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U.S. Fish and Wildlife Service
Nowitna National Wildlife Refuge

Ducks Unlimited, Inc.

Galena MOA / Nowitna NWR Earth Cover Classification

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

U.S. Fish and Wildlife Service
Nowitna National Wildlife Refuge
Galena, Alaska

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

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 Galena Military Operations Area (MOA), Nowitna National Wildlife Refuge (NWR), and associated uplands. Portions of three Landsat TM satellite scenes (Path 73, Rows 14, 15, and 16 acquired 07/02/99) were used to classify the project area into 30 earth cover categories. An unsupervised clustering technique was used to determine the location of field sites and a custom field data collection form and digital database were used to record field information. A helicopter was utilized to gain access to field sites throughout the project area. Global positioning system (GPS) technology was used both to navigate to pre-selected sites and record locations of new sites selected in the field. Data were collected from 575 field sites during a 12-day field season from 6/26/00 through 7/7/00. Approximately 30% (172) 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 87.2% at the +/-5% level of variation in interpretation of the accuracy assessment reference site.

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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 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. Thematic Mapper (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 Galena Military Operations Area (MOA) / Nowitna National Wildlife Refuge (NWR) Earth Cover Mapping project area contains diverse landscapes and is deemed important for its wildlife and recreational values. The project area extends from the Yukon River in the north, to the headwaters of the Sulukna and Nowitna Rivers in the south, to the headwaters of the Big Mud and Sethkokna Rivers in the east, and west to the village of Ruby and the airstrip at Poorman. The project area is essentially roadless and supports limited recreational use with the exception of fishing along the Yukon River and an occasional boating/canoeing trip on the Nowitna River. The project area includes at least two individual packs of wolves and an abundant moose and tundra swan population. Earth cover data will aid in the critical process of resource planning in this valuable and diverse area.

Project Objective

The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Galena MOA / Nowitna NWR 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 is an integrated GIS database that can be used for improved natural resources planning.

Project Participants

The project was administered by John Payne (BLM State Office), Beate Sterrenberg (DU), and Guy Hughes and Mike Spindler (US Fish and Wildlife Service). The fieldwork was accomplished by Jeff Campbell (Spatial Solutions, Inc./DU), Guy Hughes (USF&WS), Terry Hobbs (BLM), and multiple Biological Technicians from the Galena office of the USF&WS. The pilot for the project was Ken Deyoe from Evergreen Helicopters, Fairbanks, Alaska. Terry Hobbs and Scott Guyer (BLM) coordinated field logistics. Jeff Campbell performed the image processing. Mark Pearson (GeoNorth, Inc.) programmed the Ducks Unlimited Field Form (DUFF) database.

Project Area

The Galena MOA / Nowitna NWR mapping project consists of 5.2 million acres centered roughly on the Nowitna River's drainage area from its headwaters in the southern portion of the study area to its confluence with the Yukon River in the north. The project area falls in the center of the Ruby and Medfra 1:250,000 scale quadrangles. The Nowitna River runs through the heart of the project. It includes portions of the following United States Geological Survey (USGS) 1:250,000 scale quadrangles: Ruby, Medfra, Kantishna River, and Melozitna. The village of Ruby lies just inside the northeastern boundary of the project. While this project area encompassed a wide variety of environments ranging from glaciated mountains to lowland black spruce muskeg, the vast majority of the study area (60%+) included habitats composed of some form of Black and White Spruce cover. Minimal non-forested uplands and associated habitats were present within the study area and were found only along the extreme southern and southeastern edge of the mapping area. Although minimal in extent in this study area, these regions do form important caribou habitat. While moose abounded throughout most of the project area, evidence of frequent bear and wolf use was present throughout the study area; although none were seen during the collection of field data. 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 imagery acquisition date of July 1999, most all wildfires that had burned over the study area were indicated on the 1999 satellite imagery. However, even during collection of field data during the summer of 2000, at least two large fires (50,000 acres+) were actively burning within the study area. These recent burns obviously were not reflected on the satellite imagery and, therefore, are not shown in the resulting earth cover map.

Data Acquisition

Three Landsat-7 ETM scenes were purchased to cover the project area. Imagery from July 1999 were acquired: Path 73 Rows 14, 15, and 16. The scenes were purchased from the Earth Resources Observations System (EROS) Data Center in Albers Equal Area projection and were terrain corrected by ImageLinks, Inc., Melbourne, FL. The image data contained only very minimal cloud cover along the southeastern edge of the study area. Due to the relatively mean elevation of the study area and the mid-summer date of the imagery, no snow or ice covered any portion of the study area. Field data were collected from 575 field sites during a 12-day field season from 6/26/00 through 7/7/00. The ancillary data used in this project included: 1:60,000 aerial photographs (color infrared transparencies from 1980-82, 1984, and 1986-87), and USGS 1:250,000-scale Digital Elevation Models (DEMs).

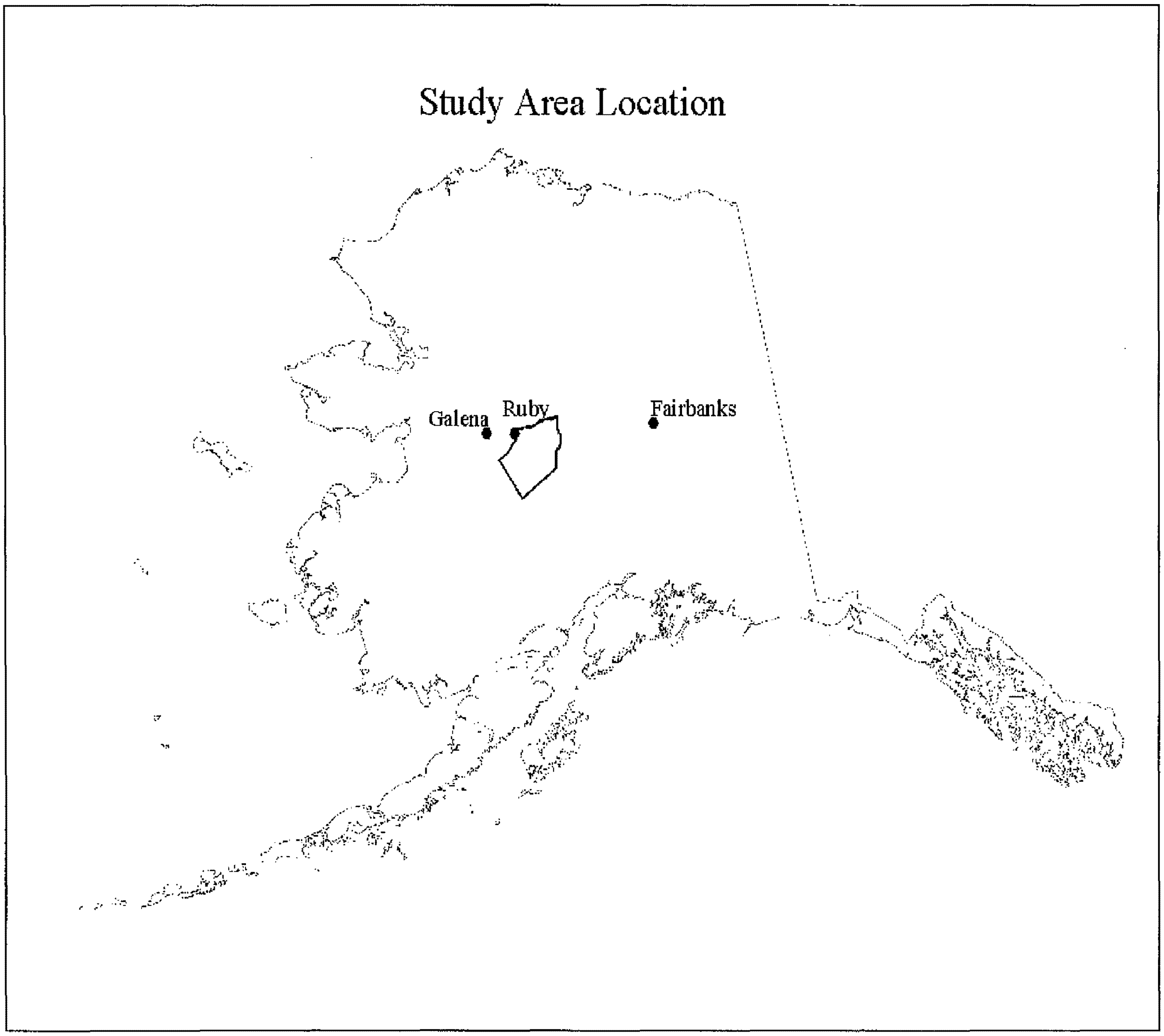


Figure 1. Galena MOA / Nowitna NWR project location.

