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

BLM-Alaska Technical Report 28
BLM/AK/ST-02/009+6500+931
September 2002

U.S. Department of the Interior
U.S. Fish and Wildlife Service

Ducks Unlimited, Inc.

Kanuti NWR/Ray Mountains/ Hogatza River Earth Cover Classification

Mission Statement

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

Partners

The Department of the Interior's Bureau of Land Management and U.S. Fish and Wildlife Service, and Ducks Unlimited, Inc. completed this project under a cooperative agreement.

Cover

The cover photo shows a portion of the Kanuti National Wildlife Refuge. It depicts the remoteness of the area and the need to use helicopters for data collection.

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Acknowledgements

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

Special thanks are extended to those who worked in the field. The Kanuti Refuge field crew included Tom Early, Rachelle Lorton (FWS), Shannon Nelson (FWS), Miles Roberts (DU – volunteer), and Ruth Spell (DU). The BLM field crew included Mike Buterri (Alaska Fire Service), Dan Fehringer (DU), Randi Jandt (BLM), and Jim Sisk (BLM). Thanks to Bill Lawrence, Larry Palma, and Marty Stauber, pilots from Tundra Copters, for safe air service. Thanks also to Bob McAlpin from Alaska Fire Service for help coordinating helicopter contracting, Dan Fehringer, Ruth Spell, and Brendan O'Hara (DU) for image processing, Mark Pearson (GeoNorth, Inc.) for programming the Ducks Unlimited Field Form (DUFF) database; and Jing Huang (DU) for programming the accuracy assessment program.

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Abstract

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. The BLM's plans to map the Ray Mountains and Hogatza River lands adjacent to the Kanuti National Wildlife Refuge (NWR) coincided with the Refuges' long term goal of obtaining updated earth cover data for the refuge. By combining efforts, overall costs associated with field logistics and image processing were reduced. This project simultaneously mapped the Kanuti NWR, the BLM's Ray Mountains and Hogatza River lands, as well as all State and Native lands between and surrounding the refuge and BLM lands. Portions of four Landsat TM satellite scenes (Path 73, Rows 13-14 acquired 2 July 1999 and Path 74, Rows 13-14 acquired 12 September 1992) were used to classify the project area into 30 earth cover categories. The path 73 and path 74 images were classified separately because of the large difference in image dates and season. The path 73 and path 74 earth cover classifications were mosaiced and edge-matched post-classification to produce a continuous earth cover map for the entire project area. An unsupervised clustering technique was used to determine the location of field sites and a custom field data collection form and digital database were used to record field information. Helicopters were utilized to gain access to field sites throughout the project area. Global positioning system (GPS) technology was used both to navigate to pre-selected sites and to record the locations of new sites selected in the field. The project area is approximately 9 million acres. A total of 457 field sites were visited during a 12 day field season. Approximately 30% (128) 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 85% at the +/-5% level of variation for the path 73 classifcation and 83% at the +/-5% level of variation for the path 74 classification.

Introduction

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

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

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

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

The Kanuti NWR/Ray Mountains/Hogatza River Earth Cover Mapping project area contains diverse landscapes and is deemed important for its wildlife and recreational values. The project area extends approximately from the Refuge's northern boundary in the north to the Yukon River in the south. The eastern and western boundaries are defined by the extent of the Landsat TM images used for the mapping.

Project Objective

The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Kanuti National Wildlife Refuge, the Ray Mountains and Hogatza River BLM lands, and associated areas. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project was an integrated GIS database that can be used for improved natural resources planning.

Project Area

The project area (Figure 1) consisted of approximately 9 million acres and included lands owned or managed by several federal and state agencies, native corporations, and private landowners (Figure 2). The Kanuti NWR (1.65 million acres) formed the bulk of the northern portion of the project area, with the BLM's Ray Mountain lands (0.3 million acres) in the southeastern portion, and the BLM Hogatza River lands (1.7 million acres) included in the western portion. Approximately 2.2 million acres of state selected and state patent land (Table 1) and 1.9 million acres of native selected and native patent land within and around the BLM and FWS lands were mapped to provide a continuous data set for the entire area. The eastern and western boundaries of the project area were defined by the extent of the satellite images used in the classification, with the exception of the northernmost section of the eastern boundary. This boundary was adjusted to exclude the Yukon Flats National Wildlife Refuge. The Yukon Flats NWR is currently performing its own satellite image classification for earth cover on its lands so it was unnecessary to duplicate their efforts. The project area contains portions of the following United States Geological Survey (USGS) 1:250,000 scale quadrangles: Bettles, Beaver, Hughes, Melozitna, and Tanana. The project area was nearly roadless. Approximately 60 miles of the Dalton Highway passed through the northeastern portion of the project area. This was the only access afforded by the state-wide road system. All other roads were limited to minor road systems associated with bush communities and native villages scattered throughout the project area.

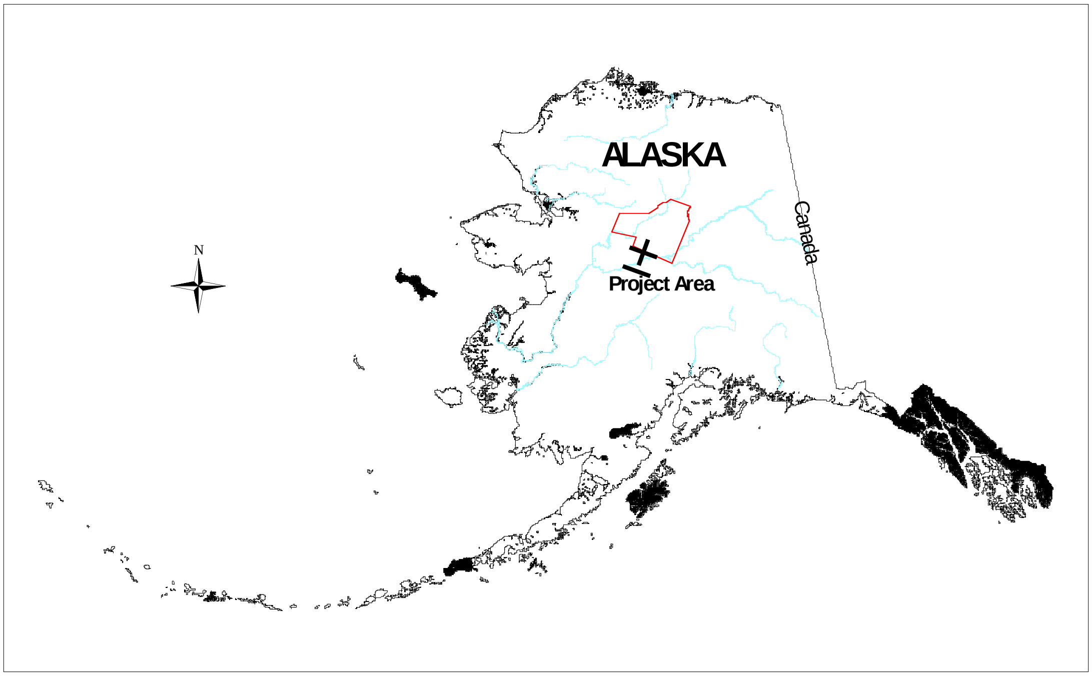

Figure 1. Kanuti NWR/Ray Mountains /Hogatza River project area.

Table 1. Acreage of project area summed by land status.

Land Status	Acres
Bureau of Land Management	3,328,100
U.S. Fish and Wildlife Service	1,543,800
State Selected	1,515,300
Native Patent or IC	1,131,000
Native Selected	804000
State Patent or TA	643,700
Military	20,900
Private	4,400
Total	8,991,200

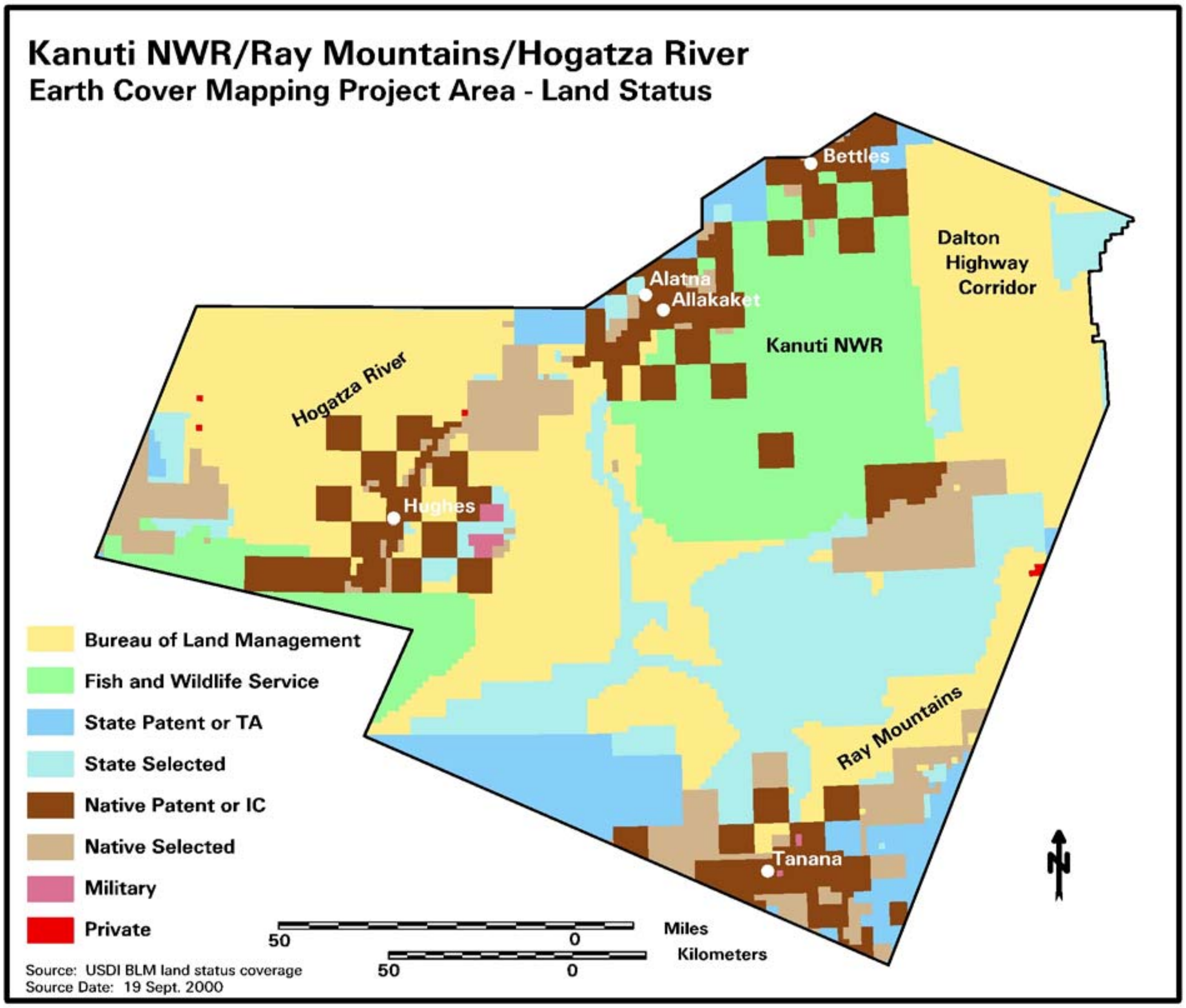

Figure 2. Land status within the project area.

The project area encompassed a wide variety of environments ranging from alpine mountains to lowland black spruce muskeg. Non-forested uplands in the Ray Mountains form important caribou habitat, the higher elevations are home to Dall sheep, while moose and bear are found throughout most of the project area. Innumerable small lakes and ponds in the Kanuti NWR as well as in surrounding areas supported the pond lilies and other aquatic vegetation that make up an important summer food source for breeding tundra swans and other waterfowl. The area is heavily influenced by fire as indicated by the numerous fire scars visible on the satellite imagery.

Data Acquisition

Kanuti NWR purchased all imagery for the project in Universal Tranverse Mercator (UTM) projection from Earth Resource Observation Systems (EROS) Data Center. Four Landsat TM scenes were originally purchased to cover the project area. Two scenes (Path 74 Rows 13 and 14) acquired on September 8, 1992 covered the western portion of the project area. The remaining two scenes (Path 72, Rows 13 and 14) acquired on September 10, 1995 covered the eastern portion of the project area. Acquisition of cloud free imagery from midsummer dates is difficult in this portion of Alaska and the relatively late summer to early autumn dates of these images resulted in the presence of leaf senescence in many stands of deciduous trees in the images, particularly at higher elevations. In addition, the images covering the eastern portion of the study area contained significant cloud cover, especially in the Ray Mountains area. A composite of these four scenes was used for the fieldwork portion of the project (Figure 3). Early in the image processing phase, the newly launched Landsat 7 (April 1999) acquired a new set of cloud free, midsummer imagery that covered the majority of the project area (TM path 73, Rows 13 & 14, acquired July 02, 1999). These images were purchased to replace the path 72 images for the image classification (Figure 4). Not only did the

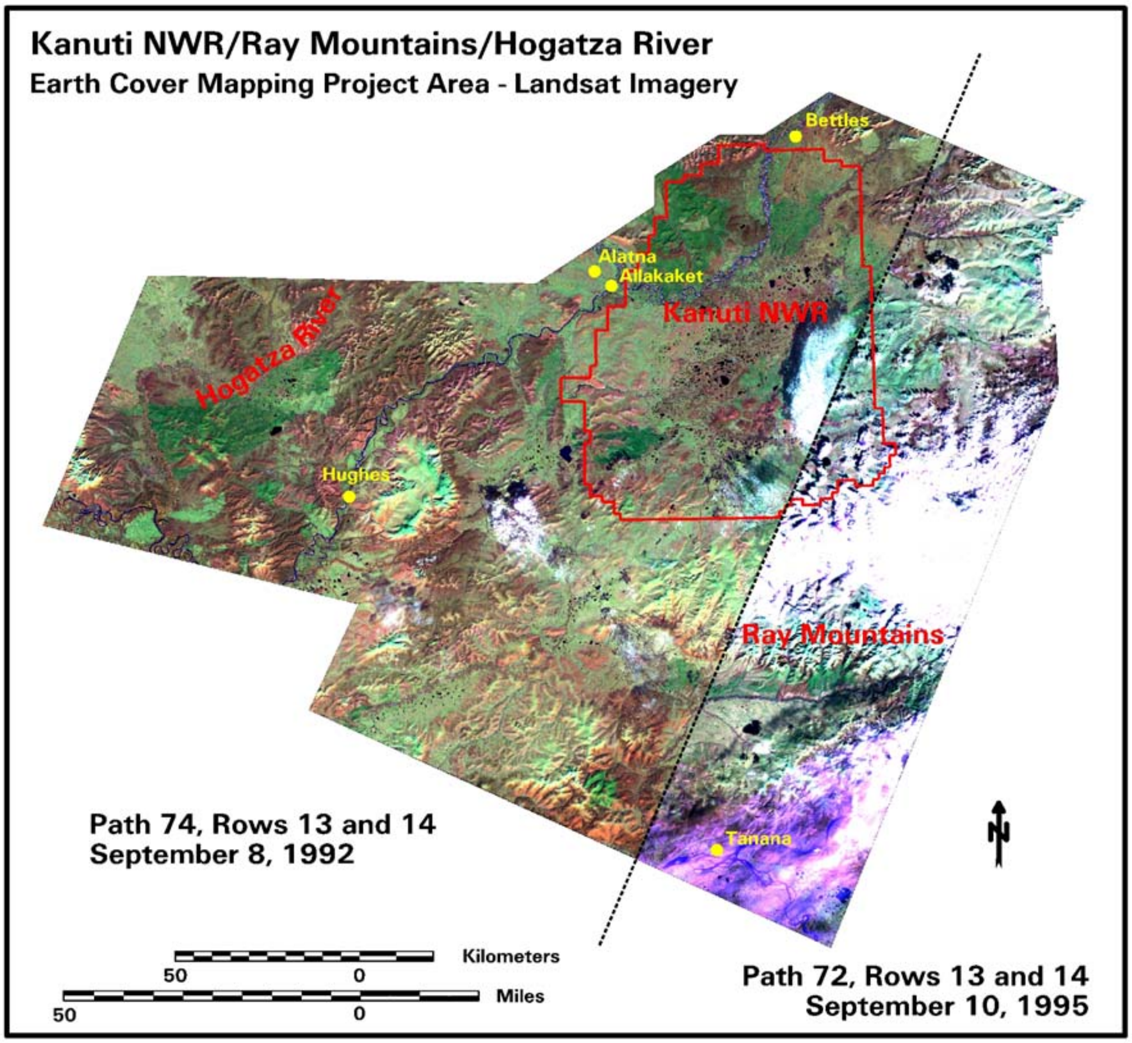

Figure 3. Satellite imagery used for fieldwork.

path 73 images replace all the clouded areas from the path72 and path 74 images, but it also provided the most currently available imagery acquired at the closest date possible to the date of the field data collection. This was a marked improvement in an area heavily influenced by fire, but it did result in a delay in the completion of the project. Field data were collected during a 12-day field season from July 16, 1998 through July 27, 1998. Ancillary data sets used in this project included: 1:60,000 scale aerial photographs (color infrared transparencies from 1980-82, 1984, and 1986-87), and USGS 1:250,000 scale Digital Elevation Models (DEM). The aerial photographs and DEMs were provided by the BLM.

