters or greater in height were entered into the DUFF database as "trees" rather than shrubs. This protocol resulted in a great

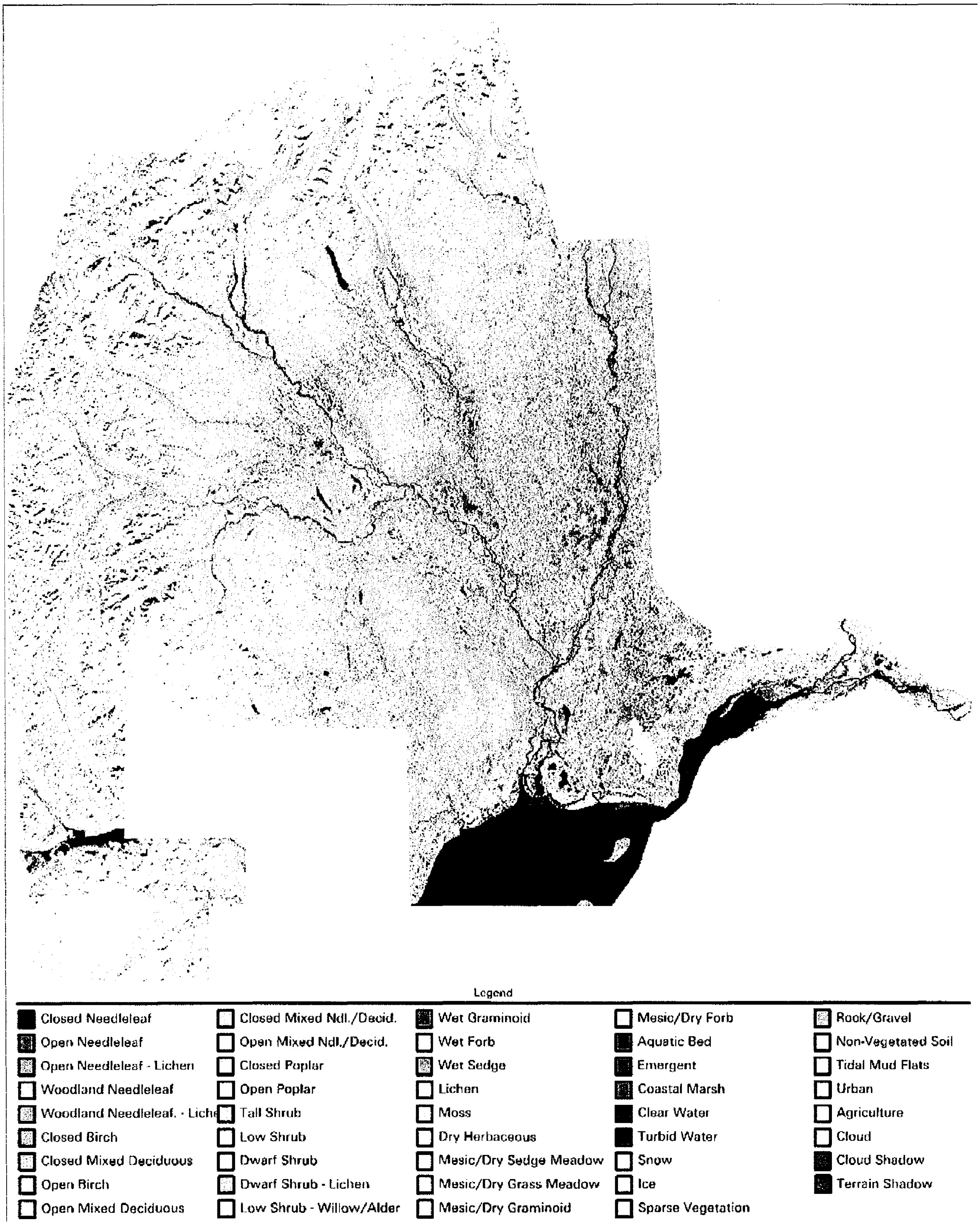


Figure 6. Susitna MOA - Final classified map.

Table 3. Acreage of earth cover classes within the project area.

CLASS NUMBER	CLASS NAME	ACRES	PERCENT COVER
1	Closed Needleleaf	5,706	0.07%
2	Open Needleleaf	338,502	4.40%
3	Open Ndl. - Lichen	2,941	0.04%
4	Woodland Needleleaf	149,250	1.94%
5	Woodland Ndl. - Lichen	5,502	0.07%
11	Closed Deciduous – Birch	408,097	5.30%
12	Closed Mixed Deciduous	596,571	7.75%
14	Open Deciduous – Birch	73,763	0.96%
15	Open Mixed Deciduous	75,921	0.99%
16	Closed Mixed Ndl./Decid.	107,401	1.40%
17	Open Mixed Ndl./Decid.	433,718	5.63%
18	Closed Poplar	10,128	0.13%
19	Open Poplar	5,331	0.07%
20	Tall Shrub	925,483	12.02%
21	Low Shrub	642,779	8.35%
24	Dwarf Shrub	213,745	2.78%
25	Dwarf Shrub - Lichen	63,872	0.83%
26	Low Shrub – Willow/Alder	29,837	0.39%
32	Wet Graminoid	179,604	2.33%
33	Wet Forb	1,112	0.01%
34	Wet Sedge	105,441	1.37%
36	Lichen	161,441	2.10%
37	Moss	26,374	0.34%
41	Mesic / Dry Sedge Meadow	1,886	0.02%
42	Mesic / Dry Grass Meadow	16,129	0.21%
43	Mesic / Dry Graminoid	1,510	0.02%
44	Mesic / Dry Forb	18,042	0.23%
60	Aquatic Bed	5,441	0.07%
61	Emergent Vegetation	67,074	0.87%
62	Coastal Marsh	5,311	0.07%
70	Clear Water	277,840	3.61%
71	Turbid Water	303,998	3.85%
72	Snow	634,885	8.25%
73	Ice	305,374	3.97%
80	Sparse Vegetation	483,277	6.28%
81	Rock/Gravel	702,186	9.12%
82	Non-Vegetated Soil	150,451	1.95%
83	Tidal Mud Flats	11,546	0.15%
90	Urban	21,700	0.28%
92/93	Cloud / Cloud Shadow	2,464	0.03%
94	Terrain Shadow	114,614	1.49%
Total		**7,697,866**	**100%**

number of tall shrub sites being "calculated" as closed or open mixed deciduous. Since these sites were spectrally identical to those alder or willow sites with 3 – 4 meter tall shrub, this resulted in a classification that mixed tall shrub and closed/open mixed deciduous in areas functioning as tall shrub. Much of the closed mixed deciduous pixels occurring in these tall shrub regions were manually edited to match their tall shrub surroundings. Similarly, many tall shrub pixels were initially found in areas of deciduous forest. In addition to spatial neighborhood models, many of these areas were manually edited to reflect the forest component to the deciduous vegetation.