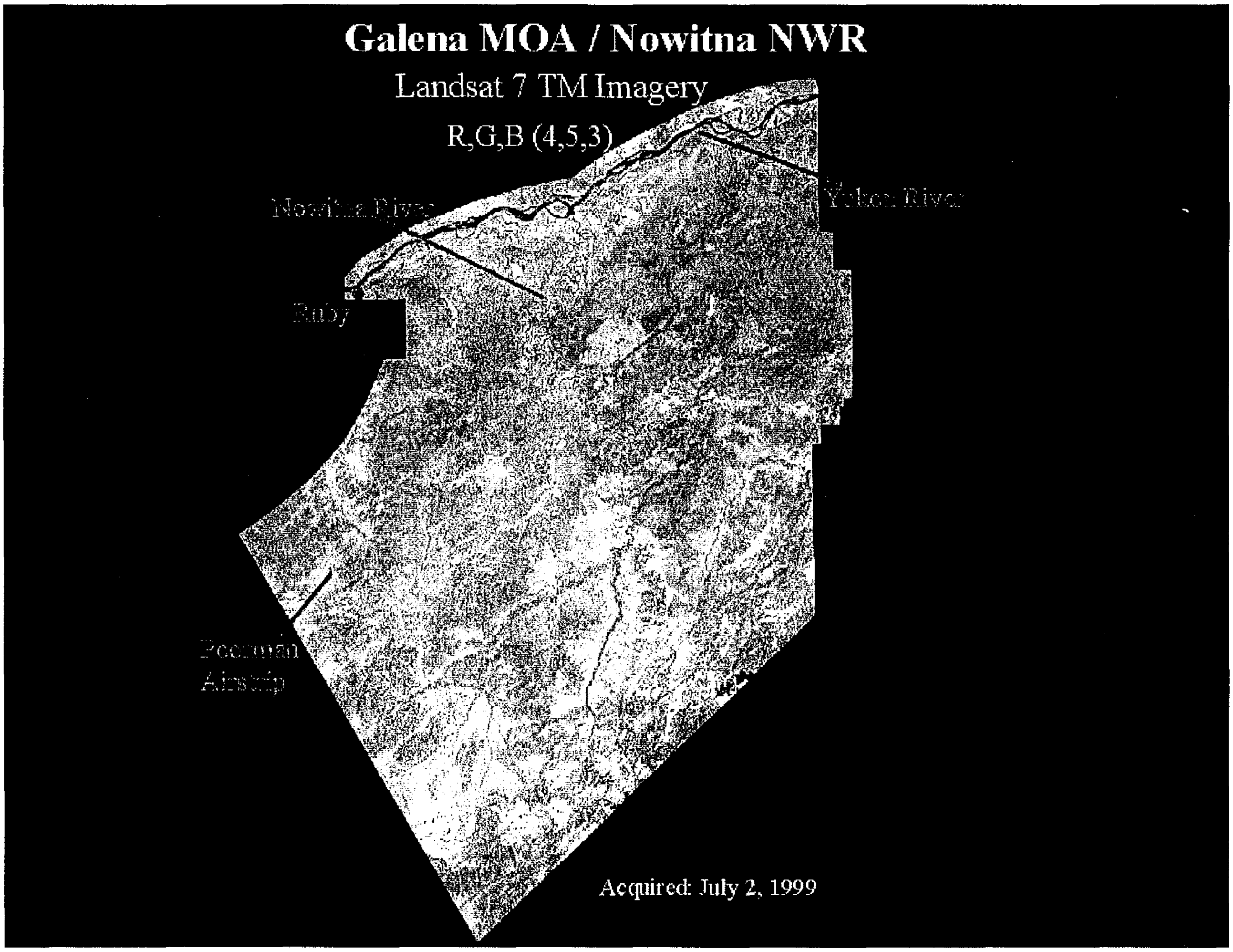


Figure 2. Satellite imagery used for the Galena MOA / Nowitna NWR earth cover mapping project.

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 be included in the classification.

Until recently, the BLM/DU classification systems were project specific. As projects expanded in size and as other cooperators began mapping and sharing data across Alaska, the necessity for a standardized classification system became apparent. At the BLM Earth Cover Workshop in Anchorage on 3-6 March 1997, a classification system based on the existing Alaska Vegetation Classification (Viereck *et al.* 1992) (Table 1) was designed to address this need. The goal of this meeting was to (1) develop an earth cover classification system for the state of Alaska that can be used in large regional mapping efforts, and (2) build consensus for the system among multiple land management agencies. The classification system has been slightly improved since this meeting. The classification scheme consisted of 10 major categories and 27 subcategories. A classification decision tree and written description (Appendices A and B) was developed in order to clarify the classification. Though based largely on Level III of the Viereck *et al.* (1992) classification, some classes have been modified, added or omitted for the earth cover mapping projects: e.g., rock, water, ice, cloud and shadow classes were added. Other classes that could not reliably be discerned from satellite imagery had to be collapsed, such as open and closed low shrub classes, or dryas, ericaceous, willow, and dwarf shrub classes. Because of the importance of lichen for site characterization and wildlife, and because the presence of lichen can be detected by satellite imagery, shrub and forested classes with and without a component of lichen were distinguished. A few classes from Level IV of the Viereck *et al.* (1992) classification were also mapped because of their identifiable satellite signature and their importance for wildlife management. These Level IV classes included tussock tundra, low shrub tussock tundra and low shrub willow/alder.

Image Preprocessing

Each image was examined for quality and consistency. Each band was examined visually and statistically by reviewing histograms. Combinations of bands were displayed to check for band-to-band registration and for clouds, shadows, and haze. Positional accuracy was checked by comparing the image to available ancillary data, adjacent imagery, hydrography, and DEMs.

In order to optimize helicopter efficiency, field sites were identified and plotted on field maps before fieldwork began.

Table 1. Classification scheme developed at the BLM earth cover workshop.

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

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

An unsupervised classification was used to identify spectrally unique areas within the study area. Training sites were individually selected by the image analyst 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 was performed when identification of dominant vegetation was uncertain. These DU/BLM procedures for collecting field data have evolved into a very efficient and effective means of data collection. The navigator used a GPS to locate the site and verified the location on the field map. As the helicopter approached the site at

Sample Field Form

Rev 7/15/97

Steese/White-Yukon Charlie Field Form

1997-YUCH - 1 - 319 Yr Project Crew Site Number	DFJHILF 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 Needleleaf Only)		

(Circle Lichen where present)

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

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

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

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

%Cov	HERBACEOUS con't	
	Forbs	
	Saxifrage	Saxifraga spp.
	Vetch	Astragalus spp.
	Horsetails	Equisetum spp.
	Fireweed	Epilobium spp.
	Coltsfoot	Petasites frigidus
	Cinquefoil	Potentilla spp.
	Bistort	Polygonum spp.
	Rubus	Rubus spp
	Bryoid	
5	(Moss)	
	Lichen	Color:

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

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

C#	COMMENTS

CALL CLASS ... NEED. NPS

Figure 3. Custom field data collection form.

about300 meters above ground level the pilot then descended to approximately 5-10 meters above the vegetation and laterally moved across the site while the biologist called out the vegetation to the recorder. The biologist took another picture with the navigator described the site and the biologist took a picture with a digital camera. 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 MS Word, Excel and Access.

