CHALLENGE COST SHARE AGREEMENT
between
Ducks Unlimited, Inc. and
Department of the Interior Bureau of Land Management

CLASSIFICATION, MAPPING, AND ANALYSIS OF WETLANDS AND WATERFOWL HABITAT IN ALASKA

U.S. Dept. of the Interor Bureau of Land Management Contract No. L974-A1-0017
Ducks Unlimited, Inc., Contract No. AK-0014-001
Pacific Meridian Resources Job No. 237

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TABLE OF CONTENTS

1. INTRODUCTION

In the early 1980's, the U.S. Geological Survey (USGS), in cooperation with several agencies in Alaska (e.g., Bureau of Land Management (BLM), National Park Service (NPS), U.S. Fish and Wildlife Service (USFWS), Minerals Management Service (MMS)) mapped vegetation land cover to assess development issues in the arctic (Gaydos et al. 1983). This work did not focus on wetland habitats, rather it provided a view of the landscape in terms of vegetative communities. This process was done for agencies throughout Alaska over a period of several years to provide maps of vegetation land cover generally used for regional or large area planning purposes. More recently, the NPS has been mapping land cover on all the park units in Alaska using TM imagery. Again, these efforts are not designed to map and evaluate wetland waterfowl habitats, they are for the purpose of identifying vegetation and land cover. SPOT multispectral (XS) imagery were used to map vegetative communities used by brant in the Teshekpuk Lake area as part of an aircraft disturbance/brant energetics study under an interagency agreement between BLM, MMS, and USFWS (Derkson et al. 1991).

Two major efforts to map wetlands in Alaska are the USFWS National Wetlands Inventory (NWI) and the BLM/Ducks Unlimited, Inc. (DU) project. The difference between the two is that the focus of NWI is to map wetlands, not waterfowl habitats. The focus of the BLM/DU effort is mainly to map waterfowl habitats. The work is highly complementary, but differs in methods. The BLM/DU approach uses satellite imagery as the primary data. Aerial photos, maps, field notes, NWI data (where available) are used as ancillary data. NWI identifies wetland features using aerial photograph interpretation and applies the Cowardin et al. 1979 classification to them. The DU/BLM project identifies those wetland features important to waterfowl using digital image processing techniques and groups them into general classes of waterfowl habitat. These generic classes can be correlated to NWI for purposes of standardizing the information.

DU and BLM have been jointly using satellite image processing techniques to map Alaska BLM administered lands since 1988. The mapping of the Lake Iliamna and Lake Clark area in the current project will complete the original joint contract. Altogether, four separate areas covered by four full and one quad Landsat Thematic Mapper (TM) scene have been completed. Figure 1 depicts the locations of the Landsat TM scenes BLM/DU has used for wetland analysis (Kempka et al, 1993). Wetland classifications were developed for a subset of the full TM scene for each area. The presence of wetlands near or on BLM administered lands and field data were used to determine the subset areas for habitat analysis.

Cooperative partners involved in this project are Ducks Unlimited, Inc. (non-profit wetlands conservation organization), U.S. Department of Interior Bureau of Land Management (BLM), and Pacific Meridian Resources (natural resources consultant).

2. PURPOSE

The primary objective of this project is to gather data regarding the size, distribution, and shape of wetland vegetation community types of the Lake Iliamna/Lake Clark area. Another

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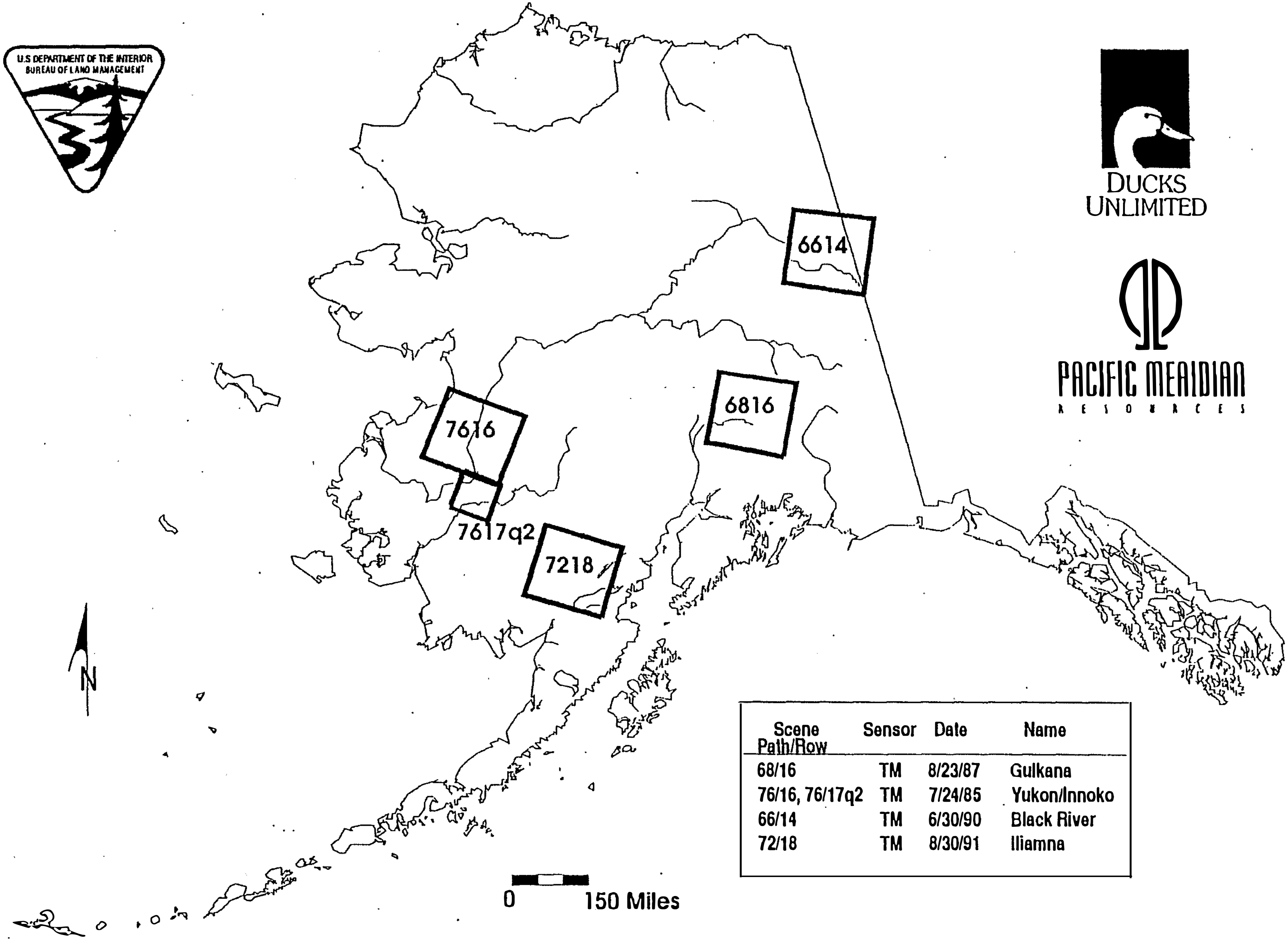


Scene Path/Row	Sensor	Date	Name
68/16	TM	8/23/87	Gulkana
76/16, 76/17q2	TM	7/24/85	Yukon/Innoko
66/14	TM	6/30/90	Black River
72/18	TM	8/30/91	Iliamna

Figure 1. Location of Completed DU/BLM Cooperative Wetland Satellite Mapping Projects in Alaska

objective is to accomplish the wetland classification utilizing DU techniques ported to commercially available image processing software. The specific product to be produced under this contract, a wetland classification map of the designated wetland classes, has also been expanded to a full landcover classification.

A GIS field data database has been designed and implemented based on sites collected in the field. Converting DU's custom image processing software to a commercial software package will enable greater use of the classified imagery and digital field data for wetlands management. This classification and field database will become part of a wetlands ecosystems database for BLM lands in Alaska.

3. PROJECT AREA

Alaska contains the largest complex of wetlands in the United States, with 170 million ± acres. The Lake Iliamna and Lake Clark region represents a microcosm of the challenging Alaska landscape of lacustrine, riverine, palustrine and tundra/lichen dominated wetlands.

The Alaska Peninsula is dominated by very large freshwater lakes and a rich diversity of tundra habitats. The Bristol Bay outwash plain contains substantial breeding habitats for ducks and tundra swans. Far more important to waterbirds is the role these wetlands play as staging habitat for migrants. Waterfowl and shorebirds which nest in the Yukon Delta gather in lagoons and estuaries of the Alaskan Peninsula in spring, prior to ice-out on the Delta (King and Lensink 1971, Lensink and Derkson 1986). Concentrations of birds gather again in August and September, prior to departure for more southerly wintering grounds. The rolling tundra habitat of this region also provides habitat for the huge Mulchatna caribou herd and substantial numbers of brown bear.

The Bristol Bay lowlands are formed on an outwash plain extending north of the Peninsula-Aleutian Mountain Range and the valleys adjacent to the Kvichak and Nushagak Rivers (King and Lensink 1971). These rivers and their major tributaries, such as the Stuvahok, Mulchatna and Koktuli Rivers, dominate the hydrologic processes of the lowlands. Substantial waterfowl habitat is present at the Kvichak River Delta as it enters Iliamna Lake. Shoreline regions of Iliamna and Clark Lakes are heavily used by migrants. Just 20 years ago this region produced fall flight numbers of ducks greater than 570,000 and tundra swan production exceeded 10,000 (King and Lensink 1971). Dominant breeding waterfowl species include greater scaup, northern pintail, mallard, American wigeon, green-winged teal, and scoter species.

The project area, depicted in Figure 2, is composed of that part of thirty 1:63,360 scale USGS quadrangles which fall within the boundary of Landsat TM image Path 72 Row 18 collected on 30 August 1991. The land in the project area contains most of the wetlands within the image and all of the training sites.

4. DATA ACQUISITION

4.1 Landsat Thematic Mapper Satellite Imagery

Wetland classifications derived from Landsat TM data are useful for depicting waterfowl habitat conditions at a single point in time (Jacobson et al. 1987), as well as for time change

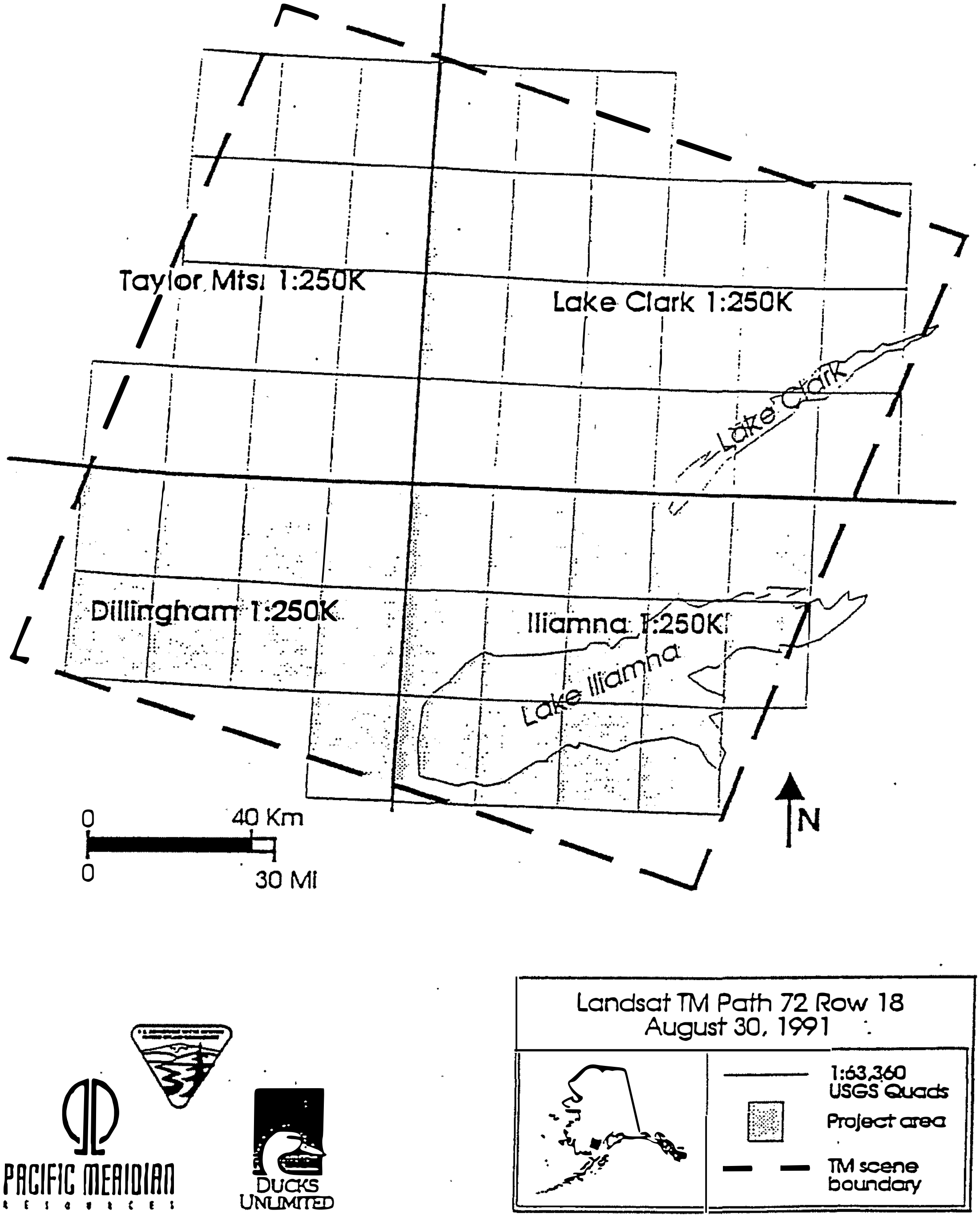


Figure 2. Project study area with Landsat TM Path 72 Row 18 and 1:63,360 USGS quadrangle boundaries.

detection. Landsat TM data were chosen for the waterfowl habitat inventory for the following reasons:

1. Large Regional Coverage - One scene covers 115 X 110 square miles or approximately 8 million acres.

2. Repeatability - Each satellite pass covers the same point on earth every 16 days, although not every pass produces useful data, especially in Alaska. This is in part due to clouds, fog, sensor lifespan, and a short growing season.

3. Wetland Identification - DU has developed image processing software that allows for efficient identification of wetland habitats and summary of corresponding acreage statistics. This wetland characterization is possible because the Landsat TM sensor collects data regarding the radiance of earth surface features in 7 different spectral bands. Specifically, the middle infrared band 5 has been determined the most useful for identifying water features.

4. Cost Effective - Based on DU figures for projects using full TM scenes, the cost of most wetlands inventory projects is less than 2 cents per acre.

5. Detailed Resolution - TM's pixel (picture element) size or smallest distinguishable unit size is 30 X 30 meters (about .2 of an acre). This level of detail is sufficient for most landscape resource management and research applications. In this project, the image was resampled to 25 X 25 meters.

Landsat TM image Path 72 Row 18 collected on 30 August 1991 was used for this land cover classification.

4.2 Ancillary Data

Ancillary data was provided by the BLM and includes the following:

- 1:60,000 scale color infrared (CIR) aerial photographs and flight lines for summer months of years ranging from 1978-1984. These were extensively used for image classification and editing.

- Digital Elevation Models (DEM) data at 1:250,000 scale

- Published 1:250,000 and 1:63,360 scale USGS quadrangles

5. METHODS

The data processing for this project was done on a SUN SPARCstation 2 using ERDAS IMAGINE® version 8.02 and 8.1, ERDAS version 7.5 and ESRI's ARC/INFO® version 6.1 software. A PC DOS based system with Borland's dBASE IV® was used for field data entry, for analysis, including feature type attributes, field data classificaton, and to apply the decision tree to categorize the training sites into feature classes. The new custom ERDAS IMAGINE® DU module was installed, tested and used for computing wetland statistics.

