Public-data File 85-51

WETLANDS MAPPING IN INTERIOR ALASKA: ANALYSIS OF SUMMER AND WINTER LANDSAT DATA

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May 1985

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TABLE OF CONTENTS

I. INTRODUCTION

Wetlands are an important national resource. To manage them effectively governmental agencies need to know their extent and location. The objective of this research project was to develop methodology for reconnaissance-level wetland mapping using computer analysis techniques with Landsat data. The intent was to separate wetlands from non-wetland areas, thus enabling 1) planners to consider the impact of land-use allocations on wetlands and, 2) regulatory agencies to make a first-cut evaluation of wetland status when reviewing proposed development.

In the course of this study, Landsat Multi-Spectral Scanner (MSS) data was analyzed for a study site in the Tanana Valley, west of Nenana. The techniques of computer-aided classification and stratification were utilized to generate a wetlands map covering the USGS Fairbanks C-6 topographic map quadrangle. In addition, a reference data set was constructed to evaluate the effectiveness of various Landsat image products. Significant problems were encountered in the construction of the reference data set and are discussed in this report.

The final wetlands map produced during this research project resulted from the combination of summer and winter image data, and yielded an 89% agreement with the reference data set.

II. BACKGROUND

Nationally, there is a concern about the loss of our wetland resources. This loss is primarily through conversion of the wetlands to cropland, timberland and development sites. In the

48 contiguous states, it is estimated that 30-40% of the nation's wetlands have been altered or destroyed (Horwitz, 1978). These areas not only provide habitat for fish and wildlife, but they also play an important role in maintaining groundwater supplies and act as a buffer along oceans, lakes and rivers during storms, floods or tidal changes.

Wetlands are lands influenced by the presence of water. These areas are either permanently or periodically flooded with water, which influences the soil and plant development. The U.S. Fish and Wildlife Service has developed a classification for wetlands to be used in the ongoing National Wetlands Inventory (Cowardin, 1979). In their definition, areas classified as wetlands have one or more of three primary attributes; 1) periodically the land supports hydrophytes, 2) they contain predominantly undrained hydric soils and 3) are saturated, or covered by shallow water, during the growing season each year.

Several agencies within the federal government are now responsible for the preservation of wetlands. This includes regulation, research, management, planning and acquisition (Horwitz, 1978). To manage this resource, it is important to know where the wetlands are located. In Alaska, there is a shortage of detailed wetland maps available for land management purposes.

The goal of this project was to devise a method for mapping wetlands from computer analysis of digital data. Due to the large aerial coverage of Landsat data (34,000 square km per scene) it is possible to evaluate large areas at a relatively low cost per unit area, in comparison with conventional mapping techniques.

Maps made from Landsat data provide resource managers with information sufficiently detailed to make planning and management decisions on a regional level. It is anticipated that as development pressures increase, more conventional, detailed inventories would be conducted on an area by area basis.

A previous study was conducted on the Fairbanks C-6 quadrangle test site in 1981 (George, 1982; Westerland, 1982). During the project, the study site was selected, Landsat data analyzed and limited field work conducted. The current study was a follow-up of the earlier work, and further explored the analysis of Landsat data for wetland mapping.

The study site is located in the Tanana Valley, near the confluence of the Kantishna and Tanana rivers (Figure 1). Three distinct landscape or terrain types are present; a floodplain, lowland and upland. The Kantishna River flows through the northwest corner of the area. Associated with the river are a series of floodplains, levies, abandoned stream channels and river terraces. Vegetation in this area ranges from white spruce forest stands on the levies to herbaceous cover in abandoned stream channels.

The center of the area is a lowland that is generally poorly drained. It is dominated by larger areas of shrublands and herbaceous plants. Large silt covered dunes with a northeast-southwest orientation are prominent features in the lowlands. The dunes are well drained and support mixed forests of aspen, paper birch and spruce. This area also contains Black Bear Lake, the largest perennial water body in the study area.

The southeast portion of the quadrangle has a gently rolling surface which consists of sand and silt over outwash deposits.