Generation of New Bands

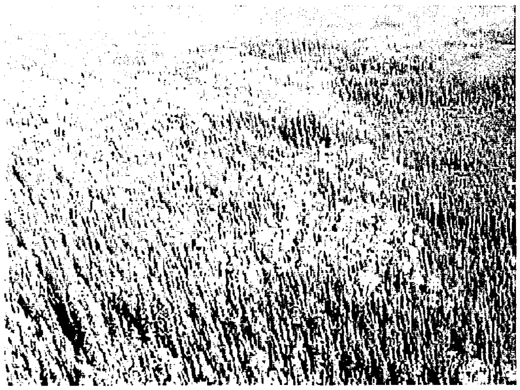
The Landsat TM imagery contained 7 bands of data: 3 visible bands, 1 near-infrared band, 2 mid-infrared bands, and 1 thermal band. One new band was generated for this project. This new band was created using a band-4/band-3 ratio, a band ratio that typically reduces the effect of shadows in the image 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

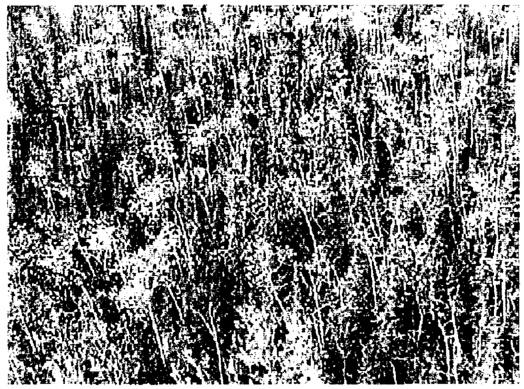
Very few clouds and their associated shadows existed in the July 1999 TM imagery used on the Galena MOA / Nowitna NWR study area. The clouds and cloud shadows that were present were removed from the image before field sites were selected. This process eliminated any confusion between clouds, cloud shadows, and other vegetation types. They were removed using an unsupervised

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

Sample Field Site - Closed Mixed Needleleaf/Deciduous

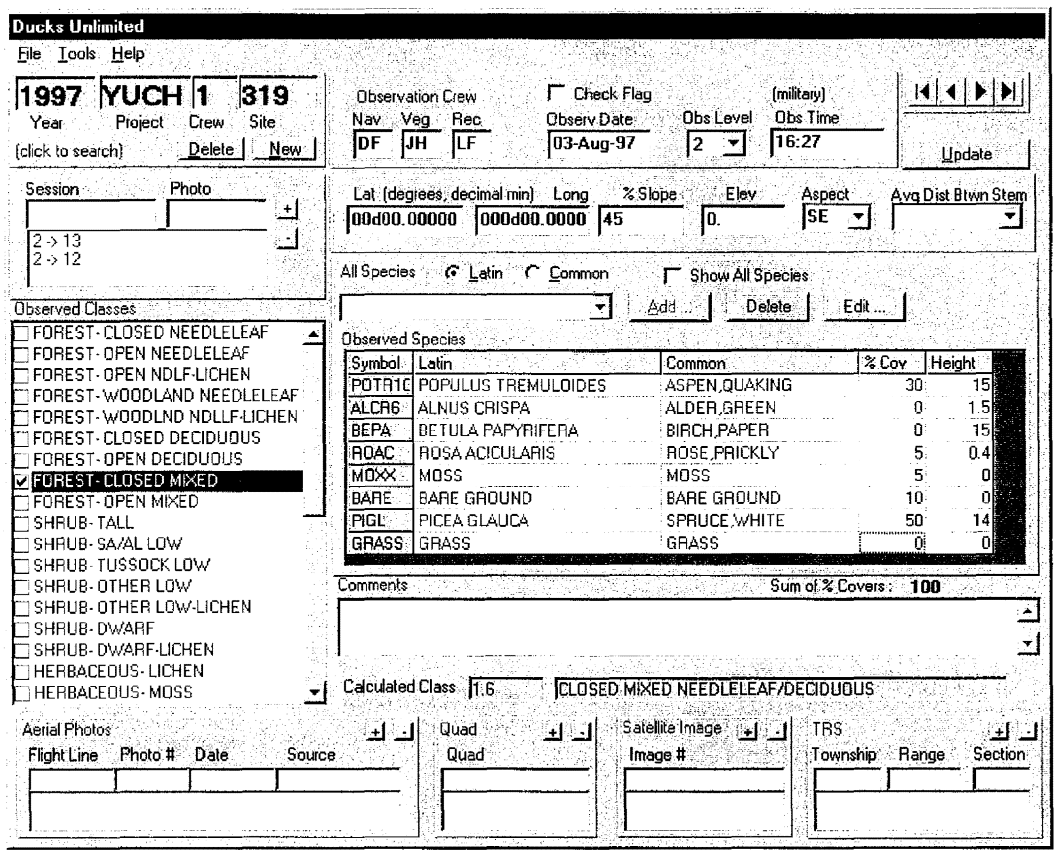


High Site Photo



Low Site Photo

DUFF INTERFACE



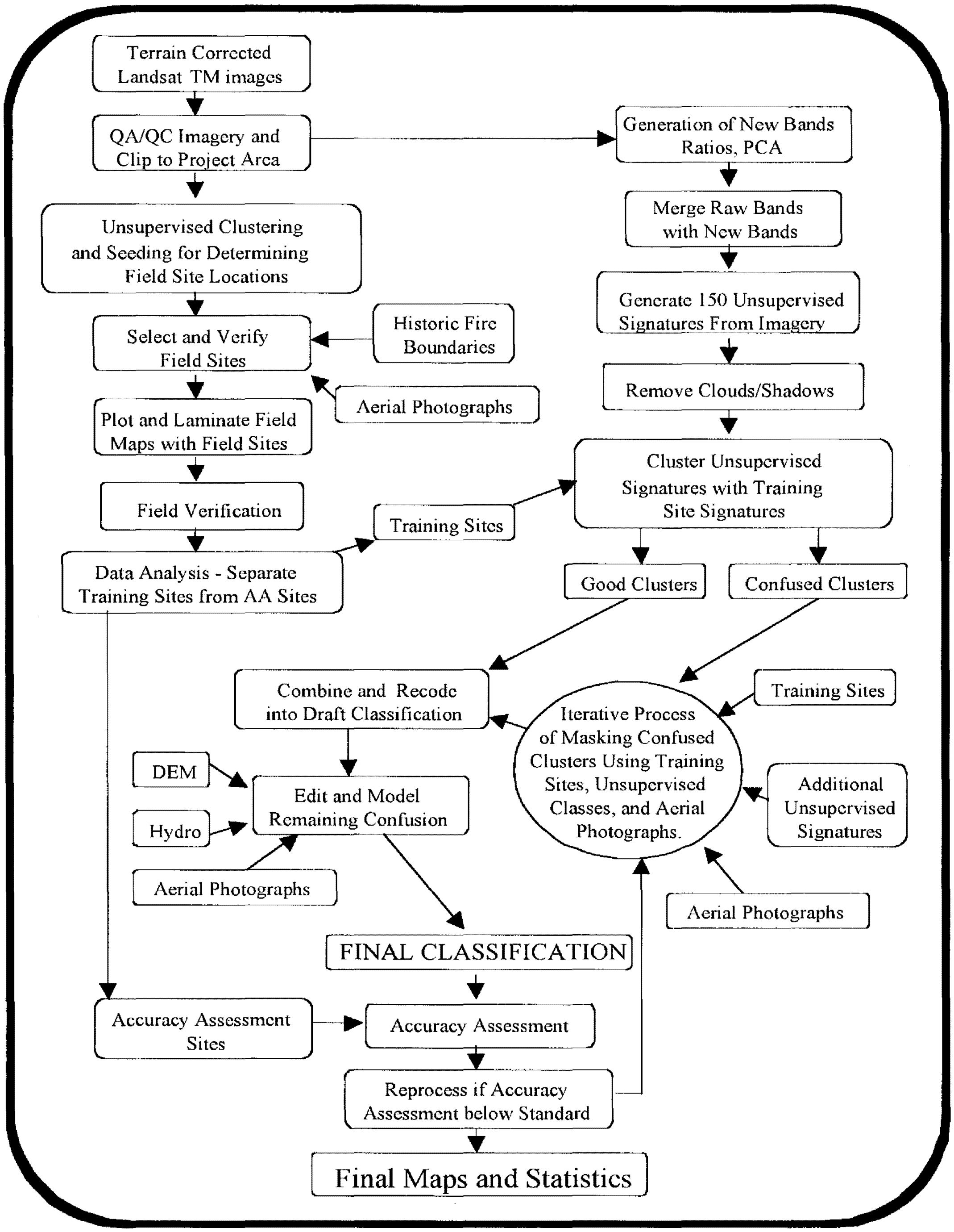


Figure 5. Image processing flow diagram.

classification and manual on-screen editing. Clouds were separated from shadows and classes were recoded to their respective class number. The cloud/shadow layer is then combined with the rest of the classified image during the last step in the classification process.

Seeding Process

Spectral signatures for the field sites to be used as training areas were extracted from the imagery using a "seeding" process in Erdas Imagine. A pixel within each training area was chosen as a "seed" and adjoining pixels were evaluated for inclusion in each training site using a threshold value based on a spectral euclidean distance.