5.1 Comparison of Image Processing Techniques: Previous vs Current Project

The flow diagram depicted in Figure 3 summarizes the techniques used by Ducks Unlimited in the previous studies. Figure 4 summarizes the techniques used by Pacific Meridian Resources in this project.

Preliminary target feature types were selected during contract preparation. These categories and the decision rules for determining them were updated during field data collection, after data entry and finally refined during the image classification process.

DU had already started processing the image before Pacific Meridian Resources commenced work on the project. Consequently, the DU classified image from step 8 below, prior to post-processing (feature class labelling, grouping and editing), was used for the field maps and the final CIR plots in the current project. That image is also the CIR classified image delivered under this contract. This CIR single-band image was not used for landcover classification, however. Pacific Meridian Resources went back to the raw TM image georeferenced by Ducks Unlimited to produce the full landcover classified image. This was done to allow the maximum amount of both wetland and upland feature types to be extracted. A different procedure was followed in this project as shown in Figure 3, and will be discussed later. The DU procedure used in previous studies and for pre-classification in this project, are discussed below.

5.2 The Ducks Unlimited Image Processing Procedure

Ducks Unlimited used Earth Resources Laboratory Applications Software (ELAS), developed by the National Aeronautics and Space Administration at the John C. Stennis Space Center, and their own custom ELAS software for preprocessing. TM bands 1-5 and 7 were used; the thermal band 6 was omitted due to differences in spatial resolution. The procedures were as follows:

1. Georeferencing - An ELAS georeferencing program was used to warp the full TM image to the Universal Transverse Mercator (UTM) coordinate system.

2. Histogram analysis - The frequency and the cumulative distribution of pixel reflectance values for each band were determined for use in later phases of image processing.

3. Principal Component Analysis (PCA) - This image rotation technique was used to reduce the 6 bands of raw data to 3 bands that retain most of the information. The resulting first three components accounted for approximately 98% of the variance in the original 6 bands.

4. Spectral class clustering - The TM data was sampled for homogeneous cells from the first three principal components with a moving 3 x 3 pixel window. This clustering technique calculates the statistical properties for the resulting spectral classes to be used for unsupervised classification.

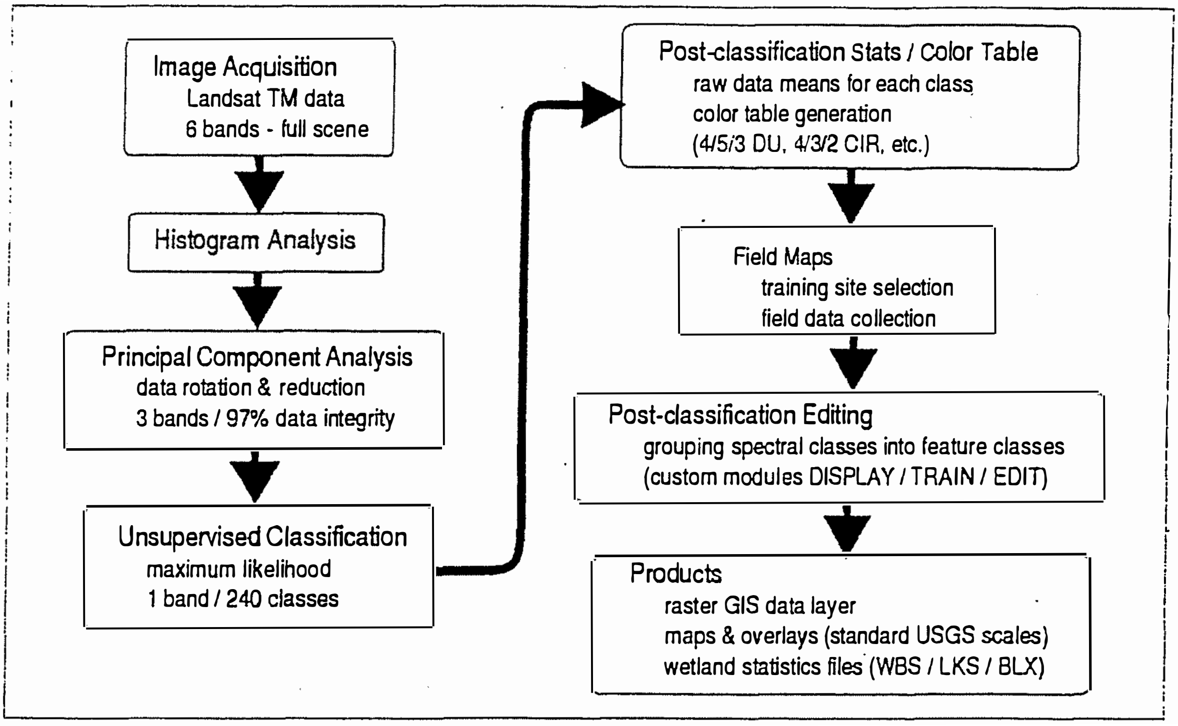


Figure 3. Ducks Unlimited Image Processing Flow Diagram (ELAS/DU Software)

5. Unsupervised maximum likelihood classification - In this process, each input pixel is assigned to the spectral class into which it best fits, statistically, in three-dimensional space.

6. Post classification statistics - Statistics for the image color table are generated by comparing the classified file to the 6 band raw data to determine raw mean value and standard deviation for each spectral class. These data are viewed graphically on the screen during image interpretation.

7. Color table generation - Color gun intensity values are created using the frequency and mean statistics for each spectral class in bands 3, 4, and 5. This band combination was chosen to emulate color infrared (CIR) photography, and to take advantage of the wetness information in band 5. For image display and field maps, the band/color gun combination of 4,5,3 in color guns red, green and blue was used.

8. The resulting one band classified image file was converted to ERDAS format. (This image was used for field maps, the final CIR plots, and delivered for the CIR plot in the Iliamna project.) DU used this ERDAS format file for post processing and feature class labelling on a PC DOS based image processing system.

9. Class identification and image editing - Raw spectral classes were aggregated into feature classes and image editing performed to eliminate 'confusion' classes, to move

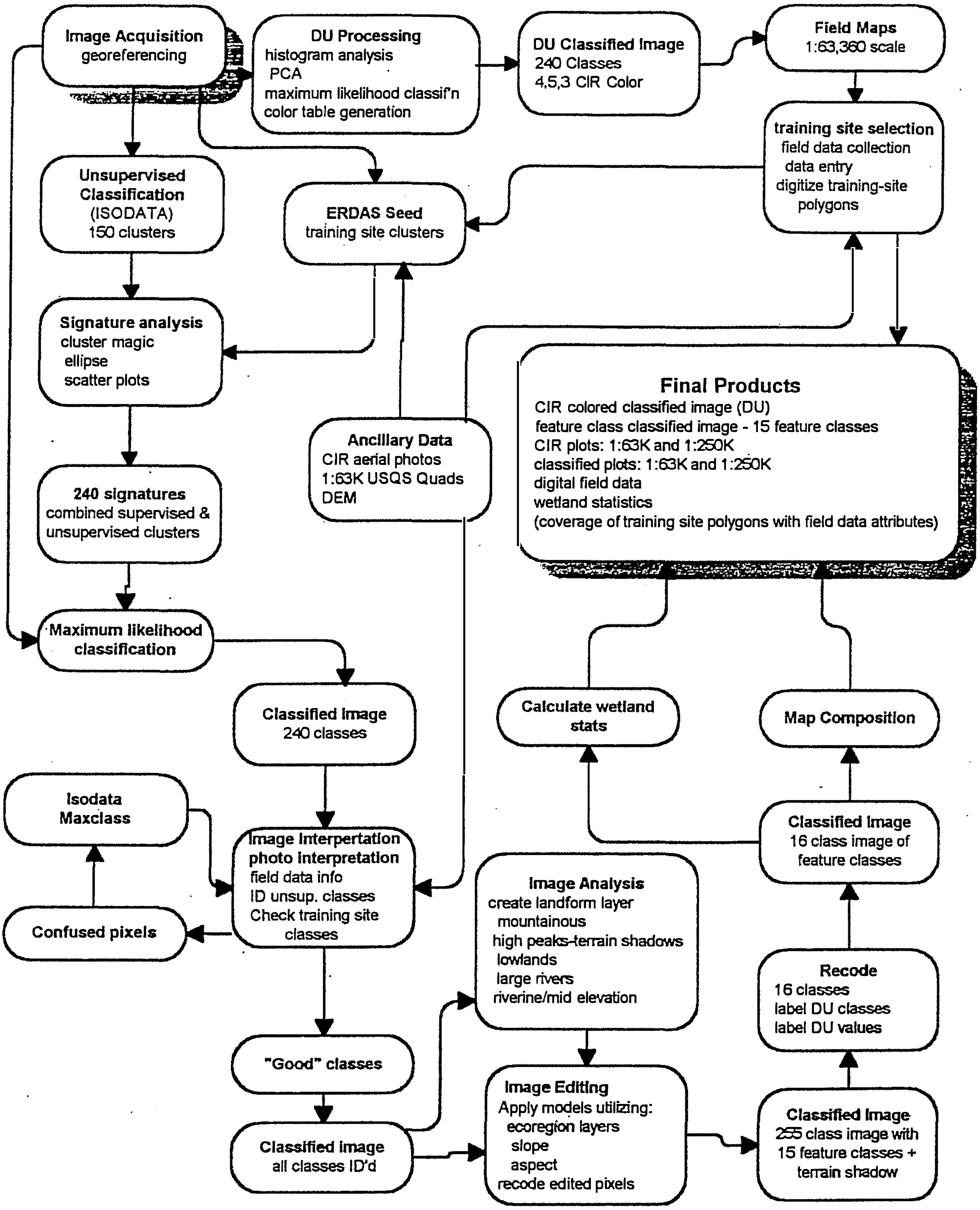


Figure 4. Image Processing Flow Diagram for Lake Iliamna/Lake Clark Project

pixels to more appropriate classes and to remove terrain shadows, cloud shadows, and non-wetland features (i.e., black spruce bogs, fire scars, etc.).

10. PC ELAS, which is an adaptation of mainframe ELAS for PC DOS based systems, and new modules developed by Ducks Unlimited, were used for class identification and image editing. The grouped and edited file was then processed by a program which uses connective components logic to develop statistics on each individual basin. These statistics, referred to as wetland statistics, report the location of each basin, which waterfowl habitat classes are contained in the basin, the acreage of each class contained in the basin, the shoreline perimeter of each basin, and other information. Basins are formed by connecting waterfowl habitat pixels, and in this case, are composed of up to five different waterfowl habitat types.

5.3 Creation of Field Maps

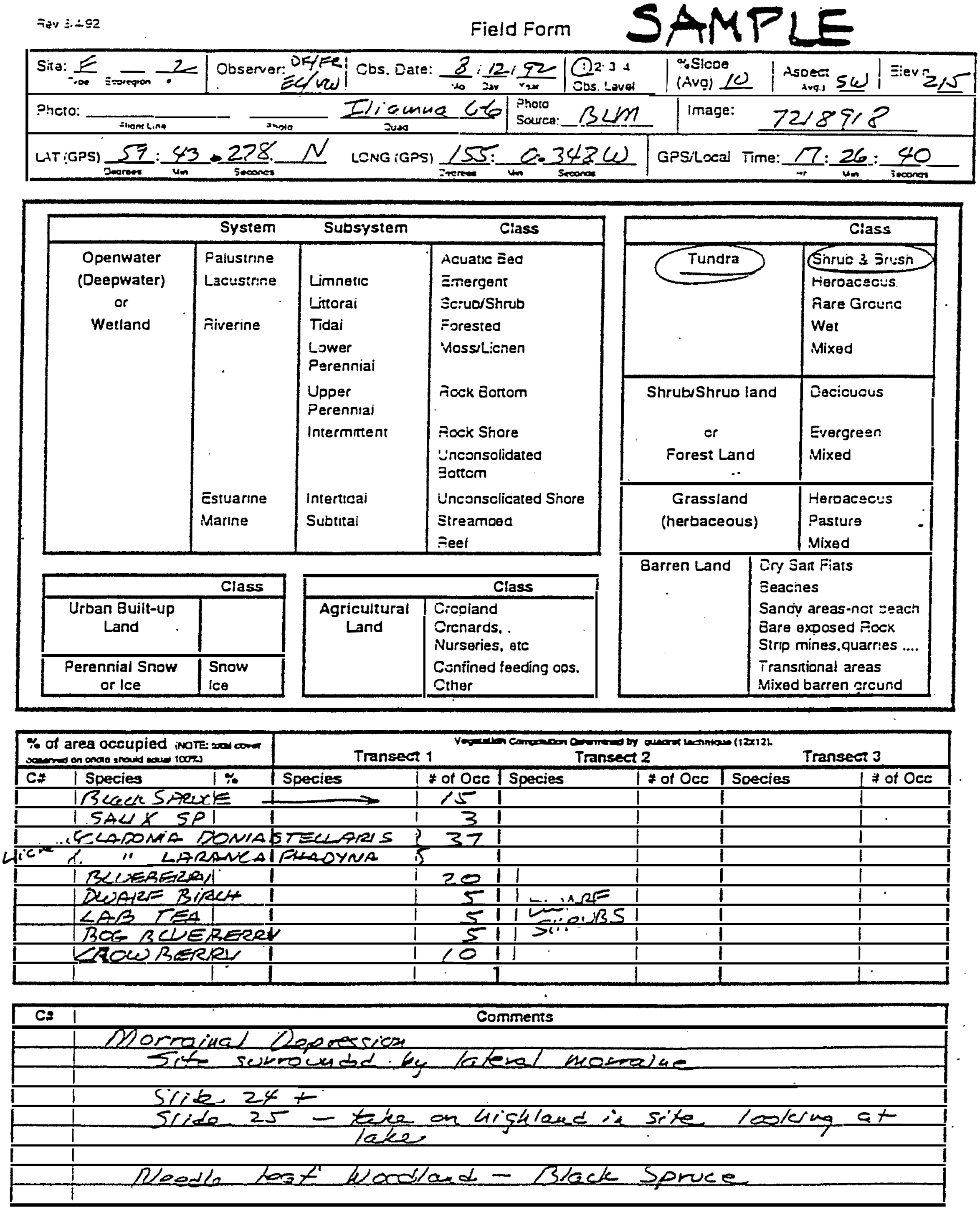
A vector file of USGS 1:63,360 scale quadrangles was used to clip several field maps from the classified CIR colored image produced by Ducks Unlimited as described above. A large format Calcomp 58436 color electrostatic plotter was used to produce plots at a 1:63,360 scale (1 inch to the mile) for use as field maps.

5.4 Field Work

Field procedures, plant lists, and a field form for data collection were devised prior to data collection. The field form is illustrated in Figure 5. A digital copy of the National List of Plant Species That Occur in Wetlands: Alaska (U.S. Fish and Wildlife Service, 1988), and *Flora of Alaska* (Hulten 1968) were used to identify an appropriate plant list/cover list specific to the Iliamna area. The most common species within each major structural type (ie. tree, shrub, grass, tundra, aquatic) was included on the field form.

The land cover field data were categorized into three separate classification systems, to provide a crosswalk to other existing and potential mapping projects. First, BLM and DU biologists developed a site specific classification tailored to their needs. Secondly, the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) Coastwatch Change Analysis Project (CCAP) classification (Klemas et al. 1993) was noted for each field training site. Generally, this is a combination of both the Anderson land cover (Anderson et al., 1976) and Cowardin wetland (Cowardin et al., 1979) classification systems. Thirdly, cover types were also recorded according to the Alaskan Vegetation Classification (Viereck et al., 1992). Having a preliminary field visit and taking the time to properly design a field form greatly simplified and speeded data collection in the field. A copy of the field data form used is illustrated in Figure 5.