The wet graminoid, primarily wet sedge, 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. Wet sedge 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, variation in standing water levels even from the time of satellite image acquisition (August 2000 and July 1989) to the time of field data collection (July/August 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 spectral confusion between open mixed needleleaf/deciduous pixels open/closed birch and open/closed mixed deciduous. As discussed earlier, the difference in spectral reflectance between two sites that both contained a substantial deciduous forest component. In addition to extensive reclassification and some spatial neighborhood analysis modeling, this confusion was corrected via manual editing utilizing photo-interpretation and review of specific field notes and photos.
Another area of note pertains to recently burned areas. Since the majority of the study area was covered by a relatively recent satellite image, no new burns had resulted subsequent to the August 2000 imagery date. However, the fire scar resulting from the large burn to the north and surrounding the east side of Big Lake is evident on the August 2000 image. The adjacent 1989 image also covers a portion of the study area that burned in this particular fire. However, the 1989 image does not show the results of the fire. This results in a clear and definite classification "seam" at the boundary of these two scenes.

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., closed needleleaf, low shrub-lichen, mesics, poplar, open birch. 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 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-three reference sites characterized as low shrub, one site was an acceptable match with dwarf shrub-other, one was an acceptable match with wet sedge, one site was an unacceptable match with tall shrub, one site was an unacceptable match with wet graminoid, and one site was an unacceptable match with wet sedge. The remainder of the sites (18) were diagonal matches with woodland needleleaf. The off-diagonal matches indicate that at least one of those sites were just on the border between dwarf shrub-other and low shrub (shrubs present averaged between .2 and .4 meters), and at least one site had a significant wet sedge component and just enough shrub cover to be considered forested (at least 25% shrub canopy cover). 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, Sparse/Barren, and Water was computed to be 83.4%.

Overall Accuracy Assessment

The difference in classification accuracy between the +/- 0% variation in interpretation level (73.9%) and the +/- 5% variation in interpretation level (87.6%) indicates that a great number of the reference data sites were characterized as being right 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 classes were near-perfect with absolutely no lumping or variation of interpretation allowed (open needleleaf = 100%, and woodland needleleaf = 75%). Of the fourteen accuracy assessment sites in the needleleaf classes (10 open needleleaf, 4 woodland needleleaf), only one woodland needleleaf site was not found to be an exact match with the map data; and that site was found to be an acceptable match with a tall shrub site. Allowing +/- 5% variation in interpretation in the reference data, the needleleaf classes achieved a 100% accuracy measure. The User's Accuracy for the same classes are comparable as only two tall shrub accuracy assessment sites were classified as woodland needleleaf; and both were considered acceptable matches. When an area is classified as one of the forested needleleaf classes, the user can have extreme confidence in the accuracy of that classification.

Similar results are found throughout the error matrix. Most notable of these are the low shrub, dwarf shrub, and moss classes. When accounting for those reference sites that characterize vegetation communities at the boundary of two or more mapping classes, consistently high accuracy measures are found for both the user's and producer's accuracy. Most 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 four reference sites exceeded 87%, with the vast majority of these sites exceeding 90% accuracy. The one obvious exception to this trend was in the emergent vegetation class. Even with only a total of seven accuracy assessment sites, this class appears to be the most troublesome class resulting from the mapping effort. Of the three accuracy assessment sites that were mis-classified, the errors fell consistently into two distinct categories. First, two of the mis-matched sites were classified as cover types also often characterized by a substantial amount of standing water present: wet sedge and clear water. Many of the wet sedge communities discriminated in this mapping effort were characterized by an average of 5 – 15% standing water. Due to the high absorptive capacity of open standing water on the spectral reflectance of Landsat TM imagery, the spectral confusion between emergent vegetation sites and wet sedge or clear water sites is not surprising. The presence/absence and/or type of vegetation occurring in these sites is very often masked by the substantial spectrally absorptive open water. The second phenomenon was confusion between the emergent aquatic vegetation such as buckbean and the highly reflective deciduous tall shrub class. While these two cover types are certainly compositionally and structurally very different, the highly reflective aquatic buckbean does possess very similar spectral characteristics to lush deciduous vegetation. In addition, from a simple observation of the satellite imagery, the often linear growing pattern of the aquatic vegetation along a water corridor is not unlike that of riparian deciduous shrub (tall shrub) vegetation. Several efforts were made to consistently discriminate these types, at least one instance is documented where thematic confusion still exists.

Despite the strong correlation between the reference data and the classified map data, one trend of potential interest to the end user is evidenced in the error matrix. From both a user's and producer's perspective, the low shrub-other class presents a slight tendency toward being over classified. While 20 out of the 23 low shrub-other reference sites were found to be classified correctly (87% producer's accuracy at the +/- 5% variation level) and 27 out of 30 reference sites that were mapped as low shrub-other were found to be classified correctly (90% user's accuracy at the +/- 5% variation level), a total of twelve non-low shrub-other reference sites were found to be classified as low shrub-other. Although nine of these twelve sites were found to be correctly classified at the +/- 5% variation level, this statistic does tend to potentially indicate that several vegetation types are being mapped disproportionately as low shrub-other. However, the error matrix does indicate that in these areas, the low shrub-other classification is much more likely than not to be an acceptable characterization of the vegetation in question. The most consistent vegetation types that are being correlated with low shrub-other, according to the error matrix, are tall shrub and dwarf shrub; indicating not an unexpected challenge in discriminating very subtle differences in vegetation height of often less than 1/3 of a meter.

The moss mapping class also seemed to present some consistent classification challenges. While areas of sphagnum in many regions of the study area presented in the typical spectrally distinct pattern (bright magenta colored in a 4,5,3 band combination) and was therefore readily mappable, the majority of the moss training sites (and accuracy assessment sites) did not present this spectral reflectance. These areas typically had a significant component of low/dwarf shrubs and/or graminoids that seemed to dilute the moss signature. This made for a difficult discrimination of the type. As seen in the error matrix, of the total of six accuracy assessment sites in the moss class, only three were directly mapped to moss; although two of the three other sites were deemed acceptable matches as low shrub – due to their significant shrub component of 20% or more. This distribution of moss accuracy assessment sites tends to indicate that many of the moss dominated sites may actually be mapped to low shrub – other or wet graminoid. However, the high user's accuracy of the category (100% with three sites) indicates that a user can have a great deal of confidence in the accuracy of the moss class when it appears on the map.

An interesting phenomenon observed in this classification process was that of the spectral effect of low shrub-other sites containing a significant component of Sweetgale. In three of the low shrub accuracy assessment sites, confusion was initially observed with the tall shrub class. The broadleaf stature of Sweetgale occurring in large dense "stands" presented a spectral signature similar to that of tall, lush deciduous shrub communities; much the way the buckbean signature presented. Since the Sweetgale communities occur at many of the same types of ecological regimes occupied by tall shrub communities, distinguishing the two cover types visually from the satellite imagery and/or 1:60,000 scale CIR photography was challenging at best. Although subsequent thorough image re-processing aimed specifically at this specific problem corrected the majority of the confusion, some areas of dense Sweetgale may still be classified as tall shrub; as indicated by the remaining off-diagonal accuracy assessment site indicating confusion between tall shrub and low shrub-other.