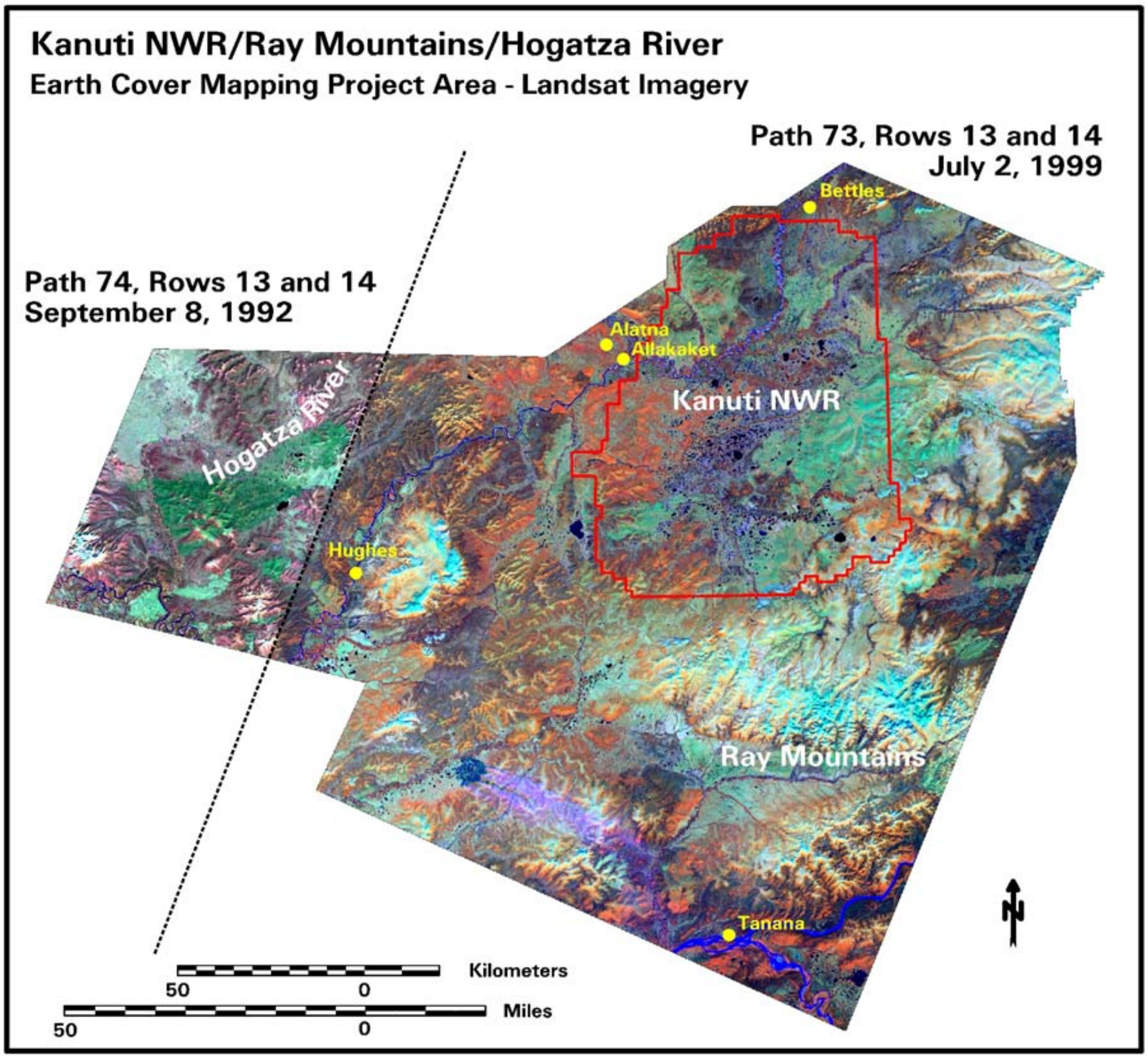

Figure 4. Satellite imagery used for the image classification.

Methods

Classification Scheme

The classification system (Table 2) 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). That is, any given area fell into only one category and every area was to be included in the classification.

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

The classification scheme consisted of 10 major categories and 27 subcategories. A classification decision tree and written description (Appendices A and B) was developed to clarify the classification. Though based largely on Level III of the Viereck *et al.* (1992) classification, some classes have been modified, added or omitted for the earth cover mapping projects: e.g., rock, water, ice, cloud and shadow classes were added. Other classes that could not reliably be discerned from satellite imagery were collapsed, such as open and closed low shrub classes, or dryas, ericaceous, willow, and dwarf shrub classes. Because of the importance of lichen for site characterization and wildlife, and because the presence of lichen can be detected by satellite imagery, shrub and forested classes with and without a component of lichen were distinguished. A few classes from Level IV of the Viereck *et al.* (1992) classification were also mapped because of their identifiable satellite signature and their importance for wildlife management. These Level IV classes included tussock tundra and low shrub tussock tundra.

Image Preprocessing

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

Table 2. 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		

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

An unsupervised classification was used to identify spectrally unique areas within the study area. The image analyst individually selected training sites from these spectrally unique areas. Whenever possible, training sites were grouped in clusters to reduce the amount of travel time between sites. The image analyst also tried to place training sites near landmarks that were easily recognizable in the field, such as lakes, streams, or abrupt changes in cover type.

A tally of the estimated number of field sites per class was kept until all of the target map classes were adequately sampled throughout the project area. The coordinates of the center points of the field sites were then uploaded into a Y-code Rockwell Precision Lightweight GPS receiver (PLGR) for navigational purposes. Training sites were overlain with the satellite imagery and plotted at 1 inch = 1 mile scale. These field maps were used for recording field notes, placing additional field sample sites, and navigating to field sites.

Field Verification

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

To obtain a reliable and consistent field sample, a custom field data collection form (Kempka *et al.*, 1994) was developed and used to record field information (Figure 5). A five person helicopter crew performed the field assessment. Each crew consisted of a pilot, biologist, recorder, navigator, and alternate. The navigator operated the GPS equipment and interpreted the satellite image derived field maps to guide the biologist to the pre-defined field site. It was valuable for the image processor to gain first-hand knowledge of the project area, therefore the image processor also fulfilled the role of the navigator. The biologist identified plant species, estimated the percent cover of each cover type, determined the overall earth cover class, and photographed the site. The recorder wrote species percentages and other data on the field form and generally assisted the biologist. The alternate was responsible for crew flight following, data entry, and substitution in case of sickness. The majority of sites were observed without landing the helicopter. Ground verification was performed when identification of dominant vegetation was uncertain.

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

Field Data Analysis

The collected field information was entered into a digital database using the Ducks Unlimited Field Form (DUFF) custom data entry application, designed jointly by the BLM and DU and programmed by GeoNorth. 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 6). The application utilized pull down menus to minimize keystrokes and checked for data integrity to minimize data entry errors. The database program also calculated an overall class name for each site based on the recorded species and their cover percentages. Digital images from each site were stored in the database and accessible from within the user interface. The number of field sites per earth cover class was tracked daily to ensure that adequate samples were being obtained within each class.

Classification

Every image is unique and presents special problems in the classification process. The approach used in this project (Figure 7) has been proven successful over many years. The image processor was actively involved in the field data collection and had first hand knowledge of every training site. The image processor's site-specific experience and knowledge in combination with high quality ancillary data overcame image problems and produced a high quality, useful product.

Erdas Imagine (vers. 8.4) was used to perform the classification. ArcInfo (vers. 7.2.1) was utilized to manage the field site polygons. Various word processing and data analysis software were also used during the image classification including 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, the Normalized Difference Vegetation Index (NDVI), was generated for this project. The NDVI was highly correlated with the 4/3 ratio, a band ratio that typically reduces the effect of shadows in the image and enhances the differences between vegetation types (Kempka *et al.* 1995, Congalton *et al.*, 1993). In addition, the NDVI has been correlated with various forest and crop canopy characteristics such as biomass and leaf area index. This NDVI band replaced the thermal band (band 6) to retain a 7-band image for classification.

Rev 7/15/97

Sample Field Form

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

%Slope (Avg) 45 | Elev | Aspect: N NE E (SE) S SW W NW Flat

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

(Circle Lichen where present)

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

TREES

%Cov	Height	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

SHRUBS

%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	Artostaphylos spp.
		Kinnikinnick	Artostaphylos uva-ursi
		Crowberry	Empetrum nigrum
		Alpine Azalea	Loiseluria procumbens
		Mountain Avens	Dryas spp.
		Mountain Bell Heather	Cassiope tetragona
		Labrador Tea	Ledum palustre
5	0.4	(Rose)	Rosa acicularis
		Cinquefoil	Potentilla spp.
		Fireweed	

HERBACEOUS

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

HERBACEOUS con't

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

AQUATIC

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

NON-VEGETATED

%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 M NEED. NPS 8/17

Figure 5. Example custom field data collection form.

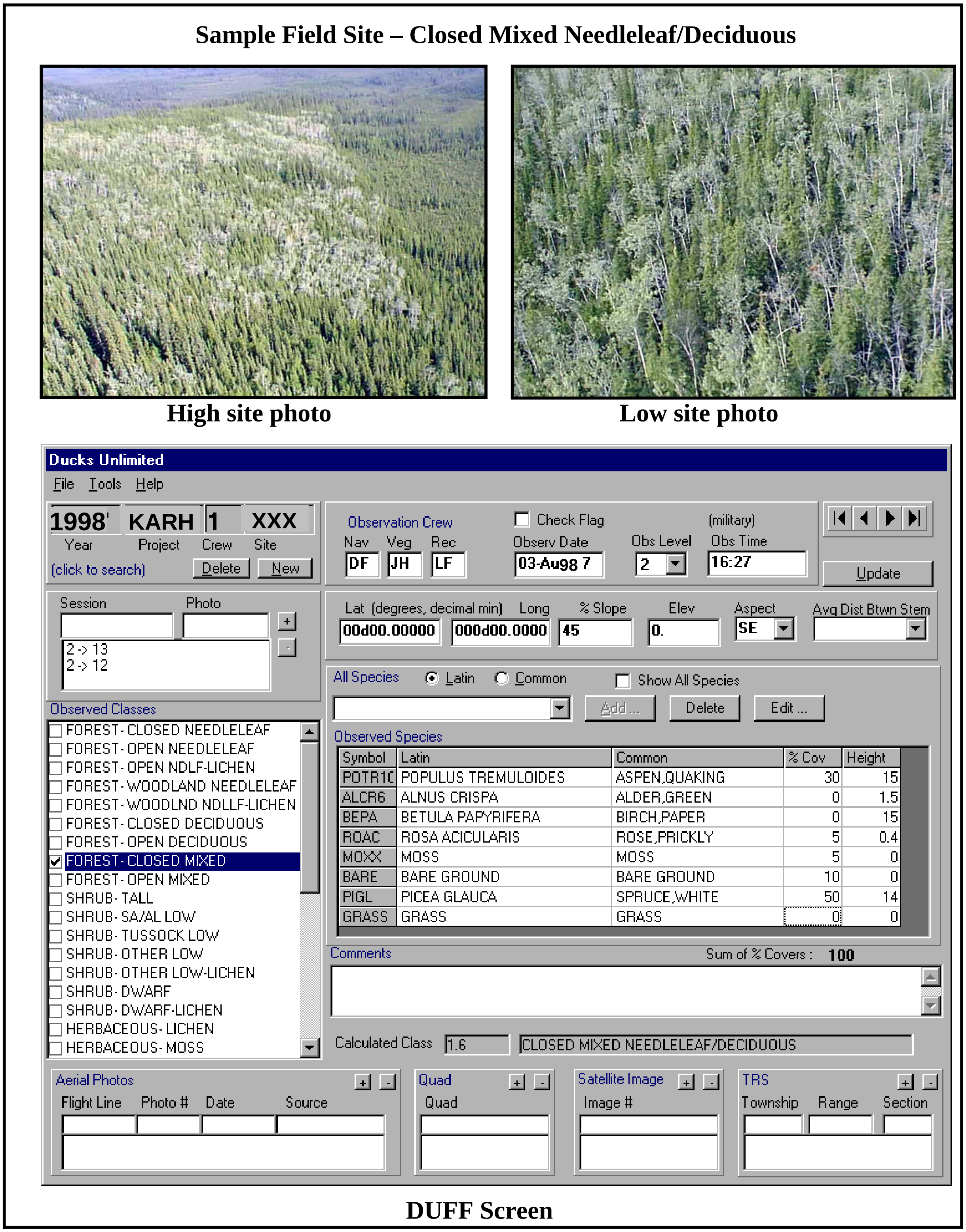

Figure 6. The customized database and user interface for field data entry (DUFF).

Removal of Clouds and Shadows

Clouds and cloud shadows in the path 72 and path 74 images were removed using an unsupervised classification and manual on-screen digitizing prior to the selection of field sites. No clouds were present in the path 73 images. The cloud free images for path 73 were not available until after the fieldwork was completed. For this reason, there are portions of the project area that contain no field sites despite being cloud free on the path 73 images. There was a large area of the path 73 image obscured by smoke from a fire burning at the time of image acquisition. The smoke area was removed using an unsupervised classification and on-screen digitizing. The degree to which the image was obscured by smoke varied greatly. It was left to the image processor's judgement as to whether partially obscured areas were labeled with an earth cover class or labeled as smoke. In general, attempts were made to classify earth cover in lightly obscured areas but more heavily obscured areas were labeled as smoke.

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

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

Seeding Process

Spectral signatures for the field sites to be used as training areas were extracted from the imagery using a "seeding" process in Erdas Imagine. A pixel within each training area was chosen as a "seed" and adjoining pixels in the training site were evaluated for inclusion using a threshold value based on a spectral Euclidean distance. The standard deviations of the seeded areas were kept close to or below 3 and all seeded areas were required to be over 15 pixels (approximately 3.75 acres) in size. Along with the field training areas, additional "seeds" were generated for clear water, turbid water, and snow classes. These classes were easily recognizable on the imagery and aerial photography. The output of the seeding process in Imagine was a signature file that contained all of the statistics for the training areas. The signature file was then used in the modified supervised/unsupervised classification.

Generation of Unsupervised Signatures

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

Modified Supervised/Unsupervised Classification

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

Editing and Modeling

Models that incorporated ancillary data sets such as elevation, slope, aspect, shaded relief, or hydrography helped to separate confused classes. For instance, terrain shadow/water confusion was easily corrected by creating a model using a shaded relief layer derived from DEMs. For this project, the final steps of the classification process were to model the confused classes remaining after the iterative supervised/unsupervised classification process and to make final edits in areas that still had classification errors. Editing of classification errors was a process of comparing the classified image to the raw satellite image, aerial photography, and notes on field maps to identify errors remaining in the classification. These errors were then corrected by manually changing the class value for the pixels that were classified in error to their correct class value.

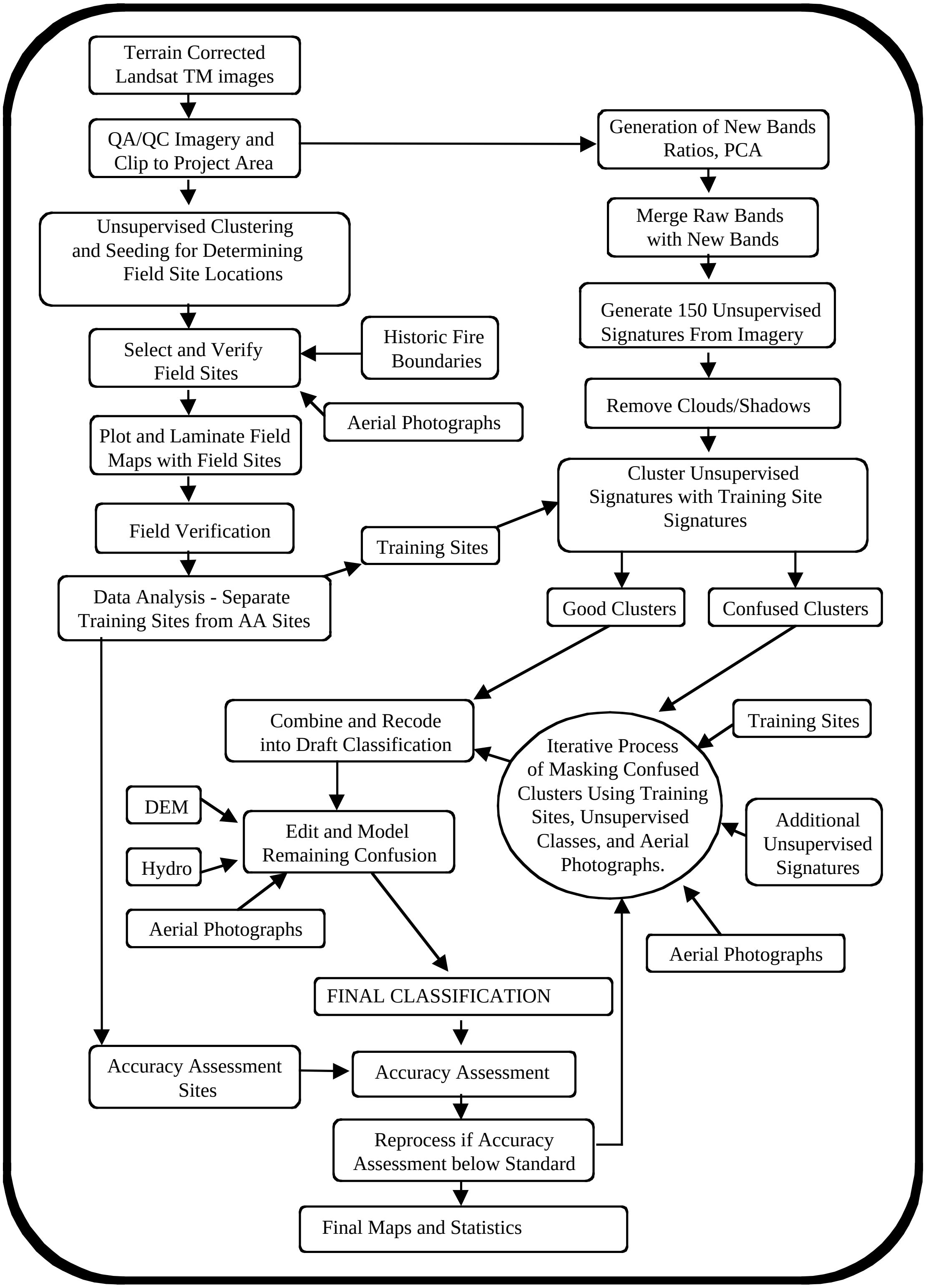

Figure 7. The image processing flow diagram

Accuracy Assessment

There were two primary motivations for accuracy assessment: (1) to understand the errors in the map (so they can be corrected), and (2) to provide an overall assessment of the reliability of the map (Gopal and Woodcock, 1992). Factors affecting accuracy included the number and location of test samples and the sampling scheme employed. Congalton (1991) suggested that 50 samples be selected for each map category as a rule of thumb. This value has been empirically derived over many projects. A second method of determining sample size includes using the multinomial distribution and specifying a given confidence in the estimate (Tortora 1978). The results of this calculation tend to favorably agree with Congalton's rule of thumb. Once a sample size is determined, it must be allocated among the categories in the map. A strictly proportional allocation is possible. However, the smaller categories in area extent will have only a few samples that may severely hamper future analysis. The other extreme is to force a given number of samples from each category. Depending on the extent of each category, this approach can significantly bias the results. Finally, a sampling scheme must be selected. A purely random approach has excellent statistical properties, but is practically difficult and expensive to apply. A purely systematic approach is easy to apply, but could result in sampling from only limited areas of the map.