Figure 5. Field Data Form for Lake Iliamna Area



Rev 3-4-92

Field Form SAMPLE

Site: E (Type) ___ (Ecoregion) 2 (#)
Observer: DF/FE EG/VW
Obs. Date: 8 (Mo) / 12 (Day) / 92 (Year)
[✓ 1] 2 3 4 Obs. Level
%Slope (Avg) 10
Aspect (Avg.) SW
Elev'n 215
Photo: ______ (Flight Line) ______ (Photo) Iliamna 66 (Quad)
Photo Source: BLM
Image: 7218918
LAT (GPS) 59 (Degrees) : 43 (Min) . 278 (Seconds) N
LONG (GPS) 155 (Degrees) : 0.342 (Min) (Seconds) W
GPS/Local Time: 17 (Hr) : 26 (Min) : 40 (Seconds)

	System	Subsystem	Class
Openwater (Deepwater) or Wetland	Palustrine		Aquatic Bed
	Lacustrine	Limnetic	Emergent
		Littoral	Scrub/Shrub
	Riverine	Tidal	Forested
		Lower Perennial	Moss/Lichen
		Upper Perennial	Rock Bottom
		Intermittent	Rock Shore
			Unconsolidated Bottom
	Estuarine	Intertidal	Unconsolidated Shore
	Marine	Subtidal	Streambed
			Reef

	Class
[✓ Tundra]	[✓ Shrub & Brush] Herbaceous Bare Ground Wet Mixed
Shrub/Shrub land or Forest Land	Deciduous Evergreen Mixed
Grassland (herbaceous)	Herbaceous Pasture Mixed
Barren Land	Dry Salt Flats Beaches Sandy areas-not beach Bare exposed Rock Strip mines,quarries .... Transitional areas Mixed barren ground

	Class
Urban Built-up Land	
Perennial Snow or Ice	Snow Ice

	Class
Agricultural Land	Cropland Orchards, Nurseries, etc Confined feeding ops. Other

% of area occupied (NOTE: total cover observed on photo should equal 100%)			Vegetation Composition Determined by quadrat technique (12x12). Transect 1		Transect 2		Transect 3	
C#	Species	%	Species	# of Occ	Species	# of Occ	Species	# of Occ
	BLACK SPRUCE		→	15				
	SALIX SP			3				
	CLADONIA DONIA		STELLARIS ?	37				
Lichen	C. " LARANCA		PHADYNA	5				
	BLUEBERRY			20				
	DWARF BIRCH			5	DWARF			
	LAB TEA			5	SHRUBS			
	BOG BLUEBERRY			5				
	CROWBERRY			10				

C#	Comments
	Morrainal Depression
	Site surrounded by lateral morraine
	Slide 24 +
	Slide 25 – take on highland in site looking at
	lake
	Needle leaf Woodland – Black Spruce

5.5 Field Work And Site Data

5.5.1 Training Site Selection

Field visitation sites were determined by random selection in the office based on unique spectral responses on the TM plots, unique colors on the CIR aerial photography and presumed habitat type. These sites were circled and numbered on the field maps.

Field Data Collection

Field data collection was conducted by DU and BLM staff members August 6 - 12, 1992, approximately 1 year from the Landsat TM scene acquisition date. A helicopter was used to transport personnel and field equipment to field site locations. The color field map plots, CIR aerial photographs, and USGS maps were used for orientation.. The goal was to cover as many different habitat sites types as possible in the relatively short time the helicopter was available for field transport. GPS locations were recorded to provide reference data should future work be done in this region. The first sites were collected on the ground to become familiar with vegetation types, structure, and phenology and to gather transects. The remainder of the sites were recorded by a team of observers in the hovering helicopter aircraft. The navigator or co-pilot seat was occupied by a the person who runs the GPS equipment and interprets the field map. The passenger behind the pilot, was the person most knowledgeable regarding the vegetation and the person behind the co-pilot would record land cover type percentages and other

Class Number	Class Code	Class Name	No. of Sites
1	NVW	Clear water	4
2	NVT	Turbid water	1
3	AB_	Aquatic bed	5
4	DM_	Deep marsh	11
5	SM_	Shallow marsh	36
6	TUW	Wet tundra	39
7	S_G	Sedge graminoid	22
8	TUL	Dry lichen tundra	21
9	TUS	Dry shrub tundra	22
10	FDE	Deciduous forest	23
11	FNL	Needleleaf forest	5
12	FMX	Mixed forest	7
13	SS_	Scrub-shrub	85
14	NVB	Non-veg bare	13
15	NVI	Ice/snow	1
		TOTAL	295

Table 1. Tally of Training Sites by Final Feature Class

data on the field form. This is a very efficient method of field data collection since much broader range of area can be covered with a orthogonal view from above similar to a satellite sensor. A tally of site types was run at the end of the day, to help ensure quality and that an appropriate number of each final map category was sampled. Table 1 is a tally of the field sites according to their final land cover class calculated by the decision tree.

5.6 Data Entry and Processing

Tabular data entry of training site data was conducted in the office following field season using a custom dBASE IV program with various lookup databases. A schematic diagram of the database is depicted in Figure 6: The ultimate output of data entry was three related files:

- A site database with one record per site. This contains site specific information such as latitude/longitude, aspect, and elevation which does not generally change over time.
- An observation database, with one record per site visitation. In the project, the sites were visited only once, so there is just one record per site. Timely information such as observer(s), date, level of observation (on ground, from the air), date of associated imagery and aerial photos, etc. are recorded in this data file.
- A cover database with one record for each land cover type noted at the site for the visitation date. The fields include site number, observation date, dominant vegetation cover, percent of coverage and height.
- A photograph database with one record for each field photo or series of photos with the same description would be useful but was not implemented on this project. General wetland types were photographed for gross comparison with field maps and field sites.
- A related database of wildlife observed would also be useful.

The data entry program put all the data for one observation into a "raw" file plus the cover file. The data from the "raw" file was later used to fill the fields in the site and observation files. The result of the decision tree was put into the CALCLASS field and arbitrary codes for the modified Cowardin-Anderson class and the Viereck class were used to fill the MCACOD and VIERECKCLS fields respectively. These database files are provided on a PCDOS formatted floppy disk and a listing of their field structures and lookup files for the codes appears in the Appendix B.

These database files were found to be invaluable during the course of this project. The cover database was the input for the vegetation decision tree program. Various reports sorted and/or grouped by covertypes, feature class, or sitenumber were handy for reference during image processing. Also the data was readily added to the ARC/INFO® coverage attribute table of training site polygons and can be easily added to ERDAS IMAGINE® raster attribute tables.

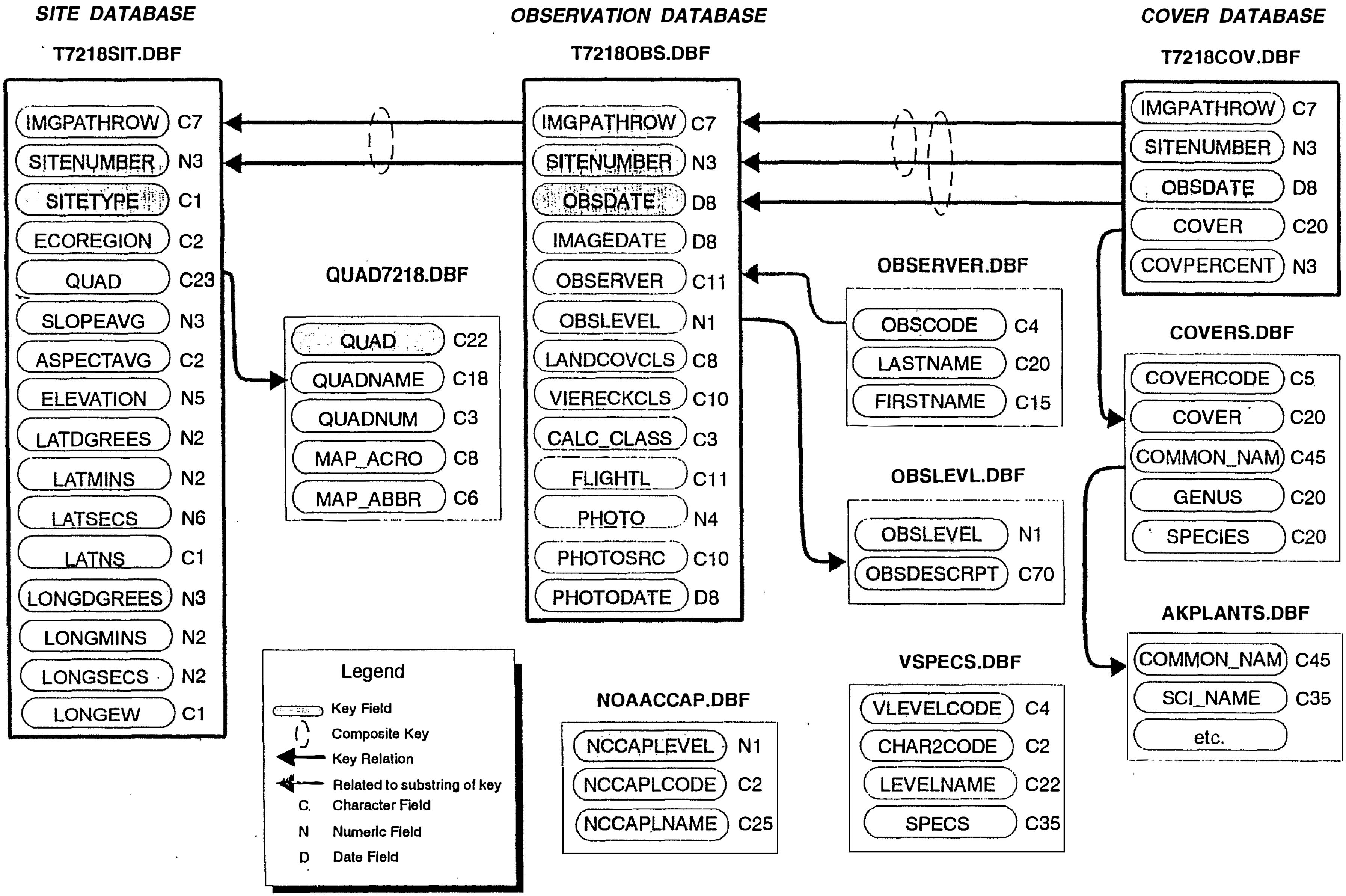


Figure 6. DU/PMR/BLM Alaska Wetlands Database for Iliamna as Implemented

5.7 Land Cover Classes and the Vegetation Decision Tree

A decision tree for grouping the detailed species types and percentages recorded in the field was developed. Though the contract only calls for a wetland classification it was later decided to attempt a full land cover classification. Since selected upland sites had been visited in the field, such a classification was feasible. The final definition of upland classes was arrived at interactively during the image interpretation/photo interpretation/spectral classification process. The original decision tree was coded into a dBASE IV program and run on the cover data and the results compared to the field classification and the classified image. As changes were made in the classes to be identified and their definitions, the decision tree program was modified accordingly and the feature type classes for the training sites recalculated. The classes finally arrived at resulted in less spectral confusion. The final vegetation decision tree is illustrated in Figure 7 and Table 2 describes these classes.

6. IMAGE CLASSIFICATION AND EDITING

The first step in classification is to collect spectral signatures representing the spectral variation of the image. Both supervised (from training sites) and unsupervised (calculated from the image using statistical parameters) were utilized. Before computing the signatures, the project area was clipped from the raw 6-band image along 1:63,360 scale USGS map sheet boundaries. This 30 quadrangle area contains most of the wetlands and all of the training sites. To reduce the computation load and increase the number of useful unsupervised signatures, pixels representing easily identified classes of ice/snow and rock were masked out. Lake Iliamna wasn't masked out because clear water was one of the target wetland classes. These pixels were selected from a 240 class ISODATA™ image using a Sun SPARC 2 workstation. After classification, these identified classes of pixels were recoded to the final class values and put back into the classified image.

6.1 The Seeding Process

The polygons drawn on the field maps for each training site were digitized using PC ARC/INFO®. (This coverage is provided as an extra along with the contracted final products). Spectral signatures were obtained for the training sites using the ERDAS 7.5 SEED program. Seeding is the process of developing spectral statistics for field training sites. The raw, six band, rectified LANDSAT TM image was displayed in a viewer and the training site poygons were displayed over the image. The cursor was positioned to a representative pixel within the polygon and the seed grown to a spectral or spatial boundary. Each preliminary seed was inspected for general conformance to the training site area (representative and within), size (at least 10 pixels), and spectral uniformity based on the standard deviation (SD) within each of the 6 bands. In most cases the average SD is under 3. A few sites could not be seeded because they were too small and/or variable. The result of the seeding process is a set of supervised (training site) spectral signatures.

	Class Name	Code	Description	Key
			Wetland Classes	
1	Clear water	NVW	Clear open water	Clear water >= 70%
2	Turbid water	NVT	Open turbid water	Turbid water >= 70%
3	Aquatic bed	AB_	Predominantly aquatic bed plants (burreed, pondweed, and sparganium) and water.	At least 40% aquatic bed plants and they are the dominant vegetation
4	Deep marsh	DM_	Predominantly emergent vegetation (Carex, buckbean, Eleocharis, cottongrass, Potentilla) and water (at least 30%)	At least 30% water with 45% or more aquatic emergent vegetation
5	Shallow marsh	SM_	Predominantly emergent vegetation (Carex, buckbean, Eleocharis, cottongrass, Potentilla) and water (5-29%)	Water >5% and <30% with 45% or more aquatic emergent vegetation
6	Wet tundra	TUW	A very mixed class. Generally predominantly sphagnum/water with not enough sedge-graminoid to be a marsh class and too wet to be sedge-graminoid or a dry tundra class. There may be a few black spruce.	Sphagnum + water >=30% or sphagnum >= 30% and not one of the above wetland, or a sedge-graminoid or upland tree or scrub-shrub class.
			Herbaceous Classes	
7	Sedge-graminoid	S_G	Predominantly grass/sedge/herbaceous and not wet enough to be wet tundra or marsh.	At least 25% vegetation, doesn't meet criteria for a forest, shrub, or wetland class and sedge-graminoid + herbs + non-tundra shrubs > lichens + tundra plants + tundra shrubs
8	Dry lichen tundra	TUL	Dry tundra with lichens predominating.	At least 25% vegetation, not a wetland or sedge-graminoid, forest or scrub-shrub site, and lichens > shrubby tundra plants.
9	Dry shrub tundra	TUS	Dry tundra with dwarf and ericaceous shrubs and other low dry-tundra plants predominating.	At least 25% vegetation, not a wetland or sedge-graminoid, forest or scrub-shrub site, and shrubby tundra plants.> lichens.
			Forest Classes (Trees > 40%)	
10	Deciduous forest	FDE	Forest of predominantly deciduous trees or deciduous trees plus deciduous shrubs (such as alder and willow)	Deciduous trees > 60% and more than 80% of the tree cover or trees > 40% and not enough needleleaf trees to be a mixed forest.
11	Needleleaf forest	FNL	Forest of predominantly needleleaf trees	Needleleaf trees > 60% and at least 90% of the woody cover.
12	Mixed forest	FMX	Mixed deciduous-needleleaf forest.	Neither of the 2 above; needleleaf trees > 40% and >80% of the woody cover.
13	Scrub-shrub	SS_	Woody cover predominantly deciduous shrubs with some (possibly) trees.	At least 25% deciduous shrubs (non-tundra) and less than 40% trees.
14	Non-veg bare	NVB	Predominantly rock, gravel, sand, (mud) or bare ground.	Non-veg >= 50% and NVB > other non-veg.
15	Ice/snow	NVI	Ice or snow	Non-veg >= 50% and ice/snow > other non-veg.