Finally, it should be noted that the calculated site label phenomenon discussed earlier for tall shrub sites containing shrubs 4-meters in height or greater was given particular consideration in the accuracy assessment process. In cases where an accuracy assessment site label was calculated to be closed- or open-mixed deciduous due to a dominant shrub component of shrubs 4 – 5 meters in height and the observed class label or notes indicated that the site actually functioned as a tall shrub site, the site was considered to be a direct match (on the diagonal) if it was characterized as tall shrub in the map.

In summary, based on the quantitative accuracy assessment, the earth cover classification map produced for the Susitna MOA is very reliable. Nearly 74% of the accuracy assessment sites matched the full detailed 44 mapping classes directly; even when taking *no* variation in interpretation and *no* class lumping into account. When as little as +/- 5% variation in interpretation was accounted for, nearly nine out of ten (87.6%) 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 while 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 initially acquired for July 1, 1986 and July 10, 1989. These were the images that were utilized to delineate the desired field locations of the project's training site data. Water levels and spectral responses in wet graminoid/sedge and emergent vegetation communities from the 1986 and 1989 imagery strongly influenced the spectral responses that guided field personnel to the sites from which training site spectral signatures would eventually be extracted. Fortunately for the project, however, a newer image that was essentially cloud-free and covered the majority of the study area became available prior to the initiation of the post-field classification process. Unfortunately, the image did not become available until *after* the collection of all field training site data. This meant that the training site locations derived from the '86/'89 satellite imagery would now be imposed on the 2000 imagery for use in the classification. While this was not an adverse issue at all in the majority of the training sites, some often substantial spectral inconsistencies were observed in attempting to extract spectral signatures for many of the sites from the 2000 imagery. Although the field vegetation characterizations from 1999 more closely matched the 2000 imagery date, often vegetation composition changes had also impacted the spectral values presented in the imagery for these sites. Many of these changes resulted in training and accuracy assessment sites that were not appropriate for use in the classification and evaluation process. All of the training and accuracy assessment sites originally delineated and characterized were used in the initial classification and accuracy assessment steps. However, upon closer review of each of these sites, several training and accuracy assessment sites were removed from further use in the project due to their spectral and/or questionable thematic composition. This accounts for the lower than usual number of sites available for quantitative accuracy assessment.

In addition to the impact of the new imagery date, the aerial photographs spanned a seven-year period from 1980-87, and the field data was collected in July-August 1999 from two different field crews. Differences due to environmental changes from the different sources as well as variations in interpretation and characterization of vegetation composition between field crews may have affected the accuracy assessment. As discussed earlier, the significant differences in standing water in many wetter sites between the images date and the field collection date 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.

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 likely 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 Susitna MOA.

Final Products

The final products included a digital earth cover classification, a hardcopy map of the entire project area, and a digital database of field data collected at 764 sites visited within the Susitna MOA project area. The digital earth cover classification was delivered in ArcInfo Grid and Erdas Imagine formats. The unclassified Landsat TM images used to create the earth cover classification were delivered as compressed, 1-band images ArcInfo Grid and Erdas Imagine formats. The field site database tables were stored as digital tables in dBase. Digital photos of the field sites were stored in jpeg format. Hardcopy maps of the entire project area at 1:250,000 scale were also produced. All of the delivered digital datasets were loaded into an Arcview project for display purposes.

Conclusions

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. This project continued with the mapping effort for the Susitna MOA project using Landsat TM satellite scenes, Path 70, Rows 16 and 17 acquired 16 August 2000 and Path 69, Row 17 acquired 10 July 1989.

The project area was classified into 44 earth cover categories with an overall accuracy of 87.6% 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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Appendices

Appendix A. Alaska Earth Cover Classification Class Descriptions

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

The deciduous tree species generally found were paper birch (*Betula 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 with a height > 1 meter. This class was very common throughout the interior of Alaska. A wide variety of understory plant groups were present, including low and tall shrubs, forbs, grasses, sedges, horsetails, mosses and lichens.

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

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

1.31 Woodland Needleleaf Lichen
From 10-24% of the cover was trees, ≥75% of the trees were needleleaf, and ≥ 20% of the understory was lichen. The lichen often occurred in small round patches between trees. Within the study area, this class was generally found along ridgetops or on riparian benches.

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

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

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

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

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

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

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

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

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

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

2.0 <u>Shrub</u>
The tall and low shrub classes were dominated by willow species, dwarf birch (*Betula nana* and *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 have included some rock.

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

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

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

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

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

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

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

3.0 <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 ≥ 50% bryoid species of which ≥50% were lichen species.

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

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

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

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

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

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

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

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

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

4.0 <u>Aquatic Vegetation</u>
The aquatic vegetation was divided into aquatic bed and emergent classes. The aquatic bed class was dominated by plants with leaves that float on the water surface, generally pond lilies (*Nuphar polysepalum*). The emergent vegetation class was composed of species that were partially

submerged in the water, and included freshwater herbs such as horsetails (*Equisetum* spp.), marestail (*Hippuris* spp.), and buckbean (*Menyanthes trifoliata*).

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

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

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

5.1 Snow
Composed of ≥50% snow.

5.2 Ice
Composed of ≥50% ice.

5.3 Clear Water
Composed of ≥80% clear water.

5.4 Turbid Water
Composed of ≥80% turbid water.

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

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

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

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

6.4 Tidal Mud Flats
This class was added to the classification scheme for this project to take into account the coastal influences of the area. These areas consist of mud flats exposed at times of low tide. They are composed of predominantly non-vegetated mud/silt/sand.

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

8.0 <u>Agriculture</u>
At least 50% of the area was agriculture. This class was found in the study area some 20 km east of the Susitna River and 5 km

north of Cook Inlet as well as throughout the area around Wasilla and Palmer.