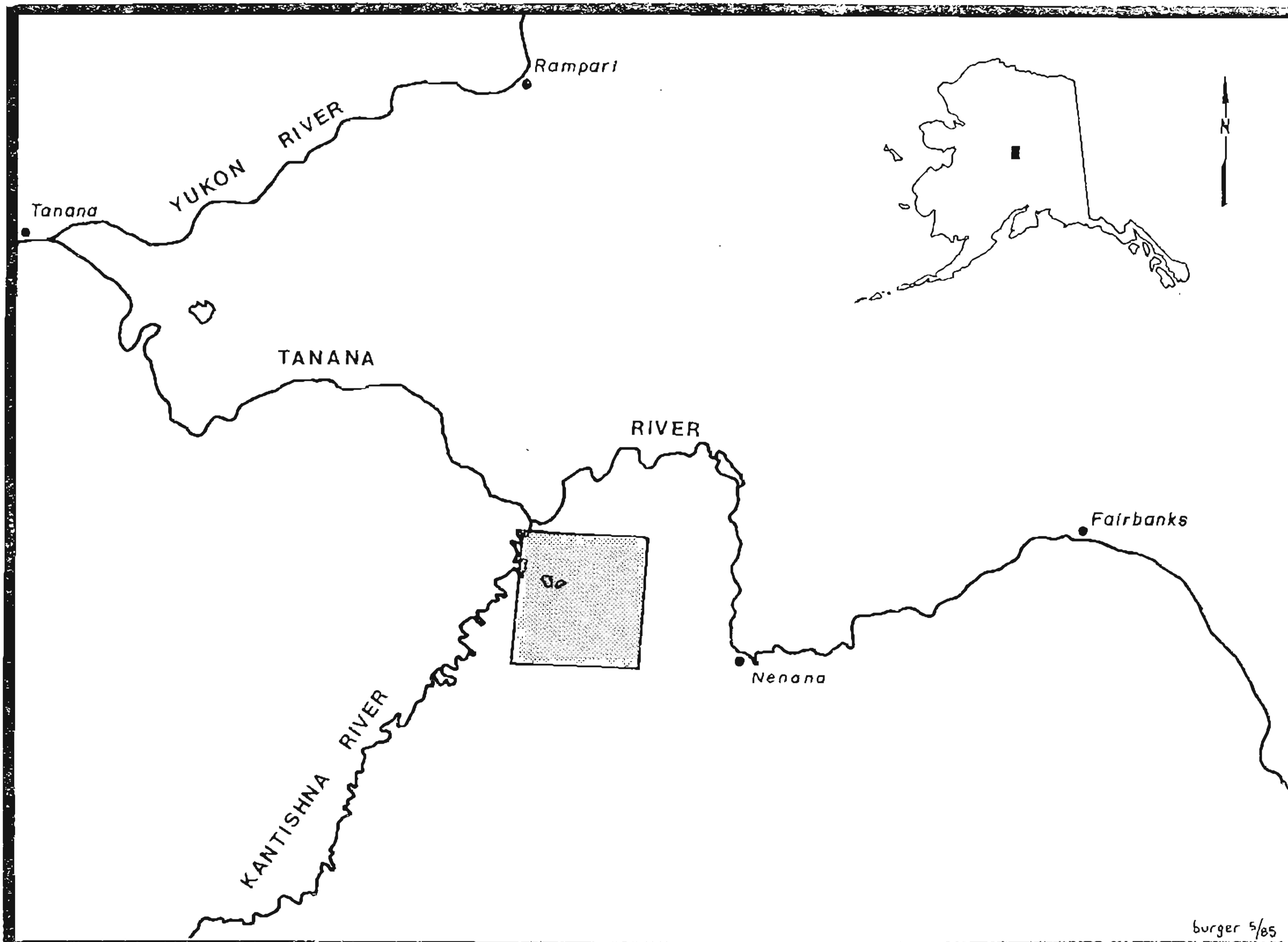


Figure 1 SITE LOCATION Study site located within Fairbanks C-6 Topographic Map SCALE: 1,000,000

This landscape is generally well drained and supports a range of forest types, including birch, aspen and black and white spruce. A significant feature of the upland area is a complex distribution of vegetation types, which are controlled largely by forest fires. The fire history of the landscape has resulted in a full range of forest types.

III. METHOD

The objective of this project was to generate a reconnaissance-level wetlands map from computer processing of Landsat MSS data. Image processing was performed on the Interactive Digital Image Manipulation System (IDIMS) operated by the U.S. Geological Survey, EROS Field Office in Anchorage. IDIMS is an HP-3000 based mini-computer system with specialized hardware and software for digital image processing. The system also has geographic entry and display capabilities, which allow analysts to encode information from maps for use with digital image data.

For purposes of discussion, the project is broken into several tasks; construction of a reference data set, analysis of summer and winter imagery and the combination of summer and winter data sets.

A. REFERENCE DATA SET

To evaluate and compare image products generated from computer analysis, a reference data set was constructed. The objective was to define homogeneous areas on the landscape which could be identified as belonging to a specific vegetation type, and further labeled with respect to wetland status. This data set, in digital form, was available to test different wetland "maps", and serve as a quantifiable basis for comparison.

Initially, over 100 points were randomly drawn and located on 1:30,000 scale color-infrared photography. A photo-interpreter then attempted to define polygons of homogeneous tone and texture surrounding each point. Many points fell into heterogeneous areas and had to be discarded and replaced by other points selected by the interpreter. Each polygon was given a tentative vegetation label by the interpreter. In addition, areas were selected to represent vegetation types not sampled by the random point distribution.

In total, 108 reference polygons were created, and transferred to an ortho-photo quad-sheet. These were digitized and converted into a digital image, matching the 50 meter Universal Transverse Mercator (UTM) grid created for Landsat image processing. Pixels outside the polygons were assigned the value zero, and pixels inside were given the value of that polygon, ranging from 1 to 108.

The reference data set was constructed during the first stage of the project, in the spring of 1981. The following summer, a brief field reconnaissance of the study site was conducted. Each reference polygon was examined, primarily from aerial observations made from a helicopter, to establish the vegetation type. Due to logistic constraints, less than 25% of the polygons were examined on the ground. Landing sites were selected to expose the field crew to the variety of terrain types in the area.