Table 2. Description of Final Land Cover Classes for Lake Iliamna/Lake Clark Area

6.2 Cluster (Signature) Analysis and Initial Classification

An unsupervised clustering was performed on the raw project area image using ERDAS 7.5 ISODATA™ optimized for 150 classes. These 150 clusters were analyzed in conjunction with the supervised clusters and the custom cluster analysis tool "Cluster Magic" developed by Pacific Meridian Resources.

"Cluster Magic" is a SAS clustering routine which takes as input the signature/class names and the means for all the bands. The resulting list output groups signatures with similar statistics in such a way that a dendogram can be created by drawing connecting lines on the printed output of the list. (An accessory dBASE IV program "Dendo Magic" takes the SAS output list and creates a dBASE file printout with the clustering numbers to speed drawing the dendogram.) The spectral relationship depicted by the dendogram is similar to a parallelepiped (minimum distance) classification. Using this information and combining and eliminating signatures, the number of signatures was reduced to about 240.

The 240 signatures were submitted to the maximum likelihood classifier to produce a 1 band file with 255 classes. The extra classes were used for recoding.

6.3 Identifying Feature Classes In The Classified Images

A color scheme was devised for the feature classes and the supervised classes colored accordingly. Linked ERDAS IMAGINE® 8.02 viewers with magnifiers and inquire cursors were used to help check the supervised classes and label the unsupervised classes. An unsupervised class would be colored brightly to locate it, its feature type identified, and then colored according to the color scheme. The CIR aerial photographs were relied on heavily at this stage.

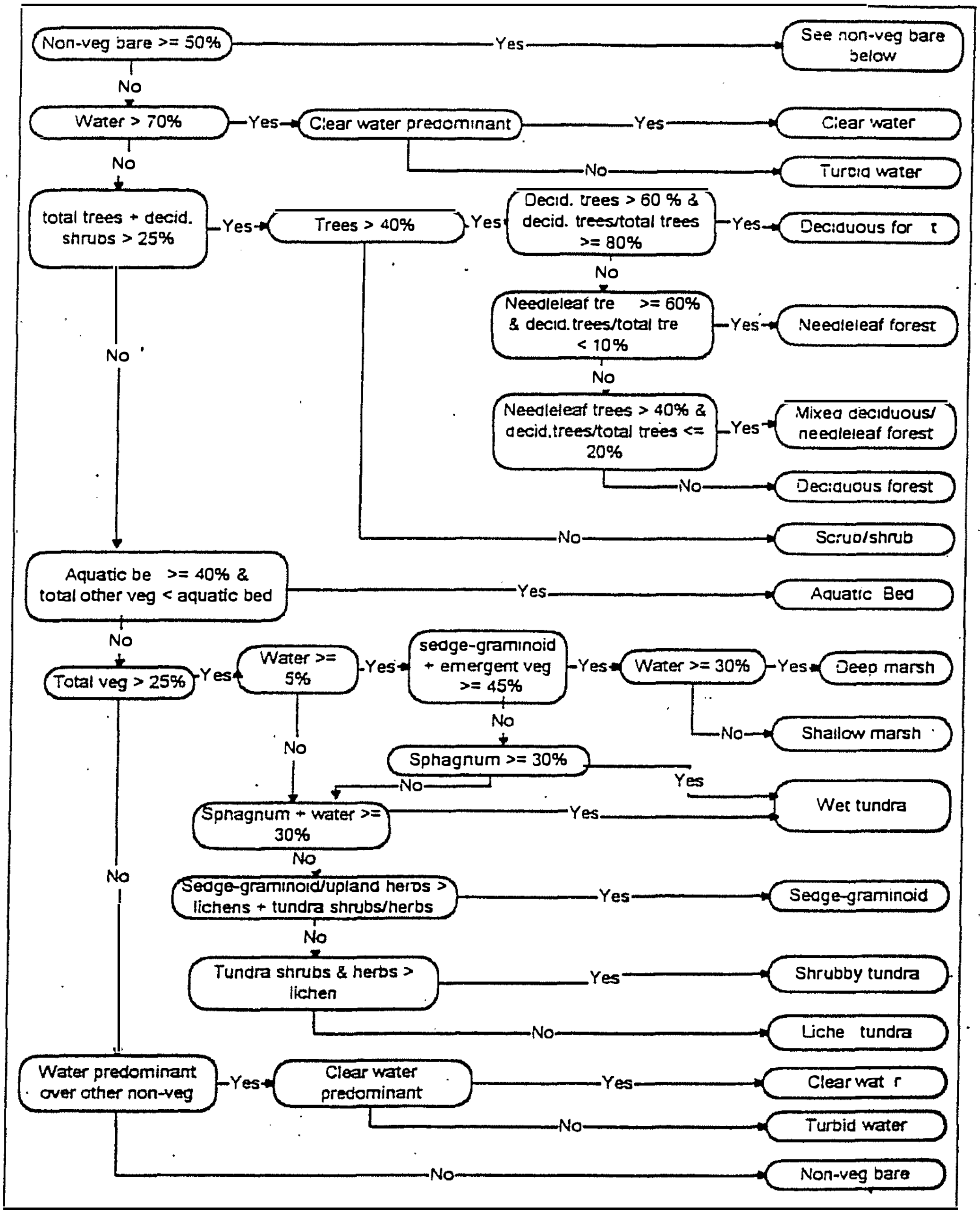
6.4 Reducing Spectral Confusion

Classes which exhibited confusion (classify areas of more than one feature type) were noted during the identification phase so they could be processed further. Also some of the supervised classes were found to be spurious. They appear correct if labelled as a different class. This may have been due to the seeding process and the "texture size" of the constituent land covers of the site. Since many of the seeds (contiguous pixels used for calculating the signature statistics) were dissected and convoluted in shape, or very small, they may not have been representative of the site taken as a whole. Such sites may be very representative but too spectrally variable for their size to be good for training. Edge problems were also observed. A pixel at the border between two types of features (such as scrub-shrub next to a creek) is a mixed pixel and will have the spectral characteristics of another feature, shallow marsh.

Wetland/Needleleaf Forest Stratification

The most noticeable confusion was shallow marsh and the needleleaf forest class. In areas of dense needleleaf forest, whether in a low or upland site, a significant proportion of the pixels classified as shallow marsh. This may be related to shadowing in the canopy and on the ground. On the other hand, in wetland areas distinct from stands of needleleaf trees (though they might be adjacent), pixels that appeared to be shallow marsh or wet tundra on photos, classified

Figure 7. Iliamna Vegetation Decision Tree



as needleleaf forest. Most of shallow marsh classes and all of the needleleaf forest classes exhibited this type of confusion, as did some of the wet tundra classes.

A "cluster busting" technique was used to help reduce this confusion. Two different runs were done, one with needleleaf forest class pixels and the other with wetland class pixels. The raw pixels representing the confused classes were masked from the raw image. An unsupervised ISODATA classification was run and the resulting signatures used for a maximum likelihood classification of the confused raw pixels. The classified pixels then were labelled as to final feature class. If any of the classes still exhibited confusion, they were labelled differently to be dealt with later. The image of relabelled pixels was recoded, overlaid on the originating classified image and a new classified image with less confusion was created. This overlaying process was done using the ERDAS IMAGINE® Spatial Modeller.

DEM Modeling

Terrain shadows tend to class as wetlands because the lack of reflectance mimics the spectral response of water. Most of the heavy terrain shadows in the image initially classed as shallow marsh, though some classed as water or deep marsh. Pixels classifiying as wet tundra pixels at the high elevations appeared to be shrubby tundra cast in light shadow.

The shadows were dealt with in two steps:

The 3 DEM's (derived from 1:250,000K topographic maps) for the project area were imported to ERDAS and projected to UTM zone 5 with a pixel size of 25 meters to match the imagery. ERDAS 7.5 was used to derive a slope layer and ERDAS IMAGINE® to derive an aspect layer. A model was created in the IMAGINE® Spatial Modeler with this logic:

- IF a wetland pixel faces E, NE, N, NW, or W and the slope is greater than 40% OR
- IF a wetland pixel faces N or NW and the slope is greater that 20%
- THEN recode that pixel to terrain shadow.

This model removed much of the heavy terrain shadow confusion. Finer parameters could not be used without recoding true wetland pixels. Slope and aspect layers from 1:63,360 DEM's would have been better, of course and fine tuning of the slope and aspect parameters would then have removed more of the shadows. However, the areas of terrain shadow in the classified image were more easily spotted after using this procedure. An "edit layer" technique was used to remove most of the remaining terrain shadow.

The "Edit Layer" Technique

The "edit layer" technique was used several times in the editing phase of classification of the image.

1. A new 16 class "edit layer" is generated from the classified project area image. The project area is coded 1 and the background is coded 0 in this image. Classes 0 and 1 are assigned an opacity of 0 (completely transparent), the rest of the classes are assigned an opacity of .2 (semi-transparent) and given different colors.

2. Using ERDAS IMAGINE®, either the raw image or the classified image is displayed in a viewer and the edit layer is displayed over it. An area to be identified for later processing (i.e., general areas that have terrain shadow, a buffer around major rivers, etc.) is digitized and the edit layer there is recoded from 1 to some value greater than one. The raster editor of IMAGINE® allows you to do this interactively. The recoded area then appears as colored hatch marks which allow the underlying image to show through. The recoded area is easy to identify and mistakes are easy to fix before the edit layer is applied with the ERDAS IMAGINE® Spatial Modeler to recode the classified image itself.

Aquatic Bed Confusion in the Larger Rivers

Because of the edge effect, many pixels in the larger rivers classed as aquatic bed (AB_). Aquatic bed plants are not found in flowing water and these pixels should have been clear water like the adjacent river. The "edit layer" technique was used to digitize along the rivers and recode the aquatic bed pixels to clear water.

Segmenting the Image By Landform

During the classification, it was noticed that confusion varied across the image. Some classes identified different feature types in different parts of the image. For instance, a class that is confused between needleleaf forest and shallow marsh might be fairly good as needleleaf forest in higher elevation, mountainous areas, good as shallow marsh in low wetland areas and middle elevation areas near large rivers. This variation by landform occurred with several large classes, some which had been subjected to iterative processing (cluster busting) and some which had not. It was evident even with some of the training site classes. By recoding these particular classes depending on the general landform, the classification could be much improved. Consequently, the "edit layer" technique was used to identify these different landforms throughout the project area. The landforms identified were:

1. Well-drained mountainous. This area was not necessarily high elevation. This included the Lake Clark quads B6-8 and C6-8, much of the area southeast of Lake Iliamna, islands in the northeastern part of Lake Iliamna and other mountainous areas.

2. Low, flat wetland areas. Iliamna B-8,and Dillingham B-1 are good examples of this landform.

3. Riverine areas, usually at middle elevations.

Ultimately,the landform chosen for an area was that which resulted in the best classification of the variable classes in that area.

6.5 The Final Recode

After all the above was done, the new recoded image with the 15 final feature classes plus terrain shadow, was created for mapping and wetland statistics calculation.

7. WETLAND STATISTICS

A discussion of wetland statistics and the three types of wetland statistics files appears in the Appendix. In the Iliamna project, the new Ducks Unlimited IMAGINE® module (DU module) was used to compute the wetland statistics from the final classified image. The final recoded image was prepared for computing wetland statistics by filling in the two DU fields, DU_Class and DU_Value. These two fields are added to the image attribute table when the DU module loads the classified file, if the fields are not already there. The code for the wetland feature class (i.e. NVW for clear water) is entered under DU Class and the numeric value for that class is entered under DU Value. It is not necessary to create a final classified file with just 16 classes, 1 for each feature class, but doing so may reduce the load when computing and certainly makes maintaining data integrity easier. (If the match between DU Class and DU Value were not kept consistent, then the results would be unpredictable.) The DU class and value were assigned just for the 5 wetland classes and wetland statistics computed with the "not in basin" option to make the results comparable to the previous studies. Another run was also made, specifying totals only and having all 16 DU classes and values filled in so as to get a table of acreages for every class by map sheet.

The DU IMAGINE® module calculated the statistics by map sheet and created a separate ASCII table for the WBS, LKS, and BLX data for each map sheet. Also a totals table was created which has one summary record for each map sheet. Three fields were added to each record during the import process: the map acronym, the map code (utilizing the official 1:63,360 map sheet abbreviation for Alaska) and the UTM zone. Other information, such as satellite sensor, that was included within the statistics files in the previous studies was not added to these files. The dBASE structure files for import of the data after running the DU module are provided on disk and described in the appendix. Sample records of each type of dBASE file (WBS, LKS, and BLX) follow.

7.1 Mapsheet Summary Data

The totals data for the 30 map sheets in the project area is given in Table 3.

Table 3. Wetland Acreage Totals by Mapsheet for the Iliamna Project Area

MAP_SHEET	ACRONYM	MAP CODE	UTM ZONE	TOTAL ACRES	WETLAND ACRES	PERCENT WETLAND	NVW	NVT	AB_	DM_	SM_
B-5 ILIAMNA	A59153B5	ILI-B5	5	146917	36331	25	33702	694	96	145	1695
B-6 ILIAMNA	A59153B6	ILI-B6	5	147047	51431	35	49800	564	91	145	831
B-7 ILIAMNA	A59153B7	ILI-B7	5	146953	89974	61	86869	1212	74	248	1571
B-8 ILIAMNA	A59153B8	ILI-B8	5	147018	87091	59	80593	3566	322	311	2299
C-4 ILIAMNA	A59153C4	ILI-C4	5	145911	40625	28	39085	390	59	74	1017
C-5 ILIAMNA	A59153C5	ILI-C5	5	145882	125294	86	119963	4452	72	54	753
C-6 ILIAMNA	A59153C6	ILI-C6	5	145776	100662	69	96710	1917	283	245	1508
C-7 ILIAMNA	A59153C7	ILI-C7	5	145920	81045	56	76817	2409	401	107	1311
C-8 ILIAMNA	A59153C8	ILI-C8	5	145988	39301	27	32511	3297	724	152	2617
D-4 ILIAMNA	A59153D4	ILI-D4	5	144814	23919	17	21970	589	121	150	1089
D-5 ILIAMNA	A59153D5	ILI-D5	5	144698	21673	15	14348	5010	311	329	1676
D-6 ILIAMNA	A59153D6	ILI-D6	5	144814	3872	3	1540	997	151	168	1017
D-7 ILIAMNA	A59153D7	ILI-D7	5	144862	2252	2	964	379	131	103	676
D-8 ILIAMNA	A59153D8	ILI-D8	5	144867	3069	2	1126	493	199	182	1068
B-1 DILLINGHAM	A59156B1	DIL-B1	5	147009	16862	11	7661	4112	654	534	3902
C-1 DILLINGHAM	A59156C1	DIL-C1	5	145887	5912	4	1853	1630	454	137	1839
C-2 DILLINGHAM	A59156C2	DIL-C2	5	146056	4133	3	1258	1074	293	138	1371
C-3 DILLINGHAM	A59156C3	DIL-C3	5	145957	7709	5	4122	1769	203	336	1279
C-4 DILLINGHAM	A59156C4	DIL-C4	5	146033	5794	4	2731	1422	131	339	1172
D-1 DILLINGHAM	A59156D1	DIL-D1	5	144792	2010	1	800	143	45	163	860
D-2 DILLINGHAM	A59156D2	DIL-D2	5	144807	8270	6	4292	1434	269	508	1767
D-3 DILLINGHAM	A59156D3	DIL-D3	5	144900	6882	5	3208	1930	126	297	1321
D-4 DILLINGHAM	A59156D4	DIL-D4	5	144919	7079	5	3817	1459	150	402	1251
A-4 LAKE CLARK	A60153A4	XLC-A4	5	143694	26008	18	5434	18717	119	199	1538
B-6 LAKE CLARK	A60153B6	XLC-B6	5	142679	1507	1	656	118	22	130	582
B-7 LAKE CLARK	A60153B7	XLC-B7	5	142649	6413	4	3707	1245	68	312	1081
B-8 LAKE CLARK	A60153B8	XLC-B8	5	142706	3025	2	1516	325	67	257	862
C-6 LAKE CLARK	A60153C6	XLC-C6	5	141604	1923	1	599	143	9	208	965
C-7 LAKE CLARK	A60153C7	XLC-C7	5	141651	1907	1	787	188	2	186	745
C-8 LAKE CLARK	A60153C8	XLC-C8	5	141593	931	1	81	34	0	201	614

Key to wetland classes: NVW = Open water NVT = Turbid Water AB_ = Aquatic bed DM_ = Deep marsh SM_ = Shallow marsh

7.2 Wetland Basin Statistics (WBS)

WBS data was calculated with the default threshhold size of 2 acres for the wetland basins. Every wetland basin, consisting of contiguous wetland pixels, is at least 2 acres in size. An example of the wetland basin statistics for some Dillingham B1 basins follows.