The standard deviations of the seeded areas were kept close to or below 3 and all seeded areas were required to be over 15 pixels (approximately 3.75 acres) in size. Along with the field training areas, additional "seeds" were generated for clear and turbid water. 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 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 pre-processing 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 30% 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 1999; the aerial photographs spanned a seven-year period from 1980 through 1987, the field data was collected in June/July 2000. 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 from 575 field sites during a 12-day field season from 6/26/00 through 7/7/00. Approximately 30% (172) of these 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.

A French A-Star helicopter was used to gain access to the field sites. A single field "camp" location was utilized during the field data collection of this project. A bed and breakfast in the village of Ruby served as the staging area for the field crew, helicopter, field equipment, and all planning activities. Main fuel depots were based at the Ruby Airstrip (2 bladders, 1000 gallons), confluence of Nowitna and Yukon Rivers (10 barrels, 550 gallons), Poorman Airstrip (2 bladders, 750 gallons), and a remote fuel site on the tundra in the south-central region of the study area (12 barrels, 650 gallons). Flight following was carried out by the alternate via satellite phone and radio from the staging area in Ruby. Alternative flight following was also conducted via radio through the USF&WS station in Galena.

Table 2. Field sites per mapped class.

Class Name	Total Field Sites per Class	Sites Withheld for Accuracy Assessment
CLOSED NEEDLELEAF	6	1
OPEN NEEDLELEAF	121	33
OPEN NEEDLELEAF - LICHEN	18	5
WOODLAND NEEDLELEAF	66	21
WOODLAND NEEDLELEAF - LICHEN	25	9
CLOSED DECIDUOUS	52	15
OPEN DECIDUOUS	10	3
CLOSED MIXED NEEDLELEAF / DECIDUOUS	23	7
OPEN MIXED NEEDLELEAF / DECIDUOUS	18	6
TALL SHRUB	37	12
LOW SHRUB - OTHER	59	19
LOW SHRUB - LICHEN	6	1
LOW SHRUB - TUSSOCK TUNDRA	33	10
DWARF SHRUB - OTHER	4	0
DWARF SHRUB - LICHEN	13	3
WET SEDGE / GRAMINOID	12	5
WET FORB	2	0
MESIC/DRY SEDGE MEADOW	6	1
MESIC/DRY GRASS MEADOW	15	4
MESIC / DRY GRAMINOID	2	0
MESIC / DRY FORB	1	0
TUSSOCK TUNDRA	2	0
TUSSOCK TUNDRA - LICHEN	2	1
EMERGENT VEGETATION	5	1
CLEAR WATER	0	3
TURBID WATER	0	6
SPARSE VEGETATION	13	3
ROCK GRAVEL	8	3
LICHEN	1	0
MOSS	1	0
OTHER	11	0
TOTAL	**575**	**172**

Table 3. List of field data collection participants.

Participant	Role	Agency
Guy Hughes	Biologist/Vegetation Expert	US Fish & Wildlife Service
Terry Hobbs	Recorder/Alternate	BLM State Office
Various Biol. Technicians	Recorder/Alternate	US Fish & Wildlife Service
Jeff Campbell	Navigator/Image Processor	DU -Spatial Solutions, Inc.

Classification

The three most extensive vegetated classes within the final classification were: open needleleaf (2,511,852 acres or 47.8% of total area), woodland needleleaf (744,909 acres or 14.2% or total area), and closed mixed needleleaf/deciduous (550,200 acres or 10.5% of total area). In addition, extensive areas of closed birch (258,927 acres or 4.9% of total area) and low shrub (927,686 acres or 10.5% of total area) were present throughout the study area. Large expanses of open/woodland spruce interspersed with low shrub-other/low shrub-tussock tundra were typical of the project area. Uplands were characterized by rolling hills covered with a mix of closed birch, open needleleaf, and closed mixed needleleaf/deciduous forest types. Only a few isolated areas presented uplands that exhibited extensive non-forest types including low shrub-other, low shrub-tussock tundra, dwarf shrub, low shrub, sparse vegetation and some dry graminoid cover types. The distribution of these types is characterized in Table 4 and Figure 7. Stands of closed canopy deciduous trees were found on steep, well-drained south-facing slopes throughout the study area. These stands were composed primarily of Birch; although occasional stands of Aspen were present.

Unfortunately, no consistent, reliable spectral signature could be derived for these often scattered and smaller stands of Aspen. Closed canopy needleleaf stands also appeared to be constrained by soil conditions and were found only near major river drainages or on the very top of flat ridges. 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, especially in the northern extent of the project area just south of the Yukon River.

Differentiating between wet and dry graminoid/forb proved to be difficult as the moisture and water level conditions visible on the 1999 satellite imagery and those observed in the field in 2000 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. As a result, there was initial confusion between forb/graminoid regions being classified as dry when there was obvious presence of standing water visible in the satellite imagery. Rock and sparse vegetation cover types were found mostly at the highest elevations, along stream and riverbanks and sandbars.

No significant, mappable regions with snow and ice were found within the study area. The only clouds present in the imagery for the Galena MOA / Nowitna NWR studyarea were found in the extreme southeast boundary of the study area. While the area classified as clouds and cloud shadow accounted for nearly 10,000 acres over the entire 5.3 million acres of the study area, the vast majority of this acreage actually fell outside of the official project area boundary but in the project buffer zone.

Modeling

Modeling was performed using a shaded relief image and an elevation zone image derived from USGS DEM at 1:250,000 scale. The shaded relief image was created in Erdas Imagine using the solar azimuth and solar elevation listed in the header file for the TM image. The DEM was often used to help separate spectrally confused classes like terrain shadow and deep water. Elevation images were also used to model cover types that were limited by slope, aspect or elevation. 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. Tussock tundra signatures were confused with dwarf shrub, but unlike dwarf shrub, tussock tundra will not occur at higher elevations or on steep slopes. Closed and open canopy needleleaf was found only 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.

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 mapped 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 mesic/dry grass meadow in the lowlands near the mouth of the Nowitna River and dwarf shrub on the higher elevation regions in the south-southeast 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. Additional 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