Following field data collection, the reference polygons were mapped into groups corresponding to vegetation types. The reference polygons were also assigned into wetland and non-wetland groups. This assignment was based on field observations, and checked against a wetland map produced independently by the Division of Geological and Geophysical Survey (DGGS).

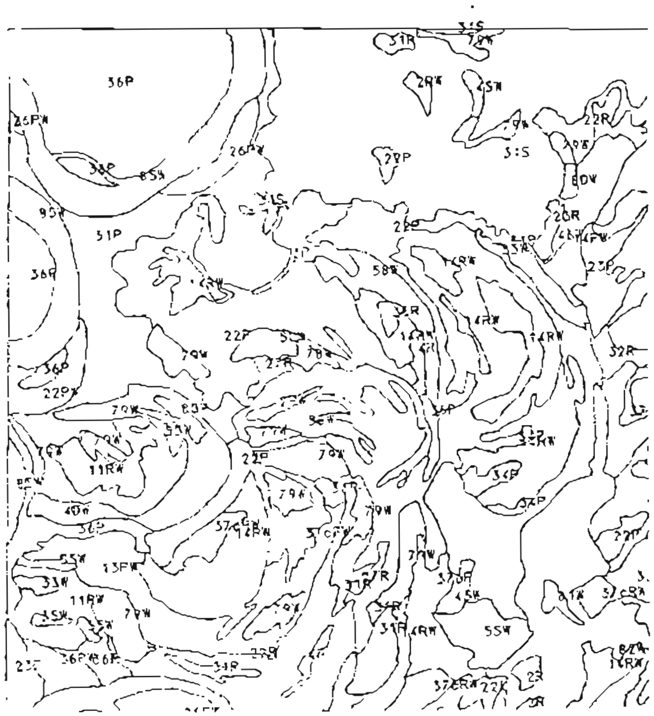
The detail sought from Landsat data in this project was a simple wetland/non-wetland separation. In the course of constructing the reference data set, some problems with the DGGS wetland map were discovered. The entire riverine portion of the study area had been identified as wetlands, including mature stands of spruce and birch trees, located on well drained soils. To explore this situation, and the relationship of wetland to vegetation type, a second "wetlands" map was located.

The United States Department of Agriculture, Soil Conservation Service (SCS), is mapping portions of the Tanana Valley as part of a river basin study. One product of the program is a vegetation/wetland map, photo-interpreted from high-altitude, color-infrared aerial photography. A preliminary copy of their map of the Fairbanks C-6 quadrangle was obtained for use in this study. Figure 2 shows a portion of the DGGS and SCS maps for the northwest corner of the study area, along the Kantishna river.

Unit number 1 is labeled on the DGGS map as a riverine wetland, unconsolidated shore category (for map unit descriptions, see Appendix A). The SCS map identifies this area as an open mixed forest, comprised of spruce and birch trees of sawtimber size. They categorize the area as a non-wetland.

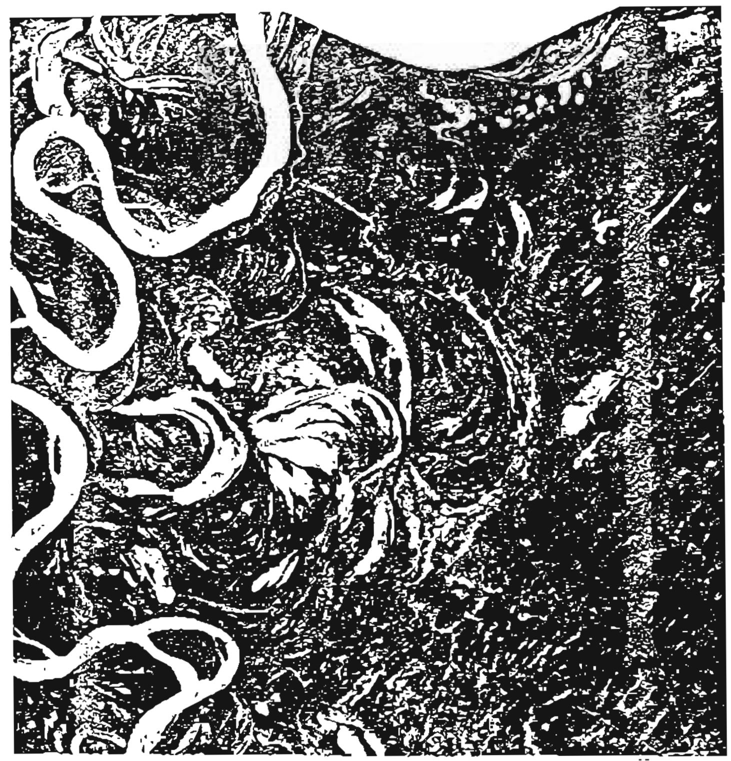
Unit number 2, on the DGGS map is identified as palustrine forested , a wetlands category vegetated by blue spruce, birch and larch trees, growing on boggy ground. On the SCS map this