Table 4. Sample Records of Wetland Basin Statistics

MAP_ACRO	MAP_ABBR	ZONE	BASIN	EASTING	NORTHING	ACRES	NVW	NVT	AB_	DM_	SM_
A59156B1	DIL-B1	5	1	313100	6600175	4.8	1.9	0.3	0.2	0.5	2.0
A59156B1	DIL-B1	5	2	313550	6600150	2.5	1.1	0.3	0.0	0.0	1.1
A59156B1	DIL-B1	5	3	312900	6600100	3.2	1.1	0.2	0.0	0.0	2.0
A59156B1	DIL-B1	5	4	311950	6600075	2.5	0.8	0.2	0.0	0.3	1.2
A59156B1	DIL-B1	5	5	314975	6600075	7.1	0.0	4.6	1.1	0.0	1.4
A59156B1	DIL-B1	5	6	316875	6600000	10.0	6.2	0.9	1.2	0.0	1.7
A59156B1	DIL-B1	5	7	313050	6599950	2.9	0.9	0.5	0.0	0.0	1.5
A59156B1	DIL-B1	5	8	317850	6599950	153.1	131.4	8.3	6.3	0.5	6.5
A59156B1	DIL-B1	5	9	315925	6599875	4.6	1.5	0.3	1.2	0.2	1.4
A59156B1	DIL-B1	5	10	319575	6599875	19.9	15.0	0.6	1.5	0.3	2.5

Key to wetland classes:	NVW =	Open water	AB_ =	Aquatic bed	SM =	Shallow marsh
	NVT =	Turbid Water	DM_ =	Deep marsh		

7.3 Land Key Statistics (LKS)

In the previous and current studies, land key statistics were reported by one kilometer block. To be consistent with the earlier studies, the "not in basins" option was used for calculating LKS statistics. This means that only wetland pixels not in basins greater that two acres are tallied. The total acres of wetland in a map sheet should therefore be the sum of the total LKS acres plus the total basin acres for the map sheet. (There may be some discrepancy due to rounding.)

The Kblock boundaries are on even 1000 meter divisions. The kblock number itself is arbitrary and is based on the geographic extent of the image used with the statistics module. The number is, however, unique within the image. If a Kblock within the project area is split by a map sheet boundary, it will appear in more than one file. However, only the wetland acreages within the map sheet boundary will be tallied in a map sheet's LKS file. In the earlier studies, this was not the case and the total wetland acres for the kblock would be in both map sheet LKS files.

Table 5. Sample Land Key Statistics Data Records for Dillingham B1.

MAP_ACRO	MAP_ABBR	ZONE	KBLOCK	EASTING	NORTHING	SIZE	ACRES	NVW	NVT	AB_	DM_	SM_
A59156B1	DIL-BI	5	26699	309000	6601000	86.6	0.2	0.0	0.0	0.0	0.0	0.2
A59156B1	DIL-BI	5	26700	310000	6601000	74.6	0.3	0.0	0.0	0.0	0.0	0.3
A59156B1	DIL-B1	5	26701	311000	6601000	62.7	5.7	0.9	1.9	0.5	0.6	1.9
A59156B1	DIL-BI	5	26891	308000	6600000	17.1	0.2	0.0	0.0	0.0	0.0	0.2
A59156B1	DIL-BI	5	26892	309000	6600000	247.1	1.2	0.0	0.0	0.0	0.0	1.2
A59156B1	DIL-BI	5	26895	312000	6600000	247.1	0.2	0.0	0.0	0.0	0.0	0.2
A59156B1	DIL-BI	5	26896	313000	6600000	247.1	0.5	0.0	0.0	0.0	0.0	0.5
A59156B1	DIL-BI	5	26898	315000	6600000	247.1	0.3	0.0	0.0	0.0	0.0	0.3
A59156B1	DIL-BI	5	26899	316000	6600000	247.1	0.6	0.0	0.3	0.0	0.2	0.2
A59156B1	DIL-BI	5	26902	319000	6600000	214.2	0.2	0.0	0.0	0.0	0.0	0.2

Key to wetland	NVW =	Open water	AB_ =	Aquatic bed	SM =	Shallow marsh
classes:	NVT =	Turbid Water	DM_ =	Deep marsh		

7.4 Basin-Land Key Cross Index (BLX) Data

The BLX file provides a cross-index relating basins, by number, and kblocks. Basins can be split between map sheets and therefore appear in more than one file. The basin numbers are unique only within a map sheet, however, so a split basin most likely will have different numbers in the two map sheets. Also the portion of the split basin within a map sheet must be greater than two acres to qualify as a basin in that map sheet. The wetland acres for each kblock/basin record will include only the area of that basin within that map sheet and that kblock.

Basins can also be split by kblocks within a map sheet. This is illustrated below where basin 4 appears in 3 different kblocks.

Table 6. Sample Basin-Land Key Cross-Reference Data Records for Dillingham B1.

MAP_ACRO	MAP_ABBR	ZONE	KBLOCK	EASTING	NORTHING	BASIN	ACRES
A59156B1	DIL-B1	5	26701	311000	6601000	4	1.1
A59156B1	DIL-B1	5	26702	312000	6601000	3	2.9
A59156B1	DIL-B1	5	26702	312000	6601000	4	0.3
A59156B1	DIL-B1	5	26703	313000	6601000	1	4.8
A59156B1	DIL-B1	5	26703	313000	6601000	2	2.5
A59156B1	DIL-B1	5	26704	314000	6601000	5	0.5
A59156B1	DIL-B1	5	26705	315000	6601000	5	3.9
A59156B1	DIL-B1	5	26894	311000	6600000	4	1.1
A59156B1	DIL-BI	5	26895	312000	6600000	3	0.3
A59156B1	DIL-BI	5	26896	313000	6600000	7	2.9

8. RESULTS

8.1 Final Feature Classes

Table 7 details the total acres for each land cover class. Figures 7 and 8 are reduced color plots of the two classified images for the Dillingham C-3 1:63,360 scale USGS quadrangle. The final land cover classes that resulted from scene analysis are described below:

Table 7. Land Cover Totals for Iliamna/Lake Clark Project Area

Land Cover Class	Class Code	Acres	Pct of Total Area	Pct of Wetlands	Pct of Uplands
Clear water	NVW	697,154	16%	86%	
Turbid water	NVT	61,634	1%	8%	
Aquatic bed	AB_	5,635	0%	1%	
Deep marsh	DM_	6,747	0%	1%	
Shallow marsh	SM_	40,215	1%	5%	
Wet tundra	TUW	198,567	5%		6%
Sedge graminoid	S_G	170,057	4%		5%
Lichen tundra	TUL	825,339	19%		24%
Shrubby tundra	TUS	856,344	20%		25%
Deciduous forest	FDE	133,497	3%		4%
Needleleaf forest	FNL	72,686	2%		2%
Mixed forest	FMX	33,993	1%		1%
Scrub shrub	SS_	868,360	20%		25%
Non-veg bare	NVB	242,933	6%		7%
Non-veg ice	NVI	156	0%		0%
Terrain shadow	tsh	34,324	1%		1%
Total		4,247,641			

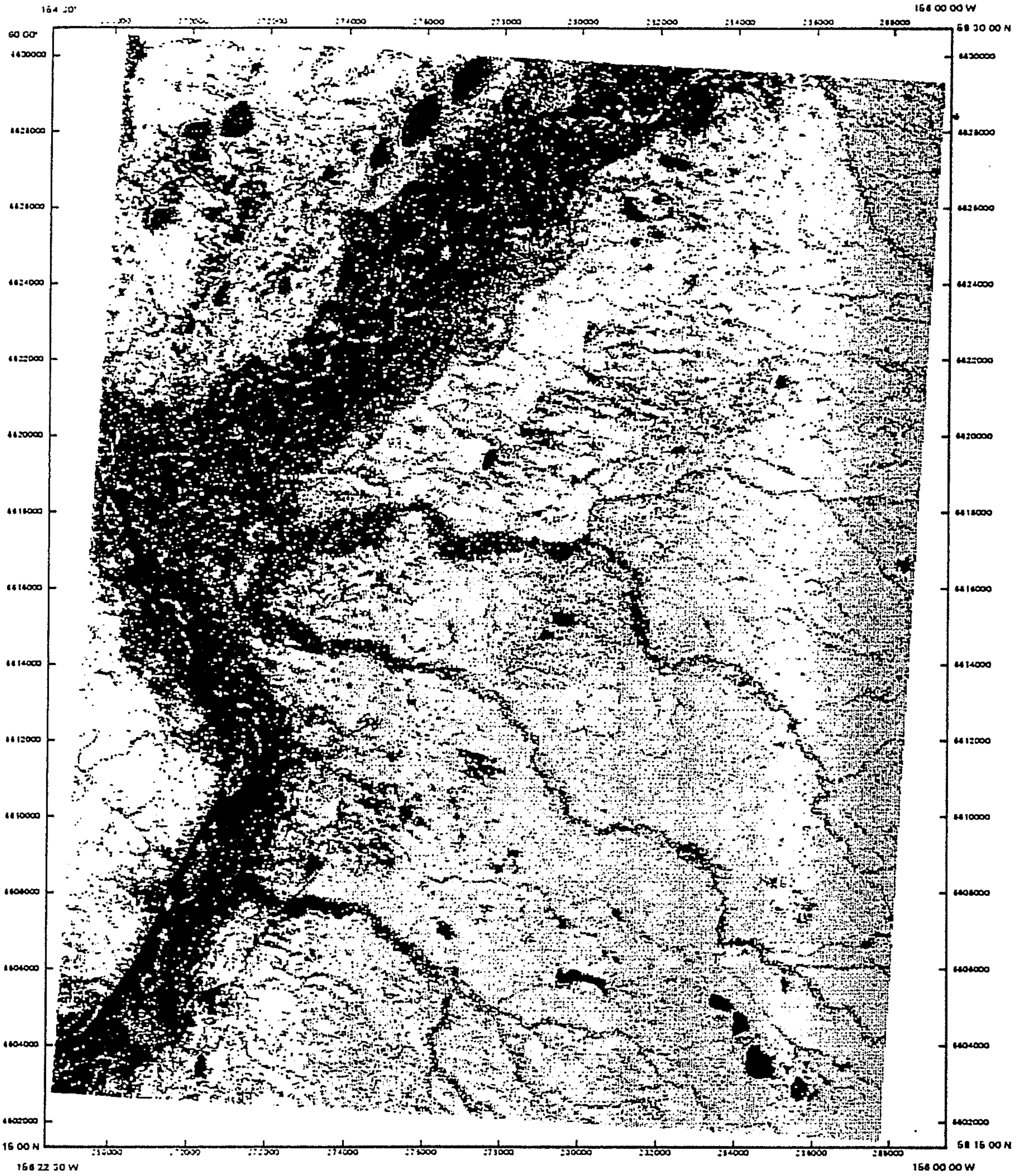
1. **Clear Water (NVW)** (697,154 acres) Clear water was well represented because of the large lakes and constituted 16% of the project area. Clear water includes most open water areas, rivers, oxbows, lakes, and ponds. Wind turbulence can cause shallow lake areas and ponds which are otherwise clear water to be turbid due to stirring up of a silty bottom. Also the location of turbidity can vary with wind direction. Thus an area may have been clear at the time of training site visitation and turbid during scene collection. It may be more meaningful to sum clear and turbid water into a class open water. At the time of scene collection, August 30th, 1991, the rivers were running clear.

2. **Turbid Water (NVT)** (61,634 acres) These areas of open water contain a large quantity of suspended sediments or dissolved solids. Small, recently slumped wetland basins make up a vast majority of this category. In other parts of Alaska, rivers and lakes laden with

Figure 7. Reduction of a 1:63,360 Scale Plot of Dillingham C-3 Quadrangle of TM 72/18 with Fifteen Final Feature Classes

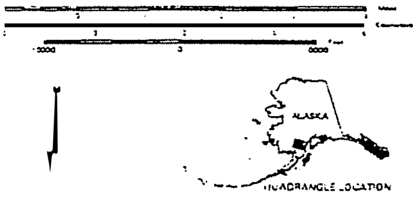
LANDSAT TM PATH 72 ROW 18
COLLECTED AUGUST 30, 1991

DILLINGHAM (C-3) QUADRANGLE
ALASKA
1:63,360 SCALE



DILLINGHAM (C-3), ALASKA

Scale 1:63,360



Legend

	Class_Names	Acres		Class_Names	Acres
■	Clear water	497154	▨	Shrubby tundra	868344
■	Turbid water	61634	■	Deciduous forest	123487
■	Aquatic bed	5635	■	Needleleaf forest	72868
■	Deep marsh	6741	■	Mixed forest	33983
	Shallow marsh	40215	■	Scrub-shrub	448360
	Wet tundra	118547	▨	Nonveg bare	242833
▨	Sedge dominated	170357		Nonveg ice	158
	Lichen tundra	325333	■	Terrain shadow	34324

Funded by the Department of the Interior Bureau of Land Management and Ducks Unlimited, Inc. Printed by Pacific Meridian Resources

Universal Transverse Mercator projection
1000 meter Universal Transverse Mercator grid ticks, zone 4

Derived from Landsat TM Path 72 Row 18 collected on August 30, 1991
Ground truth field data collected August 12-18, 1992. 1:60,000 scale color infrared aerial photographs taken in the summers of 1978-1982 used for ground verification.