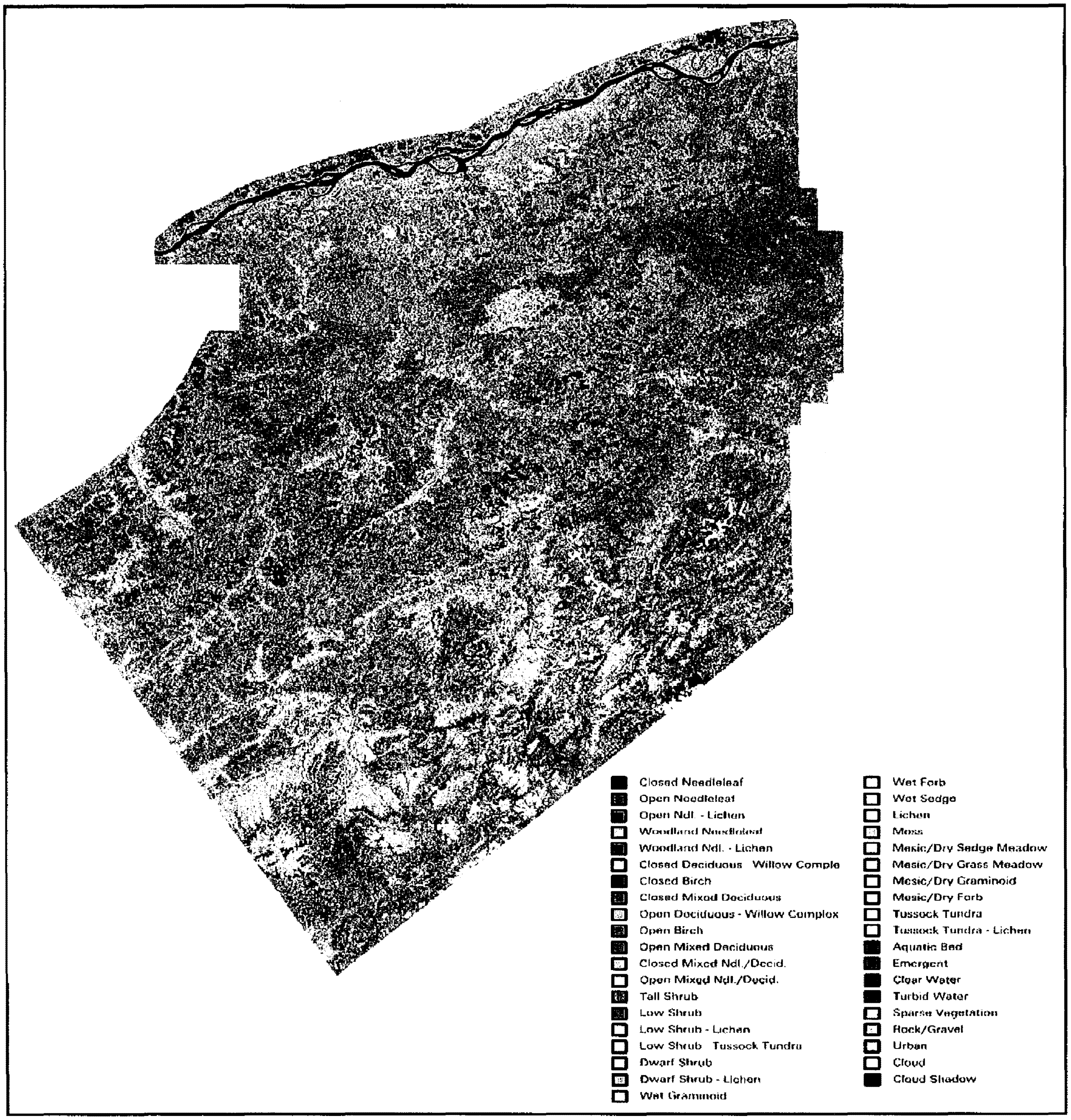


Figure 6. Galena MOA / Nowitna NWR final classified map.

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 0.3 meters were confused with dwarf shrub areas with a height of 0.2 meters. Also, low shrub areas at a height of 1 meter were confused with tall shrub areas of only 1.5 meters in height. These transitional areas and signatures had to be examined and a classification decision made based on the available data.

In some cases, a single pixel fell across two cover types, for example, between the edge of 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 difficult landcover types to consistently distinguish spectrally and thematically were found with the "recent" burn areas. Even the field training sites located in these areas were filled with a high degree of variability that described landcover types ranging from low shrub-other to open birch to tall shrub. In fact, many sites were calculated to be open birch with more than 40% 1-meter tall birch trees that the vegetation caller characterized as the tall shrub class. A review of the field data sheets for many of these burn area training sites showed that these highly variable locations could be described by two or more landcover type classes with only a 5-10% change in vegetation estimation or height. The primary confusion was centered on the presence of young birch regeneration that often functions as tall shrub *and* open deciduous. While the final classification of these burn areas did result in a consistent and reliable characterization of the area, much landcover class variation is found throughout the burns that are associated with only slight changes in the actual vegetation composition. Much manual editing and spatial modeling techniques were used specifically within regenerating burn areas to assure a reliable, consistent characterization of these unusual regions of the study area.

Another set of landcover types that exhibited consistent spectral confusion was the combination of dry graminoid types: dry graminoid, mesic/dry grass meadow, mesic/dry sedge meadow. While these types are often compositionally very different and unique, they are often spectrally very similar when some substantial moisture regimes are not present to aid in the discrimination of those areas more likely to be sedge dominated as opposed to grass dominated. Significant manual editing and spatial modeling were used to obtain a reliable and consistent discrimination of these types in the final map. As demonstrated in the project final accuracy analysis matrix in the following section, a good characterization of these types seem to have resulted from these efforts.

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. Emergent vegetation typically occurred in narrow strips, often only a few pixels wide, making it very difficult to obtain reliable ground samples. Wet sedge sites were more

Table 4. Acreage of earth cover classes within the project area.

CLASS			PERCENT
2	Open Needleleaf	2,511,852	47.80%
3	Open Ndl. - Lichen	146,556	2.79%
4	Woodland Needleleaf	744,909	14.18%
5	Woodland Ndl. - Lichen	128,192	2.44%
10	Closed Deciduous - Willow Complex	11,276	0.21%
11	Closed Deciduous - Birch	258,927	4.93%
12	Closed Mixed Deciduous	43,484	0.83%
13	Open Deciduous - Willow Complex	371	0.01%
14	Open Deciduous - Birch	8,622	0.16%
15	Open Mixed Deciduous	4,373	0.08%
16	Closed Mixed Ndl./Decid.	550,200	10.47%
17	Open Mixed Ndl./Decid.	100,484	1.91%
20	Tall Shrub	83,485	1.59%
21	Low Shrub	248,023	4.72%
22	Low Shrub - Lichen	11,466	0.22%
23	Low Shrub - Tussock Tundra	89,231	1.70%
24	Dwarf Shrub	14,849	0.28%
25	Dwarf Shrub - Lichen	39,388	0.75%
32	Wet Graminoid	12,408	0.24%
33	Wet Forb	89	0.00%
34	Wet Sedge	6,956	0.13%
36	Lichen	102	0.00%
37	Moss	4,295	0.08%
41	Mesic / Dry Sedge Meadow	1,186	0.02%
42	Mesic / Dry Grass Meadow	6,046	0.12%
43	Mesic / Dry Graminoid	447	0.01%
44	Mesic / Dry Forb	5,492	0.10%
50	Tussock Tundra	13,410	0.26%
51	Tussock Tundra -Lichen	3,922	0.07%
60	Aquatic Bed	454	0.01%
61	Emergent Vegetation	1,735	0.03%
70	Clear Water	40,692	0.77%
71	Turbid Water	71,036	1.35%
80	Sparse Vegetation	27,459	0.52%
81	Rock/Gravel	10,003	0.19%
90	Urban	65	0.00%
92/93	Cloud / Cloud Shadow	9,765	0.18%
Total		**5,254,762**	**100**

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 level even from the time of satellite image acquisition (July 1999) to the time of field data collection (July 2000) was evident. Therefore, the editing associated with this type of confusion focused on best representing conditions as they were at the time of satellite image capture. Each of these conditions was edited manually to insure consistency and reliability in the final representation of each affected class.

A final case of spectral classification confusion involved the misclassification of open mixed needleleaf/deciduous pixels in areas of open and woodland needleleaf that exhibited a dense low and tall shrub understory, primarily composed of alder. The mix of the sparse needleleaf trees and the deciduous shrubs mimicked the spectral signatures of open mixed needleleaf/deciduous field training sites. This confusion was corrected via manual editing utilizing photo-interpretation and review of specific field notes and photos. Fortunately, the areas exhibiting this vegetation composite were limited to only a few regions of the study area.

Finally, at the request of U.S. Fish & Wildlife project participants, an attempt was made to further stratify the mixed deciduous classes into closed- and open deciduous classes that discriminated the willow dominated communities from other mixed deciduous types. This effort was focused on the younger willow communities found along the riparian corridors of the Yukon, Nowitna, Sulukna, and Sulatna Rivers. These willow communities were spectrally quite distinct from the older, more established closed birch forests that occupied portions of the riparian corridor usually just inland from the willow communities and river's edge. Therefore, a consistent and reliable stratification of willow-dominated forests from other mixed deciduous forests was achieved. The total acreage of the willow-complex classes is presented in Table 4.

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, open deciduous, aquatic bed. In the past, classes with an inadequate sample size were collapsed into the next hierarchical cover type for accuracy assessment of the classification. This grouping often resulted in only 8-10 accuracy assessment classes vs. the 30+ classes present in the classification. In addition, this approach grouped classes based solely on their specific mapping class labels versus grouping individual sites based on their ecological composition or function. By grouping classes in this manner, one loses all ability to evaluate and measure the relationship between regions of the map that classify nicely into the "heart" of a mapping class and those regions that occur on the classification and ecological boundaries between the discrete mapping classes. For example, a vegetation caller may have interpreted a site to contain 10% tree cover 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-one reference sites characterized as woodland needleleaf, three sites were an acceptable match with open needleleaf, one was an acceptable match with low shrub-other, one was an acceptable match with low shrub-tussock tundra, and one site was an unacceptable match with open needleleaf.