FIGURE 2
Wetlands Map Comparison



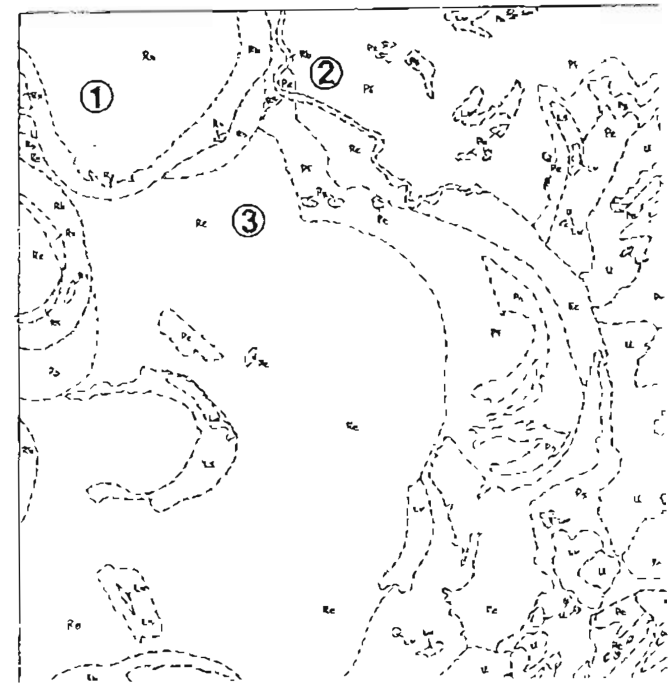
A. USDA Soil Conservation Service Vegetation/Wetland Map

This wetlands map from a portion of the Fairbanks C-6 Quadrangle was prepared by the SCS. Wetlands are identified with a "W" at the end of the map unit label. For a full description of the vegetation labels, see Appendix B.



B. High Altitude Aerial Photograph

Both SCS and DGGS maps were prepared by photo-interpretation of color-infrared versions of this photograph, at a scale of 1:31,680. The area shown here is the northwest corner of the Fairbanks C-6 Quadrangle map.



C. Division of Geological & Geophysical Surveys Wetlands Map

This map was derived from geologic maps previously produced. The units are labeled with a wetlands coding adapted from the U.S. Fish and Wildlife Service. A complete description of the units is given in Appendix A unit is part of a larger unit identified as closed spruce-birch forest, also identified as a non-wetland.

Unit number 3 is a large area on the DGGS map also labeled as riverine emergent. The area is broken into a number of types on the SCS map, including forested, non-wetland classes and herbaceous wetland areas.

These areas were evaluated by comparison with aerial photography and an aerial reconnaissance of the riverine region. It was concluded that the DGGS map poorly characterized this region and needs modification.

Through study of the map and discussions with DGGS, two factors were identified which could lead to the discrepancies cited. The wetlands map was a secondary interpretation of a geologic map of the area. During the transfer process, improper map unit labels may have been assigned, resulting in cartographic errors. The other problem is with the wetlands categories used in the mapping process. The mapping classification used by DGGS (see Appendix A) is based on landforms, modeled after the Fish and Wildlife Service wetlands classification (Cowardin, 1979). In the riverine section of the classification, there exist no categories describing forest vegetation. Any forested classes that are considered to be wetlands would be categorized as palustrine forested, while non-wetlands belong in the upland category. It is conceivable that there might be some reluctance to label units in an area of riverine origin as belonging to an upland category.

The SCS map of the Fairbanks C-6 quadrangle was constructed in a different manner. The map is being interpreted for both vegetation type and wetland status. Map labels are an alphanumeric code which identify a vegetation type. An additional letter designation is attached to units which are identified as wetlands (see Appendix B). To determine the wetland category, a map user must look at a supplemental legend which cross-walks vegetation classes to Fish and Wildlife Service wetland categories. An evaluation of this map showed good agreement with our photo-interpretation and field data. The SCS map was adopted for use in this study as a reference map for vegetation and wetland types.

B. SUMMER LANDSAT IMAGE ANALYSIS

The primary task of the project was to perform conventional image classification techniques tailored to 1) the study area and 2) the goal of making a wetland/non-wetland map. Landsat images 30537-20434 and 30537-20441, acquired August 24, 1979, were mosaiced together and geometrically corrected to a 50 meter UTM projection. In the previous study, an unsupervised classification had been performed on the MSS data set. The objective of the present study was to perform a modified cluster analysis (Fleming, 1977) utilizing both supervised and cluster analysis techniques. Image analysis was performed on the IDIMS system operated by the U.S. Geological Survey EROS Field Office in Anchorage.

Training sets were selected for the range of vegetation cover-types present in the study area, as represented by the SCS vegetation map. Fields of each type were identified and spectrally analyzed to determine the mean and covariance values in each MSS band. Twenty spectral classes were identified. The sample data set was then processed using an unsupervised clustering algorithm to determine the number of spectrally significant clusters. A total of 22 classes were derived. Both sets of cluster statistics were combined and edited to produce a final set of 16 spectral classes.