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

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

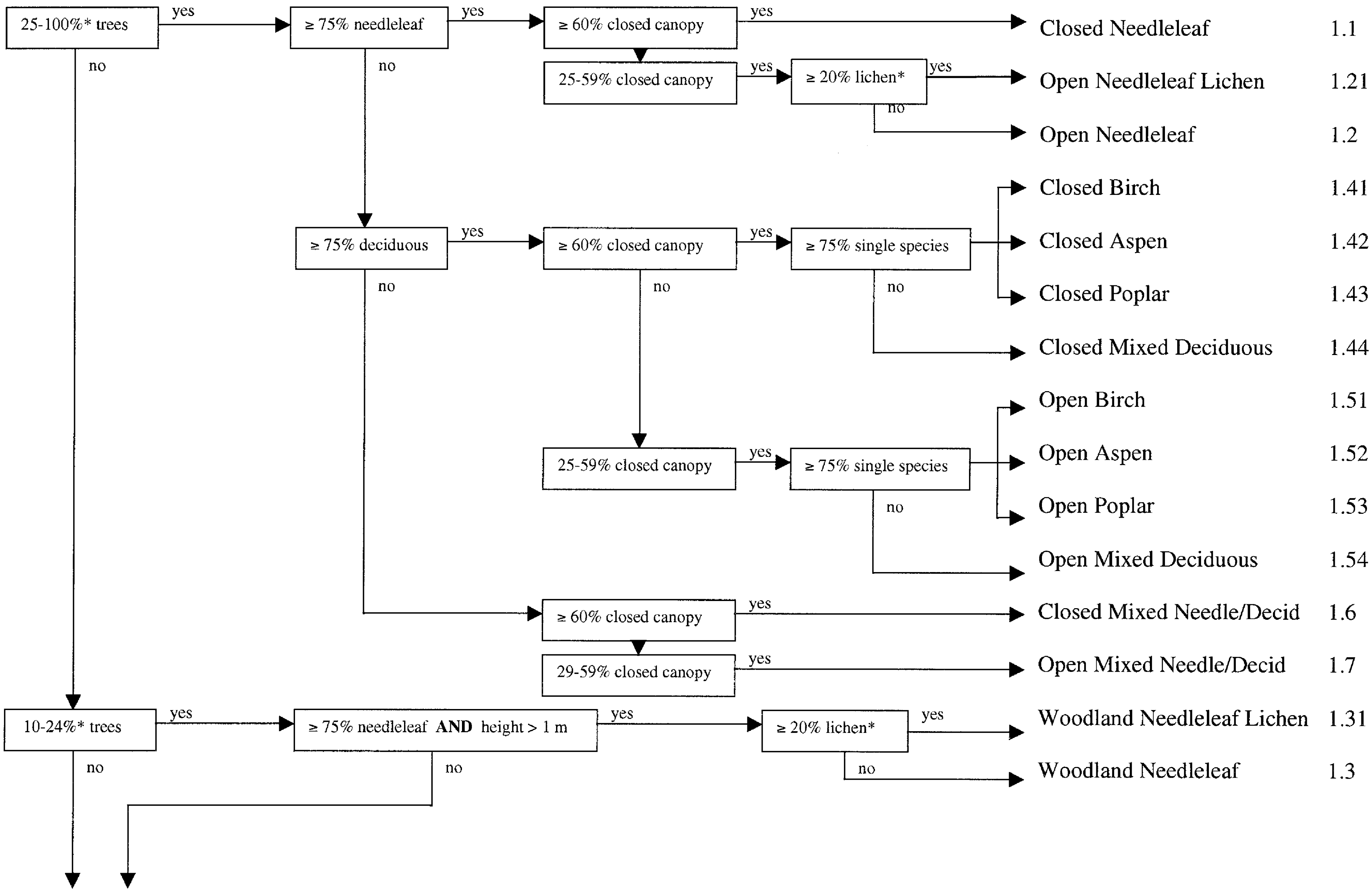
9.1 Cloud Shadow
At least 50% of the cover was made up of cloud shadows.

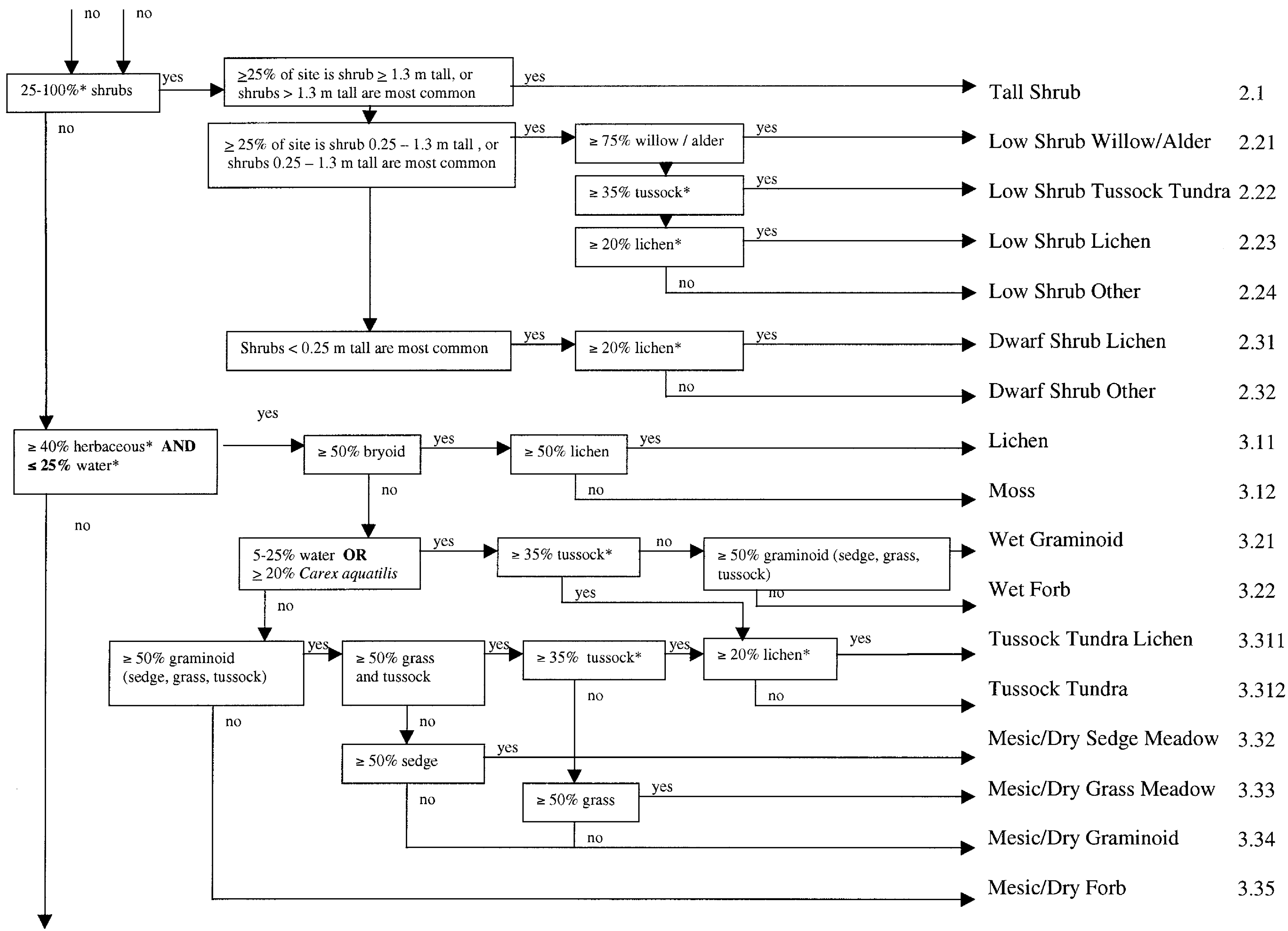
9.3 Terrain Shadow
At least 50% of the cover was made up of terrain shadows.