The remainder of the sites (15) were diagonal matches with woodland needleleaf. The off-diagonal matches indicate that at least three of those sites was just on the border between woodland and open needleleaf (20-25% tree canopy cover), and at least two sites had a significant low shrub (tussock) component and just enough tree canopy cover to be considered forested (10-15% tree canopy cover). Similarly, since the number of misclassified sites are still indicated in the matrix, a user can determine in which classes the map is least reliable and with which mapping classes the unreliable classes are confused. If lumping of classes is still desired, this can easily be accomplished through application of the techniques utilized in previous projects. Although the matrix of lumped classes is not presented in this report, the classification accuracy of the grouped classes of Open Needleleaf, Woodland Needleleaf, Deciduous, Mixed Needleleaf/Deciduous, Tall Shrub, Low Shrub, Dwarf Shrub, Forb/Graminoid, and Barren was computed to be 83.1%.

Overall Accuracy Assessment

The difference in classification accuracy between the +/- 0% variation in interpretation level (72%) and the +/- 5% variation in interpretation level (87%) 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 acceptable with absolutely no lumping or variation of interpretation allowed (open needleleaf = 81%, and woodland needleleaf = 71%). Allowing +/- 5% variation in interpretation in the reference data, much greater accuracies are demonstrated (94%, and 95%). The User's Accuracy for the same classes is comparable. These measures are extremely encouraging since over 60% of the study area is mapped as one of these two forested needleleaf classes. When an area is classified as one of the forested needleleaf classes, the user can have extreme confidence in the accuracy of that classification. Of the 18 off-diagonal needleleaf reference sites, 14 were considered acceptable matches at the +/- 5% variation in interpretation level. This indicates that the vast majority of the reference sites that were not direct matches with the map sites were right on the boundary between two different mapping classes; one of which the map presented for the site.

The open and woodland needleleaf classes were the most difficult class to map due to their high diversity of possible components. For example, a woodland site could include 40% graminoid cover and just 10% trees, or it could contain 20% trees and 50% shrubs. In some cases, cover types other than trees dominated the signature of woodland sites, whereas in other cases, spruce trees dominated. A great deal of effort was expended in separating these two classes from one another as well as from other similar non-forested sites. The error matrix indicates that only four of the 68 needleleaf reference sites were mapped incorrectly when allowing for only +/- 5% variation in interpretation of the reference data.

Similar results are found throughout the error matrix. 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 three reference sites exceeded 82%, with the vast majority of these sites exceeding 90% accuracy. The one obvious exception to this trend was in the open mixed class. Even with only a total of six accuracy assessment sites, this class appears to be the most confused class resulting from the mapping effort. Of the four accuracy assessment sites that were mis-classified, the errors fell consistently into two distinct categories; both of which have been discussed in previous sections of this report.

First, two of the mis-classified sites were located in recent burn areas where they were confused with low shrub classes. This is not too surprising since these sites consistently contained your birch and spruce seedlings that were just large enough to be considered "trees"; although they appeared spectrally, and visually, to function more as a low shrub community in the regenerating burn. The second phenomenon was confusion between the open mixed and closed mixed classes. This was generally not a case of simply overestimating the total canopy cover in the stand. Rather, these two sites both contained total tree canopy cover mix of spruce and birch between 35-50% and a dense alder understory comprising at least 40-45% visible cover. The strong influence of the alder in the understory resulted in a spectral reflectance for the stand that greatly resembled that of a stand containing a much larger deciduous tree component. Although several efforts were made to consistently discriminate these closed mixed from the open mixed stands in these areas, adequate reliable spectral information was not available to distinguish these types.

Despite the strong correlation between the reference data and the classified map data, one trend of potential interest to an end user is evidenced in the error matrix. From a both a user's and producer's perspective, the low shrub-other class presents a slight tendency toward being over classified. While 19 out of the 20 low shrub-other reference sites were found to be classified correctly (95% producer's accuracy at the +/- 5% variation level) and 21 out of 24 reference sites that were mapped as low shrub-other were found to be classified correctly (87.5% user's accuracy at the +/- 5% variation level), a total of nine non-low shrub-other reference sites were found to be classified as low shrub-other. Although six of these nine 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 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 (found almost exclusively in regenerating burn areas) and low shrub-tussock tundra (where the percentage of tussock-forming species is between 30-40%).

In summary, based on the quantitative accuracy assessment, the earth cover classification map produced for the Galena MOA / Nowitna NWR is very reliable. Over 72% of the accuracy assessment sites matched the full detailed 32 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 (87.2%) 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 acquired on July 2, 1999. The aerial photographs spanned a seven-year period from 1980-87, and the field data was collected in June-July 2000. Differences due to environmental changes from the different sources may have affected the accuracy assessment. As discussed earlier, the significant differences in standing water in many older oxbows and other wetter sites between the image date 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. The other primary area of confusion revealed in the analysis of accuracy pertains to the recently burned areas. As previously discussed, these regions of the study area are actively regenerating. The consistent presence of low shrubs, tall shrubs, 1/2 to 2-meter tall birch and spruce trees of varying densities throughout many of these burned areas resulted in a mix of woodland needleleaf, open birch, open mixed, low shrub, and tall shrub classes, each of which is often separated by only a few canopy cover percentage points estimated by a single interpreter. Such a scenario is fraught with potential spectral and thematic overlap and confusion even though the basic form and function of the regenerating vegetation is fairly consistent.

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 Galena MOA / Nowitna NWR.

Final Products

The deliverables for this earth cover mapping project include a digital classification, map, and database of 39 earth cover classes within the Galena MOA / Nowitna NWR project area as well as a map of wildlife sighting locations observed during the collection of field data. The digital classification map is delivered in ArcInfo Grid and Erdas Imagine format. The unclassified Landsat TM images used to create the cover map are also delivered. The field site database, a species list and earth cover acreage tables are stored as digital tables in Microsoft Excel and Access format. The wildlife sightings map is delivered as an ArcInfo point coverage. Digital photos of the field sites are stored as jpeg's. Plots of the entire project area at 1:250,000 scale, and selected 1:63,360 scale quadrangles were also produced. All of the delivered datasets were loaded into ArcView projects for display purposes.

Summary

The Bureau of Land Management (BLM) - Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. This project continued with the mapping effort for the Galena MOA / Nowitna NWR project using Landsat TM satellite scenes, Path 73, Rows 14, 15, and 16 acquired July 2, 1999. The project area was classified into 39 earth cover categories with an overall accuracy of 87.2% 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 digital ArcInfo point coverage of wildlife sighting locations observed during the collection of field data, 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. This class was very common throughout the interior of Alaska. A wide variety of understory plant groups were present, including low and tall shrubs, forbs, grasses, sedges, horsetails, mosses and lichens.

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

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

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

1.4 Closed Deciduous (Mixed Deciduous Species 1.45)
At least 60% of the cover was trees, and ≥75% of the trees were deciduous. Occurred in stands of limited size, generally on the floodplains of major rivers, but occasionally on hillsides, riparian gravel

bars, or bordering small lakes. This class included Paper Birch, Aspen, or Cottonwood.

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

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

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

1.44 Closed Deciduous -Willow Complex
At least 60% of the cover was trees, $\geq$75% of the trees were deciduous, and $\geq$60% of the deciduous trees were of the Salix genera, tree form.

1.5 Open Deciduous (Mixed Deciduous Species 1.55)
From 25-59% of the cover was trees, and $\geq$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, $\geq$75% of the trees were deciduous, and $\geq$75% of the deciduous trees were paper birch. This class was very rare. No examples of this class were found in the study area.

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

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

1.54 Open Deciduous - Willow Complex
At least 25-59% of the cover was trees, $\geq$75% of the trees were deciduous, and $\geq$60% of the deciduous trees were of the Salix genera, tree form.

1.6 Closed Mixed Needleleaf/Deciduous
At least 60% of the cover was trees, but neither needleleaf nor deciduous trees made up $\geq$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 $\geq$75% of the tree cover. This class occurred in regenerating burns, on hill slopes, or bordering lakes.

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

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

2.1 Tall Shrub
Shrubs made up 40-100% of the cover and shrub height was ≥1.3 meters. This class generally had a major willow component that was mixed with dwarf birch and/or alder, but could also have been dominated by nearly pure stands of alder. It was found most often in wet drainages, at the head of streams, or on slopes.

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

2.22 Other Low Shrub/Tussock Tundra
Shrubs made up 40-100% of the cover, shrub height was .25-1.3 meters, and ≥35% of the cover was made up of tussock forming cotton grass *(Eriophorum vaginatum*). This class was found in extensive patches in flat, poorly drained areas. It was generally made up of cotton grass, ericaceous shrubs, willow and/or alder shrubs, other graminoids, and an occasional black spruce.