The raw Landsat MSS data was classified using a maximum likelihood classifier. A stratification mask had been previously developed to separate the study area into three physiographic provinces (Figure 3). This mask was applied to the classified image, which enabled the analyst to treat each area as a separate classification. The classification was examined on the color video monitor to compare spectral classes with aerial photographs and reference maps. A vegetation cover-type map with 9 categories was constructed (Figure 4). Each category in the cover-type map was assigned to either a wetland or non-wetland class based on field observations and the SCS vegetation/wetland map. The wetland map is shown in Figure 5.

C. WINTER LANDSAT IMAGE ANALYSIS

Most Landsat vegetation mapping projects utilize summer color-infrared imagery to separate vegetation categories. Monochrome winter images have been used as a supplement to photo-interpretation (Anderson, 1976). When the landscape is snow covered, as is generally the case in interior Alaska during the winter months, shades of gray correspond to the density and structure of vegetation. The low sun-angle of winter imagery also tends to enhance subtle topographic features on the landscape. Interpretation of these images has also been used to divide study areas into physiographic regions for computer classification (George, 1981).

FIGURE 3
Stratification Mask

The study area was geographically divided into three regions to stratify Landsat classification results. The area boundaries were derived from photo-interpretation of winter Landsat images and topographic maps.

COLOR	CLASSIFICATION
Red	-riverine
Yellow	-lowlands
Green	-uplands

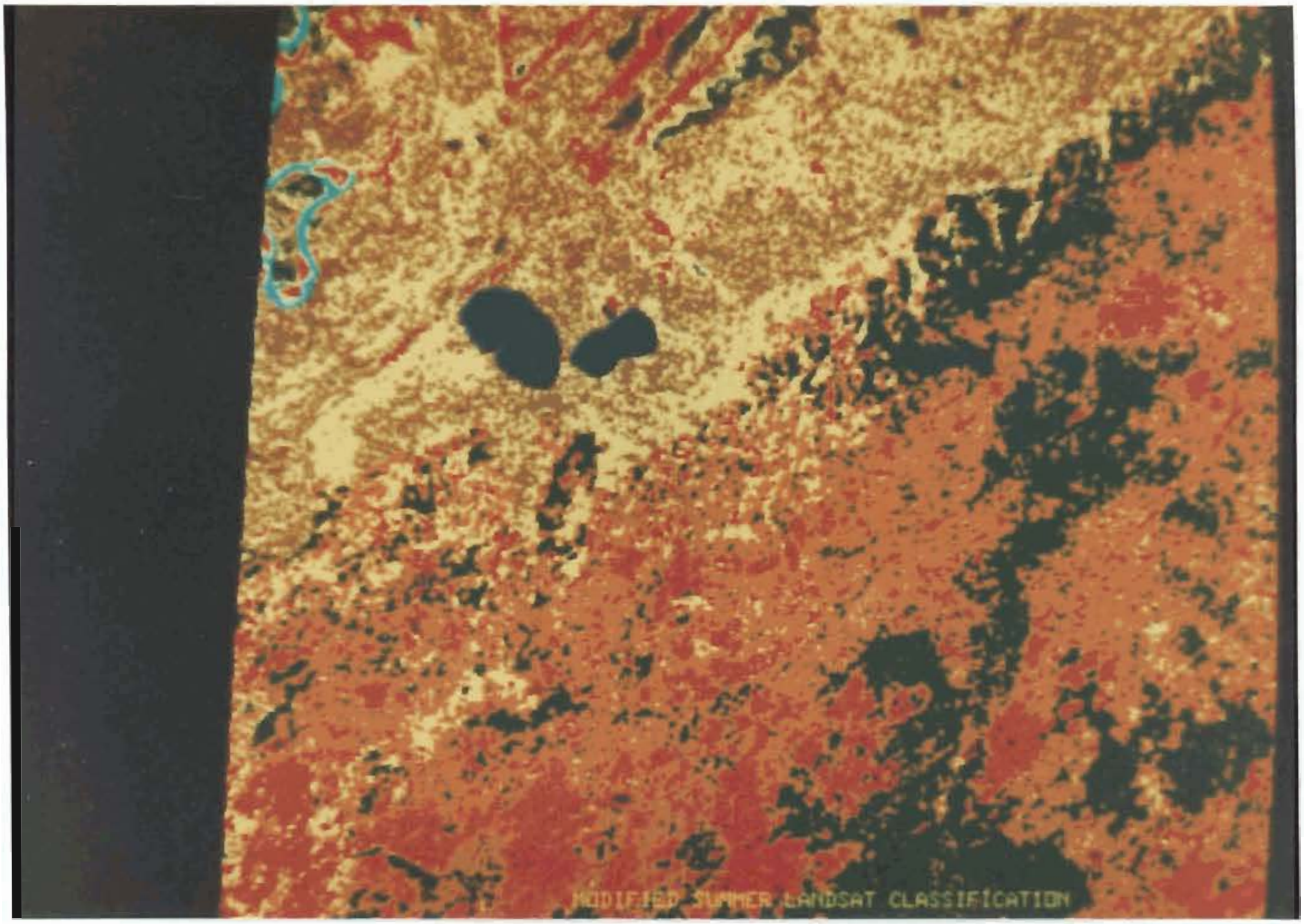


FIGURE 4
Modified Supervised Classification of Summer Landsat Imagery

COLOR	CLASSIFICATION
Red	- deciduous forest (Non-wetland)
Orange	- upland mixed forest (Non-wetland)
Brown	- lowland mixed forest (Wetland)
Tan	- open spruce forest (Non-wetland)
Green	- closed spruce forest (Non-wetland)
Sand	- shrubland (Wetland)
Dark Gray	- herbaceous/sedge/grass (Wetland)
Aqua	- silty river water
Blue	- lakes and ponds
Black	- unclassified