Alaska Perspective

Obtaining adequate reference data for performing an accuracy assessment can be extremely expensive in remote areas. Aircraft is the only means of transportation throughout most of Alaska. Aerial photographs are available for most of Alaska, but most are at a scale that makes it difficult if not impossible to distinguish some vegetation classes. Ideally, fieldwork would be performed during one summer, the classification would be performed during the winter, and the reference data would be collected the next summer. This procedure would allow a stratified random sample of the classification and ensure adequate sampling of all the classes. Unfortunately, this methodology is not typically feasible due to the cost of obtaining the field data in Alaska.

In this project, the fieldwork for obtaining the training sites for classifying the imagery and the reference data for the accuracy assessment was accomplished at the same time. Special care was taken during the preprocessing stage and in the field to make sure adequate samples were obtained. However, funding limitations did not allow for the number of samples suggested for each class (n=50) for the accuracy assessment. Some earth cover classes were naturally limited in size and distribution so that a statistically valid accuracy assessment sample could not be obtained without additional field time. For classes with low sample sizes few, if any, field sites were withheld for the accuracy assessment. This does not indicate that the classification for these types is inaccurate but rather that no statistically valid conclusions can be made about the accuracy of these classes.

However, withholding even a small percentage of sites for the accuracy assessment provided some confidence in the classification and guided the image processor and end user in identifying areas of confusion in the classification.

Selection of Accuracy Assessment Sites

Approximately 30% of the collected field sites were set aside for use in the assessment of map accuracy while the remainder were utilized in the classification process. Unfortunately, given time and budget constraints it was not always possible to obtain enough sites per class to perform both the classification and a statistically valid accuracy assessment. A minimum of 15 sites in an individual class (5 for accuracy assessment, 10 for image processing training sites) were required before any attempt was made to assess the accuracy of that class. Classes with less than 15 field sites were still classified, but all field sites were utilized during the classification process and none were withheld for later use in accuracy assessment. Accuracy assessment sites were selected randomly across the project area to reduce bias.

Qualification of Accuracy Assessment Standards

While the accuracy assessment performed in this project was not a statistically robust test of the classification, it gives the user some confidence in using the classification. It also provides enough detail for the end user to determine where discrepancies in the classification may cause a problem while using the data. It is also important to note the variations in the dates of the imagery, aerial photographs, and field data. For this project, the imagery was from 1992 and 1999; the aerial photographs spanned a seven-year period from 1980 through 1987, and the field data was collected in July 1998. Differences due to environmental changes from the different sources may impact the accuracy assessment. Primarily this affects the path 74 classification where several earth cover changes occurred throughout the study area during the 7 years between the acquisition date of the satellite imagery and the date of field data collection. These changes are most noticeable in areas of past fire activity, where the image shows the predominance of snags and litter that resulted from the fire, but the field data shows the presence of naturally occurring post-fire re-vegetation. Other changes result from river/stream channel meandering, and re-vegetation of formerly sparse or barren areas such as gravel bars. The objective of this mapping project was to classify and map earth cover conditions as they existed at the dates of the satellite images: 1992 for the areas mapped with the path 74 imagery, and 1999 for the areas mapped with the path 73 imagery. Capturing field data in 1998 for training and accuracy assessment of 1992 imagery obviously results in the potential introduction of error and/or variation in human interpretation of land cover composition that may impact the reliability and consistency of the reference accuracy assessment and training site data.

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

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

Error Matrix

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

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

Results

Field Verification

Data were collected on 547 field sites during a 16-day field season from July 14, 1998 through July 29, 1998 (Figure 8). 464 sites were in the area covered by the path 73 image. 83 sites were on the path 74 image. Daily flight time did not exceed 6 hours. The proportions of sites per class (Table 3) largely reflected the proportions of corresponding earth cover types within the project area, though proportionally more sites were collected for classes that exhibited greater variation in growth form and/or spectral response on the satellite imagery. Approximately 30% (134) of the path 73 field sites were set aside for accuracy assessment and not used in any phase of the image classification. All field sites in the path 74 image were used both for training the classification and for accuracy assessment. Although this was not the proper methodology for an accuracy assessment, it was the only option

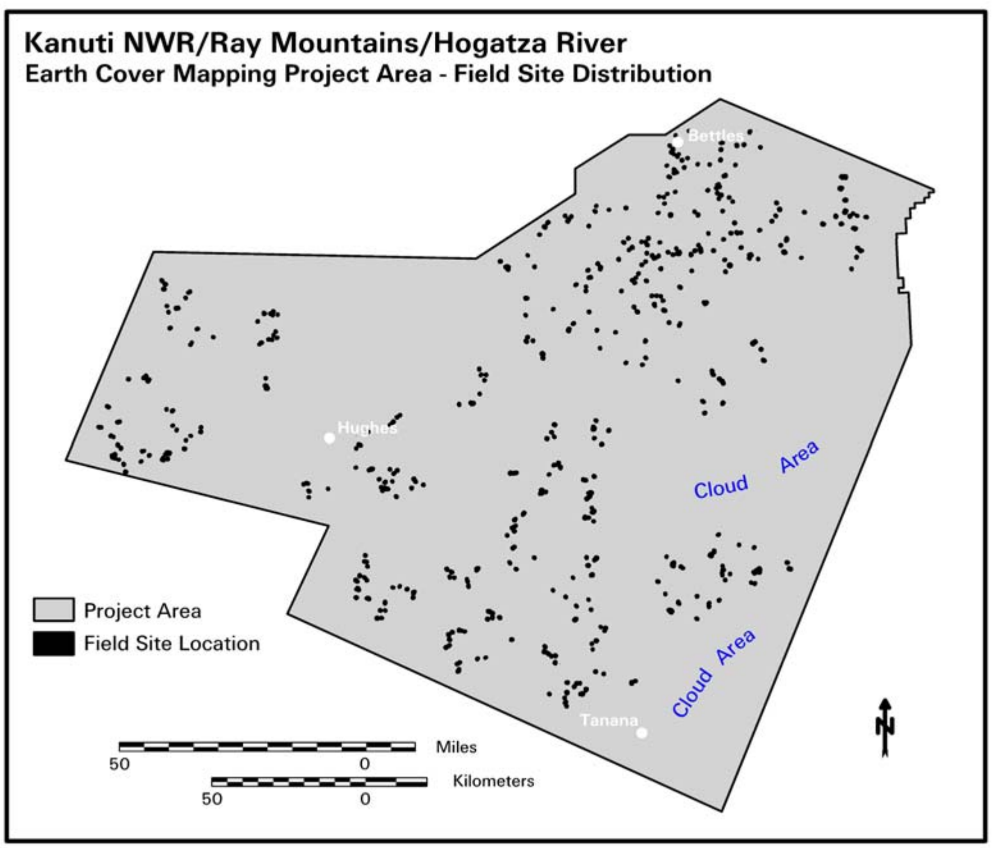

Figure 8. Distribution of field sites for the Kanuti/Ray Mountains/Hogatza River project area.

Table 3. Field sites and accuracy assessment sites per class for Kanuti/Ray Mountains/Hogatza River project.

Class Name	Path 73 Total Field Sites per Class	Path 73 Sites Withheld for Accuracy Assessment	Path 74 Total Field Sites per Class	Path 74 Sites Used for Accuracy Assessment
CLOSED NEEDLELEAF	15	5	5	5
OPEN NEEDLELEAF	48	16	5	5
OPEN NEEDLELEAF – LICHEN	17	6	3	3
WOODLAND NEEDLELEAF	35	11	5	5
WOODLAND NEEDLELEAF – LICHEN	15	5	1	1
CLOSED DECIDUOUS	41	14	10	10
OPEN DECIDUOUS	20	7	0	0
CLOSED MIXED NEEDLELEAF / DECIDUOUS	18	6	7	7
OPEN MIXED NEEDLELEAF / DECIDUOUS	18	6	0	0
TALL SHRUB	40	13	5	5
LOW SHRUB – OTHER	34	11	7	7
LOW SHRUB – LICHEN	7	4	0	0
LOW SHRUB – TUSSOCK TUNDRA	39	13	3	3
LOW SHRUB – WILLOW/ALDER	4	0	0	0
DWARF SHRUB – OTHER	18	5	2	2
DWARF SHRUB – LICHEN	9	4	2	2
LICHEN	13	0	0	0
MOSS	11	0	3	3
WET GRAMINOID	7	0	8	8
MESIC / DRY GRAMINOID	2	0	6	6
TUSSOCK TUNDRA	21	8	1	1
TUSSOCK TUNDRA – LICHEN	3	0	0	0
AQUATIC BED	8	0	3	3
EMERGENT VEGETATION	7	0	4	4
SPARSE VEGETATION	6	0	1	1
CLEAR WATER	1	0	0	0
ROCK GRAVEL	6	0	0	0
OTHER	1	0	2	2
TOTAL	**464**	**134**	**83**	**83**

considering the limited number of field sites. Bell Long Ranger helicopters were used to gain access to the field sites. For the BLM crew, field camps were located at the Fish and Wildlife Service bunkhouse in Bettles, the BLM/Alaska Fire Service fire station in Tanana, and the U.S. Air Force facilities at Indian Mountain. Commercial fuel was purchased at Bettles. Barrel fuel was stored at Tanana and Indian Mountain. In addition, a remote fuel cache was set up at the Hogatza Mine landing strip on the far, western side of the project area. For the Kanuti Refuge crew, all fieldwork was done from the Refuge bunkhouse in Bettles. In addition to the fuel at Bettles, a small supply of fuel was transported down Fish Creek to use as a remote fuel site. A remote fuel cache at the Fish and Wildlife Service cabin within the refuge was unusable because of excessive flooding of the lake near the cabin.

Classification

32 earth cover classes were mapped in the final earth cover map (Figure 9). Table 4 presents the total acreage per class. Class acreage by ownership is presented in Appendix C, tables C1-C6. The three most extensive vegetative classes within the final classification were open needleleaf (21.7% of total area), low shrub (8.7% of total area), and woodland needleleaf (8.2% of total area). This agrees with observations made during field data collection. Large expanses of open/woodland spruce interspersed with low shrub and tussock tundra was typical of the project area, especially at lower elevations. Tussock tundra and low shrub tussock tundra cover types were also found on relatively flat areas and toe slopes at higher elevations where soil types appeared to be wetter. These high elevation tussock areas often differed from lower elevation tussock cover types in that a tussock forming *Carex* species made up the most significant portion of the tussocks. At lower elevations, tussocks were nearly always

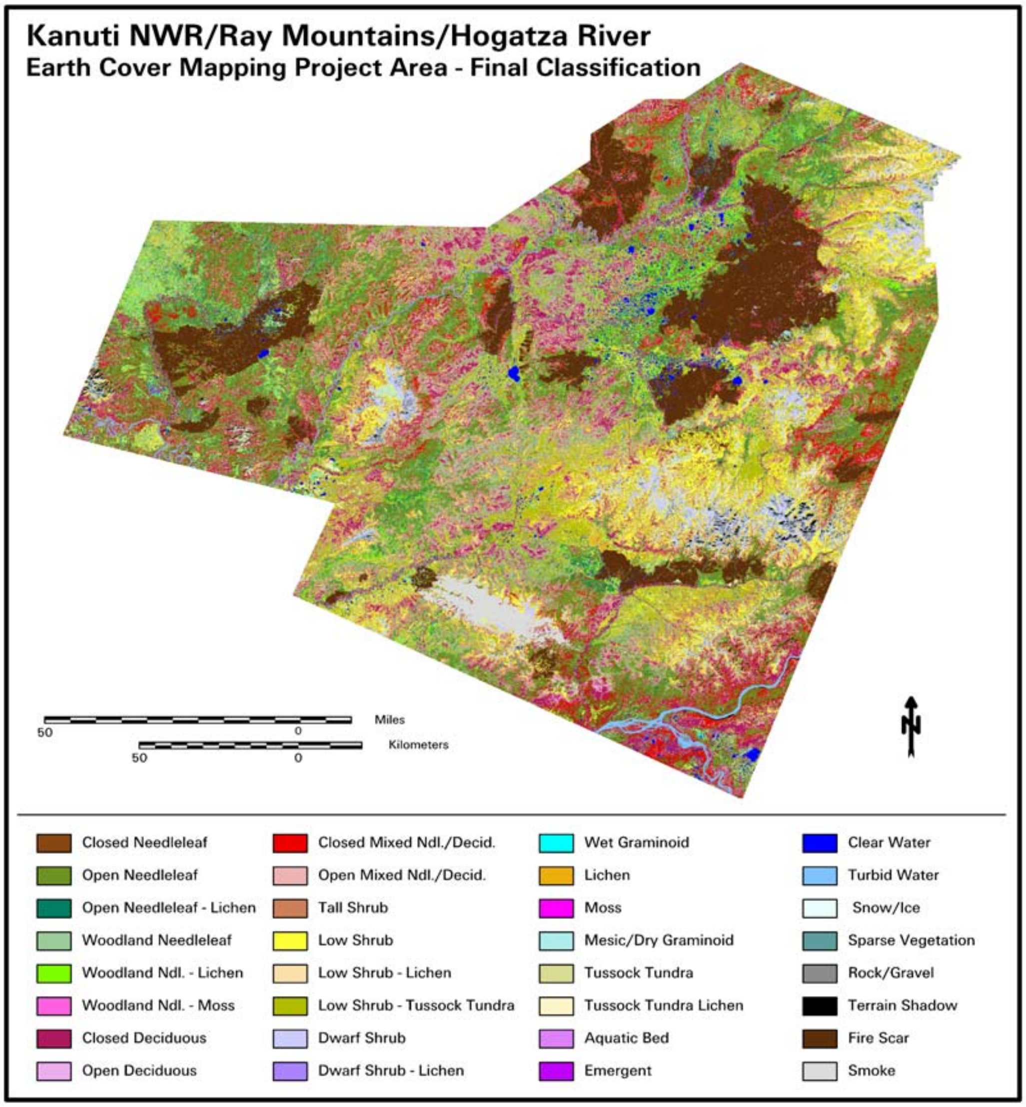

Figure 9. Kanuti NWR/Ray Mountains/Hogatza River project earth cover map.

comprised of *Eriophorum vaginatum* only. The higher elevation tussocks, especially those formed by the *Carex* species, were also much smaller in size than the *Eriophorum* tussocks found at lower elevations. These higher elevation tussocky sites were often spectrally similar to mesic/dry graminoid sites, and to dwarf shrub sites that contained a significant herbaceous component.

The mountainous uplands were characterized by dwarf shrub, low shrub, tall shrub, sparse vegetation, rock/gravel, and dwarf shrub – lichen cover types. There was difficulty in discriminating between dwarf shrub and dwarf shrub – lichen cover types on the path 73 images. Most training sites for both cover types included high percentages of rock, which dominated the signature and made it difficult to separate the two classes. In addition, several of the dwarf shrub lichen sites were on steep, shaded, north or west facing slopes which made it difficult to obtain signatures that were consistent with other portions of the image. As a result of these difficulties, no attempt was made to distinguish dwarf shrub – lichen from dwarf shrub in the path 73 classification. All areas classified as dwarf shrub – lichen in the final earth cover classification were in the area classified using the path 74 image.

Open and closed deciduous cover types were typically found on well-drained slopes, and on the broad alluvial plains of large rivers. Open deciduous stands were also common in areas regenerating from fire disturbance. Paper birch (*Betula papyrifera*) was by far the most common deciduous tree. Balsam poplar (*Populus balsamifera*) stands were less common and found exclusively along river flood plains and drainages. Aspen (*Populus tremuloides*) stands were found on the most well-drained slopes, especially in recently burned areas. Due to a limited number of balsam poplar and aspen field sites as well as to their spectral similarity to paper birch, attempts to distinguish birch, poplar, and aspen sub-classes within the open and closed deciduous cover classes were unsuccessful and therefore not included in the final classification.

Open and closed mixed needleleaf deciduous stands were most commonly associated with river drainages and flood plains, and with well-drained hillsides. There were three different growth forms of the open mixed needleleaf/deciduous class. The first included mature stands of large, openly-spaced mixed spruce and deciduous trees typically found on well-drained, productive sites. The second was typically found in successional areas and consisted of openly spaced, smaller, sapling-sized spruce and deciduous trees. This form was the least common of the three. The third was similar in appearance to the second growth form, but was found on poorer sites. These appeared to be open needleleaf sites of marginal productivity with an encroachment of stunted birch and aspen scattered in with the more dominant spruce. Spectrally, this third growth form was very similar to open needleleaf sites that had a heavy tall shrub component in the understory.

Closed canopy needleleaf stands were primarily stands of large white spruce (*Picea glauca*) found along major river drainages. Occasionally white spruce stands on hillsides attained a closed canopy also. This was especially true in the hilly areas along the Tozitna River and north of the Yukon River. Closed mixed needleleaf/deciduous stands also were found along river drainages and were common on hill slopes.