2.23 Other Low Shrub/Lichen
Shrubs made up 40-100% of the cover, shrub height was .25-1.3 meters, and ≥20% of the cover was made up of lichen. This class was found at mid-high elevations. The shrub species in this class were nearly always dwarf birch.

2.24 Other Low Shrub
Shrubs made up 40-100% of the cover, shrub height was .25-1.3 meters. This was the most common low shrub class. It was generally composed of dwarf birch, willow species, *Vaccinium* species, and ledum species.

2.31 Dwarf Shrub/Lichen
Shrubs made up 40-100% of the cover, shrub height was ≤.25 meters, and ≥20% of the cover was made up of lichen. This class was generally made up of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids. It was nearly always found at higher elevations on hilltops, mountain slopes and plateaus. This class may be more open than the Other Dwarf Shrub class.

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

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

3.11 Lichen
Composed of ≥40% herbaceous species, ≤25% water, and ≥ 60% lichen species.

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

3.21 Wet Graminoid
Composed of ≥40% herbaceous species, ≤25% water, and where ≥60% of the herbaceous cover was graminoid, and ≥20%

of the graminoid cover was made up of *Carex aquatilis*. This class represented wet or seasonally flooded sites. It was often present in stands too small to be mapped at the current scale.

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

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

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

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

4.0 Aquatic Vegetation
The aquatic vegetation was divided into aquatic bed and emergent classes. The aquatic bed class was dominated by plants with leaves that float on the water surface, generally pond lilies (*Nuphar polysepalum*). The emergent vegetation class was composed of species that were partially submerged in the water, and included freshwater herbs such as horsetails (*Equisetum* spp.), marestail (*Hippuris* spp.), and buckbean (*Menyanthes trifoliata*).

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

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

5.1 Clear Water
Composed of ≥80% clear water.

5.2 Turbid Water
Composed of ≥80% turbid water.

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

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

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

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

7.0 Urban
At least 50% of the area was urban. This class was only found in the study area within the village of Ruby.

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

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

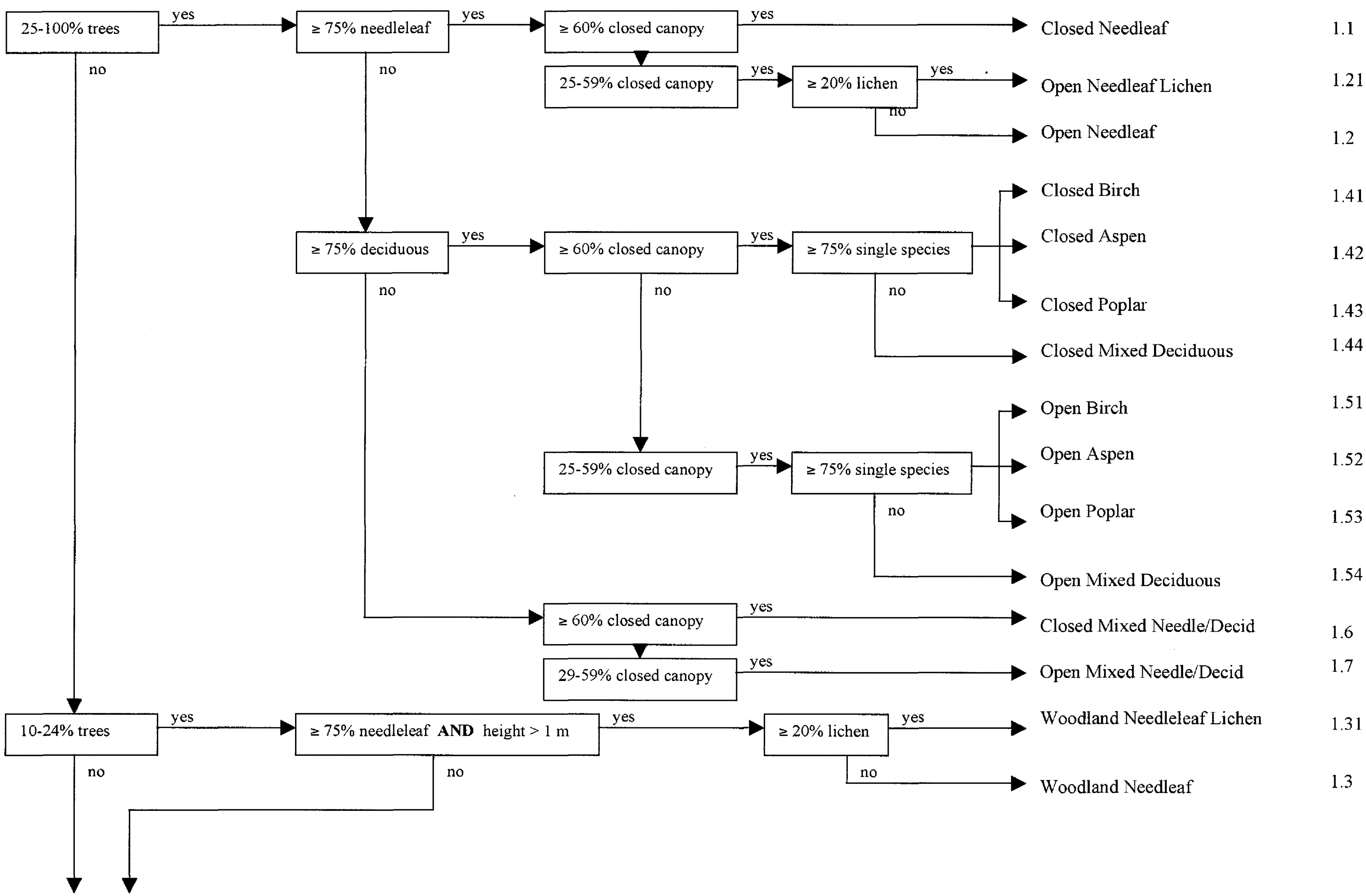
9.1 Cloud
At least 50% of the cover was made up of clouds.

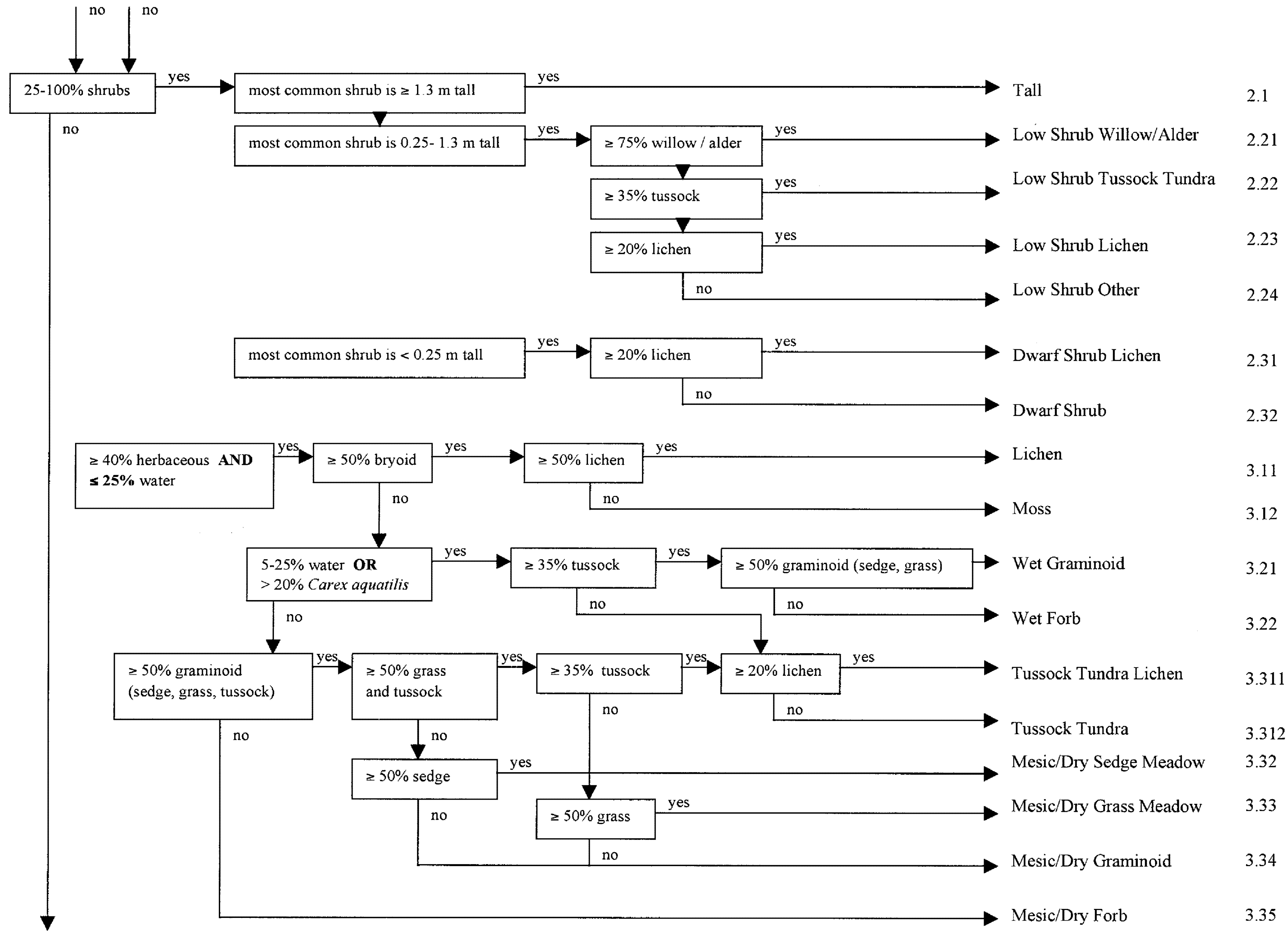
9.2 Cloud Shadow
At least 50% of the cover was made up of clouds shadows.