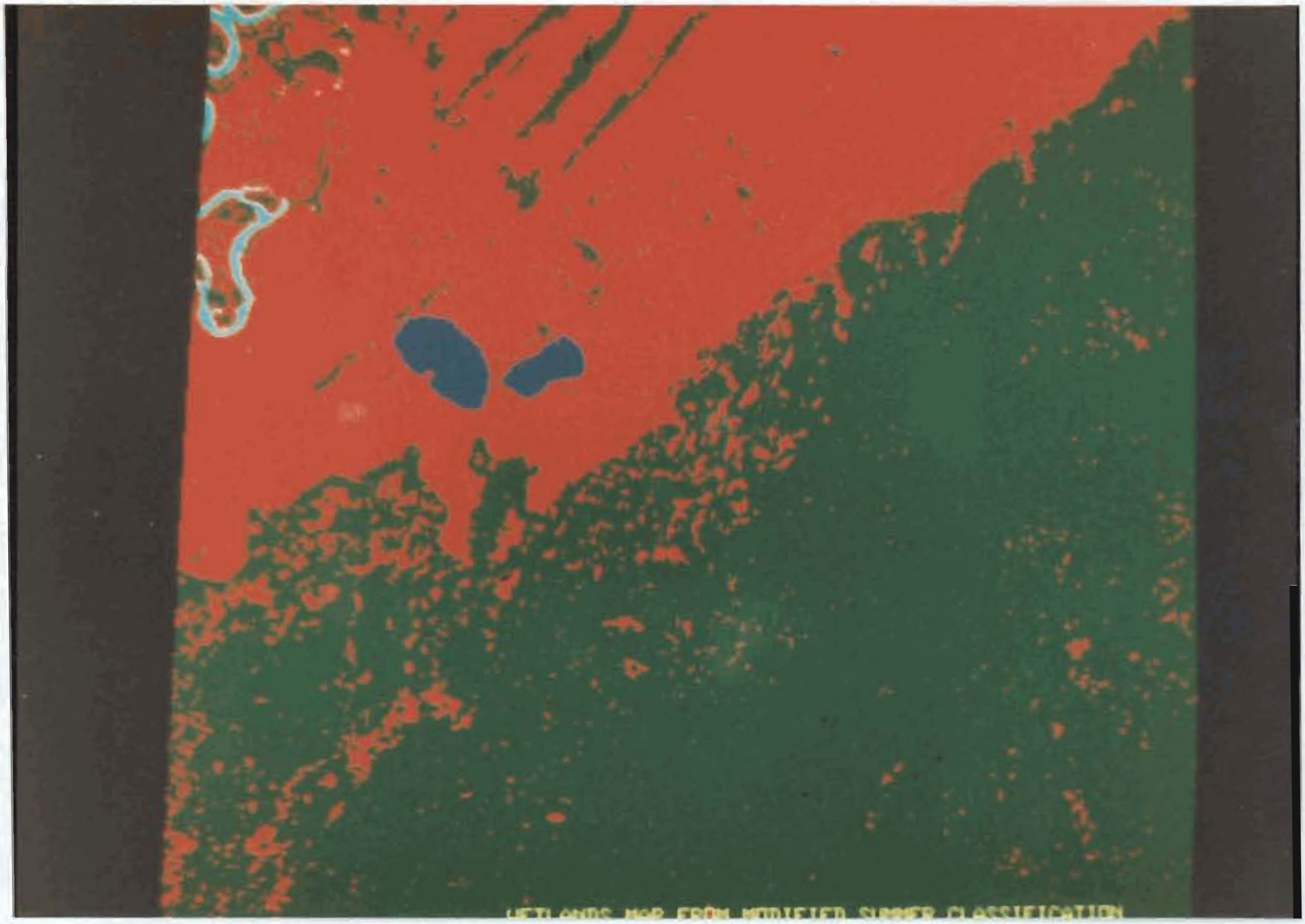


FIGURE 5
Wetlands Map of Summer Landsat Classification

COLOR	CLASSIFICATION
Red	-wetlands
Green	-Upland
Aqua	-silty river water
Blue	-lakes and ponds

Landsat scene 30357-20453, acquired February 25, 1979, was used in this study. Photographic enlargements were made and used in conjunction with summer imagery and a topographic map to divide the Fairbanks C-6 quadrangle into the three physiographic regions previously described. The resulting map was digitized and transformed into a digital mask used in the classification of the summer Landsat data (previously described in section III B).