The aquatic bed, emergent vegetation, and wet graminoid classes were most commonly

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

CLASS NAME		ACRES	PERCENT COVER
Closed Needleleaf		131,878	1.47%
Open Needleleaf		1,953,346	21.72%
Open Ndl. – Lichen		170,919	1.90%
Woodland Needleleaf		735,850	8.18%
Woodland Ndl. – Lichen		154,442	1.72%
Woodland Ndl. – Moss		3,546	0.04%
Closed Deciduous		576,398	6.41%
Open Deciduous		133,171	1.48%
Closed Mixed Ndl./Decid.		433,453	4.82%
Open Mixed Ndl./Decid.		657,004	7.31%
Tall Shrub		635,560	7.07%
Low Shrub		789,026	8.74%
Low Shrub – Lichen		15,059	0.17%
Low Shrub - Tussock Tundra		618,290	6.88%
Dwarf Shrub		313,201	3.48%
Dwarf Shrub – Lichen		6,192	0.07%
Wet Graminoid		49,663	0.55%
Lichen		40,744	0.45%
Moss		5,070	0.06%
Mesic/Dry Graminoid		26,159	0.29%
Tussock Tundra		105,681	1.18%
Tussock Tundra – Lichen		57,074	0.63%
Aquatic Bed		21491	0.24%
Emergent Vegetation		2,861	0.03%
Clear Water		104970	1.17%
Turbid Water		61,290	0.68%
Snow/Ice		1,337	0.01%
Sparse Vegetation		64,251	0.71%
Rock/Gravel		67,346	0.75%
Terrain Shadow		32,077	0.36%
Smoke		90,164	1.00%
Fire Scar		331,152	3.68%
Fire Scar – Regeneration		606,597	6.75%
Regeneration Class	Acres		
Open Needleleaf	57,670		
Wdlnd. Ndllf.	22,258		
Wdlnd. Ndl. Lichen	517		
Closed Deciduous	283		
Open Deciduous	2,605		
Open Mixed Ndl./Dec.	996		
Tall Shrub	148,11		
Low Shrub	109,432		
Low Shrub Tussock Tundra	226,090		
Tussock Tundra	38,735		
Total	606,597		
Total		**8,992,262**	**100%**

found in and around the innumerable ponds and lakes within the Kanuti NWR. They were also common around the lakes and ponds throughout flat lowlands in the remainder of the project area. There was wide variation in the spectral signatures of all three of these cover classes depending on the percentage of water present. When a high percentage of water was present, there was spectral confusion not only between these three classes, but also with the closed needleleaf, open needleleaf, and terrain shadow classes. Jensen (1986) states that a 5/2 band ratio is useful in discriminating wetlands. To alleviate the spectral confusion between these aquatic/wet classes and the needleleaf classes in the path 73 image, a 5/2 band ratio was added to the image. This new image was then run through several iterations of unsupervised classifications to separate the aquatic classes from the needleleaf classes. This was somewhat successful in limited portions of the image, but a great deal of on-screen digitizing, using aerial photos as reference, was still needed to separate these classes across the rest of the image.

Wildland fire plays a significant role in the ecology of the project area and has significant impact on the vegetative regimes within the project area. The effect of fire on the landscape was evident in the spectral signatures detected by the Landsat TM imagery even many years after a fire burned through the area. The presence of post-fire snags and litter as well as patches of bare soil are the most likely cause of changes in spectral reflectance in these areas. The ability to collect suitable spectral data for vegetative regeneration in these areas is severely limited by several factors. First, snags and litter do not absorb any infrared wavelengths. In areas with significant percentages of snags and litter, the high reflectance in these wavelengths seems to overshadow the signatures of vegetation in the area. Second, vegetative succession occurs rapidly in many burned areas. Field data must be collected in very close proximity to the date of image acquisition, or significant discrepancies can occur between the vegetation represented by the field data and the vegetation represented by the spectral signatures within the image. Third, fires of many ages result in vegetative succession in many stages and with a variety of spectral reflectance. The ability to collect a suitable number of field sites to fully represent this wide range of spectral reflectance is not possible in the limited time allotted for field data collection without seriously reducing the number of field sites visited in the non-burned portions of the project area.

Nearly 1 million acres of the project area were characterized as having spectral signatures indicating recent wildfire activity. At the time of field data acquisition all available satellite imagery was 3 or more years old and, therefore, field sampling was limited in these post-fire areas. Pre-selected field sites within the post-fire areas were visited during the early stages of the fieldwork but it quickly became apparent that changes in vegetation were occurring. Even while using GPS receivers to navigate to these sites it was difficult to verify that the site being described in the field coincided with the site indicated on the satellite image field maps. A total of 33 field sites in post-burn areas were visited during the fieldwork.

For the final earth cover classification, post burn areas were treated separately from non-burned areas. Post-burn areas were masked out of the image and an unsupervised classification was run on these areas in an attempt to identify regeneration classes within the burns. Pixels with signatures that were highly impacted by the presence of snags, litter, or bare soil, and showed little indication of the presence of regeneration were labeled as a general “fire scar” class. For pixels that had a significant vegetative signature, attempts were made to assign an earth cover class label using the field sites collected in the post-fire areas as training sites. To differentiate these post-fire pixels labeled with earth cover regeneration classes from the non-burned areas labeled with the same earth cover classes, the post-burn regeneration pixels were coded with values of 100 or greater in the final earth cover classification. For example, the low shrub – other class is coded as class #21 in the non-burn areas of the map. The fire-scar regeneration low shrub – other class is coded as class #121. Similarly, non-burn tall shrub is class #20, and fire scar regeneration tall shrub is class #120. Two color schemes are provided with the final earth cover classification. The first displays all fire-scar regeneration classes in one color to identify areas of fire history where field sampling was limited (Figure 9). The second displays the fire-scar regeneration classes using the same color scheme as the non-burn areas (Figure 10).

Modeling

Modeling was performed using shaded relief, slope and elevation images derived from USGS DEMs at 1:63,360 scale. The shaded relief image was created in Erdas Imagine using the solar azimuth and solar elevation listed in the header file for the path 73 TM image. The elevation layer was created by grouping the DEM into 250 ft. elevation zones. The slope image was created using the “Slope” function in Erdas Imagine. The slope unit was defined as percent slope rather than degree of slope. This allowed for ease of comparison with the field site data sets in which slope was also estimated as percent slope. It is important to note that the modeling process was used primarily to identify *potentially* misclassified cover types throughout the study area. In order to maximize the reliability and classification accuracy in this mapping effort, manual review and editing techniques were utilized to correct the misclassified pixels to their appropriate mapping classification.

Approximately 32,000 acres or 0.36% (Table 4) of the project area was modeled and edited to the terrain shadow class. A much larger portion of the image was affected by shadows, but not completely blackened by those shadows. The majority of these areas were labeled with an earth cover class, but some areas were too dark to discriminate. Attempts were made to classify any areas that showed even a small degree of spectral reflectance, but it was left up to the image processor’s judgement whether or not to edit the shadowed area into the terrain shadow class.

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

Elevation modeling was also used to aid in classifying the dwarf shrub class. Dwarf shrub was typically found on mountaintops. Some dwarf shrub signatures were spectrally confused with tussock tundra – lichen and wet graminoid signatures. Dwarf shrub pixels below 2000 feet elevation were "flagged" with an elevation model for further review. Most of these could be relabeled to the tussock tundra – lichen or wet graminoid classes. Dwarf shrub was occasionally found on wide gravel bars at lower elevations.

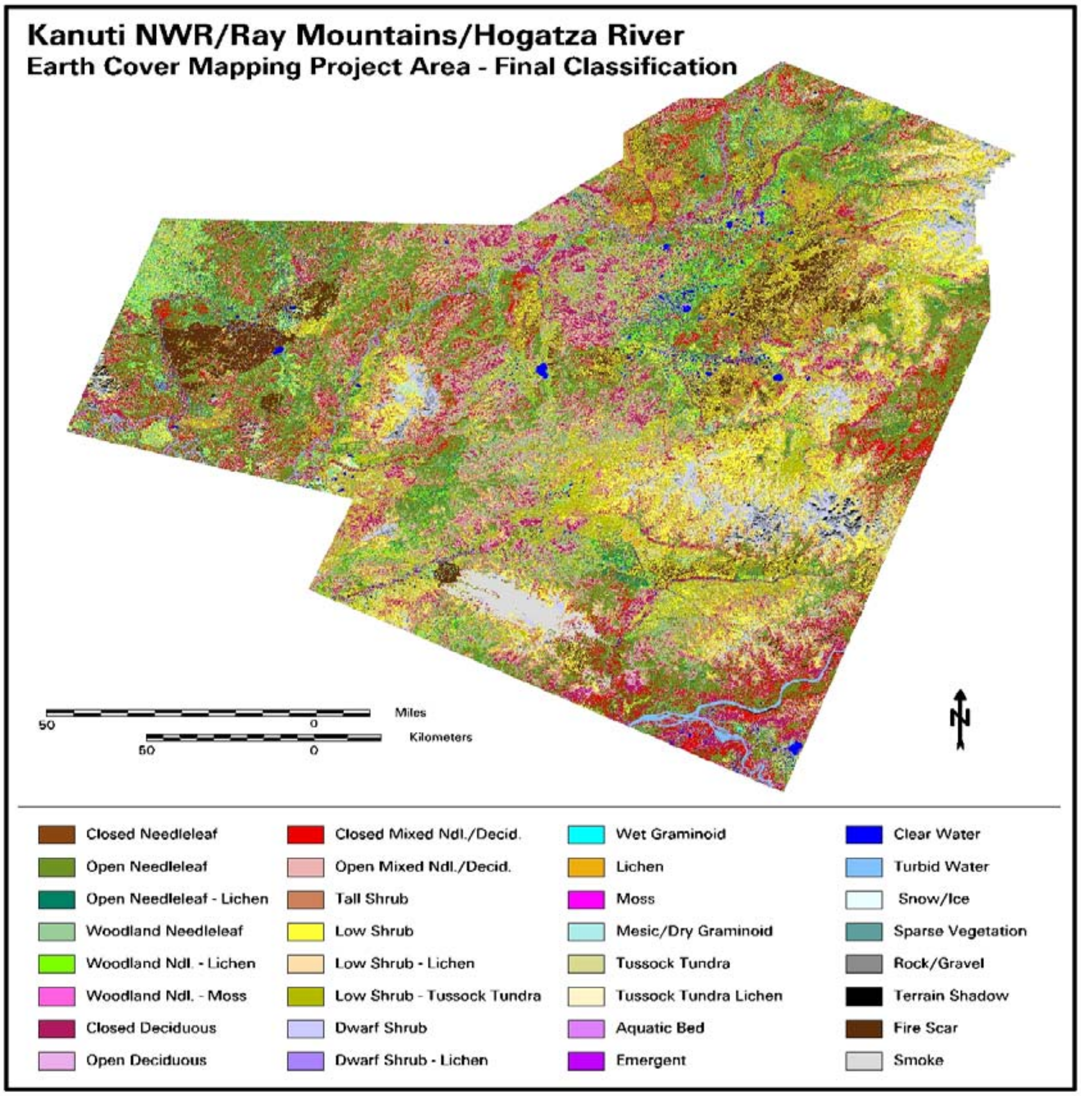

Figure 10. Kanuti NWR/Ray Mountains/Hogatza River project earth cover map – color scheme #2.

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

Editing

Editing was performed on all classes to various extents depending on how well the iterative classification and modeling processes worked for each. The edits were verified with field sites, aerial photography and field notes wherever possible. Some editing centered on ecological differences across the project area. For example, a single signature classified low shrub in the flats within and around Kanuti NWR and dwarf shrub in the Ray Mountains. Editing in this case consisted of correctly labeling and separating classes along ecological boundaries. Because the project area was relatively diverse, this kind of editing was often necessary, especially in the transitional areas from treeline into the low shrub/dwarf shrub/sparse vegetation zones.

Editing was also required to classify areas that fell in the middle of the gradient between one class and another, e.g., between woodland needleleaf and shrub. A woodland area of 10-15% trees was easily confused with a shrub area of 5-9% trees. The most prevalent example of the confusion within the gradient between classes was found between open- and woodland needleleaf. As evidenced by the field training sites, a large number of the open and woodland needleleaf classes exhibited a tree crown cover between 20% and 30%. Similarly, low shrub areas at a height of .3 meters were confused with dwarf shrub areas with a height of .2 meters. Also, low shrub areas at a height of 1 meter were confused with tall shrub areas of only 1.5 meters in height. These transitional areas and signatures had to be examined and a classification decision made based on the available data. In some cases, a single pixel fell across two cover types, for example, between a lake and the land surrounding it. These half-water, half-land signatures were often confused with emergent and open needleleaf signatures. Many of the small lakes and ponds had a 1 pixel wide ring of open needleleaf or emergent surrounding them in the classified map after the combined supervised/unsupervised classification was completed. Editing was done to separate legitimate emergent, and open needleleaf pixels based on aerial photography, field notes and topography. Too many lakes, ponds, and wetlands were scattered throughout the image to confidently say that all confusion between the open needleleaf and water/land pixels was edited out of the maps. Undoubtedly, some lakes and ponds in the final classification will contain an erroneous scattering of open needleleaf pixels.

The wet graminoid and emergent classes were also heavily edited based on aerial photography and field notes. These cover types commonly required extra editing because they were generally both limited in extent and highly variable. Emergent vegetation typically occurred in narrow strips, often only a few pixels wide, making it very difficult to obtain reliable ground samples. Wet graminoid sites were more extensive and common, but they were highly variable with respect to spectral reflectance. Small differences in soil moisture content, density of vegetation, and the proportion of senescent plants drastically affected the reflectance values. Standing water created a very dark signature, while senescent plants created a very bright signature. Wet graminoid signatures were confused with a wide variety of other cover types including open needleleaf, open and closed mixed needleleaf/deciduous, low shrub, emergent, moss, dwarf shrub, and even open and closed deciduous. Each of these conditions was edited manually to ensure consistency and reliability in the final representation of each affected class.

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

Accuracy Assessment

Some earth cover classes were not adequately represented in the field data available for training and accuracy assessment, primarily because of their scarcity within the project area, e.g., low shrub-lichen, open deciduous, open and woodland needleleaf lichens, open and closed mixed needleleaf/deciduous. In the past, classes with an inadequate sample size were collapsed into the next hierarchical cover type for accuracy assessment of the classification. This grouping often resulted in only 8-10 accuracy assessment classes vs. the 30+ classes present in the classification. In addition, this approach grouped classes based solely on their specific mapping class labels versus grouping individual sites based on their ecological composition or function. By grouping classes in this manner, one loses all ability to evaluate and measure the relationship between regions of the map that classify nicely into the “heart” of a mapping class and those regions that occur on the classification and ecological boundaries between the discrete mapping classes. For example, at field site #2030 (Figure 10) the vegetation caller interpreted the site to contain 22% tree cover (17% black spruce, 5% paper birch, and 78% various shrub and herbaceous understory species). This interpretation results in a woodland needleleaf label for the site. The final classified map labeled the majority of this as open needleleaf. The error matrix would tally this label as an incorrect label. Since the literature generally accepts that even the most experienced visual estimates of earth cover consider a range of variation in interpretation of +/-10% to be acceptable, this particular accuracy assessment site containing 22% tree cover would also be considered acceptably classified as open needleleaf 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.

The error matrices provided in Appendix E - H represent the reliability/accuracy of the earth cover classification. Accuracy assessment data is presented for the path 73 sites separately from the path 74 sites. The error matrices should not be combined to produce one error matrix for the entire project area because the processing was done separately for these two images and then stitched together after the classification for each was completed. The accuracy of classes within the path 73 portion of the map is independent of the class accuracies in the path 74 portion of the map. In the matrices, no lumping of mapping classes has occurred. Therefore, the user can evaluate the performance and interrelationships of *all* mapping classes represented in the final earth cover. The error matrices present values for user's accuracy, producer's accuracy, and the overall accuracy for 0% and +/-5% variation in the vegetation caller's interpretation of the reference data. In the error matrices, numbers along the main diagonal of the matrices indicate exact matches between the reference labels and map labels of the accuracy assessment sites. A tally of these numbers divided by the total number of sites indicates the overall accuracy of the map at the 0% variation in interpretation level. If two numbers occupy a non-diagonal cell, the left number indicates an acceptable match between the reference data site and the map assuming a +/- 5% variation in reference data interpretation. The number on the right indicates the number of sites that are not acceptable matches. A tally of the numbers within the diagonal along with the acceptable numbers in the off-diagonal cells (left number(s)) indicates the overall accuracy of the map at the +/- 5% variation in interpretation level.

A number of important analyses can be made regarding the relationship of the mapped data with the actual vegetation distributions throughout the study area using this method of accuracy assessment. Since the off-diagonal acceptable matches are presented, an indication of the number of field sites that represent vegetation compositions on the boundary of two or more mapping classes is given. The acceptance or non-acceptance of each accuracy assessment site with an off-diagonal map class provides insight into the vegetation composition of that reference site. For instance, in Appendix E, of the ten accuracy assessment sites with a reference label of woodland needleleaf, one site was an acceptable match with open needleleaf, one was a non-acceptable match with open mixed needleleaf/deciduous, and one was a non-acceptable match with low shrub - other. The remainder of the sites (7) were diagonal matches with woodland needleleaf. The off-diagonal matches indicate that at least one of those sites was on the border between woodland and open needleleaf (20-25% 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.

Path 73 Accuracy Assessment

The difference in classification accuracy between the 0% variation in interpretation level, 76% (Appendix E), and the +/- 5% variation in interpretation level, 85%, indicates that a number of the reference data sites were characterized as being on the boundary of two or more mapping classes. As stated earlier, it is generally accepted that variation in interpretation of +/- 10% is common and accepted for human interpreters estimating vegetative crown cover, either from aerial photography or on the ground. When this natural and accepted variation is measured and accounted for (as in the case of the error matrix in Appendix

E), a more reliable and informative measure of accuracy and reliability is presented. At the +/- 5% level of variation the accuracy of all needleleaf classes other than woodland needleleaf was 100%. Accuracy of the woodland needleleaf class was 80%. The lower accuracy for woodland needleleaf is not surprising. With tree crown cover between 10% and 25% in this earth cover class, the majority (75% - 90%) of the signature for these areas was comprised of vegetative species other than spruce. This made the woodland needleleaf class one of the most difficult to map. It could be spectrally confused with nearly any other earth cover class. For example, woodland sites with a significant tall shrub understory could be spectrally confused with the tall shrub class, the open and closed deciduous classes, or the open mixed needleleaf /deciduous class. Sites with a significant low shrub understory were easily confused with the low shrub and low shrub – tussock tundra classes, and sites with 15%-24% spruce were easily confused with open needleleaf sites that had 25%-35% spruce. In addition, woodland needleleaf cover types could be found nearly anywhere throughout the project area. Other than elevation constraints, which limited the presence of woodland needleleaf at the highest elevations, there were no environmental attributes (e.g. – slope, aspect, distance to water, etc.) that could be used in models to differentiate between woodland needleleaf and other spectrally similar classes. The open needleleaf class was similar to the woodland needleleaf class in its confusion with a variety of other cover classes. Again this was the result of very mixed spectral signatures that were dominated by understory species in the many of the open needleleaf sites. Although the producer's accuracy for the open needleleaf class (100% at the 0% level of variation) was very high, it is evident from the user's accuracy for this class (79% at the 0% level of variation) that there was confusion between open needleleaf and other classes. Two conclusions can be drawn from looking at the user's accuracy for the open needleleaf class. First, the high producer's accuracy and lower user's accuracy indicate that too much area is being labeled as open needleleaf on the map. Second, the difference in the user's accuracy at the 0% and +/-5% levels of variation indicate that many of the areas incorrectly classified as open needleleaf are in the transitional areas between the open needleleaf class and the other confused classes.