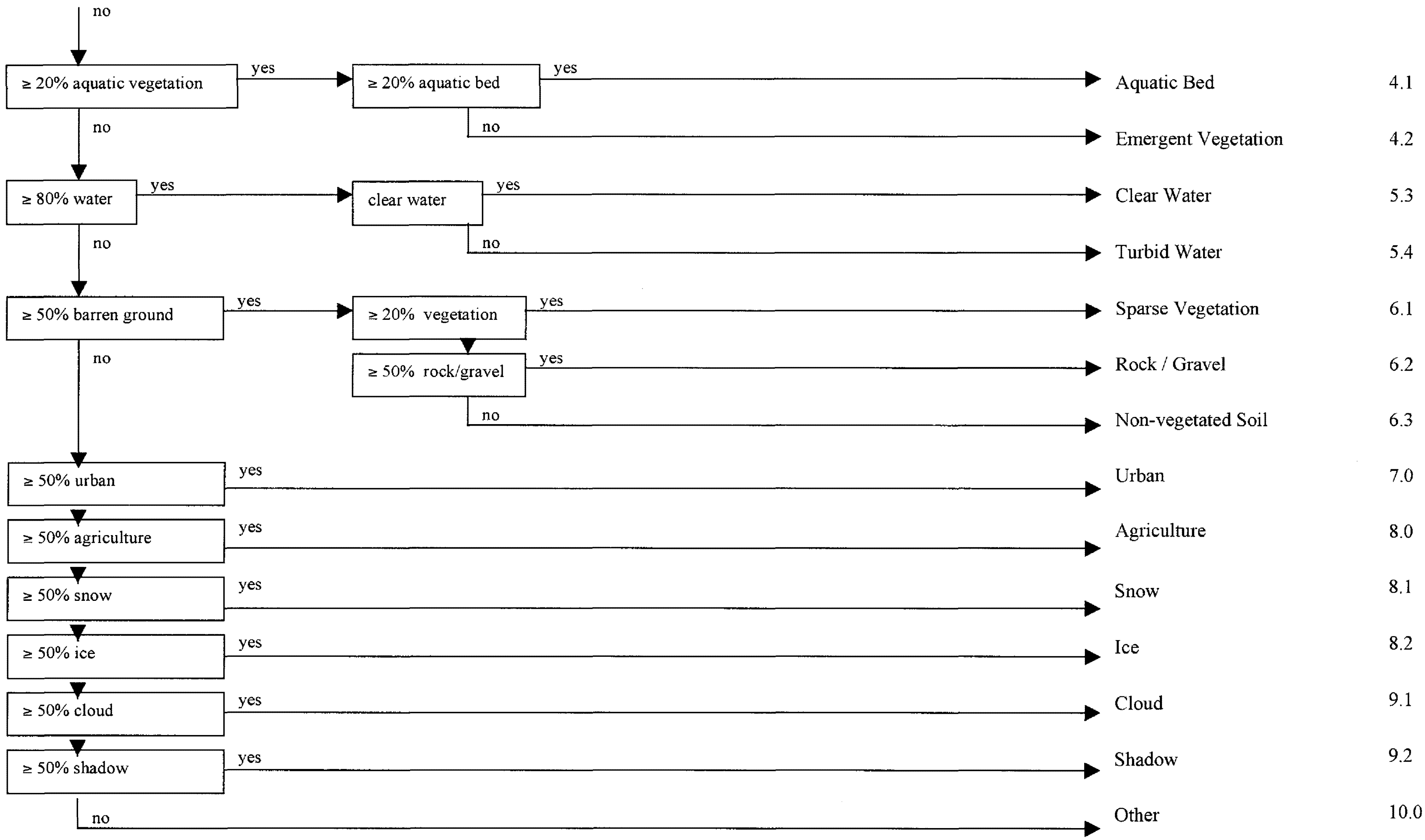
9.3 Terrain Shadow
At least 50% of the cover was made up of terrain shadows.

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

Appendix B. Earth cover classification decision tree.




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


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

Appendix C. 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 FRUTICOSA	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

Site Tally		Symbol		Species		Common Name
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

Site Tally		Symbol		Species		Common Name
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. Galena MOA / Nowitna NWR Accuracy Assessment Error Matrix

Galena MOA / Nowitna NWR

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	User's Accuracy
1) Closed Needleleaf																																	n/a
2) Open Needleleaf	1,0	27		3,1						0,1	0,1																						91%
3) Open Needleleaf - Lichen		0,1	4																														80%
4) Woodland Needleleaf		4,1	0,1	15	4,0																												92%
5) Woodland Needleleaf - Lichen					4																												100%
6) Closed Deciduous						1	0,1																										50%
7) Closed Birch							12																										100%
8) Open Decidiuous								1																									100%
9) Open Birch												0,2																					0%
10) Closed Mixed										5	1,2																						75%
11) Open Mixed										0,1	1				0,1																		33%
12) Tall Shrub							0,1		1,0			8																					90%
13) Low Shrub - Other				1,0					0,1		0,1	2,0	15		3,0				0,1														88%
14) Low Shrub - Lichen					1,0								0,1																				50%
15) Low Shrub - Tussock Tundra				1,0									3,0	1,0	6																		100%
16) Dwarf Shrub - Other																																	n/a
17) Dwaft Shrub - Lichen																	2														0,1		66%
18) Wet Graminoid																																	n/a
19) Wet Sedge																			4														100%
20) Mesic/Dry Sedge Meadow																				1													100%
21) Mesic/Dry Grass Meadow																					4						0,1						80%
22) Mesic/Dry Graminoid																																	n/a
23) Mesic/Dry Forb																																	n/a
24) Tussock Tundra																																	n/a
25) Tussock Tundra - Lichen																									1								100%
26) Aquatic Bed																																	n/a
27) Emergent																																	n/a
28) Clear Water																												3					100%
29) Turbid Water																													6				100%
30) Snow/Ice																																	n/a
31) Sparse Vegetation																	0,1														2	0,1	50%
32) Rock/Gravel																																2	100%
Reference Site Totals:	1	33	5	21	9	1	14	1	2	7	6	12	19	1	10	0	3	0	5	1	4	0	0	0	1	0	1	3	6	0	3	3	
Producer's Accuracy (+/-5%):	100%	94%	80%	95%	100%	100%	86%	100%	50%	71%	33%	83%	95%	100%	90%	n/a	66%	n/a	80%	100%	100%	n/a	n/a	n/a	100%	n/a	0%	100%	100%	n/a	66%	66%	

Total =	172
Diagonal =	124
Off-Diagonal =	26
Overall Accuracy (0% var) =	72.09%
Overall Accuracy (+/- 5% var) =	87.21%

Appendix E. 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 photogragh flight lines

For more information please contact:

Bureau of Land Management
Alaska State Office
222 West 7th Avenue, #13
Anchorage, AK 99513-7599
907-271-3431

Ducks Unlimited, Inc.
3074 Gold Canal Drive
Rancho Cordova, CA 95670-6116
916-852-2000

U.S. Fish and Wildlife Service
Nowitna National Wildlife Refuge
Galena, Alaska