While working with the winter image it became apparent that a correlation existed between the highly reflective snow covered areas on the image and the majority of the wetlands. Digital data was obtained for the February image, and rectified to the summer image. After evaluation of the image on the video monitor a threshold value was identified and a simple density slicing technique applied to make a wetlands mask. Figure 6 is the resulting image. Highly reflective areas corresponding to snow cover are white, while areas of dense vegetative cover are black.

In comparison to the summer classification and derivative wetlands map (Figures 4 & 5), the winter mask separates the open areas of herbaceous and shrub cover from forested areas. Also included in the open category are lakes, ponds and the surface of the Kantishna River, which are snow covered during the winter. This image product clearly shows the low, open areas, much more realistically than the summer classification. The areas delineated on the winter image products are for the most part, wetlands. It is a conservative map of wetlands in that the poorly drained lowland forest categories tend to be grouped with the better drained upland forest areas. Another short coming of the winter image is confusion between wetlands and recent wildfire scars. The highly reflective surface that is normally

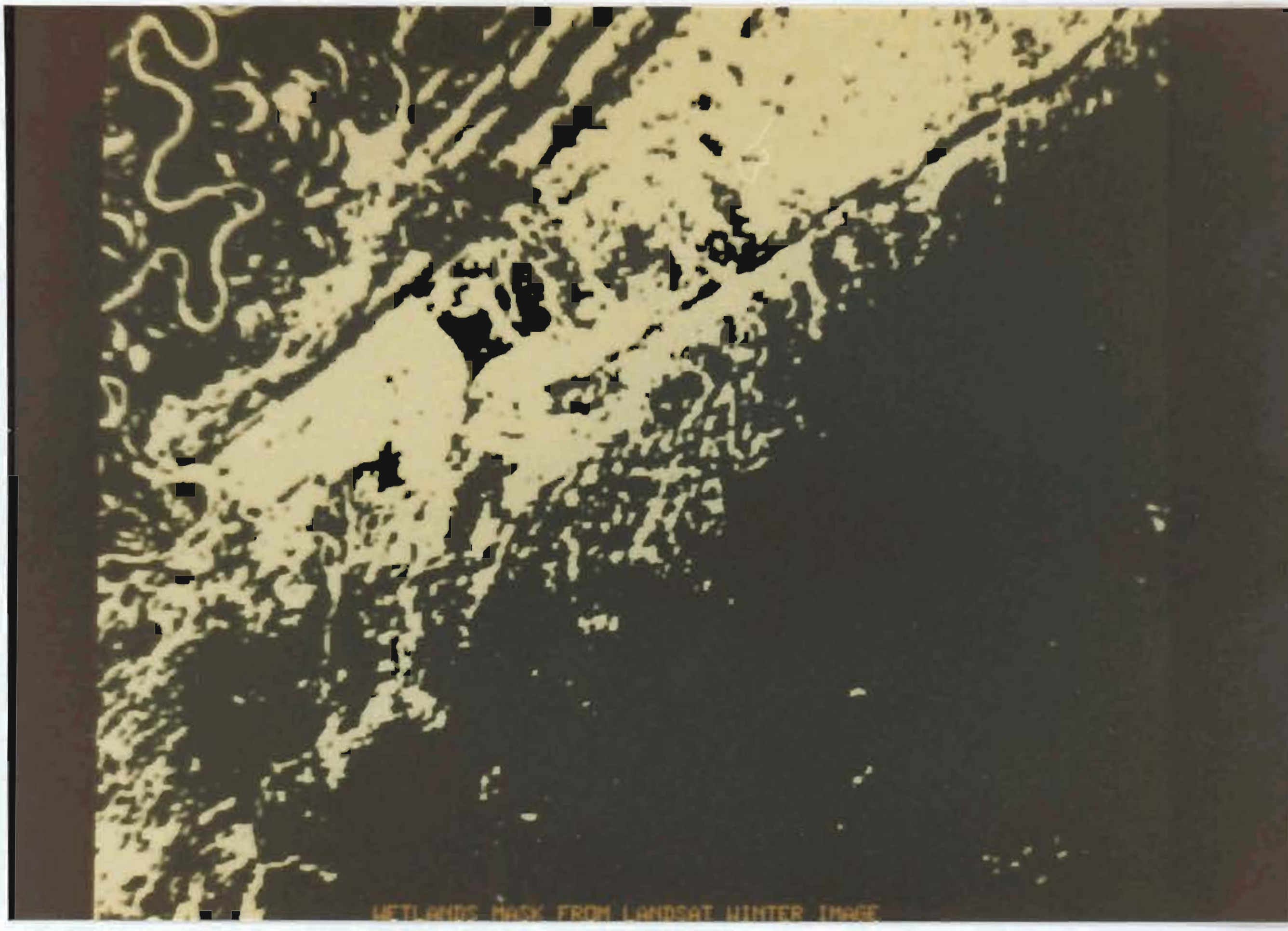


FIGURE 6
Winter Wetlands Mask

A "map" of wetlands by density slicing a winter Landsat image.

COLOR	CLASSIFICATION
White	-wetlands
Green	-non-wetlands

associated with low, open wetlands is also typical of upland areas that have been burned. Several cases of this confusion were observed in the southwest portion of the study area.