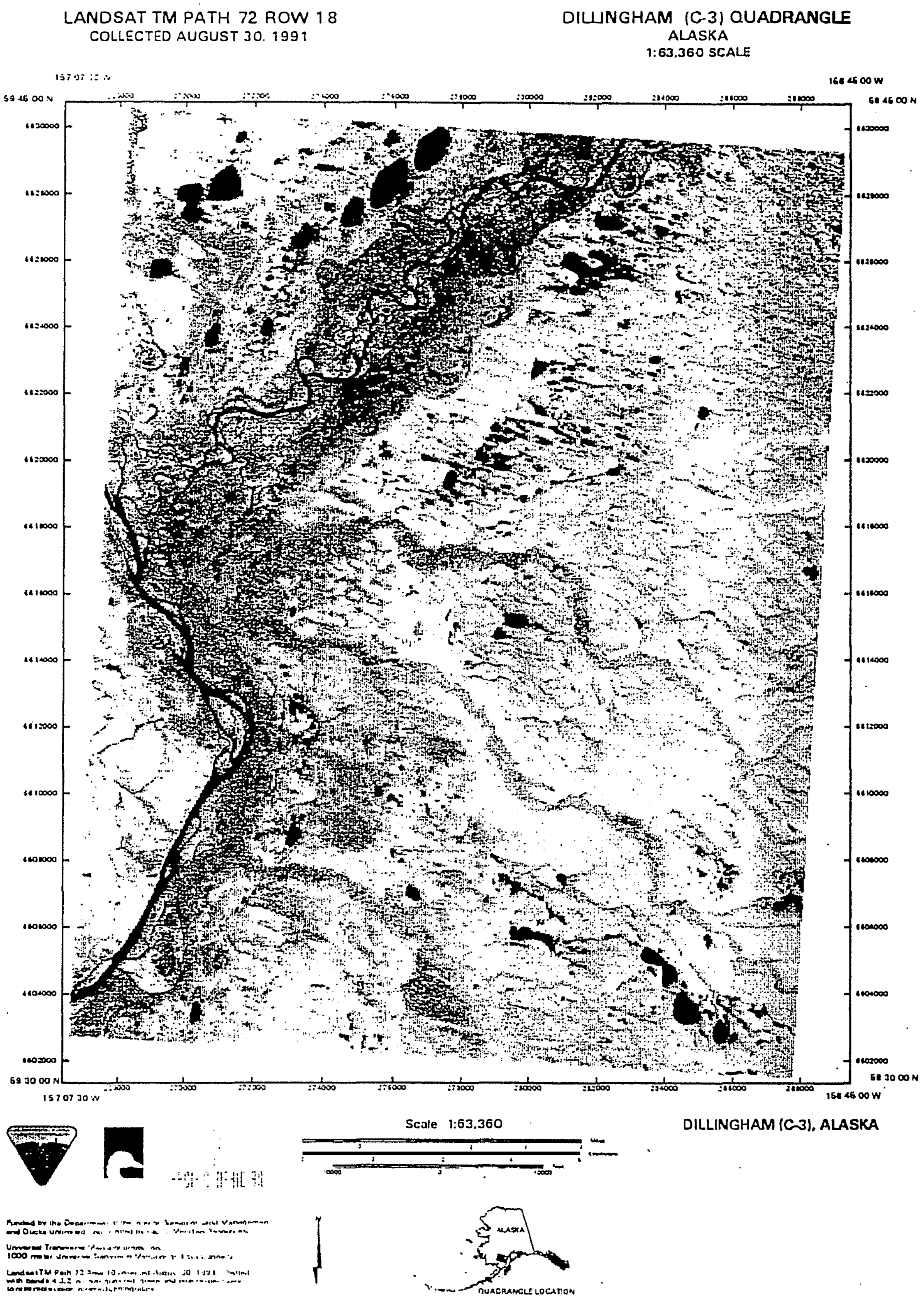


Figure 8. Reduction of 1:63,360 Scale Plot of Dillingham C-3 Quadrangle of TM 72/18 with Coloration to Resemble CIR Photography.

glacial flour contribute to this category but not in this area. Turbid water made up 9% of the project area overall and 8% of the wetlands.

3. **Aquatic Bed (AB_)** (5,635 acres) Less than 1% of the entire project area and 1% of the wetland area. These are wetlands dominated by non-emergent vegetation that grows principally on or below the surface of the water. Some common types of vegetation includes, water lily, buckbean, pondweed, etc. There was much confusion between aquatic bed and water/turbid water and aquatic bed may be under-represented in the final classified image. The spectral response of aquatic bed is between that of water and deep marsh and some confusion between them can be expected.

4. **Deep Marsh (DM_)** (6.747 acres) Less than 1% of the entire project area and 1% of the wetland area. This is emergent vegetation growing in areas of persistent surface water. Common vegetation types in this class include carex species, horsetail, etc. Deep marsh in this project is defined as emergent wetlands with more than 30% open water and at least 45% emergent vegetation.

5. **Shallow Marsh (SM_)** (40,215 acres) 1% of the project area and 5% of the wetlands. Wetland with emergent vegetation where water depth is less than 20 cm (approximately) and surface water occurs intermittently or semi-permanently due to drawdown during dry seasons or years. These sites are often located along the fringes of wetland basins and in former stream channels.

   Though the marsh labels connote water depth, as regards spectral response, shallow and deep water look much the same. Presumably greater extent is associated with greater depth. Because of the mixed response at the edge between feature types (water next to deep marsh or shallow marsh or next to shrubs or meadow), there is confusion among the marsh classes and aquatic bed. Much of the confusion between shallow marsh and needleleaf forest and terrain shadow was fixed as described earlier. Further reduction in confusion can be accomplished by manual editing on a very small scale of small areas on the image was not done as in the previous projects.

6. **Wet tundra (TUW)** (198,567 acres) 5% of the project area. In many cases, wet tundra contains sedges, grasses, and lichens that are saturated or intermittently flooded. Wet tundra can be very close to shallow marsh in spectral response. It tends to be located just beyond the edge of ponds.

7. **Sedge-graminoid (S_G)** (170,057 acres) This class represented 5% of the upland area in the image. It can vary from a lush blue-joint meadow along meandering streams to more sparsely vegetated sedge grasslands with some shrubs but not enough water or sphagnum to be wet tundra or shallow marsh. The high growing-vegetation or biomass response in the meadows can confuse with scrub-shrub, which is not surprising considering that some scrub-shrub training sites had 50% or more grass and herbs. At the other extreme it can verge on the tundra classes.

8. **Dry lichen tundra (TUL)** (825,339 acres) Tends to be bright like a mixed vegetated/bare area in the images and confuses with such areas like roads. This class was very extensive and represented 24% of the upland area of the image. It had a very bright spectral response. It verges into dry shrubby tundra depending on which predominates.

9. **Dry shrub tundra (TUS)** (856,344 acres) This class also is very extensive and represented 25% of the upland area. It is composed of predominantly ericaceous, dwarf deciduous and other dry tundra shrubs but can have a very large component of carex. Much of this class at the high elevations was recoded from wet tundra.

10. **Deciduous forest (FDE)** (133,497 acres) 4% of the upland area. This class is found mostly along rivers. A very large percentage of the land cover must be deciduous trees to be this class. Much of the understory may be deciduous shrubs which give a similar response. Much of what might be termed open decidous forest is classed as scrub-shrub so this class may be undercounted. This class may also have a large percentage of needleleaf trees, up to 40%, but the sum of decidous trees plus deciduous shrubs will be greater.

11. **Needleleaf forest (FNL)** (72,686 acres) This class includes black and white spruce trees as well as hemlock. Many classes originally calculated to be needleleaf forest were confused with marsh due to their dark texture and required "cluster busting" (described earlier). This class could probably be called closed needleleaf forest since it is over 60% needleleaf trees. It comprises 2% of the uplands.

12. **Mixed forest (FMX)** (33,993 acres) This class always has a large component of needleleaf trees, over 40%, and could be termed open needleleaf forest as well. It may also have a large component of deciduous shrubs and trees. This class comprises 1% of the uplands.

13. **Scrub-shrub (SS_)** (868,360 acres) After open water, this is the largest class, comprising 25% of the uplands and 20% of the total area. It is a very inclusive class and verges on the forest and tundra shrub classes.

14. **Non-vegetated bare (NVB)** (242,933 acres) Some training sites that were labelled as a vegetated feature class in the field had a large proportion of non-vegetated land cover. Since this non-vegetated component was very bright, it tended to dominate the spectral signal picked up by the sensor so these classes confused with the non-veg classes. Therefore the threshhold of vegetated cover required to differentiate a vegetated class was raised to 50% to accomodate this. This modification eliminated much of this type of confusion. Most of this class is found up in the mountains or at the high elevation and as patches of bare ground in the tundra. It also occurs along sand sand and gravel bars next to rivers. Non-vegetated bare comprises 6% of the image.

15. **Ice and snow (NVI)** (156 acres) At the end of August, this class comprises a very small percentage of the land area, less than 1%.

16. **Terrain shadow (tsh)** (34,324 acres) This is a recode class. It occurs at the steeper elevations where the terrain casts a shadow on the side opposite to sun illumination. The

actual land cover is one of the upland classes listed above and, obviously, the terrain within the shadow is one of the (upland) classes above.

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10. REFERENCES

Cowardin, L.M., V. Carter, F.C. Golet and E.L. LaRoe. 1979. Classification of Wetlands and Deep Water Habitats of the United States, U.S. Fish and Wildlife Service. FWS/OBS-79/31.

Derksen, D.V., K.S. Bollinger, D. Esler, K.C. Jensen, E.J. Taylor, M.W. Miller and M.W. Weller. 1991. Effects of Aircraft On Behavior and Ecology of Molting Brant Near Teshekpuk Lake, Alaska. 1990 Progress Report, USFWS, Anchorage.

Gaydos, L. and R.E. Witmer. 1983. Mapping of Arctic Land Cover Utilizing Landsat Digital Data. Pages 343-346 in Permafrost: Fourth International Conference, National Academy Press, Washington, D.C.

Hulten, E. 1968. Flora of Alaska and Neighboring Territories. Stanford Univ. Press, 1008pp.

Jacobson, J.E., R.A. Ritter, and G.T. Koeln. 1987. Accuracy of Thematic Mapper Derived Wetlands As Based On National Wetland Inventory Data. ASPRS Tech Papers, Reno, NV.

Kempka, R.G., F.A. Reid, and R.C. Altop. 1993. Developing Large Regional Databases For Waterfowl Habitat In Alaska Using Satellite Inventory Techniques: A Case Study of the Black River. Pages 581-591 in GIS93, Vancouver, B.C.

King, J.G. and C.J. Lensink. 1971. An Evaluation of Alaskan Habitat for Migratory Birds. U.S. Dep. Inter., Bur. Sport Fish. and Wildl., Admin. Rep., Anchorage, 74pp.

Lensink, C.J. and D.V. Derksen. 1986. Evaluation of Alaskan Wetlands for Waterfowl. Pages 45-84 in A. van der Valk and J. Hall, eds. Alaska: Regional wetland functions. Univ. Mass., Amherst.

Viereck, L.A., C.T. Dryness, A.R. Batten, and K.J. Wenzlick. 1992. The Alaska Vegetation Classification, U.S. Forest Service General Tech. Report PNW-GTR-286.

APPENDIX A

WETLAND STATISTICS FILES - OVERVIEW

Wetland Basins and Wetland Statistics Files

After the image is classified to wetland types, each set of contiguous wetland pixels is identified as a wetland basin. Summary statistics are then computed by wetland type and basin size and reported in two different ways: 1) In Wetland Basin Statistics files (WBS) by 1:63,360 USGS quadrangle mapsheet and basin identify for wetland basins greater than or equal to 2 acres in size, and 2) in Land Key Statistics files (LKS) by 1 kilometer blocks for basins less than 2 acres in size. The third file, the basin/land key statistics file (BLX), cross-indexes by map sheet, the basin-ID to the 1 kilometer block which contains the basin.

The larger wetland basins, 2 acres or more in size, are uniquely identified by their 1:63,360K USGS quad and an identifier number. (Other large basins may have the same ID number but are in different quads.) The location of a basin label is determined by the UTM coordinates of the pixel that is most northerly, then most westerly. These coordinates appear in the WBS file and locate the label for each larger wetland basin (2 or more acres) on maps. Small basins (less than 2 acres) do not receive an identifier number but they still have a unique location.

Wetland Maps

Wetland statistics are depicted graphically not only on the colored classified image itself but also on the wetland information maps created to scale for each USGS 1:63,360 quad. All wetland acreage pixels, whatever the basin size they occur in, appear in various black patterns (depending on the wetland type) on the wetland information maps. The wetland identifier maps which overlay the wetland information maps label the larger basins with a + sign and the basin ID number. The wetland identifier maps also have the 1 kilometer grid drawn so smaller basins can be located.

Map Name Acronym

The map name appearing in the wetland statistics files is a code for the 1:63,360 USGS quad name and is derived as follows (for Dillingham B-1):

Position 1	A	Alaska
Position 2-3	59	The degrees latitude of the southeast corner of the parent 1:250,000 scale USGS map
Position 4-6	156	The degrees of longitude of the southeast corner of the parent 1:250,000 scale USGS map
Position 7-8	B1	The code for the 1:63,360 scale USGS quad map.

ALASKA AREAS STUDIED

Wetland statistics have been computed for four different study areas:

Year	Image Used	Area Name	Study Area Quads
1989	T6816878	Glenallen	Some Gulkana, Talkeetna Mts, Mt. Hayes and Mt. Healy quads
1990	T7616857 and T7617857q2	Innoko	Some Russian Mission and Holy Cross quads
1992	T6614915	Black River	Some Black River and Charley River quads
1993	T7218918	Iliamna	Some Iliamna, Dillingham, and Lake Clark quads

Different sets of wetland classes were identified in these classified scenes so the fields reported in the statistics files vary among the scenes. Consequently, the database structure is somewhat different for each scene.

WETLAND STATISTICS DATA

In the Iliamna study, the new Ducks Unlimited Imagine module was used to compute the wetland statistics from the final classified image. These statistics are calculated by mapsheet and a separate ASCII table is created for the WBS, LKS, and BLX data for each mapsheet. Also a totals table is created which has one summary record for each mapsheet. An example of each of these files after import to dBASE follows. Three fields were added to each record during the import process: the map acronym, the map code utilizing the official 1:63,360 mapsheet abbreviation for Alaska and the UTM zone. Other information, such as satellite sensor, that was included within the statistics files in the previous studies was not added to these files. The dBASE structure files for import of the data is provided on disk and described in Appendix B.

WETLAND STATISTICS FROM PREVIOUS STUDIES

Under this contract the ASCII data from the earlier studies has been imported to dBASE to facilitate further analysis on PCs. In each of the previous studies, one WBS, one LKS and one BLX file was created which covered all the mapsheets (1:63,360K quad) in the particular study area. Each of these files had header records, one per mapsheet, giving satellite collection information, followed by the data records corresponding to that header, and, when present, a summary record with mapsheet summary data for the preceding data records. Since the data structure necessary for header records and data (and summary records, when present) is different, two dBASE files were created from each ASCII statistics file: 1) a header file of header records with a field for the header ID number, and 2) the file of data (and summary) records with a field for the header ID of the corresponding header record.

Following are examples of the 3 types of statistics data files. Data from the different study areas is used to indicate the different wetland types identified in the different study areas.

Wetland Basin Statistics Data (WBS)

Table 1 is a sample of Wetland Basin Statistics (WBS) data for Black River. WBS data files tabulate only the acreages for larger wetland basins (2 acres or more). Ordinary data records have a 1 or 4 in the CODE field whereas summary records have a 7 in the code field. The totals in the summary records are probably more accurate (due to rounding) than the totals that could be obtained by summing the individual data records for a mapsheet. Since the summary records appear in the same database with the data records, care must be taken not to double count when summarizing the data. The summary records can be copied to another file and then deleted from the WBS file to avoid such problems.

Table 2 lists the summary data records for Black River WBS. Note that code = 7. The basin ID, zone, easting, northing, shape index and water chemistry refer to particular basins so are not applicable to summary records and should be ignored.

Table 3 depicts summary information for larger (>= 2 acres) Black River wetland basins. The map area data for each quad was obtained from an ArcInfo coverage of the Alaska 1:63,360 USGS quads. The area edited for each mapsheet was obtained by clipping that coverage with the coverage of the scene boundary. The scene covered only part of some mapsheets.