The open and closed deciduous classes had somewhat lower accuracy than the needleleaf classes in general. This is consistent with past earth cover mapping projects in other parts of Alaska and results from confusion within the deciduous earth cover classes. 75% of the incorrectly classified open deciduous accuracy assessment sites were confused with the closed deciduous class. If these two mapping classes were combined into one general deciduous class, the accuracy would be 80% (16/20) at the 0% level of variation and 85% (17/20) at the +/- 5% level of variation. Most of the confusion with non-deciduous classes occurred with mixed needleleaf/deciduous classes and with the tall shrub class. The mixed needleleaf/deciduous classes also showed somewhat lower accuracy than the needleleaf classes, but because of the small sample size for each of these classes the figures may be unreliable. The error matrix for the training sites used in the classification (Appendix G) presents a larger sample size for these classes. There is bias associated with using training sites to analyze the accuracy of the map so the accuracy figures from this matrix should not be interpreted, but the off-diagonal cells are useful for examining patterns in the data.

As with the pure deciduous classes, much of the confusion in these classes appears to occur between the open and closed mixed classes, and not with other cover types. In general, there appears to be a little too much open mixed needleleaf/deciduous in the final map. In addition to the confusion with the closed mixed needleleaf/deciduous class there is also some confusion with the open and closed deciduous classes, and the woodland needleleaf class.

All of the shrub classes, with the exception of low shrub – lichen (25% at the 0% level of variation), had very acceptable accuracy assessment results. Low shrub – lichen was a difficult class to map because it was relatively uncommon and, when present, was usually found in small patches. In addition it was often found as a very inconsistent or patchy cover type which made it difficult to select a consistent sample of pixels when extracting signatures (Figure 11). Because of this, relatively few areas in the final map are classified as low shrub – lichen. There is probably more low shrub – lichen present within the project area than is represented by the final map. In general, the low shrub – lichen class was most often confused with the low shrub – other, dwarf shrub – other, and dwarf shrub – lichen classes. The low shrub – other class was the most difficult shrub class to map because of its wide variability. This is evident from the relatively large number of off-diagonal sites in the error matrices (Appendix E and Appendix G) that fell into the rows and columns for low shrub – other class. Although the producer's accuracy for low shrub – other was 80%, the user's accuracy was lower (67%) and indicates that there may be too much area labeled as low shrub in the final map. Typically this confusion occurred with other shrub or herbaceous classes and not with the forested classes. The low shrub – tussock tundra class was mapped with high accuracy. The majority of confusion occurred with the tussock tundra class. Dwarf shrub was the only other class that showed confusion with low shrub tussock tundra in the error matrices.

The error matrices also indicate that the dwarf shrub class was mapped with high accuracy. Appendix E indicates that most confusion in this class occurred with the low shrub and low shrub – lichen classes. It is the image processor's opinion that there is also confusion between the dwarf shrub class and the sparsely vegetated and rock/gravel/sand classes. These cover types were typically found at high elevations and on steep slopes that limited safe access by helicopter. As a result, too few field sites were available to withhold any sparsely vegetated or rock/gravel/sand sites for accuracy assessment purposes. However, by examining the off-diagonal cells in the training site error matrix (Appendix G), the confusion between the dwarf shrub and these classes is evident. Three of the twelve sparsely vegetated and rock/gravel/sand training sites were incorrectly mapped as dwarf shrub. All other sparsely vegetated and rock/gravel/sand training sites were mapped correctly. The confusion between these three earth cover classes is due to the large percentage of rock and gravel often present in all three cover types. In addition, models to differentiate the three types were not available because all three cover types are found in similar geophysical locations.

Field sites were limited for several cover types and no accuracy assessment sites were reserved for the following classes: wet graminoid, lichen, moss, mesic/dry graminoid, aquatic bed, emergent vegetation, sparsely vegetated, and rock/gravel/sand. Appendix G presents an error matrix for all the training sites used in

Figure 11. Example of the "patchy" look of many low shrub – lichen areas.

the classification. As stated previously, there is bias associated with this error matrix because the field sites used in this matrix were also the primary source of reference data during the image classification phase. The true accuracy for the overall map and for any individual classes is assumed to be slightly lower than the figures presented in this error matrix. This assumption appears to be true when comparing the accuracy figures in this matrix to the accuracy figures presented in the formal accuracy assessment error matrix (Appendix E). Examination of the training site error matrix does, however, provide some insight into some trends in the data.

A noticeable trend in the training site error matrix was the confusion within the aquatic classes. Both aquatic bed and emergent vegetation sites were often mapped as clear water due to the large amount of water present in their signatures. Although not indicated by the error matrix, there was also significant confusion between the emergent vegetation and wet graminoid classes. Again this was due to the water component in both of these classes and the high degree of influence that water has on spectral reflectance. The bryoid classes, moss and lichen, both had very distinct signatures that were accurately classified. The most difficult aspect of identifying moss areas was their limited size. Moss sites were typically dominated by sphagnum mosses and were found in small, drained lakebeds and ponds. The small size of the moss areas resulted in many of the pixels containing mixed signatures of moss and whatever earth cover type happened to be surrounding the moss, typically low shrub or woodland needleleaf. These "mixed" pixels would sometimes classify as moss and sometimes as low shrub, woodland needleleaf or open needleleaf. Moss sites with a high water content were occasionally confused with emergent or wet graminoid sites. The wet graminoid class was also confused with emergent vegetation and with open and closed needleleaf. The high water content mixed with the vegetation produced a very dark signature that was spectrally similar to these dark needleleaf classes.

It should be noted that no field sites, and therefore no accuracy assessment sites, were captured representing the clear water, turbid water, or snow/ice classes. These classes are among the most straightforward to discriminate and map from Landsat TM satellite imagery. Therefore, the limited field data collection time was focused on capturing data to assist in the discrimination and mapping of the more spectrally and ecologically complex vegetation communities throughout the study area. These two mapping classes accounted for approximately 2% of the earth cover within the project area. Due to their spectral distinctiveness, it is certain that both the user's and producer's accuracy for these classes would be at or very near 100%, thus only acting to improve the overall accuracy calculations for the final earth cover map.

Path 74 Accuracy Assessment

Only 83 field sites were collected in the portion of the project area covered by the path 74 TM image. To produce the best possible map all of the field sites were used in the classification process and none were reserved for accuracy assessment. The error matrix for the path 74 image (Appendix I) is based on the training sites used in the classification process. As explained earlier, there is bias associated with an error matrix produced with this methodology because the field sites used in the matrix were also the primary source of reference data during the image classification phase. The true accuracy for the overall map and the accuracy estimates for each of the individual classes are assumed to be slightly lower than the figures presented by this error matrix. The matrix presents accuracy figures at both the 0% and +/-5% level of variation in the vegetation caller's interpretation of the training sites. There was only a 3% increase in accuracy between the 0% and +/-5% level of variation for the sites in this matrix. This would indicate that few of the off-diagonal training sites were characterized as being on the boundary between two earth cover classes.

The limited number of off-diagonal sites limits the ability to interpret the known errors within the path 74 classification. However, three trends can be seen in the off-diagonal sites of the error matrix. First, the low shrub – other and open mixed needleleaf/deciduous classes appear to contain a significant portion of the error in the final map. This was a result of the wide range of variation within these two classes and of the limited number of field sites available for training of the classification. No open mixed sites were available in the areas mapped using the path 74 imagery. Spectral signatures for this class were extracted in areas of overlap between the path 73 and path 74 images. These areas of overlap were mapped using the path 73 images because of the more recent acquisition date of the path 73 images. A second trend seen in the error matrix is the difficulty in mapping the mesic/dry graminoid class. This resulted from the difficulty in finding mesic/dry graminoid sites of sufficient extent to extract high quality spectral signatures. The third trend seen is the confusion of the aquatic bed and emergent vegetation classes with the clear water class. This confusion was also seen in the path 73 accuracy assessment and is a result of the strong effect that water has on spectral signatures. Error matrices for accuracy assessment sites and training sites in post-burn areas are presented in Appendices F and H, respectively. The sample sizes are very limited but the matrices do indicate the difficulty in accurately classifying the regeneration in post-burn areas. To adequately map these areas, a significant amount of additional fieldwork would be necessary using imagery acquired very near the date of fieldwork. In addition, significant amounts of pre-fieldwork processing would need to be done on the images to plan efficient data collection. All ages of burns would need to be adequately sampled in all earth cover classes. It should also be noted that the biologists involved in the field work for this project often thought that post-burn areas in early stages of regeneration did not easily fit into any one of the earth cover classes described by the classification scheme used for this project. If additional work is done in post-burn areas to identify regeneration there may be reason to consider the development of a revised classification scheme that better suits the early successional vegetation found in these areas.

Discussion

A major assumption of quantitative accuracy assessments is that the label from the reference data represents the "true" label of the site and that all differences between the remotely sensed map classification and the reference data are due to classification and/or delineation error (Congalton and Green, 1993). Unfortunately, error matrices can be inadequate indicators of map error because they are often confused by non-map error differences. Some of the non-map errors that can cause confusion are: (1) registration differences between the reference data and the remotely sensed map classification, (2) digitizing errors, (3) data entry errors, (4) changes in land cover between the date of the remotely sensed data and the date of the reference data, (5) mistakes in interpretation of reference data, and perhaps most significant (6) variation in classification and delineation of the reference data due to inconsistencies in human interpretation of vegetation. The error matrices developed and presented in this report attempt to capture, measure, and account for the most significant of these sources of inconsistency and error in the development of the reference data set: variation in human interpretation. The results presented and discussed in this report provide the end user with valuable information regarding the accuracy and reliability of the earth cover data mapped for the project area.

Final Products

The final products included a digital earth cover classification, a hard-copy map of the entire project area, and a digital database of field data collected for the 547 field sites visited during this project. The digital map was delivered in ArcInfo Grid and Erdas Imagine format. The field site database, and vegetative species list were stored as digital tables in Dbase IV format. Digital photographs of the field sites are stored in .jpg format. Hardcopy maps of the entire project area at 1:250,000 scale, and selected 1:63,360 scale quadrangles were also produced as requested by cooperators. All of the delivered datasets were loaded into ArcView projects for display purposes.

Conclusions

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. This project continued with the mapping in a joint effort with the Kanuti NWR to map the BLM Ray Mountains and Hogatza River lands, the Kanuti National Wildlife Refuge and all State and Native lands between and surrounding the BLM and Refuge lands. Classification was performed using Landsat TM satellite scenes, Path 73, Row 13 and 14 acquired July 2, 1999 and Landsat TM Path 74, Row 13 and 14 acquired September 8, 1992. The project area was classified into 30 earth cover categories with an overall accuracy of 85% at the +/- 5% level of variation in interpretation. The digital database and map of the classification were the primary products of this project along with hard copy maps of the classification, a complete field database including digital site photos, and an ArcView project.

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APPENDICES

Appendix A. Alaska Earth Cover Classification Class Descriptions.

1.0 <u>Forest</u>

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. 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. This class was very rare.

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. Stands of pure cottonwood were occasionally found on riparian gravel bars.

1.5 Open Deciduous (Mixed Deciduous Species 1.54)
From 25-59% of the cover was trees, and $\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.

1.6 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 <u>Shrub</u>
The tall and low shrub classes were dominated by willow (*Salix* spp.), alder (*Alnus* spp.), dwarf birch (*Betula nana* and *Betula glandulosa*) and *Vaccinium* species. 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. It is nearly always found on hilltops or mountain plateaus, and may have included some rock. BLM biologists indicate that the dwarf shrub class is likely to contain rare plant species, although the presence of these rare species is probably not indicated in the field site database due to the helicopter sampling methods used for this project.

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 0.25-1.3 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 0.25-1.3 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 0.25-1.3 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 0.25-1.3 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 ≤ 025 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.

2.32 Other Dwarf Shrub
Shrubs made up 40-100% of the cover, the generally made up of dwarf ericaceous shrubs and *Dryas* species, but often included shrub height is ≤0.25 meters. This class was a variety of forbs and graminoids, and some rock. It was nearly always found at higher elevations on hilltops, mountain slopes, and plateaus.

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

3.11 Lichen
Composed of ≥40% herbaceous species, ≤ 25% water, and ≥60% lichen or moss species, with lichen being the majority of the moss/lichen component.

3.12 Moss
Composed of ≥40% herbaceous species, ≤25% water, and ≥60% lichen or moss species, with moss being the majority of the moss/lichen component.

3.21 Wet Graminoid
Composed of ≥40% herbaceous species, 5% to 25% water, and where ≥ 60% of the herbaceous cover was graminoid, or ≥20% of the graminoid cover was made up of *Carex aquatilis*. This class represented wet or seasonally flooded sites. It was common

throughout the lowlands in the study area, especially surrounding small lakes and ponds, but it was often present in stands too small to be mapped at the current scale.

3.31 Tussock Tundra

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

3.311 Tussock Tundra - Lichen

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

3.34 Mesic/Dry Graminoid

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

3.35 Mesic/Dry Forb

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

4.0 Aquatic Vegetation

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

4.1 Aquatic Bed

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

4.2 Emergent Vegetation

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

5.1 Clear Water

Composed of ≥80% clear water.

5.2 Turbid Water

Composed of ≥80% turbid water.

6.0 Barren

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

6.1 Sparse Vegetation

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

6.2 Rock/Gravel

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

6.3 Non-vegetated Soil

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

7.0 Urban

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

8.0 Agriculture

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

9.0 Cloud/Shadow

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

9.1 Cloud

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

9.2 Cloud Shadow

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

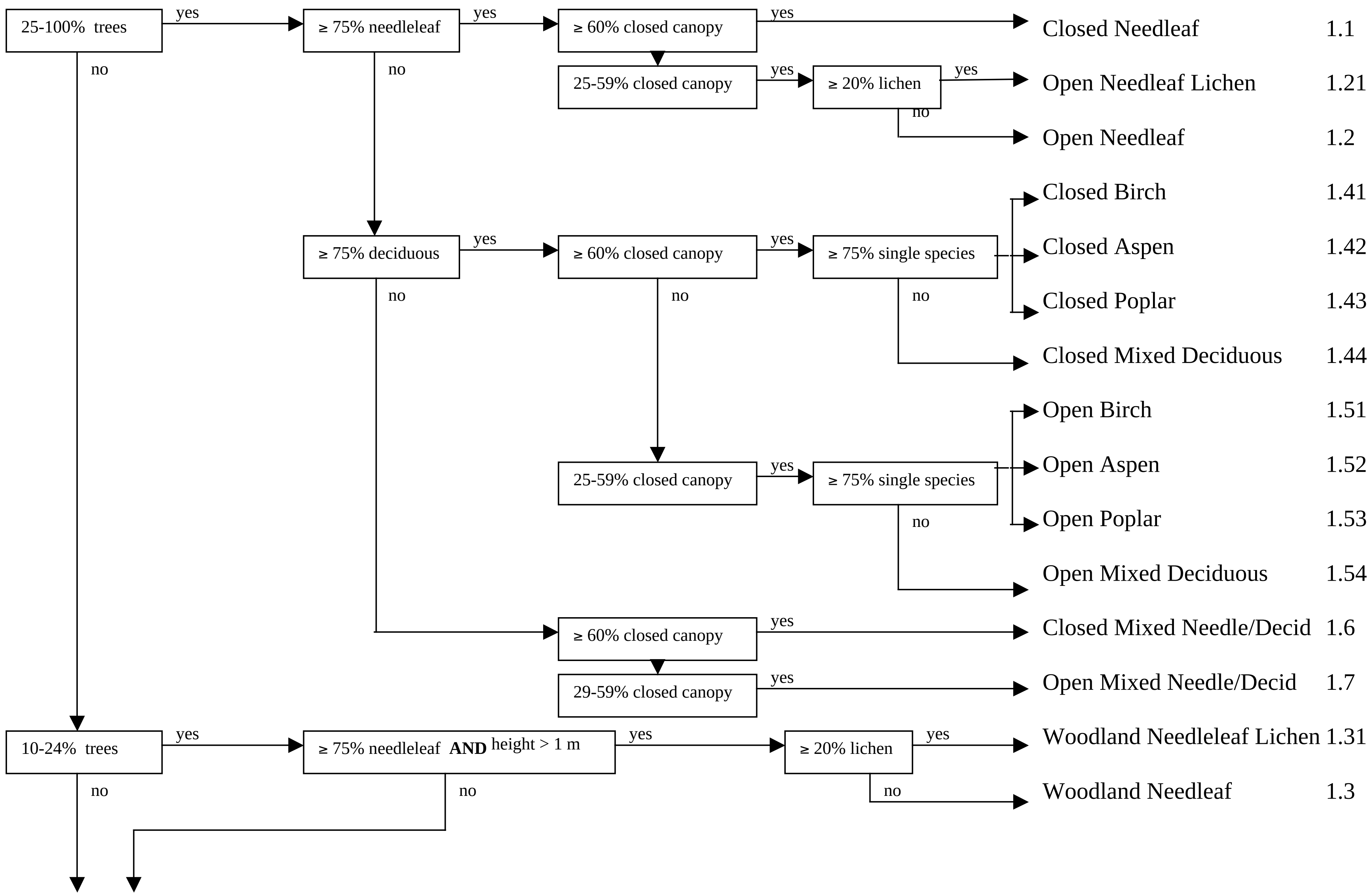
9.3 Terrain Shadow

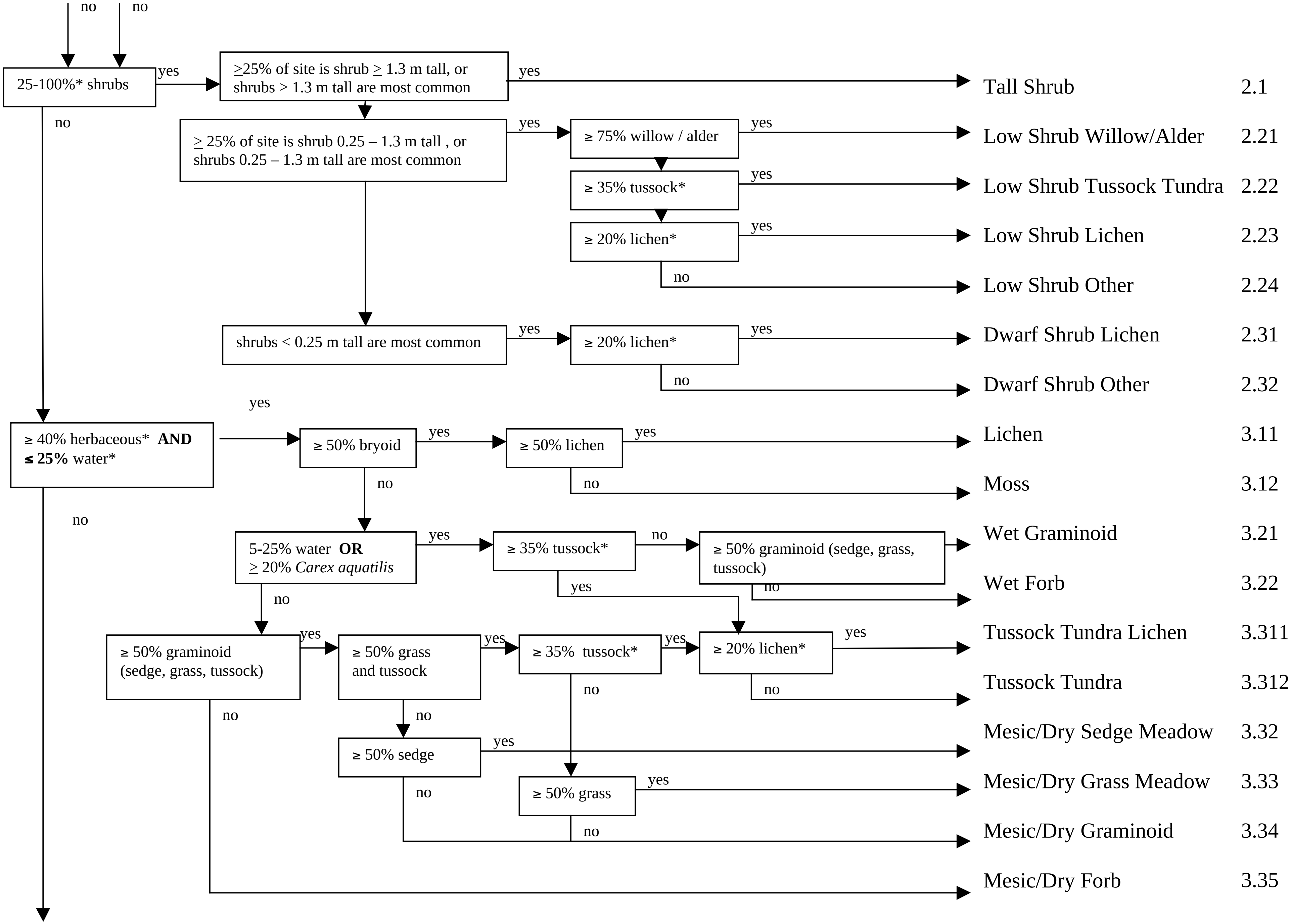
At least 50% of the cover was made up of terrain shadows.