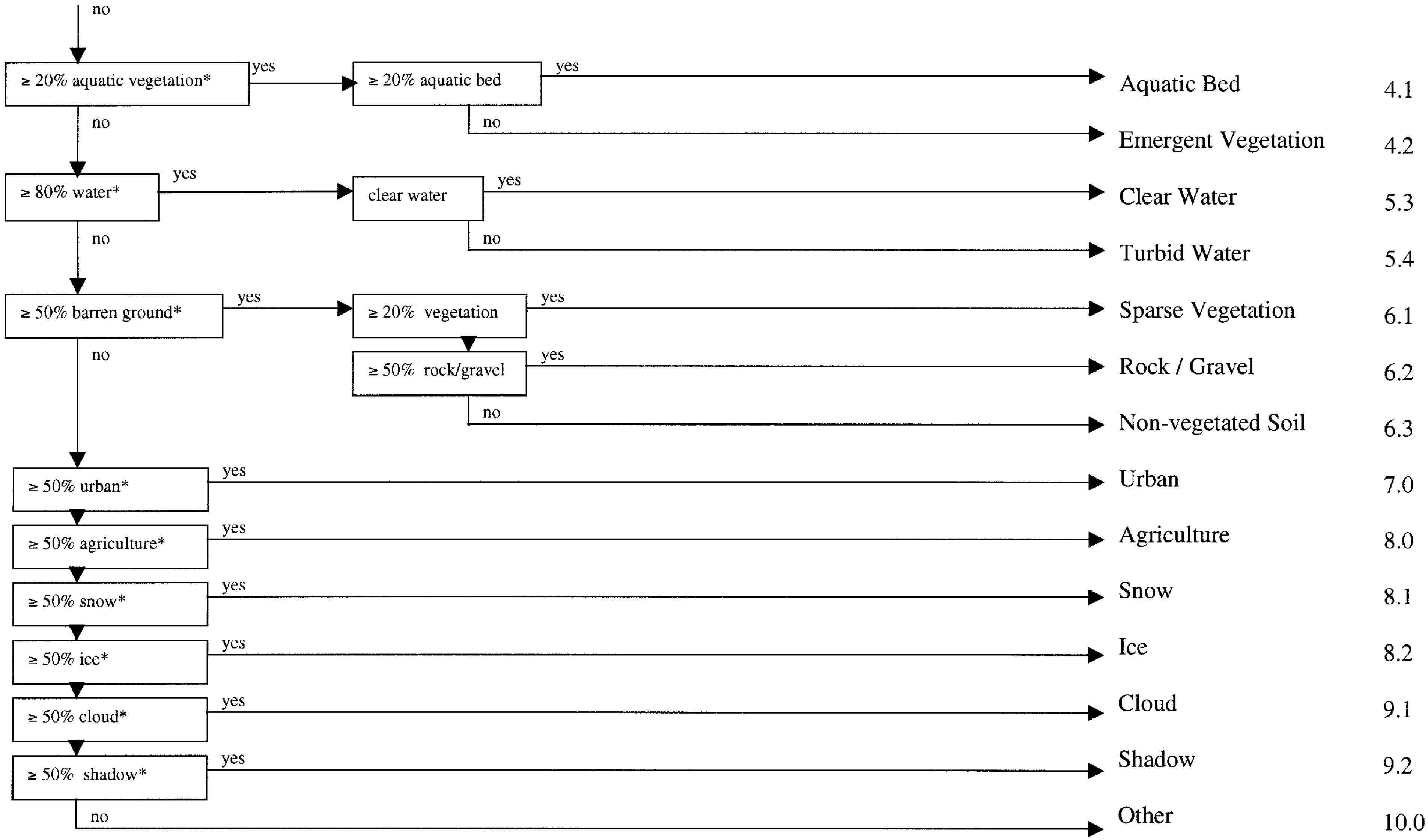
10.0 Other
Sites that did not fall into any other category were assigned to other. For example, sites containing 25%-80% water, <25% shrub and <20% aquatic vegetation were classed as Other. Sites classed as other may have also included extensive areas of vegetative litter, such as downed wood.

Appendix B. Alaska Earth Cover Classification Decision Tree

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




no
no
25-100%* shrubs
yes
≥25% of site is shrub ≥ 1.3 m tall, or shrubs > 1.3 m tall are most common
yes
Tall Shrub 2.1
no
≥ 25% of site is shrub 0.25 – 1.3 m tall , or shrubs 0.25 – 1.3 m tall are most common
yes
≥ 75% willow / alder
yes
Low Shrub Willow/Alder 2.21
≥ 35% tussock*
yes
Low Shrub Tussock Tundra 2.22
≥ 20% lichen*
yes
Low Shrub Lichen 2.23
no
Low Shrub Other 2.24
Shrubs < 0.25 m tall are most common
yes
≥ 20% lichen*
yes
Dwarf Shrub Lichen 2.31
no
Dwarf Shrub Other 2.32
yes
≥ 40% herbaceous* **AND** ≤ 25% water*
≥ 50% bryoid
yes
≥ 50% lichen
yes
Lichen 3.11
no
no
Moss 3.12
no
5-25% water **OR** ≥ 20% *Carex aquatilis*
yes
≥ 35% tussock*
no
≥ 50% graminoid (sedge, grass, tussock)
Wet Graminoid 3.21
yes
no
Wet Forb 3.22
no
≥ 50% graminoid (sedge, grass, tussock)
yes
≥ 50% grass and tussock
yes
≥ 35% tussock*
yes
≥ 20% lichen*
yes
Tussock Tundra Lichen 3.311
no
no
Tussock Tundra 3.312
no
no
≥ 50% sedge
yes
Mesic/Dry Sedge Meadow 3.32
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
≥ 50% rock/gravel
yes
Rock / Gravel
6.2
no
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
402	MOXX	MOSS	MOSS
351	VAUL	VACCINIUM ULIGINOSUM	BLUEBERRY,BOG
335	LITT	LITTER	LITTER
321	LEPA	LEDUM PALUSTRE	LABRADOR TEA
311	LIXX	LICHEN	LICHEN
284	SAX_	SALIX SPP	WILLOW
262	BEGL	BETULA GLANDULOSA	BIRCH,DWARF ARCTIC
193	CACA4	CALAMAGROSTIS CANADENSIS	REEDGRASS,BLUE-JOINT
172	CAXX	CAREX SPP	SEDGE SPP
148	PIMA	PICEA MARIANA	SPRUCE,BLACK
129	EMNI	EMPETRUM NIGRUM	CROWBERRY,BLACK
127	ALCR6	ALNUS CRISPA	ALDER,GREEN
125	PIGL	PICEA GLAUCA	SPRUCE,WHITE
106	EQXX	EQUISETUM SPP	HORSETAILS SPP
105	BEPA	BETULA PAPYRIFERA	BIRCH,PAPER
104	PISP	PICEA SPP.	SPRUCE, MIXED WHITE AND BLACK
96	RUCH	RUBUS CHAMAEMORUS	CLOUDBERRY
88	EPAN2	EPILOBIUM ANGUSTIFOLIUM	FIREWEED
88	ERXX	ERIOPHORUM SPP	COTTON-GRASS
79	DRXX	DRYAS SPP	MOUNTAIN-AVENS
79	SPBE	SPIRAEA BEAUVERDIANA	SPIRAEA,BEAUVERED
65	CLWA	CLEAR WATER	CLEAR WATER
64	LALA	LARIX LARICINA	LARCH,AMERICAN
62	BENA	BETULA NANA	BIRCH,SWAMP
61	SADW	SALIX DW.	WILLOW, DWARF
59	ROCK	ROCK	ROCK
57	GRAV	GRAVEL	GRAVEL
56	POFR	POTENTILLA FRTICOSA	CINQUEFOIL, BUSH
49	FERN	FERN SPP	FERN
49	STDE	STANDING DEAD	STANDING DEAD
44	POBA2	POPULUS BALSAMIFERA	POPLAR,BALSAM
39	ERVA4	ERIOPHORUM VAGINATUM	COTTON-GRASS,TUSSOCK
36	CAAQ	CAREX AQUATILIS	SEDGE,WATER
36	COCA13	CORNUS CANADENSIS	BUNCHBERRY,CANADA
36	VAVI	VACCINIUM VITIS-IDAEA	CRANBERRY,MOUNTAIN
33	ROAC	ROSA ACICULARIS	ROSE,PRICKLY
30	PEFR5	PETASITES FRIGIDUS	COLTSFOOT,ARCTIC SWEET
26	POTR10	POPULUS TREMULOIDES	ASPEN,QUAKING
24	FESP	FESTUCA SPP	FESCUE
24	MYGA	MYRICA GALE	SWEETGALE