Table 1 :FIRST HEADER RECORD AND THE FIRST FEW CORRESPONDING DATA RECORDS FOR CHARLEY RIVER QUADS OF WBS DATA

Header Number	Type	Map Name	Sensor	Path	Row	Collection Date	Date_2	Classification Date	UTM Zone	Habitat Classes
0001	0	A65141D3	T5	66	14	6/30/90	/ /	3/23/92	7	1111100

Code *	Map Name	Basin ID	UTM Zone	Easting	Northing	Total wetland acres*	OW	DM	SM	TW	AB	No data		Shore length	Shape Index	Water chemistry	Header No.
1	A65141D3	36	7	443121	7320291	10.7	7.6	0.0	1.6	0.0	1.6	0	0	0.6	1.2	U	0001
1	A65141D3	51	7	442431	7320321	69.6	53.2	0.0	9.3	0.0	7.1	0	0	2.0	1.7	U	0001
1	A65141D3	52	7	448461	7320201	4.2	2.7	0.0	1.1	0.4	0.0	0	0	0.6	2.0	U	0001
4	A65141D3	53	7	447831	7320201	16.0	13.3	0.0	0.0	0.0	2.7	0	0	1.2	2.1	U	0001
4	A65141D3	54	7	449841	7320141	10.7	6.2	0.0	2.4	0.0	2.0	0	0	0.7	1.6	U	0001
4	A65141D3	55	7	448191	7320111	4.4	3.1	0.0	0.0	0.4	0.9	0	0	0.8	2.6	U	0001
4	A65141D3	56	7	448281	7320111	4.2	2.9	0.0	0.0	0.0	1.3	0	0	0.6	2.0	U	0001
4	A65141D3	57	7	450831	7320081	3.8	1.3	0.0	0.9	0.0	1.6	0	0	0.4	1.5	U	0001
4	A65141D3	58	7	449061	7319931	10.9	8.7	0.0	0.0	0.2	2.0	0	0	1.0	2.2	U	0001

Wetland acreage is for basins greater than or equal to 2 acres.

Key to wetland classes:

OW = Open water

SM = Shallow marsh

AB = Aquatic bed

DM = Deep marsh

TW = Turbid Water

*Code Key: 1 or 4 is a completion code. Code = 7 indicates a summary record for that mapsheet (header)

TABLE 2: THE UNEDITED WBS SUMMARY RECORDS FOR BLACK RIVER

CODE	Map Name	Basin ID*	ZONE*	Easting*	Northing*	Total Wetland	Open Water	Deep Marsh	Shallow Marsh	Turbid Water	Aquatic Bed	No data		Shore Length	Shape Index*	CHEM*	Header Number
7	A65141D3	626	7	0	0	1959.5	1303.2	51.4	202.4	46.3	356.3	0.0	0.0	183.5	0.0		0001
7	A65141D6	287	7	0	0	3694.3	918.5	10.5	609.8	1825.8	329.8	0.0	0.0	139.1	0.0		0002
7	A66141A2	1076	7	0	0	4130.0	2321.1	371.8	767.9	47.6	621.6	0.0	0.0	308.6	0.0		0003
7	A66141A3	882	7	0	0	6420.0	4032.6	333.8	586.2	64.5	1402.8	0.0	0.0	462.0	0.0		0004
7	A66141A5	744	7	0	0	3163.9	2228.3	21.1	272.7	48.9	592.9	0.0	0.0	247.1	0.0		0005
7	A66141A6	124	7	0	0	1113.3	609.1	39.8	263.5	0.7	200.2	0.0	0.0	60.5	0.0		0006
7	A66141B2	176	7	0	0	1468.0	960.9	53.8	156.3	17.3	279.5	0.0	0.0	98.1	0.0		0007
7	A66141B3	152	7	0	0	1788.5	1046.1	0.0	236.2	16.9	489.3	0.0	0.0	112.8	0.0		0008
7	A66141B4	261	7	0	0	3935.9	2578.8	0.0	544.4	3.8	808.8	0.0	0.0	222.6	0.0		0009
7	A66141B5	703	7	0	0	3196.9	2225.2	0.0	280.0	70.7	620.9	0.0	0.0	264.1	0.0		0010

* The basin ID, zone, easting, northing, shape index and water chemistry refer to particular basins so are not applicable to summary records and should be ignored.

TABLE 3: SUMMARY OF WBS DATA FOR BLACK RIVER

Map Name	Total wetland acres	OW	DM	SM	TW	AB	Total Upland	Area edited	Map Area	% Edited
Black River A2	4130.0	2321.1	371.8	767.9	47.6	621.6	149578.3	153708.3	153708.3	100
Black River A3	6420.0	4032.6	333.8	586.2	64.5	1402.8	147260.3	153680.3	153680.3	100
Black River A5	3163.9	2228.3	21.1	272.7	48.9	592.9	150531.9	153695.8	153695.8	100
Black River A6	1113.3	609.1	39.8	263.5	0.7	200.2	50590.9	51704.2	153694.3	34
Black River B2	1468.0	960.9	53.8	156.3	17.3	279.5	52973.4	54441.4	152203.2	37
Black River B3	1788.5	1046.1	0.0	236.2	16.9	489.3	103392.5	105181.0	152176.2	69
Black River B4	3935.9	2578.8	0.0	544.4	3.8	808.8	142780.1	146716.0	152193.8	96
Black River B5	3196.9	2225.2	0.0	280.0	70.7	620.9	119443.8	122640.7	152193.8	81
Charley River D3	1959.5	1303.2	51.4	202.4	46.3	356.3	153232.5	155192.0	155192.0	100
Charley River D6	3694.3	918.5	10.5	609.8	1825.8	329.8	128257.9	131952.2	155203.1	85
TOTAL	30870.3	18223.8	882.2	3919.4	2142.5	5702.1	1198041.6	1076301.0	1533940.7	80

Wetland acreage is for basins greater than or equal to 2 acres.

Key to wetland classes:

OW = Open water
SM = Shallow marsh
AB = Aquatic bed
DM = Deep marsh
TW = Turbid Water

Land Key Statistics Data (LKS)

Table 4: First header record and the first few data records corresponding to the first header record for Innoko Land Key Statistics (LKS) data

Header Number	Type	Map Name	Sensor	Path	Row	Collection Date	Date_2	Classification Date	Zone	Classes	Analysis Type
0001	0	A61159C2	T5	76	16	7/24/85	/ /	12/28/89	4	1111111	K

Kblock	Zone	Easting	Northing	Size	Total wet-land acres	DF	SF	AB	TW	DM	SM	WM	Header No.
K	4	350	6915	26.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0001
K	4	351	6915	110.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0001
K	4	352	6915	113.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0001
K	4	353	6915	110.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0001
K	4	354	6915	110.1	3.3	0.0	0.0	0.0	0.0	0.2	0.0	3.1	0001
K	4	355	6915	113.4	15.8	0.2	0.9	1.3	0.0	1.1	2.4	9.8	0001
K	4	356	6915	110.1	4.9	0.2	0.9	0.2	0.0	0.0	0.2	3.3	0001
K	4	357	6915	110.1	28.5	12.9	4.0	3.1	0.0	0.4	0.4	7.6	0001

Key to wetland classes:

DF = Deep freshwater
SF = Shallow freshwater
AB = Aquatic bed
TW = Turbid Water
DM = Deep marsh
SM = Shallow marsh
WM = Wet Meadow

All the acreage numbers in the LKS data files refer to wetland basins smaller than 2 acres.

The analysis type K refers to Kblock, meaning the data is summarized by 1 kilometer blocks. The K blocks listed above are at the edge of the study area and fall partly into another mapsheet; hence the small size.

Basin-Land Key Cross Index Data (BLX)

Table 5 indicates that basin 107 of map sheet A62144A5 (Gulkana A-5) falls in the 1 km block with UTM easting=535 and northing = 6902.

TABLE 5: THE FIRST HEADER RECORD AND A SAMPLE OF DATA CORRESPONDING TO THE FIRST HEADER OF GLENALLEN DATA.

Header_no	Sensor	Path	Row	Collection Date	Date 2	Classification Date
0001	T5	68	16	8/23/87	/ /	11/10/88

Kblock	UTM Zone	Easting 1000	Northing 1000	Map Name	Basin ID	Area	Header_no
K	6	535	6902	A62144A5	107	1.3	0001
K	6	537	6902	A62144A5	103	1.6	0001
K	6	539	6902	A62144A5	104	1.6	0001
K	6	540	6902	A62144A5	105	2.2	0001
K	6	541	6902	A62144A5	108	0.2	0001
K	6	545	6902	A62144A5	88	10.2	0001
K	6	546	6902	A62144A5	88	4.7	0001
K	6	546	6902	A62144A5	12	22.7	0001
K	6	547	6902	A62144A5	12	44.0	0001

Summary Data For All Wetland Basins: Combining WBS and LKS Data

To total wetland area for all size basins by mapsheet in the previous studies, both the WBS data and LKS data must be processed and combined, taking into consideration that WBS data is by map sheet and LKS data is by 1 kilometer block. The procedure and approximations used are detailed in appendix E. Summary data for Glenallen is given in Table 6. The quad area statistics for quads split by the scene boundary were not computed in the following table.

TABLE 6: SUMMARY DATA FOR WETLAND BASINS OF ALL SIZES: GLENALLEN DATA

Quad Name	Total area in larger wetlands	Total area in small wetlands*	Total wetland area, all basins*	Total quad area	% of map area in larger wetlands	% of map area in small wetlands*	% of map area in wetlands*
Gulkana A-5	23367.9	12470.0	35837.9	--------	----	----	----
Gulkana A-6	19612.7	10442.7	30055.4	179963	10.9	5.8	16.7
Gulkana B-4	28001.1	16592.3	44593.4	--------	----	----	----
Gulkana B-5	55554.6	28183.1	83737.7	179963	30.9	15.7	46.5
Gulkana B-6	70781.0	33313.8	104094.8	179963	39.3	18.5	57.8
Gulkana C-4	19328.8	9729.8	29058.6	--------	----	----	----
Gulkana C-5	31323.0	14433.3	45756.3	179963	17.4	8.0	25.4
Gulkana C-6	30048.1	14892.9	44941.0	179963	16.7	8.3	25.0
Gulkana D-3	2384.8	2462.0	4846.8	--------	----	----	----
Gulkana D-4	13698.9	5813.3	19512.2	179963	7.6	3.2	10.8
Gulkana D-5	16097.8	8553.4	24651.2	179963	8.9	4.8	13.7
Gulkana D-6	4408.5	2249.8	6658.3	179963	2.4	1.3	3.7
Talkeetna Mts A-1	3439.2	1608.8	5048.0	--------	----	----	----
Talkeetna Mts B-1	7482.3	3874.0	11356.3	179963	4.2	2.2	6.3
Talkeetna Mts C-1	21940.2	9703.2	31643.4	179963	12.2	5.4	17.6
Talkeetna Mts D-1	14228.4	7427.3	21655.7	179963	7.9	4.1	12.0
Mt Hayes A-3	9143.6	4935.3	14078.9	--------	----	----	----
Mt Hayes A-4	19313.4	9514.4	28827.8	179963	10.7	5.3	16.0
Mt Hayes A-5	13606.0	6772.3	20378.3	179963	7.6	3.8	11.3
Mt Hayes A-6	8146.3	3445.5	11591.8	179963	4.5	1.9	6.4
Healy A-1	8899.4	4645.5	13544.9	179963	4.9	2.6	7.5
TOTAL	420806.0	12470.0	433276.0	--------	----	----	----

* A small error is introduced in the small basin area totals. Since some 1km blocks at the edge of a mapsheet may fall partly in another mapsheet, for such 1 km blocks, the area statistics are included in the totals for the mapsheet that has the larger or largest proportion of the area of the 1 km block.

Key to abbreviations:

DF =	Deep freshwater	AB =	Aquatic bed	DM =	Deep marsh
SF =	Shallow freshwater	TW =	Turbid Water	SM =	Shallow marsh

small basins = basins < 2 acres

larger basins = basins >= 2 acres

APPENDIX B:

WETLAND STATISTICS FILES SUPPLIED ON FLOPPY DISK FOR THE EARLIER STUDIES

Structure files for Glenallen Data provided as an example - other study areas identified different sets of wetland types

Note that all the fields of glenwin (the file created by ASCI.DBF) are of type character. Other that that, the field names and lengths are the same as the data records for Glenallen WBS. This is always the case.

Structure for table: glenwin.dbf

Field Name	Type	Width
CODE	Character	1
MAP_NAME	Character	9
BASIN_ID	Character	6
ZONE	Character	2
EASTING	Character	6
NORTHING	Character	7
TOT_WETLND	Character	8
DEEPFRESHW	Character	8
SHALFRESHW	Character	7
AQUATICBED	Character	7
TURBID_H2O	Character	7
DEEP_MARSH	Character	7
SHALWMARSH	Character	7
NO_DATA	Character	7
SHORLENGTH	Character	7
SHORESHAPE	Character	4
WATER_CHEM	Character	2
HEADER_NO	Character	4

Structure for table: glenwhdr.dbf

Field Name	Type	Width
HEADER_NO	Character	4
TYPE	Numeric	1
MAP_NAME	Character	8
SENSOR	Character	2
PATH	Numeric	3
ROW	Numeric	3
DATE_1	Date	8
DATE_2	Date	8
CLASSDATE	Date	8
ZONE	Numeric	2
CLASSES	Character	7

Structure for table: glenwdta.dbf

Field Name	Type	Width	Dec
CODE_	Numeric	1	
MAP_NAME	Character	8	
BASIN_ID	Numeric	6	
ZONE	Numeric	2	
EASTING	Numeric	6	
NORTHING	Numeric	7	
TOT_WETLND	Numeric	8	1
DEEPFRESHW	Numeric	8	1
SHALFRESHW	Numeric	7	1
AQUATICBED	Numeric	7	1
TURBID_H2O	Numeric	7	1
DEEP_MARSH	Numeric	7	1
SHALWMARSH	Numeric	7	1
NO_DATA	Numeric	7	1
SHORLENGTH	Numeric	7	1
SHORESHAPE	Numeric	4	1
WATER_CHEM	Character	1	
HEADER_NO	Character	4	

Structure for table: glenlin.dbf

Field Name	Type	Width	Dec
KBLOCK	Character	1	
ZONE	Character	3	
EASTING	Character	5	
NORTHING	Character	6	
SIZE	Character	6	
TOT_WETLND	Character	6	
DEEPFRESHW	Character	5	
SHALFRESHW	Character	5	
AQUATICBED	Character	5	
TURBID_H2O	Character	5	
DEEP_MARSH	Character	5	
SHALWMARSH	Character	5	
NO_DATA1	Character	5	
NO_DATA2	Character	6	
WETLND_CNT	Character	3	
HEADER_NO	Character	4	

Structure for table: glenlhdr.dbf

Field Name	Type	Width
HEADER_NO	Character	4
TYPE	Numeric	1
MAP_NAME	Character	8
SENSOR	Character	2
PATH	Numeric	3
ROW	Numeric	3
DATE_1	Date	8
DATE_2	Date	8
CLASSDATE	Date	8
ZONE	Numeric	2
CLASSES	Character	7
ANALYS_TYP	Character	1

Structure for table: glenldta.dbf

Field Name	Type	Width	Dec
KBLOCK	Character	1	
ZONE	Numeric	2	
EASTING	Numeric	4	
NORTHING	Numeric	5	
SIZE	Numeric	5	1
TOT_WETLND	Numeric	5	1
DEEPFRESHW	Numeric	5	1
SHALFRESHW	Numeric	5	1
AQUATICBED	Numeric	5	1
TURBID_H2O	Numeric	5	1
DEEP_MARSH	Numeric	5	1
SHALWMARSH	Numeric	5	1
NO_DATA1	Numeric	5	1
NO_DATA2	Numeric	6	1
WETLND_CNT	Numeric	3	
HEADER_NO	Character	4	

Structure for table: glenbin.dbf

Field Name	Type	Width	Dec
KBLOCK	Character	1	
ZONE	Character	3	
EASTING	Character	5	
NORTHING	Character	6	
MAP_NAME	Character	9	
BASIN_ID	Character	7	
AREA	Character	6	
HEADER_NO	Character	4	

Structure for table: glenbhdr.dbf

Field Name	Type	Width
HEADER_NO	Character	4
SENSOR	Character	2
PATH	Numeric	3
ROW	Numeric	3
DATE_1	Date	8
DATE_2	Date	8
CLASSDATE	Date	8

Structure for table: glenbdta.dbf

Field Name	Type	Width	Dec
KBLOCK	Character	1	
ZONE	Numeric	2	
EASTING	Numeric	4	
NORTHING	Numeric	5	
MAP_NAME	Character	8	
BASIN_ID	Numeric	6	
AREA	Numeric	5	1
HEADER_NO	Character	4	

SUMMARIZING THE WETLAND STATISTICS

To total all wetland acres for a mapsheet, regardless of basin size, it is necessary and desirable to total information from both the WBS and the LKS files since considerable wetland acreage occurs in basins of less than 2 acres.