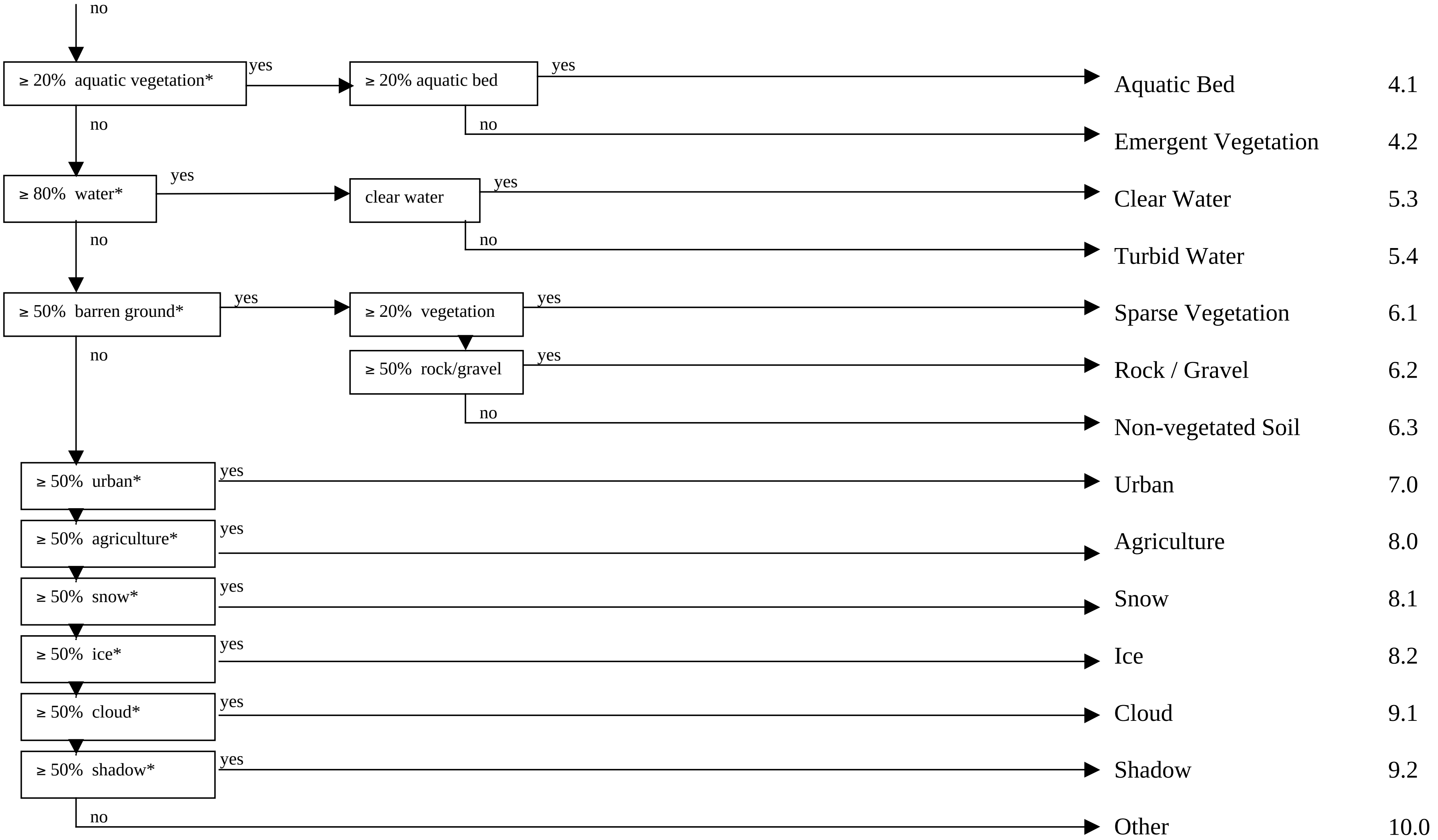
10.0 Other

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

Appendix B. Alaska earth cover classification decision tree.




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



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

Appendix C. Earth cover class acreage summaries by general land status.

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

C1. Earth cover class acreages for Bureau of Land Management lands.

CLASS NAME			ACRES	PERCENT COVER
Closed Needleleaf			32,649	0.98%
Open Needleleaf			875,032	26.30%
Open Needleleaf - Lichen			94,734	2.85%
Woodland Needleleaf			335,232	10.08%
Woodland Ndl. - Lichen			61,768	1.86%
Woodland Ndl. - Moss			955	0.03%
Closed Deciduous			156,265	4.70%
Open Deciduous			50,948	1.53%
Closed Mixed Ndl./Decid.			138,722	4.17%
Open Mixed Ndl./Decid.			247,970	7.45%
Tall Shrub			240,003	7.21%
Low Shrub			292,279	8.78%
Low Shrub - Lichen			7,126	0.21%
Low Shrub - Tussock Tundra			250,394	7.53%
Dwarf Shrub			91,181	2.74%
Dwarf Shrub - Lichen			4,827	0.15%
Wet Graminoid			15,325	0.46%
Lichen			14,321	0.43%
Moss			1,265	0.04%
Mesic/Dry Graminoid			7,092	0.21%
Tussock Tundra			36,517	1.10%
Tussock Tundra Lichen			19,708	0.59%
Aquatic Bed			1,934	0.06%
Emergent			212	0.01%
Clear Water			18,552	0.56%
Turbid Water			322	0.01%
Snow/Ice			542	0.02%
Sparse Vegetation			15,302	0.46%
Rock/Gravel			8,991	0.27%
Terrain Shadow			7,243	0.22%
Smoke			1,179	0.04%
Fire Scar			150,665	4.53%
Fire Scar - Regeneration			148,058	4.45%
	Regeneration Class	Acres		
	Open Needleleaf	10,594		
	Wdlnd. Ndllf.	8,834		
	Wdlnd. Ndllf. Lichen	387		
	Closed Deciduous	24		
	Open Deciduous	1,955		
	Open Mixed Ndl./Dec.	626		
	Tall Shrub	40,153		
	Low Shrub	24,475		
	Low Shrub Tussock Tundra	47,705		
	Tussock Tundra	13,305		
	Total	148,058		
Total			**3,327,309**	**100%**

C2. Earth cover class acreages for State Patented and State Selected lands.

CLASS NAME		ACRES	PERCENT COVER
Closed Needleleaf		32,680	1.51%
Open Needleleaf		310,614	14.40%
Open Needleleaf - Lichen		16,357	0.76%
Woodland Needleleaf		140,749	6.52%
Woodland Ndl. - Lichen		15,968	0.74%
Woodland Ndl. - Moss		786	0.04%
Closed Deciduous		122,176	5.66%
Open Deciduous		29,223	1.35%
Closed Mixed Ndl./Decid.		81,600	3.78%
Open Mixed Ndl./Decid.		130,521	6.05%
Tall Shrub		204,447	9.48%
Low Shrub		284,004	13.16%
Low Shrub - Lichen		7,807	0.36%
Low Shrub - Tussock Tundra		187,086	8.67%
Dwarf Shrub		163,775	7.59%
Dwarf Shrub - Lichen		200	0.01%
Wet Graminoid		6,168	0.29%
Lichen		17,161	0.80%
Moss		381	0.02%
Mesic/Dry Graminoid		8,720	0.40%
Tussock Tundra		44,755	2.07%
Tussock Tundra Lichen		24,673	1.14%
Aquatic Bed		2,995	0.14%
Emergent		83	0.00%
Clear Water		16,117	0.75%
Turbid Water		5,468	0.25%
Snow/Ice		640	0.03%
Sparse Vegetation		29,966	1.39%
Rock/Gravel		29,122	1.35%
Terrain Shadow		13,608	0.63%
Active Fire		111	0.01%
Smoke		86,256	4.00%
Fire Scar		44,649	2.07%
Fire Scar - Regeneration		98,820	4.58%
Regeneration Class	Acres		
Open Needleleaf	8,039		
Wdlnd. Ndllf.	3,433		
Closed Deciduous	22		
Open Deciduous	411		
Open Mixed Ndl./Dec.	14		
Tall Shrub	16,865		
Low Shrub	23,203		
Low Shrub Tussock Tundra	37,144		
Tussock Tundra	9,687		
Total	98,820		
Total		**2,157,682**	**100%**

C3. Earth cover class acreages for U.S. Fish and Wildlife Service lands.*

CLASS NAME		ACRES	PERCENT COVER
Closed Needleleaf		8,824	0.57%
Open Needleleaf		310,220	20.10%
Open Needleleaf - Lichen		29,205	1.89%
Woodland Needleleaf		124,932	8.09%
Woodland Ndl. - Lichen		55,579	3.60%
Woodland Ndl. - Moss		1,193	0.08%
Closed Deciduous		107,468	6.96%
Open Deciduous		15,648	1.01%
Closed Mixed Ndl./Decid.		56,219	3.64%
Open Mixed Ndl./Decid.		104,103	6.74%
Tall Shrub		73,400	4.75%
Low Shrub		69,277	4.49%
Low Shrub - Lichen		6	0.00%
Low Shrub - Tussock Tundra		88,577	5.74%
Dwarf Shrub		8,736	0.57%
Dwarf Shrub - Lichen		314	0.02%
Wet Graminoid		15,290	0.99%
Lichen		2,109	0.14%
Moss		2,022	0.13%
Mesic/Dry Graminoid		1,243	0.08%
Tussock Tundra		9,823	0.64%
Tussock Tundra Lichen		5,565	0.36%
Aquatic Bed		12,047	0.78%
Emergent		1,637	0.11%
Clear Water		43,746	2.83%
Turbid Water		9,062	0.59%
Snow/Ice		1	0.00%
Sparse Vegetation		4,668	0.30%
Rock/Gravel		6,042	0.39%
Terrain Shadow		959	0.06%
Smoke		17	0.00%
Fire Scar		105,639	6.84%
Fire Scar - Regeneration		270,164	17.50%
Regeneration Class	Acres		
Open Needleleaf	30,058		
Wdlnd. Ndllf.	7,243		
Open Deciduous	29		
Open Mixed Ndl./Dec.	109		
Tall Shrub	65,678		
Low Shrub	48,504		
Low Shrub Tussock Tundra	107,140		
Tussock Tundra	11,403		
Total	270,164		
Total		**1,543,735**	**100%**

* Includes all Kanuti NWR and the northernmost portion of Koyokuk NWR.

C3a. Earth cover class acreages for Kanuti NWR lands.*

CLASS NAME			ACRES	PERCENT COVER
Closed Needleleaf			1,798	0.11%
Open Needleleaf			347,725	21.24%
Open Needleleaf - Lichen			28,587	1.75%
Woodland Needleleaf			135,343	8.27%
Woodland Ndl. - Lichen			58,110	3.55%
Woodland Ndl. - Moss			1,294	0.08%
Closed Deciduous			109,627	6.70%
Open Deciduous			14,861	0.91%
Closed Mixed Ndl./Decid.			67,618	4.13%
Open Mixed Ndl./Decid.			110,116	6.72%
Tall Shrub			60,519	3.70%
Low Shrub			68,401	4.18%
Low Shrub - Tussock Tundra			76,261	4.66%
Dwarf Shrub			8,200	0.50%
Wet Graminoid			14,500	0.89%
Lichen			1,994	0.12%
Moss			2,490	0.15%
Mesic/Dry Graminoid			518	0.03%
Tussock Tundra			4,295	0.26%
Tussock Tundra Lichen			1,856	0.11%
Aquatic Bed			13,444	0.82%
Emergent			1,988	0.12%
Clear Water			48,513	2.96%
Turbid Water			6,183	0.38%
Snow/Ice			8	0.00%
Sparse Vegetation			5,871	0.36%
Rock/Gravel			8,801	0.54%
Terrain Shadow			248	0.02%
Fire Scar			116,331	7.10%
Smoke			9	0.00%
Fire Scar - Regeneration			321,921	19.67%
	Regeneration Class	Acres		
	Open needleleaf	37,768		
	Woodland needleleaf	8,327		
	Tall shrub	80,051		
	Low shrub	54,186		
	Low shrub tussock tundra	129,135		
	Tussock tundra	12,454		
	Subtotal	321,921		
Total			**1,637,430**	**100%**

* The area within the Kanuti NWR boundary includes some in-holdings of Native Patented and Native Selected lands. These lands are included in the acreage figures, above.

C4. Earth cover class acreages for Native Patented and Native Selected lands.

CLASS NAME			ACRES	PERCENT COVER
Closed Needleleaf			57,277	2.96%
Open Needleleaf			453,123	23.43%
Open Needleleaf - Lichen			30,206	1.56%
Woodland Needleleaf			133,469	6.90%
Woodland Ndl. - Lichen			20,859	1.08%
Woodland Ndl. - Moss			588	0.03%
Closed Deciduous			187,476	9.69%
Open Deciduous			36,888	1.91%
Closed Mixed Ndl./Decid.			155,160	8.02%
Open Mixed Ndl./Decid.			171,896	8.89%
Tall Shrub			114,765	5.93%
Low Shrub			137,731	7.12%
Low Shrub - Lichen			117	0.01%
Low Shrub - Tussock Tundra			91,666	4.74%
Dwarf Shrub			45,149	2.33%
Dwarf Shrub - Lichen			828	0.04%
Wet Graminoid			12,738	0.66%
Lichen			7,033	0.36%
Moss			1,399	0.07%
Mesic/Dry Graminoid			8,619	0.45%
Tussock Tundra			14,400	0.74%
Tussock Tundra Lichen			7,048	0.36%
Aquatic Bed			4,514	0.23%
Emergent			927	0.05%
Clear Water			26,361	1.36%
Turbid Water			46,285	2.39%
Snow/Ice			150	0.01%
Sparse Vegetation			13,570	0.70%
Rock/Gravel			21,332	1.10%
Terrain Shadow			10,029	0.52%
Smoke			2,737	0.14%
Fire Scar			30,191	1.56%
Fire Scar - Regeneration			89,532	4.63%
	Regeneration Class	Acres		
	Open Needleleaf	9,012		
	Wdlnd. Ndllf.	2,744		
	Wdlnd. Ndllf. Lichen	131		
	Closed Deciduous	237		
	Open Deciduous	213		
	Open Mixed Ndl./Dec.	248		
	Tall Shrub	25,296		
	Low Shrub	13,223		
	Low Shrub Tussock Tundra	34,102		
	Tussock Tundra	4,326		
	Total	89,532		
Total			**1,934,063**	**100%**

C5. Earth cover class acreages for U.S. Military lands.*

CLASS NAME		ACRES	PERCENT COVER
Closed Needleleaf		80	0.38%
Open Needleleaf		1,866	8.92%
Open Needleleaf - Lichen		81	0.39%
Woodland Needleleaf		768	3.67%
Woodland Ndl. - Lichen		80	0.38%
Woodland Ndl. - Moss		23	0.11%
Closed Deciduous		2,443	11.67%
Open Deciduous		387	1.85%
Closed Mixed Ndl./Decid.		592	2.83%
Open Mixed Ndl./Decid.		1,956	9.35%
Tall Shrub		2,705	12.92%
Low Shrub		2,117	10.11%
Low Shrub - Tussock Tundra		369	1.76%
Dwarf Shrub		4,058	19.38%
Wet Graminoid		9	0.04%
Lichen		103	0.49%
Moss		4	0.02%
Mesic/Dry Graminoid		451	2.15%
Tussock Tundra		167	0.80%
Tussock Tundra Lichen		75	0.36%
Aquatic Bed		0	0.00%
Clear Water		6	0.03%
Turbid Water		126	0.60%
Snow/Ice		1	0.01%
Sparse Vegetation		678	3.24%
Rock/Gravel		1,774	8.47%
Terrain Shadow		17	0.08%
Total		**20,933**	**100%**

C6. Earth cover class acreages for private lands.