23	SESP	SENECIO SPP	SENECIO
18	VEVI	VERATRUM VIRIDE	FALSE-HELLEBORE,AMERICAN
17	ARSP	ARCTOSTAPHYLOS SPP.	BEARBERRY
17	METR3	MENYANTHES TRIFOLIATA	BUCKBEAN
16	BARE	BARE GROUND	BARE GROUND
15	CATE11	CASSIOPE TETRAGONA	BELL-HEATHER,ARCTIC
14	GELI2	GEOCAULON LIVIDUM	TOADFLAX,NORTHERN RED-FRUIT
14	SAXX	SAXIFRAGA SPP	SAXIFRAGE SPP
13	ARTSP	ARTEMISIA SPP.	SAGE, SPP.
13	CHCA2	CHAMAEDAPHNE CALYCULATA	LEATHERLEAF
12	ANPO	ANDROMEDA POLIFOLIA	ROSEMARY,BOG
12	HELA4	HERACLEUM LANATUM	COW-PARSNIP
12	MUDX	MUD	MUD
12	SACA14	SANGUISORBA CANADENSIS	BURNET,CANADA
11	ARNS	ARNICA SPP.	ARNICA
11	ASXX	ASTRAGALUS SPP	VETCH
11	GEPR4	GERANIUM PRATENSE	CRANE'S-BILL,MEADOW
11	LUPS	LUPINUS SPP.	LUPINE
11	POPA14	POTENTILLA PALUSTRIS	CINQUEFOIL,MARSH
10	ACDE2	ACONITUM DELPHINIFOLIUM	MONKSHOOD,LARKSPUR-LEAF
10	EQFL	EQUISETUM FLUVIATILE	HORSETAIL,WATER
8	SERO2	SEDUM ROSEA	STONECROP,ROSEROOT
8	SIAC	SILENE ACAULIS	CAMPION,MOSS
6	DIUN	DIAPENSIA	DIAPENSIA
6	LYSP	LYCOPODIUM SPP.	CLUBMOSS
6	PESP	PEDICULARIS SPP	LOUSEWORT
6	POBI5	POLYGONUM BISTORTA	BISTORT,MEADOW
6	SHCA	SHEPHERDIA CANADENSIS	BUFFALO-BERRY,CANADA
5	ALTRE	ALNUS SPP TREE	ALDER, TREE
5	GRASS	GRASS	GRASS
5	JUCO	JUNIPERUS COMMUNIS	JUNIPER, COMMON MOUNTAIN
5	MEPA	MERTENSIA PANICULATA	BLUEBELLS,TALL
4	BORI	BOYKINIA RICHARSONI	BEARPLANT
4	CALA7	CAMPANULA LASIOCARPA	BELLFLOWER,COMMON ALASKA
4	POAL5	POLYGONUM ALASKANUM	RHUBARB,ALASKA WILD
4	SAND	SAND	SAND
4	VIED	VIBURNUM EDULE	SQUASHBERRY
3	AGBO2	AGROSTIS BOREALIS	BENTGRASS,NORTHERN
3	ANMO	ANTENNARIA MONOCEPHALA	PUSSYTOE
3	CIDO	CICUTA DOUGLASII	WATER-HEMLOCK,WESTERN
3	COSP	CORNUS SPP.	DOGWOOD SPP.
3	COST4	CORNUS STOLONIFERA	DOGWOOD,RED-OSIER
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
3	SAEX2	SAXIFRAGA EXILIS	SAXIFRAGE
2	CAMS	CAMPANULA SPP.	CAMPANULA
2	CAPA5	CALTHA PALUSTRIS	MARSH-MARIGOLD,COMMON
2	CASP	CASTILLEJA	CASTILLEJA
2	DEGL3	DELPHINIUM GLAUCUM	LARKSPUR,TOWER
2	FOXX	FORB SPP	FORB SPP
2	IRSE	IRIS SETOSA	IRIS,BEACH-HEAD
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
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	CARO2	CAMPANULA ROTUNDIFOLIA	BELLFLOWER,SCOTCH
1	EPAN4	EPILOBIUM ANAGALLIDIFOLIUM	WILLOW-HERB,PIMPERNEL
1	EQSP	EPILIOLIUM SPP	FIREWEED
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	SATRE	SALIX TREE	WILLOW TREE
1	VAAL	VACCINIUM ALASKAENSE	BLUEBERRY,ALASKA
1	VISP	VIOLA SPP	VIOLET