To Total The Wetland Acres In The WBS Files By Mapsheet

Totals for each mapsheet in a WBS file appear in the summary records (code = 7) of the file. First copy these records to another file:

```
.USE <glenwdta>
```

```
.COPY TO wtot FOR code = 7
```

Mapsheet Area

The total acreage for each map sheet is obtained from the polygon attribute table at of the arc coverage of mapsheets. Copy the fields itm_name and area from the .pat for the desired mapsheets to another dBASE file. This can be done by copying the records for a particular 250K quad name to a new file. Delete those records for mapsheets not in the study from this new file. Repeat this for each 250K quad in the study and then append the new files into one file. To this file of all the quads in the study, add the field map_name and fill it with the map_name acronym for that quad. This file is referred to as <quads> in the following discussion.

Totalling The Wetland Acres In The LKS Files By Mapsheet

The LKS statistics are presented for basins under 2 acres (= "small basins" in this discussion) by 1 kilometer blocks. A 1 km block, which is uniquely identified by the UTM easting and northing of its northwest corner, may fall on more than one USGS 63,360 K mapsheet. When this occurs, the summary wetland statistics for that 1 km block appear under more than one header (each header being a different mapsheet). Fortunately, the LKS field SIZE indicates how many acres of the 1 km block are in that mapsheet. However there is no way to determine from the wetland statistics data given exactly how much small basin wetland occurs in each mapsheet area for that block. Consequently, a reasonable method of allocating those wetland acres between the two mapsheets must be devised. Since preliminary processing indicated that allocating all the small basin wetland area to the mapsheet which had the greater proportion of the 1 km block introduced just a small error (only 30 acres over all the mapsheets for glenallen would be misallocated), it was the method chosen.

Detailed instructions follow for the commands to use from the dBASE prompt for totalling the wetland acres by mapsheet. dBASE commands are in capital letters; <> surround optional filenames. You must be logged onto the subdirectory with the data to be totalled. Be sure to check over each new database after indexing to be sure all is OK before proceding to the next step.

```
USE <glen>ldta
```

```
INDEX ON STR( 1000 - size ) + STR( easting ) + STR( northing ) TO <tmp>
```

This assures that the LKS data will appear in descending order of size and then by unique 1 km block. Therefore, when a particular 1 km block appears more than once, the 1st occurrence of that block will be the record for the mapsheet that has the larger (or largest) proportion of the area.

```
COPY TO <g_ldata2> FIELDS map_name, tot_wetlnd, header_no
```

A new file of just the desired fields in the desired order is created. If you wish to total the different wetland types for small basins as well, include those fields too.

```
USE
```

```
USE <g_ldata2>
```

```
INDEX ON STR( easting ) + STR( northing ) TO <tmp> UNIQUE
```

The UNIQUE switch assures that only one instance of each 1 km block will be in the index. Due to the way the index is created when multiple records for a 1 km block occur, the record with the largest size field will be represented, since it was the one that appeared first.

```
COPY TO gl_data3
```

This assures that only the desired records, those in the index, will be totalled.

```
USE
```

```
USE <g_ldata3>
```

```
INDEX ON header_no TO tmp3
```

Or you could index on map_name, in which case you would total on mapname in the next step.

```
TOTAL ON header_no TO <wetltot1>
```

This creates a new file with 1 record for each map and totals for each numeric field. If you get a message about data overflow, one or more of the totals were too big to fit in the field. Asterisks will appear in the field in records where overflow occurred. If this is a field you want, MODIFY STRUCTURE, enlarge the field size, save, index again and do the total again.

```
USE
```

```
USE <wetltot1>
```

```
MODIFY STRUCTURE
```

Add the following fields:

Name of Field	Description	Data type	Length	No. decimal places
itm_name	i.e. GULKANA A3 from the .pat of USGS quads	character	23	
map_area	Area for that map, from the .pat	numeric	13	6
totwet_gt2	Total wetland area in larger basins	numeric	8	1
totallwet	Field for the sum of total wetland in both small and large basins.	numeric	8	1
dummy	Field with same value in all records. Used for totalling to get grand total	numeric	2	
etc....	Whatever other fields you want, such as percent of map area in wetlands, percent of total wetlands in small basins, etc.			

Also change the name of the tot_wetlnd field to totwet_u2 to prevent confusion when this data is combined with the totals from the .WBS file for larger wetlands. The commands for setting up a relation between <wetltot1> and <quads> on map_name follow..

```
SELECT 2
```

```
USE <quads>
```

Quads is a dBASE file of the quads in the study area derived from the .pat of the ArcInfo coverage. It has the fields itm_name, area, and map_name. The map_name is the acronym for that quad which matches the map_name field in the wetltot1 file created above.

```
INDEX ON map_name TO <quadsm>
```

```
SELECT 1
```

```
SET RELATION TO map_name INTO <quads>
```

```
REPLACE ALL itm_name WITH quads->itm_name, map_area WITH quads->area
```

Now the quad name and quad map area fields are filled.

```
TOTAL ON dummy TO wetltot2
```

This will create one record for the grand totals. If there is data overflow, fix the data structure, index and total again.

```
APPEND FROM wetltot2
```

This will add the grand total record to the end of the file. Wetltot2 must not be open.

Now by relating on map_name as above but setting the relation into the dBASE file of WBS totals, totals for WBS data can be used to fill the new fields that were added to the data base wetltot1.

APPENDIX C

DU/BLM/PMR Alaska Training Site Database for Lake Iliamna/Lake Clark Project

Each database file is described below. Shaded fields/files were not implemented The dBASE files are provided on a DOS formatted disk as one of the deliverables

Site Database Imagesit.dbf (i.e. t7218sit.dbf)

Composed of fields whose values will not change for a site - 1 record per training site. The key fields image_pr and sitenumber should be combined into a composite primary key if data from more than one image_pr are in the same database.

Field Name	Field Type	Length	Decimal Places	Description	Key field in other databases
IMGPATHROW	C	7	0	Initial of image type + pathrow.	Observation and cover databases (imageobs.dbf & imagecov.dbf)
SITENUMBER	N	3	0	Site Number	Observation and cover databases (imageobs.dbf & imagecov.dbf)
SITETYPE	C	1	0	Field, photoaccuracy, etc.	Sitetyps.dbf LUT
ECOREG	C	2	0	Ecoregion	
QUAD.	C	23	0	250K name + A-1, etc.	Can be related to combination of ----------- & ---------- in Akquads.dbf
SLOPEAVG	N	3	0	Average slope of site	
ASPECTAVG	C	2	0	Aspect of site (facing direction)	
ELEVATION	N	5	0	Elevation in meters	
LATDGREES	N	2	0	Degrees of latitude	
LATMINS	N	2	0	Minutes of latitude	
LATSECS	N	6	3	Seconds of latitude	
LATNS	C	1	0	North or South latitude	
LONGDGREE	N	3	0	Degrees of longitude	
LONGMINS	N	2	0	Minutes of longitude	

LONGSECS	N	6	3	Seconds of longitude	
LONGEW	C	1		East or west longitude	

Observation Database Imageobs.dbf (i.e. T7218obs.dbf)

Composed of fields which may change with each field site observation - one or more records per training site. Here again, composite keys will have to be constructed when more than one observation per site occurs in the database.

Field Name	Field Type	Length	Decimal Places	Description	Key field in other databases
IMGPATHROW	C	7	0	Initial of image type + pathrow.	Site and cover databases imagesit.dbf & imagecov.dbf)
**SITENUMBER*	N	3	0	Site number	Site and cover databases (imagesit.dbf & imagecov.dbf)
OBSDATE	D	8	0	Date of observation	Cover database (imagecov.dbf)
IMAGEDATE	D	8		Date of the image to be classified using this observation info and/or used to select the training site.	
OBSERVER	C	11	0	Initials (2 or 3 letters each)of person(s) making the observation	Observer.dbf LUT
OBSLEVEL	N	1	0	Observation level (1-4)	Obslevl.dbf LUT
LANDCOVCLS	C	6		Modified NOAA-CCAP classification code	noaaccap.dbf LUT
NCCAP_LVL1	C	22		Level 1 name	noaaccap.dbf LUT
NCCAP_LVL2	C	10		Level 2 name	noaaccap.dbf LUT
NCCAP_LVL3	C	15		Level 3 name	noaaccap.dbf LUT
NCCAP_LVL4	C	25		Level 4 name	noaaccap.dbf LUT
VIERECKCLS	C	10		Viereck classification code, i.e. II.A.1.b.	Viereckc.dbf LUT
VIERK_LVL1	C	22		Viereck level 1 name	
VIERK_LVL2	C	22		Viereck level 2 name	

VIERK_LVL3	C	22		Viereck level 3 name	
VIERK_LVL4	C	26		Viereck level 4 name	
FLIGHTL	C	11		Air photo flight line	
PHOTO	N	4		Air photo number	
PHOTOSRC	C	10		Air photo source	
PHOTODATE	D	8		Air photo date	
PHOTOREEL	N	3		Fieldsite photo reel number	
PHOTOFRAME	C	5		Range of frames i.e.14-21 on the fieldsite photo reel	
PHOTO_DIRN	C	2		Direction the camera was pointing - i.e. NE	

With the SITE key and date, the air photo (flight line, photo, photo source and photo date)could be kept in a file of air photos rather than in this database. This file would have one record per site/photo.

With the SITE key and date, the field photos (photoreel, photoframe) could be kept in a file of field photos rather than in this database. This file would have one record per site-date/photoframe range.

Cover Database Imagecov.dbf (T7218cov.dbf)

This file will have one record per cover item (which may be a species, a genus, water, rocks, etc.) to which a % has been attached. Usually there will be several records per site observation.

Field Name	Field Type	Length	Decimal Places	Description	Key field in other databases
IMGPATHROW	C	7	0	Initial of image type + pathrow.	Site and observation databases imagesit.dbf & imageobs.dbf)
SITENUMBER	N	3	0	Site number	Site and observation databases (imagesit.dbf & imageobs.dbf)
OBSDATE	D	8	0	Date of observation	Observation database (imageobs.dbf)
COVER	C	20	0	May be a species, a genus, water, rocks, etc.	Covers.dbf LUT
COVPERCENT	N	3	0	Percent of site covered by this cover	

Look Up Tables (LUT's) and List databases

Database files which can be related to one of the above databases. This may be to expand a code to a description..

Cover types datafile COVERS.DBF

The Alaska list of wetland species*[1]. AKSPPLST.DBFcan be used as a lookup table when an approved common name or scientific name (genus + species) is used.

Field Name	Field Type	Length	Decimal Places	Description	Key field in other databases
COVER	C	20	0	May be a species, a genus, water, rocks, etc.	Cover database Imagecov.dbf (T7218cov.dbf)
COMMON_NAM	C	45		The common name. This corresponds to that on the Alaska plant list	Aksppslst.dbf.
GENUS	C	20		The genus as used in the Alaska plant list.	Matches the 1st part of the SCI-NAM in the Alaska plant list for this COM_NAM
SPECIES	C	20		The species as used in the Alaska plant list.	Matches the 2nd part of the SCI_NAM in the Alaska plant list for this COM_NAM

---

[1] The National List of Species that Occur in Wetlands, Alaska Region. This list is available in digital form.

Viereck datafile VIERECK.DBF

Field Name	Field Type	Length	Decimal Places	Description
VLEVELCODE	C	4		Level name, I, II, III, or IV
LEVEL_NAME	C	22		Name of level, i.e. Needleleaf (Conifer) is a level II level name, Closed is a level III level name.
CHAR2CODE	C	2		Intuitive 2 character code for the level_name such as CL for closed
SPECS	C	35		Description

Observers datafile OBSERVERS.DBF

Field Name	Field Type	Length	Decimal Places	Description
OBS_CODE	C	4		Initials (2 or 3 as entered) of the person making the observation plus a number to break ties. The data sheets will have to be annotated with this tie-breaker so it will be entered from the start.
LASTNAME	C	20		The observer's last name
FIRSTNAME	C	15		The observer's first name and middle initial if given.
OBS_SEASON	C	5		The season of observation, such as SU 92 for summer 1992.

Types data file TYPES.DBF

Field Name	Field Type	Length	Decimal Places	Description
TYPE	C	1		The type code, such as F forField training site
TYPE_NAME	C	50		The descriptive name of the type, like Field training site.

Observation level datafile OBSLEVL.DBF

Field Name	Field Type	Length	Decimal Places	Description
OBSLEVLCOD	N	1		
OBS_LEVEL	C	50		Descriptive name for the level. 1 = complete walk-thru of site

It may be desirable to distinguish level 1 observations made by taking transects from other level 1 observations.

APPENDIX D

DU MODULE ILIAMNA WETLAND STATISTICS

Files Supplied on Disk

Structure files - First Step from ASCII to dBASE

tot_str1.dbf	Structure file for importing the ASCII totals (.tot) file
wbs_str1.dbf	Structure file for importing the ASCII WBS files
lks_str1.dbf	Structure file for importing the ASCII LKS files
blx_str1.dbf	Structure file for importing the ASCII BLX files

Structure Files for Final dBASE Wetland Statistics Files

tot_str1.dbf	Structure file for final dBASE totals file
wbs_str2.dbf	Structure file for final dBASE WBS files
lks_str2.dbf	Structure file for final dBASE LKS files
blx_str2.dbf	Structure file for final dBASE BLX files

Final Wetland Statistics Files

prj-tot.dbf	dBASE Totals file for the Iliamna project
prj_wbs.dbf	dBASE WBS file for the Iliamna project
prj_lksn.dbf	dBASE LKS file for the Iliamna project. The Land Key Statistics are calculated for basins of 2 or fewer acres to be comparable to the statistics calculated for the earlier projects.
prj_blx.dbf	dBASE BLX file for the Iliamna project

Converting Wetland Statistics from DU Module ASCII Tables into dBASE

Structure files have been created which can be used to directly import the ASCII totals, WBS, LKS, and BLX files to dBASE. These are customized for the Iliamna data so as to create final dBASE files that are similar to those for the earlier projects. The structure files would have to be modified for new projects to reflect the actual wetland classes used in the case of the WBS and LKS structure files.

The procedure to follow is as follows:

- Create the empty dBASE files to receive the wetland statistics data. For each customized structure file:

  ```
  . CREATE <filename> FROM <structure file>            i.e. for WBS:
  . CREATE dilb1win FROM wbs_str1                      (dilb1 - w(bs) - in)
  ```

- Append the ASCII data for each file, i.e., for WBS in dBASE:
  (open the file from the step above if it is not already open: . use dilb1win)

  ```
  . APPEND FROM <ASCII wbs file> SDF                   i.e. for Dillingham B-1
  . APPEND FROM b-1_dillingham SDF
  ```

  and browse the file to be sure all is OK.

- Add the map sheet information to each file record. In the case of Dillingham B1:

  ```
  . REPLACE ALL map_abbr WITH "DIL-B1", map_accro WITH "A59156B1", zone
  WITH 5
  ```

- Now the field order can be rearranged with the map abbreviation and map acronym first by appending the file just created to an empty file with the final structure. Be sure to close the file first. Then:

  ```
  . CREATE dilb1wbs FROM wbs_str2
  . APPEND FROM dilb1win
  ```

The same procedure can be followed with the LKS, BLX and totals ASCII files. The totals file will be in the final form as soon as it is imported because the map sheet info is already in each record.