CLASS NAME			ACRES	PERCENT COVER
Closed Needleleaf			245	5.55%
Open Needleleaf			1,453	32.85%
Open Needleleaf - Lichen			124	2.81%
Woodland Needleleaf			246	5.57%
Woodland Ndl. - Lichen			30	0.68%
Woodland Ndl. - Moss			360	8.14%
Closed Deciduous			58	1.31%
Open Deciduous			828	18.73%
Closed Mixed Ndl./Decid.			364	8.24%
Open Mixed Ndl./Decid.			73	1.65%
Tall Shrub			191	4.33%
Low Shrub			46	1.04%
Low Shrub - Tussock Tundra			5	0.11%
Dwarf Shrub - Lichen			2	0.04%
Wet Graminoid			59	1.34%
Moss			1	0.02%
Mesic/Dry Graminoid			8	0.19%
Tussock Tundra			2	0.05%
Aquatic Bed			0.44	0.01%
Clear Water			175	3.96%
Sparse Vegetation			16	0.35%
Rock/Gravel			40	0.91%
Terrain Shadow			87	1.97%
Fire Scar			6	0.14%
Fire Scar - Regeneration			1.78	0.04%
	Regeneration Class	Acres		
	Wdlnd. Ndllf.	0.22		
	Tall Shrub	0.44		
	Low Shrub	0.22		
	Low Shrub Tussock Tundra	0.89		
	Total	1.78		
Total			**4,423**	**100%**

Appendix D. Plant species and frequency.

Site_Tally	Symbol	Species	Common Name
432	MOXX	MOSS	MOSS
390	LITT	LITTER	LITTER
345	LEPA	LEDUM PALUSTRE	LABRADOR TEA
301	PIMA	PICEA MARIANA	SPRUCE,BLACK
296	VAUL	VACCINIUM ULIGINOSUM	BLUEBERRY,BOG
288	LIXX	LICHEN	LICHEN
269	SAX_	SALIX SPP	WILLOW
224	BEPA	BETULA PAPYRIFERA	BIRCH,PAPER
211	ALCR6	ALNUS CRISPA	ALDER,GREEN
187	BEGL	BETULA GLANDULOSA	BIRCH,DWARF ARCTIC
182	ERVA4	ERIOPHORUM VAGINATUM	COTTON-GRASS,TUSSOCK
179	CLWA	CLEAR WATER	CLEAR WATER
169	BENA	BETULA NANA	BIRCH,SWAMP
155	EQXX	EQUISETUM SPP	HORSETAILS SPP
136	GRASS	GRASS	GRASS
120	GRXX	GRAMINOID SPP	GRAMINOID SPP
100	PIGL	PICEA GLAUCA	SPRUCE,WHITE
86	CAXX	CAREX SPP	SEDGE SPP
86	PEFR5	PETASITES FRIGIDUS	COLTSFOOT,ARCTIC SWEET
75	RUCH	RUBUS CHAMAEMORUS	CLOUDBERRY
64	ROAC	ROSA ACICULARIS	ROSE,PRICKLY
59	BARE	BARE GROUND	BARE GROUND
59	POTR10	POPULUS TREMULOIDES	ASPEN,QUAKING
59	RUBS	RUBUS SPP.	RUBUS SPP.
56	ROCK	ROCK	ROCK
53	VAVI	VACCINIUM VITIS-IDAEA	CRANBERRY,MOUNTAIN
48	CHCA2	CHAMAEDAPHNE CALYCULATA	LEATHERLEAF
45	ERXX	ERIOPHORUM SPP	COTTON-GRASS
42	LITT2	LITTER STANDING	STANDING LITTER
37	SATRE	SALIX TREE	WILLOW TREE
36	GRAV	GRAVEL	GRAVEL
36	METR3	MENYANTHES TRIFOLIATA	BUCKBEAN
35	ARSP	ARCTOSTAPHYLOS SPP.	BEARBERRY
35	EMNI	EMPETRUM NIGRUM	CROWBERRY,BLACK
34	ANPO	ANDROMEDA POLIFOLIA	ROSEMARY,BOG
34	DRXX	DRYAS SPP	MOUNTAIN-AVENS
34	EQSP	EPILOBIUM SPP	FIREWEED
32	ALTRE	ALNUS SPP TREE	ALDER, TREE
32	POAL5	POLYGONUM ALASKANUM	RHUBARB,ALASKA WILD
31	CAAQ	CAREX AQUATILIS	SEDGE,WATER
27	EPAN2	EPILOBIUM ANGUSTIFOLIUM	FIREWEED
26	POPA14	POTENTILLA PALUSTRIS	CINQUEFOIL,MARSH
25	POBA2	POPULUS BALSAMIFERA	POPLAR,BALSAM

Site_Tally	Symbol	Species	Common Name
23	COCA13	CORNUS CANADENSIS	BUNCHBERRY,CANADA
21	CATU	CAREX SPP - TUSSOCK	SEDGE,SPP-TUSSOCK
20	SADW	SALIX DW.	WILLOW, DWARF
18	NUPO	NUPHAR POLYSEPALUM	WATER LILY
17	SPBE	SPIRAEA BEAUVERDIANA	SPIRAEA,BEAUVERED
16	CACA4	CALAMAGROSTIS CANADENSIS	REEDGRASS,BLUE-JOINT
14	POFR4	POTENTILLA FRUTICOSA	CINQUEFOIL,SHRUBBY
13	LYSP	LYCOPODIUM SPP.	CLUBMOSS
12	SPRO	SPIRANTHES ROMANZOFFIANA	LADIES'-TRESSES,HOODED
11	ARNS	ARNICA SPP.	ARNICA
11	SAND	SAND	SAND
10	ARRU	ARCTOSTAPHYLOS RUBRA	BEARBERRY, RED
10	NYTE	NYMPHAEA TETRAGONA	WATER-LILY,PYGMY
9	LOPR	LOISELURIA PROCUMBENS	AZALEA, ALPINE
9	MYGA	MYRICA GALE	SWEETGALE
8	LUAR	LUPINUS ARCTICUS	ARCTIC LUPINE
8	PISP	PICEA SPP.	SPRUCE, MIXED WHITE AND BLACK
8	POBI5	POLYGONUM BISTORTA	BISTORT,MEADOW
8	VIED	VIBURNUM EDULE	SQUASHBERRY
7	CATE11	CASSIOPE TETRAGONA	BELL-HEATHER,ARCTIC
7	LUPS	LUPINUS SPP.	LUPINE
7	MISP	MINUARTIA SPP.	
6	CALA7	CAMPANULA LASIOCARPA	BELLFLOWER,COMMON ALASKA
6	DIUN	DIAPENSIA	UNKNOWN
6	LUSP	LUPINUS SPP.	LUPINE
6	OXNI	OXYTROPIS NIGRESCENS	OXYTROPE,BLACKISH
6	POSP	POTAMEGETON SPP.	PONDWEED
5	ARAR	ARTEMISIA ARCTICA	SAGE, ARCTIC
5	DRFR	DRYOPTERIS FRAGRANS	FERN,FRAGRANT
5	MUDX	MUD	MUD
5	RUID	RUBUS IDAEUS	RASPBERRY,COMMON RED
4	ARUV	ARCTOSTAPHYLOS UVA-URSI	KINNEKINNICK
4	MEPA	MERTENSIA PANICULATA	BLUEBELLS,TALL
4	POAC	POLEMONIUM ACUTIFLORUM	JACOB'S-LADDER,STICKY TALL
4	POTS	POTENTILLA SPP.	CINQUEFOIL
4	SILT	SILT	SILT
4	SISU2	SIUM SUAVE	WATER-PARSNIP,HEMLOCK
3	ACDE2	ACONITUM DELPHINIFOLIUM	MONKSHOOD,LARKSPUR-LEAF
3	ANPA	ANEMONE PARVIFLORA	THIMBLE-WEED,SMALL-FLOWER
3	ANFR	ANTENNARIA FRIESIANA	PUSSYTOES
3	ARAL3	ARTEMISIA ALASKANA	SAGEBRUSH, ALASKA
3	CIMA	CICUTA MACKENZIANA	WATER-HEMLOCK,MACKENZIE
3	EQAR	EQUISETUM ARVENSE	HORSETAIL,FIELD
3	LOIN	LICHEN WHITE	LICHEN WHITE
3	MIAR	MINUARTIA ARCTICA	STITCHWORT, ARCTIC
3	PAMA5	PAPAVER MACOUNII	POPPY,MACOUN'S
3	PAPA8	PARNASSIA PALUSTRIS	GRASS-OF-PARNASSUS,NORTHERN
3	SAXX	SAXIFRAGA SPP	SAXIFRAGE SPP

Site_Tally	Symbol	Species	Common Name
2	ARBI2	ARTEMISIA BIENNIS	WORMWOOD,BIENNIAL
2	ARTSP	ARTEMISIA SPP.	SAGE, SPP.
2	CASP	CASTILLEJA	SPECIES
2	JUCO	JUNIPERUS COMMUNIS	JUNIPER, COMMON MOUNTAIN
2	LIBO3	LINNAEA BOREALIS	TWINFLOWER
2	MOLA6	MOEHRINGIA LATERIFLORA	SANDWORT,GROVE
2	OXMI	OXYCOCCUS MICROCARPUS	CRANBERRY,BOG
2	PALA9	PAPAVER LAPPONICUM	POPPY,ARCTIC
2	PEVE	PEDICULARIS VERTICILLATA	LOUSEWORT,WHORLED
2	SAAR4	SALIX ARCTICA	WILLOW,ARCTIC
2	SAPU	SALIX PULCHRA	WILLOW,COMMON
2	SESP	SENECIO SPP	UNKNOWN
2	SPAN	SPARGANIUM ANGUSTIFOLIUM	BUR REED
1	ANMO	ANTENNARIA MONOCEPHALA	PUSSYTOE
1	CNCN	CNIDIUM CNIDIIFOLIUM	PARSLEY,JAKUTSK SNOW
1	DEGL3	DELPHINIUM GLAUCUM	LARKSPUR,TOWER
1	DRAN	DROSERA ANGLICA	SUNDEW,ENGLISH
1	EPLA	EPILOBIUM LATIFOLIUM	BEAUTY,RIVER
1	ERAC3	ERIGERON PUMILIS	FLEABANE
1	ERRU2	ERIOPHORUM RUSSEOLUM	COTTON-GRASS,RUSSET'S
1	FOXX	FORB SPP	FORB SPP
1	GELI2	GEOCAULON LIVIDUM	TOADFLAX,NORTHERN RED-FRUIT
1	HEAL	HEDYSARUM ALPINUM	SWEETVETCH,ALPINE
1	HISP	HIPPURIS SPP.	MARE'S TAIL
1	JUCA6	JUNCUS CASTANEUS	RUSH,CHESTNUT
1	LEM2	LEMNA SPP.	DUCKWEED
1	LUNO	LUPINUS NOOTKATENSIS	LUPINE,NOOTKA
1	LYAL3	LYCOPODIUM ALPINUM	CLUBMOSS,ALPINE
1	PECA2	PEDICULARIS CAPITATA	LOUSEWORT,CAPITATE
1	PELA	PEDICULARIS LABRADORICA	LOUSEWORT,LABRADOR
1	PELA14	PEDICULARIS LANATA	LOUSEWORT,WOOLLY
1	POLS	POLYGONUM SPP.	BISTORT
1	POMO1	POTAMOGETON MOGETON	
1	POFR	POTENTILLA FRUTICOSA	CINQUEFOIL, BUSH
1	ROPA2	RORIPPA PALUSTRIS	YELLOW-CRESS,BOG
1	RUAR6	RUMEX ARCTICUS	DOCK,ARCTIC
1	SAAL	SALIX ALAXENSIS	WILLOW,FELT-LEAF
1	SAAR3	SALIX ARBUSCULOIDES	WILLOW,LITTLE-TREE
1	SARO2	SALIX ROTUNDIFOLIA	WILLOW,LEAST
1	SABR6	SAXIFRAGA BRONCHIALIS	SAXIFRAGE,YELLOW-DOT
1	SECO2	SENECIO CONGESTUS	GROUNDSEL,MARSH
1	SHCA	SHEPHERDIA CANADENSIS	BUFFALO-BERRY,CANADA
1	SIAC	SILENE ACAULIS	CAMPION,MOSS
1	SOMU	SOLIDAGO MULTIRADIATA	GOLDEN-ROD,MOUNTAIN
1	SPEM2	SPARGANIUM EMERSUM	BURREED,NARROW-LEAF
1	STCA	STELLARIA CALYCANTHA	STARWORT,NORTHERN
1	TOPU	TOFIELDIA PUSILLA	FALSE-ASPHODEL,SCOTCH
1	VAOX	VACCINIUM OXYCOCCOS	CRANBERRY,SMALL

Appendix E. Error Matrix for Path 73 Image Classification – Accuracy Assessment Sites.

		Reference Class																			
		Closed Needleleaf	Open Needleleaf	Open Ndl. - Lichen	Woodland Needleleaf	Wd. Ndl. - Lichen.	Closed Deciduous	Open Deciduous	Closed Mixed	Open Mixed	Tall Shrub	Low Shrub	Low Shrub - Lichen	Low Shrub - Tussock	Dwarf Shrub	Lichen	Moss	Tussock Tundra	Total	User's Accuracy +/- 0%	User's Accuracy +/- 5%
Majority (Map) Class	Closed Needleleaf	**3**																	3	100%	100%
	Open Needleleaf	2,0	**15**		1,0				0,1										19	79%	95%
	Open Ndl. - Lichen			**5**															5	100%	100%
	Woodland Needleleaf				**7**		0,1												8	88%	88%
	Wdlnd. Ndl. - Lichen			1,0		**5**													6	83%	100%
	Closed Deciduous						**11**	1,2		0,1									15	73%	80%
	Open Deciduous							**2**				0,1							3	67%	67%
	Closed Mixed Ndl./Dec.								**3**										3	100%	100%
	Open Mixed Ndl./Dec.				0,1		0,1		0,1	**3**									6	50%	50%
	Tall Shrub						0,1				**10**								11	91%	91%
	Low Shrub - Other				0,1						0,1	**8**	0,1					0,1	12	67%	67%
	Low Shrub - Lichen												**1**						1	100%	100%
	Low Shrub - Tussock													**9**	0,1			1,1	12	75%	83%
	Dwarf Shrub											0,1	1,1		**6**				9	67%	78%
	Lichen							1,0		1,0									2	0%	100%
	Moss														1,0				1	0%	100%
	Tussock Tundra																	**3**	3	100%	100%
	Total	5	15	6	10	5	14	6	5	5	11	10	4	9	8	0	0	6	119		
	Producer's +/- 0%	60%	100%	83%	70%	100%	79%	33%	60%	60%	91%	80%	25%	100%	75%	-----	-----	50%			
	Producer's +/- 5%	100%	100%	100%	80%	100%	79%	67%	60%	80%	91%	80%	50%	100%	86%	-----	-----	67%			

Total # of Accuracy Assessment Sites:	119
Diagonal Total:	91
Off-diagonal Total:	28
Off-diagonal Acceptable:	10
Overall Accuracy +/- 0% variation:	76%
Overall Accuracy +/- 5% variation:	85%

Appendix F. Error Matrix for Path 73 Image Classification – Accuracy Assessment Sites in Fire Scar Regeneration Areas.

		Reference Class																			
	Class	Closed Needleleaf	Open Needleleaf	Open Ndl. - Lichen	Woodland Needleleaf	Wd. Ndl. - Lichen.	Closed Deciduous	Open Deciduous	Closed Mixed	Open Mixed	Tall Shrub	Low Shrub	Low Shrub - Lichen	Low Shrub - Tussock	Dwarf Shrub	Lichen	Moss	Tussock Tundra	Burn - No Label	Total	User's Accuracy
Majority Class	Burn - Closed Needleleaf																			0	----
	Burn - Open Needleleaf																			0	----
	Burn - Open Ndl. Lichen																			0	----
	Burn - Woodland Ndllf.																			0	----
	Burn - Wdlnd. Ndl. Lichen																			0	----
	Burn - Closed Decid.																			0	----
	Burn - Open Decid.																			0	----
	Burn - Cl. Mix Ndl./Dec.																			0	----
	Burn - Op. Mix Ndl./Dec.																			0	----
	Burn - Tall Shrub		1								**2**									3	67%
	Burn - Low Shrub													1						1	0%
	Burn - Low Shrub Lichen																			0	----
	Burn - L.S. Tuss. Tundra													**3**						3	100%
	Burn - Dwarf Shrub																			0	----
	Burn - Lichen																			0	----
	Burn - Moss																			0	----
	Burn - Tuss. Tundra																	**1**		1	100%
	Burn - No Label											1								1	0%
	Total	0	1	0	0	0	0	0	0	0	2	1	0	4	0	0	0	1	0	9	
	Producer's	----	0%	----	----	----	----	----	----	----	100%	0%	----	75%	----	----	----	100%	----		

Total # of Accuracy Assessment Sites:	9
Diagonal Total:	6
Off-diagonal Total:	3
Overall Accuracy:	67%

Appendix G. Error Matrix for Path 73 Image Classification – Training Sites.