Appendix D. Susitna MOA Accuracy Assessment Error Matrix

Susitna MOA

AA Matrix — **REFERENCE**

	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	30	31	32	33	34	35	User's Accuracy
1) Closed Needleleaf																																				
2) Open Needleleaf		10																																		100%
3) Open Needleleaf - Lichen																																				
4) Woodland Needleleaf				3										1,0																						100%
5) Woodland Needleleaf - Lichen														1,0																						100%
6) Closed Deciduous						9	0,1		1,1	0,1																										76.9%
7) Closed Birch							6																													100%
8) Closed Poplar																																				
9) Open Decidiuous								0,1	6								0,1																			75.0%
10) Open Birch																																				
11) Open Poplar																																				
12) Closed Mixed												1																								100%
13) Open Mixed							0,1					1,0	7																							88.9%
14) Tall Shrub				1,0										22	0,1															0,1						92.0%
15) Low Shrub - Other														2,1	18		1,0	3,0	1,0	0,2								2,0								90.0%
16) Low Shrub - Lichen																																				
17) Low Shrub - Alder/Willow																	1	0,1																		50.0%
18) Dwarf Shrub - Other															1,0			4	1,0						1,0											100%
19) Dwaft Shrub - Lichen																		1,0	4			0,1												1,0		85.7%
20) Wet Graminoid															0,1			1,0		12								0,1		1,0						87.5%
21) Wet Sedge															1,1					0,1										1,1						40.0%
22) Lichen																						2														100%
23) Mesic/Dry Grass Meadow																							1													100%
24) Mesic/Dry Graminoid																																				
25) Mesic/Dry Forb																																				
26) Coastal Mud Flat																										1										100%
27) Tussock Tundra - Lichen																																				
28) Moss																												3								100%
29) Aquatic Bed																													1							100%
30) Emergent																														2						100%
31) Clear Water																													1,0	0,1	4					83.3%
32) Turbid Water																													0,1			3				75.0%
33) Snow/Ice																																	3			100%
34) Sparse Vegetation																																		2		100%
35) Rock/Gravel																																				
Reference Site Totals:	0	10	0	4	0	9	8	1	8	1	0	2	7	27	23	0	3	10	6	15	0	3	1	0	1	1	0	6	3	7	4	3	3	3	0	169
Producer's Accuracy (+/-5%):		100%		100%		100%	75.0%	0%	87.5%	0%		50.0%	100%	96.3%	86.9%		66.6%	90.0%	100%	80.0%		66.6%	100%		100%	100%		83.3%	66.6%	57.1%	100%	100%	100%	100%		

Total = 169

Diagonal = 125

Off-Diagonal = 24

Overall Accuracy (0% var) = 73.96%

Overall Accuracy (+/- 5% var) = 88.17%

Appendix E. Susitna MOA Earth Cover Classification Metadata.

Filename: susi_earthcov
Filetype: Arc/Info Grid

Metadata:

- Identification_Information
- Data_Quality_Information
- Spatial_Reference_Information
- Entity_and_Attribute_Information
- Metadata_Reference_Information

Identification_Information:
  Citation:
    Citation_Information:
      Originator: Ducks Unlimited,Inc.
      Publication_Date: 092801
      Publication_Time:
      Title: susi_earthcov
      Edition:
      Geospatial_Data_Presentation_Form: map
  Description: Susitna MOA Earth Cover Classification
    Abstract:
    The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. The goal of this project was to continue the mapping effort by mapping the Susitna Military Operations Area (MOA) and associated uplands. Portions of three Landsat TM satellite scenes (Path 70, Rows 16 and 17 acquired 08/16/00 and Path 69, Row 17 acquired 07/10/89) were used to classify the project area into 44 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. Data were collected on 343 field sites during a 12-day field season from 7/15/99 through 7/26/99 and 421 field sites during an 11-day field season from 8/01/99 through 8/11/99. Of the total sites visited, only 679 sites were actually utilized as either image classification training sites or accuracy assessment sites. A total of 514 sites were used as training sites while approximately 25% (165) 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 87.6% at the +/-5% level of variation in interpretation of the accuracy assessment reference sites.

Purpose:
The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Susitna MOA, Palmer Hay Flats, 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.

Time_Period_of_Content:
Time_Period_Information:
Multiple_Dates/Times:
Single_Date/Time:
Calendar_Date:081600
Single_Date/Time:
Calendar_Date:071089
Currentness_Reference:092801
Status:
Progress:complete
Maintenance_and_Update_Frequency: none
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -148.272
East_Bounding_Coordinate: -153.065
North_Bounding_Coordinate: 62.990
South_Bounding_Coordinate: 60.882
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: Susistna
Place_Keyword: MOA
Place_Keyword: Alaska
Temporal:
Temporal_Keyword_Thesaurus:
Temporal_Keyword: 2000
Temporal_Keyword: 1989
Point_of_Contact:
Contact_Information:
Contact_Organization: Ducks Unlimited, Inc.

Contact_Person:
Contact_Position: GIS Manager
Contact_Address:
Address_Type:
Address: 3074 Gold Canal Drive
City: Rancho Cordova
State_or_Province: California
Postal_Code: 95670
Country:U.S.A
Contact_Voice_Telephone: (916)852-2000
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report: See Final Report
Quantitative_Attribute_Accuracy_Assessment:
Attribute_Accuracy_Value:
Attribute_Accuracy_Explanation:
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator: EROS Data Center
Publication_Date: 2000 and 1989
Publication_Time:
Title: Landsat7 ETM Imagery From Path 70, Rows 16-17 acquired 08/16/00 and Landsat 4 Imagery from Path 69, Row 17 acquired 7/10/89
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: 2000
Single_Date/Time:
Calendar_Date: 1989
Process_Step:
Process_Discription: See "Susitna MOA Earth Cover Classification" report
Source_Used_Citation_Abbreviation:
Process_Date: 2000/2001
Process_Time:
Source_Produced_Citation_Abbreviation:
Spatial_Data_Organization_Information:
Indirect_Spatial_Reference:
Direct_Spatial_Reference_Method: Raster
Raster_Object_Information:

Raster_Object_Type: Pixel
Row_Count: 8548
Column_Count: 8525
Vertical_Count:
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution:
Longitude_Resolution:
Geographic_Coordinate_Units:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 5
Transverse_Mercator:
Scale_Factor_at_Central_Meridian:0.999600
Longitude_of_Central_Meridian: -153.000000
Longitude_of_Projection_Origin:0.000000
False_Easting:500000.000000
False_Northing:0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method:row and column
Coordinate_Representation:
Abscissa_Resolution:28.500000
Ordinate_Resolution:28.500000
Planar_Distance_Units:meters
Geodetic_Model:
Horizontal_Datum_Name:NAD27 (Alaska)
Ellipsoid_Name: Clarke 1866
Semi-major_Axis:6378206.400000
Denominator_of_Flattening_Ratio:294.978698
Metadata_Reference_Information:
Metadata_Date: 092801
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, Inc.
Contact_Person:
Contact_Position: GIS Manager
Contact_Address:

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

Appendix F. Susitna MOA Earth Cover Mapping Field Sites Metadata

Filename:susi_fld_sts
Filetype:Arc/Info coverage

Metadata:

Identification_Information
Data_Quality_Information
Spatial_Reference_Information
Entity_and_Attribute_Information
Metadata_Reference_Information

Identification_Information:
Citation:
Citation_Information:
Originator:Ducks Unlimited, Inc.
Publication_Date:09/2001
Publication_Time:
Title:karh_fld_sts
Edition:
Geospatial_Data_Presentation_Form:map
Description:
Abstract:
The field data collected for the Susitna MOA Earth Cover Mapping Project is included on the final products CD's. susi_fld_sts is an Arcinfo coverage of all sites that were visited in the field. susi_fld_sts includes site information about each polygon. Three DBASE files (susi_photo.dbf, susi_site_species.dbf, and susi_species.dbf) are also included on the final products CD's. All three of these files can be linked to the ArcInfo polygon coverage to provide the complete database of information collected for each fieldsite. The links are made by the duff.avx ArcView extension included on the final products CD's.
Purpose:
The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Susitna MOA, Palmer Hay Flats, 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.
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date:09/2001
Currentness_Reference:09/2001
Status:

Progress:complete
Maintenance_and_Update_Frequency:none
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate:-152.873418
East_Bounding_Coordinate:-148.346149
North_Bounding_Coordinate:62.756248
South_Bounding_Coordinate:60.996670
Keywords:
Theme:
Theme_Keyword_Thesaurus:
Theme_Keyword:Field Sites
Theme_Keyword:ArcInfo Coverages
Theme_Keyword:Land Cover Classification
Theme_Keyword:Earth Cover Classification
Place:
Place_Keyword_Thesaurus:
Place_Keyword:Susitna
Place_Keyword:MOA
Place_Keyword:Alaska
Stratum:
Stratum_Keyword_Thesaurus:
Stratum_Keyword:
Temporal:
Temporal_Keyword_Thesaurus:
Temporal_Keyword:2001
Access_Constraints:
Use_Constraints:
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:Ducks Unlimited, Inc.
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:
Address_Type:
Address:3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province:California
Postal_Code:95670
Country:U.S.A.
Contact_Voice_Telephone:916 852-2000
Contact_TDD/TTY_Telephone:

Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:See Final Report
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:Ducks Unlimited, Inc.
Publication_Date:2001
Publication_Time:
Title:ArcInfo polygon coverage for Susitna MOA field sites and associated Dbase files.
Edition:
Geospatial_Data_Presentation_Form:ArcInfo polygon coverage. DBASE files.
Process_Step:
Process_Description:See "Susitna MOA Earth Cover Classification"
Source_Used_Citation_Abbreviation:
Process_Date:1999
Process_Time:
Source_Produced_Citation_Abbreviation:
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:Ducks Unlimited, Inc.
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:
Address_Type:
Address:3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province:California
Postal_Code:95670
Country:U.S.A
Contact_Voice_Telephone:916-852-2000
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:

Cloud_Cover:
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name:Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number:5
Transverse_Mercator:
Scale_Factor_at_Central_Meridian:0.999600
Longitude_of_Central_Meridian:-153.000000
Latitude_of_Projection_Origin:0.000000
False_Easting:500000.000000
False_Northing:0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method:row and column
Coordinate_Representation:
Abscissa_Resolution:0.000512
Ordinate_Resolution:0.000512
Planar_Distance_Units::meters
Geodetic_Model:
Horizontal_Datum_Name:NAD27 (Alaska)
Ellipsoid_Name: Clarke1866
Semi-major_Axis:6378206.400000
Denominator_of_Flattening_Ratio:
Entity_and_Attribute_Information:
Overview_Description:
Entity_and_Attribute_Overview:
See Appendix G in "Susitna MOA Earth Cover Classification Final Report"
Entity_and_Attribute_Detail_Citation:
Metadata_Reference_Information:
Metadata_Date:09/2001
Metadata_Review_Date:
Metadata_Future_Review_Date:
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:Bureau of Land Management Alaska
Contact_Organization_Primary:
Contact_Organization:
Contact_Person:
Contact_Position:
Contact_Address:
Address_Type:
Address:222 West 7th avenue

City:Anchorage
State_or_Province:Alaska
Postal_Code:99513
Country:U.S.A
Contact_Voice_Telephone:
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Metadata_Standard_Name:
Metadata_Standard_Version:
Metadata_Time_Convention:
Metadata_Access_Constraints:
Metadata_Use_Constraints:
Metadata_Security_Information:
Metadata_Security_Classification_System:
Metadata_Security_Classification:
Metadata_Security_Handling_Description:
Metadata_Extensions:
Online_Linkage:
Profile_Name:

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

Field Site Polygon Coverage Attribute Table
susi_fld_sts.pat:

Field	Width	Output	Type	#Decimals	Description
AREA	4	12	F	-	ArcInfo internal fields
PERIMETER	4	12	F	-	ArcInfo internal fields
coverage#	4	5	B	-	ArcInfo internal fields
coverage-ID	4	5	B	-	ArcInfo internal fields
SITE_NUM	4	4	I	-	Field site number
YEAR	4	4	I	-	Year of field data collection.
AREA_NAME	10	10	C	-	Name of project area.
CREW_NUM	1	1	I	-	Id number of crew that collected data
OBS_NAV	2	2	C	-	Navigator for field data collection
OBS_VEG	2	2	C	-	Vegetation caller for field data collection
OBS_REC	2	2	C	-	Recorder for field data collection
OBS_DATE	8	8	D	-	Date of field data collection
PERCNT_SLP	3	3	I	-	Percent slope of site
ASPECT_DIR	2	2	C	-	Aspect of site (8 compass points – N,NE,E,etc., FL=Flat)
LATITUDE	10	10	N	5	Latitude of polygon labelpoint – Decimal Degrees
LONGITUDE	11	11	N	5	Longitude of polygon labelpoint – Decimal Degrees
OBS_LEVEL	1	1	I	-	Observation level, where: 1 = site visited on the ground,

2 = viewed from above (ie from helicopter), 3 = viewed from a distance, 4 = viewed on air photos.

STEM_DIST	2	2	I	-	Distance between tree stems(applies to Open or Woodland Needleaf only).
OBS_ID	2	2	I	-	Id of site class as observed by the vegetation caller.
MAJ_OBS	20	20	C	-	Level 1 class of classification hierarchy.
OBS_CLASS	25	25	C	-	Vegetation caller's observed class for site.
COMMENTS	200	200	C	-	Notes made by vegetation caller while at the site.
CALC_CLASS	50	50	C	-	Classification of site as calculated using the project decision tree
CALC_CL_ID	6	6	N	3	ID number of calculated class
AA_FLAG	1	1	I	-	Indicates if site was used as accuracy assessment or training data. 0 = site used for training. 1 = site used for accuracy assessment.

Data exported from Ducks Unlimited Field Form Software.

SUSI_SITE_PHOTO.dbf Dbase IV file containing site photo information.

YEAR	Year of field data collection
AREA_NAME	Name of project area
CREW_NUM	Id number of crew that collected data
SITE_NUM	Field site number; relates to SITE_NUM of field site polygon coverage in a one-to-many relationship (i.e. each site may have multiple photos).

SESS_NUM Session number for field data collection. Photos are uniquely numbered within each session.

PHOTO_NUM Photo number. Photos are numbered consecutively within each session.

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

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

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

SUSI_SPECIES.dbf

SYMBOL	Species code - usually a combination of the first two letters of the genus and first two letters of the species.
FAMILY	Plant family.
SPECIES	Plant genus and species.
AUTHOR	Author citation for species information.

COMMON Common name.

ALT_NAME Alternate name.

GENERAL General plant type; used to pipe information correctly through the decision tree.

SPECIFIC Specific plant type; used to pipe information correctly through the decision tree.

Appendix H. 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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