Map Class	Class	Reference Class: Closed Needleleaf	Open Needleleaf	Open Ndl. - Lichen	Woodland Needleleaf	Wdlnd. Ndl. - Lichen.	Closed Deciduous	Open Deciduous	Closed Mixed	Open Mixed	Tall Shrub	Low Shrub	Low Shrub - Lichen	Low Shrub - Tussock	Dwarf Shrub	Wet Graminoid	Lichen	Moss	Mesic/Dry Graminoid	Tussock Tundra	Tussock Tundra - Lichen	Aquatic Bed	Emergent Vegetation	Clear Water	Sparsely Vegetated	Rock/Gravel/Sand	Total	User's accuracy +/- 0%	User's accuracy +/- 5%
	Closed Needleleaf	**6**	0,1																								7	86%	86%
	Open Needleleaf	0,1	**27**	2,0	2,0		0,1		0,1																		34	79%	91%
	Open Ndl. - Lichen	1,0		**7**																							8	88%	100%
	Woodland Needleleaf				**17**						1,0	1,1		0,1													21	81%	90%
	Wd. Ndl. - Lichen.		0,1	1,1		**10**				1,0							1,0										15	67%	87%
	Closed Deciduous						**22**	0,1			0,1																24	92%	92%
	Open Deciduous							**9**																			9	100%	100%
	Closed Mixed	0,2					0,1		**7**																		10	70%	70%
	Open Mixed				0,2		0,1	1,0	0,3	**8**																	15	53%	60%
	Tall Shrub						0,2	0,1			**17**	0,1															21	81%	81%
	Low Shrub										1,0	**13**			0,3	0,1	0,1							1,0			20	65%	75%
	Low Shrub - Lichen												**3**														3	100%	100%
	Low Shrub - Tussock													**19**	1,0												20	95%	100%
	Dwarf Shrub														**13**										1,1	0,1	16	81%	88%
	Wet Graminoid											1,0				**4**											5	80%	100%
	Lichen									1,0							**10**	0,1									12	83%	92%
	Moss											1,0						**8**									9	89%	100%
	Mesic/Dry Graminoid																		**2**								2	100%	100%
	Tussock Tundra										0,1	0,1		1,0						**11**							14	79%	86%
	Tussock Tundra - Lichen																1,0				**3**						4	75%	100%
	Aquatic Bed																					**4**	0,1				5	80%	80%
	Emergent Vegetation																						**6**				6	100%	100%
	Clear Water											1,0				0,1						1,3	0,1				7	0%	29%
	Sparsely Vegetated																								**3**		3	100%	100%
	Rock/Gravel/Sand																								2,0	**4**	6	67%	100%
	Total	10	29	11	21	10	27	12	11	10	21	20	3	21	17	6	13	9	2	11	3	8	8	1	7	5	296		
	Producer's +/- 0%	60%	93%	64%	81%	100%	81%	75%	64%	80%	81%	65%	100%	90%	76%	67%	77%	89%	100%	100%	100%	50%	75%	0%	43%	80%		**78.7%**	
	Producer's +/- 5%	70%	93%	91%	90%	100%	81%	83%	64%	100%	90%	85%	100%	95%	82%	67%	92%	89%	100%	100%	100%	63%	75%	100%	86%	80%			**86.8%**

Total # of Training Sites:	296
Diagonal Total:	233
Off-diagonal Total:	63
Off-diagonal Acceptable:	24
Overall Accuracy +/- 0% variation:	79%
Overall Accuracy +/- 5% variation:	87%

Appendix H. Error Matrix for Path 73 Image Classification – Training Sites in Fire Scar Regeneration Areas.

		Reference Class											
	Class	Open Needleleaf	Wdlnd. Needleleaf	Open Deciduous	Tall Shrub	Low Shrub	Low Shrub - Tuss. Tundra	Moss	Tussock Tundra	No Label	Total	User's +/- 0%	User's +/- 5% level
Map Class	Burn - Open Ndl. Regen.										0	-----	----
	Burn - Wdlnd Ndl. Regen.					0,1					1	0%	0%
	Burn - Open Dec. Regen.			**1**							1	100%	100%
	Burn - Tall Shrub Regen.				**1**	0,1					2	50%	50%
	Burn - Low Shrub Regen.	0,1				**2**					3	67%	67%
	Burn - Low Sh. Tuss. Tund. Regen.		0,1		0,4		**3**		2,0		10	30%	50%
	Burn - Moss Regen.										0	-----	-----
	Burn - Tussock Tundra Regen.						1,0				1	0%	100%
	Burn - No Label		1,0			1,0	0,1	2,0		**1**	6	17%	83%
	Total	1	2	1	5	5	5	2	2	1	24		
	Producer's +/- 0% level	0%	0%	100%	20%	40%	60%	0%	0%	100%		33%	
	Producer's +/- 5% level	0%	50%	100%	20%	60%	80%	100%	100%	100%			63%

Total # of Training Sites:	24
Diagonal Total:	8
Off-diagonal Total:	16
Off-diagonal Acceptable:	7
Overall Accuracy +/- 0% variation:	33%
Overall Accuracy +/- 5% variation:	63%

Appendix I. Error Matrix for Path 74 Image Classification.

Majority Class	Reference Class: Closed Needleleaf	Open Needleleaf	Open Ndl. - Lichen	Woodland Needleleaf	Wd. Ndl. - Lichen.	Closed Deciduous	Open Deciduous	Closed Mixed	Open Mixed	Tall Shrub	Low Shrub	Low Shrub - Lichen	Low Shrub - Tussock	Dwarf Shrub	Lichen	Moss	Mesic/Dry Graminoid	Tussock Tundra	Aquatic Bed	Emergent Vegetation	Clear Water	Sparsely Vegetated	Fire scar - Tall Shrub	Total	User's accuracy +/- 0%	User's accuracy +/- 5%
Closed Ndl.	**5**							1,0																6	83%	100%
Open Ndl.		**5**	0,1																	0,1				7	74%	71%
Open Ndl. - Lichen			**2**																					2	100%	100%
Woodland Ndl.				**3**																				3	100%	100%
Wdlnd. Ndl. - Lichen					**1**																			1	100%	100%
Closed Decid.						**8**																		8	100%	100%
Open Decid.						0,1																		1	0%	0%
Closed Mixed Ndl./Dec.								**5**																5	100%	100%
Open Mixed Ndl./Dec.						0,1		0,1																2	0%	0%
Tall Shrub										**3**							0,1							4	75%	75%
Low Shrub - Other										0,1	**7**				0,1		0,2							11	64%	64%
Low Shrub - Tussock				2,0								**3**												5	60%	100%
Dwarf Shrub													**1**											1	100%	100%
Dwarf Shrub - Lichen													0,1	**2**										3	67%	67%
Wet Graminoid															**9**									9	100%	100%
Moss																**3**								3	100%	100%
Mesic/Dry Graminoid																	**3**							3	100%	100%
Tussock Tundra																		**1**						1	100%	100%
Aquatic Bed																			**2**					2	100%	100%
Emergent																				**2**				2	100%	100%
Clear Water																			0,1	0,1				2	0%	0%
Sparsely Vegetated																						**1**		1	100%	100%
Fire Scar - Tall Shrub																							**1**	1	100%	0%
Total	5	5	3	5	1	10	0	7	0	4	7	3	2	2	10	3	6	1	3	4	0	1	1	83		
Producer's +/- 0%	100%	100%	67%	60%	100%	80%	----	-71%	----	-75%	100%	100%	50%	100%	90%	100%	50%	100%	67%	50%	----	-100%	----			
Producer's +/- 5%	100%	100%	67%	100%	100%	80%	----	-86%	----	-75%	100%	100%	50%	100%	90%	100%	50%	100%	67%	50%	----	-100%	----			

Total # of Accuracy Assessment Sites:	83
Diagonal Total:	66
Off-diagonal Total:	17
Off-diagonal Acceptable:	3
Overall Accuracy +/- 0% variation:	80%
Overall Accuracy +/- 5% variation:	83%

Appendix J. Kanuti/Ray Mountains/Hogatza River Earth Cover Mapping Classified Image Metadata.

Filename:KARH_earthcov
Filetype:Arc/Info Grid

Metadata:

- Identification_Information
- Data_Quality_Information
- Spatial_Reference_Information
- Entity_and_Attribute_Information
- Metadata_Reference_Information

Identification_Information:
  Citation:
    Citation_Information:
      Originator:Ducks Unlimited,Inc.
      Publication_Date:032001
      Publication_Time:
      Title: karh_earthcov
      Edition:
      Geospatial_Data_Presentation_Form:map
  Description: Kanuti NWR/Ray Mtns./Hogatza River Earth Cover Classification
    Abstract:
      The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. The BLM's plans to map the Ray Mountains and Hogatza River lands adjacent to the Kanuti National Wildlife Refuge (NWR) coincided with the Refuges' long term goal of obtaining updated earth cover data for the refuge. By combining efforts, overall costs associated with field logistics and image processing were reduced. This project simultaneously mapped the Kanuti NWR, the BLM's Ray Mountains and Hogatza River lands, as well as all State and Native lands between and surrounding the refuge and BLM lands. Portions of four Landsat TM satellite scenes (Path 73, Rows 13-14 acquired 2 July 1999 and Path 74, Rows 13-14 acquired 12 September 1992) were used to classify the project area into 30 earth cover categories. The path 73 and path 74 images were classified separately because of the large difference in image dates and season. The path 73 and path 74 earth cover classifications were mosaiced and edge-matched post-classification to produce a continuous earth cover map for the entire project area. An unsupervised clustering technique was used to determine the location of field sites and a custom field data collection form and digital database were used to record field information. Helicopters were utilized to gain access to field sites throughout the project area. Global positioning system (GPS) technology was used both to navigate to pre-selected sites and to record

the locations of new sites selected in the field. The project area is approximately 9 million acres. A total of 457 field sites were visited during a 12 day field season. Approximately 30% (128) 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 85% at the +/-5% level of variation for the path 73 classifcation and 83% at the +/-5% level of variation for the path 74 classification.

Purpose:

The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Kanuti National Wildlife Refuge, the Ray Mountains and Hogatza River BLM lands and associated areas. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project was an integrated GIS database that can be used for improved natural resources planning.

Time_Period_of_Content:
- Time_Period_Information:
  - Multiple_Dates/Times:
  - Single_Date/Time:
    - Calendar_Date:07021999
  - Single_Date/Time:
    - Calendar_Date:09081992
- Currentness_Reference:032001

Status:
- Progress:complete
- Maintenance_and_Update_Frequency:none

Spatial_Domain:
- Bounding_Coordinates:
  - West_Bounding_Coordinate:-156.065
  - East_Bounding_Coordinate:-149.746
  - North_Bounding_Coordinate:67.025
  - South_Bounding_Coordinate:64.939

Keywords:
- Theme:
  - Theme_Keyword_Thesaurus:
  - Theme_Keyword:Land Cover Classification
  - Theme_Keyword:Earth Cover Classification
  - Theme_Keyword:Landsat TM
- Place:
  - Place_Keyword_Thesaurus:
  - Place_Keyword:Kanuti NWR
  - Place_Keyword:Ray Mountains
  - Place_Keyword:Alaska
- Temporal:
  - Temporal_Keyword_Thesaurus:

Temporal_Keyword:1992
Temporal_Keyword:1999
Point_of_Contact:
Contact_Information:
Contact_Organization:Ducks Unlimited, Inc.
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:
Address_Type:
Address:3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province:California
Postal_Code:95670
Country:U.S.A
Contact_Voice_Telephone:(916)852-2000
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:See Final Report
Quantitative_Attribute_Accuracy_Assessment:
Attribute_Accuracy_Value:
Attribute_Accuracy_Explanation:
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:EROS Data Center
Publication_Date:1992 and 1999
Publication_Time:
Title:Landsat7 ETM Imagery From Path 73, Rows 13-14 acquired 7/02/99 and Path 74, Rows 13-14 acquired 9/08/92
Edition:
Geospatial_Data_Presentation_Form:remote sensing image
Source_Scale_Denominator:
Type_of_Source_Media:
Source_Time_Period_of_Content:
Time_Period_Information:
Multiple_Dates/Times:
Single_Date/Time:
Calendar_Date:1992
Single_Date/Time:
Calendar_Date:1999
Process_Step:
Process_Discription:See "Kanuti NWR/Ray Mtns./Hogatza River Earth Cover Classification" report
Source_Used_Citation_Abbreviation:
Process_Date:1999/2000

Process_Time:
Source_Produced_Citation_Abbreviation:
Spatial_Data_Organization_Information:
Indirect_Spatial_Reference:
Direct_Spatial_Reference_Method:Raster
Raster_Object_Information:
Raster_Object_Type:Pixel
Row_Count:9480
Column_Count:11455
Vertical_Count:
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution:
Longitude_Resolution:
Geographic_Coordinate_Units:
Planar:
Map_Projection:
Map_Projection_Name:
Albers_Conical_Equal_Area:
1st_Standard_Parallel:65
2nd_Standard_Parallel:55
Longitude_of_Central_Meridian:-154
Latitude_of_Projection_Origin:50
False_Easting:
False_Northing:
Geodetic_Model:
Horizontal_Datum_Name:NAD27 (Alaska)
Ellipsoid_Name:Clarke 1866
Semi-major_Axis:
Denominator_of_Flattening_Ratio:
Metadata_Reference_Information:
Metadata_Date:032001
Metadata_Review_Date:
Metadata_Future_Review_Date:
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:Ducks Unlimited
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:
Address_Type:

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

Appendix K. Kanuti NWR/Ray Mountains/Hogatza River Earth Cover Mapping Field Sites Metadata

Filename:karh_fld_sts
Filetype:Arc/Info coverage

Metadata:

Identification_Information
Data_Quality_Information
Spatial_Reference_Information
Entity_and_Attribute_Information
Metadata_Reference_Information

Identification_Information:
  Citation:
    Citation_Information:
      Originator:Ducks Unlimited, Inc.
      Publication_Date:03/2001
      Publication_Time:
      Title:karh_fld_sts
      Edition:
    Geospatial_Data_Presentation_Form:map
  Description:
    Abstract:
      The field data collected for the Kanuti NWR/Ray Mtns./Hogatza River Earth Cover Mapping Project is included on the final products CD's. karh_fld_sts is an Arcinfo coverage of all sites that were visited in the field. karh_fld_sts includes site information about each polygon. Three DBASE files (karh_photo.dbf, karh_site_species.dbf, and karh_species.dbf) are also included on the final products CD's. All three of these files can be linked to the ArcInfo polygon coverage to provide the complete database of information collected for each fieldsite. The links are made by the duff.avx ArcView extension included on the final products CD's.
    Purpose:
      The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Kanuti NWR and the BLM's Ray Mountains and Hogatza River lands and associated areas. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project was an integrated GIS database that can be used for improved natural resources planning.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date:03/2001
    Currentness_Reference:03/2001

Status:
  Progress:complete
  Maintenance_and_Update_Frequency:none
Spatial_Domain:
  Bounding_Coordinates:
    West_Bounding_Coordinate:-155.843
    East_Bounding_Coordinate:-150.249
    North_Bounding_Coordinate:66.933
    South_Bounding_Coordinate:65.256
  Keywords:
    Theme:
      Theme_Keyword_Thesaurus:
      Theme_Keyword:Field Sites
      Theme_Keyword:ArcInfo Coverages
      Theme_Keyword:Land Cover Classification
      Theme_Keyword:Earth Cover Classification
    Place:
      Place_Keyword_Thesaurus:
      Place_Keyword:Kanuti National Wildlife Refuge
      Place_Keyword:Ray Mountains
      Place_Keyword:Alaska
    Stratum:
      Stratum_Keyword_Thesaurus:
      Stratum_Keyword:
    Temporal:
      Temporal_Keyword_Thesaurus:
      Temporal_Keyword:2001
  Access_Constraints:
  Use_Constraints:
  Point_of_Contact:
    Contact_Information:
      Contact_Person_Primary:
        Contact_Person:
        Contact_Organization:
      Contact_Organization_Primary:
        Contact_Organization:Ducks Unlimited, Inc.
        Contact_Person:
      Contact_Position:GIS Manager
      Contact_Address:
        Address_Type:
        Address:3074 Gold Canal Drive
        City:Rancho Cordova
        State_or_Province:California
        Postal_Code:95670
        Country:U.S.A.
      Contact_Voice_Telephone:916 852-2000

Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:See Final Report
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:Ducks Unlimited, Inc.
Publication_Date:2000
Publication_Time:
Title:ArcInfo polygon coverage for Kanuti NWR/Ray Mtns./Hogatza River field sites and associated Dbase files.
Edition:
Geospatial_Data_Presentation_Form:ArcInfo polygon coverage. DBASE files.
Process_Step:
Process_Description:See "Kanuti NWR/Ray Mtns./Hogatza River Earth Cover Classification"
Source_Used_Citation_Abbreviation:
Process_Date:1998
Process_Time:
Source_Produced_Citation_Abbreviation:
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization:Ducks Unlimited, Inc.
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:
Address_Type:
Address:3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province:California
Postal_Code:95670
Country:U.S.A
Contact_Voice_Telephone:916-852-2000
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:

Hours_of_Service:
Contact_Instructions:
Cloud_Cover:
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name:
Albers_Conical_Equal_Area:
1st_Standard_Parallel:65
2nd_Standard_Parallel:55
Longitude_of_Central_Meridian:-154
Latitude_of_Projection_Origin:50
False_Easting:
False_Northing:
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method:
Coordinate_Representation:
Abscissa_Resolution:
Ordinate_Resolution:
Geodetic_Model:
Horizontal_Datum_Name:NAD27 (Alaska)
Ellipsoid_Name:Clarke1866
Semi-major_Axis:
Denominator_of_Flattening_Ratio:
Entity_and_Attribute_Information:
Overview_Description:
Entity_and_Attribute_Overview:
See Appendix L in “Kanuti NWR/Ray Mtns./Hogatza River Earth Cover Classification Final Report" or see Fielddata_documentation.doc on final deliverable CD.
Entity_and_Attribute_Detail_Citation:
Metadata_Reference_Information:
Metadata_Date:03/2001
Metadata_Review_Date:
Metadata_Future_Review_Date:
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:Bureau of Land Management Alaska
Contact_Organization_Primary:
Contact_Organization:
Contact_Person:
Contact_Position:
Contact_Address:
Address_Type:

Address:222 West 7th avenue
City:Anchorage
State_or_Province:Alaska
Postal_Code:99513
Country:U.S.A
Contact_Voice_Telephone:
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Metadata_Standard_Name:
Metadata_Standard_Version:
Metadata_Time_Convention:
Metadata_Access_Constraints:
Metadata_Use_Constraints:
Metadata_Security_Information:
Metadata_Security_Classification_System:
Metadata_Security_Classification:
Metadata_Security_Handling_Description:
Metadata_Extensions:
Online_Linkage:
Profile_Name:

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

Field Site Polygon Coverage Attribute Table
karh_fld_sts.pat:

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

3 = viewed from a distance, 4 = viewed on air photos.

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

Data exported from Ducks Unlimited Field Form Software.

KARH_SITE_PHOTO.dbf Dbase IV file containing site photo information.

YEAR Year of field data collection

AREA_NAME Name of project area

CREW_NUM Id number of crew that collected data

SITE_NUM Field site number; relates to SITE_NUM of field site polygon coverage in a one-to-many relationship (i.e. each site may have multiple photos).

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

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

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

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

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

KARH_SPECIES.dbf

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

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

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

Appendix M. Contact Information

The following additional data is available:

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

For more information please contact:

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. Department of the Interior
U.S. Fish and Wildlife Service
101 12th Ave., Rm 262
Fairbanks, AK 99701