In summary, the winter image offers a more realistic spatial delineation of low, open wetland sites than a summer color-infrared image. This information must be interpreted carefully to avoid mistaking lakes, rivers or burned areas for wetlands since they also have a highly reflective snow covered surface.

D. COMBINATION OF WINTER AND SUMMER DATA

One benefit of working with digital data is the relative ease of combining two or more data sets. A number of creative methods are now available to manipulate different layers of data, which are in this case maps. Since the summer Landsat classifications and winter image were both rectified to the same UTM grid, it is possible to add the two together and create a new map product.

The wetland mask previously generated contained pixels with two categories, wetland and nonwetland. These categories were assigned new numerical values, 10 for wetland and 0 for nonwetland. Next, the winter wetland image was added to the summer classification. A new image was created where each pixel could be evaluated with respect to both vegetation class and and wetland status as defined by the winter image. A new wetlands map was created based on both summer and winter information (Figure 7).

A visual comparison of the composite wetlands map was performed. The addition of the winter image added more wetlands to the map primarily in the zone between the lowlands and the

FIGURE 7
Wetlands Map from Summer/Winter Landsat Data

COLOR	CLASSIFICATION
Red	-wetlands
Green	-non-wetlands
Aqua	-silty river water
Blue	-lakes and ponds

uplands stratification boundary. Unfortunately, the fire scar in the southwest corner of the area was still labeled wetland since the shrub class contained the summer image is also a wetland indicator. Overall, the winter image appears to add some spatial detail to the wetlands map.

IV. RESULTS

A. COMPARISON OF IMAGE PRODUCTS

The reference data set constructed in the early stage of the project allows a quantitative comparison of the different image products. Table I was constructed by tabulating the pixels within the reference polygons with the corresponding pixels on each map product. These tables show an interesting comparison of wetlands map products. The initial unsupervised classification resulted in an overall agreement with the reference data of 84 percent. By performing a modified supervised classification of the summer data, where "known" training sets were selected to derive spectral classes, results improved to 88 percent agreement.

It is interesting that the wetland mask made from winter imagery (Table IC) shows 83 percent agreement with the reference data set. This figure sounds impressive for a "map" that is derived from a simple density slice of a single banded Landsat image. If one inspects the actual map (Figure 6) it is readily apparent that the wetland category includes the Kantishna River and all the water bodies in the area. This product fails to differentiate lakes and rivers, which would normally be used by a map user for orientation.

TABLE I
Wetland Map Contingency Table

A. Unsupervised Summer Classification

REFERENCE DATA

IMAGE DATA	Wetland	Non-wetland	Total
Wetland	4010	248	4258
Non-wetland	1187	3631	4818
			9076

7642 correct
9076 total = .84 agreement

B. Modified Supervised Summer Classification

REFERENCE DATA

IMAGE DATA	Wetland	Non-wetland	Total
Wetland	4489	563	5052
Non-wetland	555	3378	3933
			8985

7867 correct
8985 total = .88 agreement

C. Winter Image Wetlands Mask

REFERENCE DATA

IMAGE DATA	Wetland	Non-wetland	Total
Wetland	3659	118	3777
Non-wetland	1401	3824	5225
			9002

7483 correct
9002 total = . 83 agreement

D. Combined Winter/Summer Wetlands Map

REFERENCE DATA

IMAGE DATA	Wetland	Non-wetland	Total
Wetland	4652	392	5044
Non-wetland	573	3368	3941
			8985

8020 correct
8985 total = .89 agreement

Tables constructed by comparison of pixels within reference polygons to each Landsat image/map.

By combining the information from the summer and winter images, only a small improvement was achieved, to 89 percent agreement. The small change is probably due to the nature of the reference polygons, which were selected to represent homogeneous areas. Most changes caused by the addition of information from the winter image occur in the transitional boundaries, primarily between lowland and upland areas.

In summary, the modified supervised classification of summer data shows substantial improvement over the unsupervised results.

The summer image relies on tonal variation between vegetation types to differentiate wetland and nonwetland classes. In this study area, herbaceous meadows, shrublands and black spruce forest categories generally correspond with wetlands, while deciduous and mixed forest types, indicate nonwetlands. The difficulties encountered attempting to separate mixed forest classes from shrublands were a severe problem. Fortunately, image stratification into riverine, lowland and upland categories helped overcome this limitation. The addition of winter data doesn't make much additional improvement (1%) as represented by the numerical comparison with reference data. The winter image adds detail to the wetlands map in transitional areas which are not represented adequately by the reference data set. Our subjective evaluation is that the combined winter/summer classification is improved in the transitional areas.

B. VEGETATION TYPES AS AN INDICATOR OF WETLANDS

Classification of summer Landsat imagery for wetlands mapping relies heavily on the identification of vegetation types. The assumption is made that vegetation is an indicator of wetlands. According to the U.S. Fish and Wildlife classification, discussed previously, wetlands are defined by a combination of factors including soils and surface hydrology in addition to vegetation. To positively identify an area as being wetland requires a field inspection. There is sometimes variability in the determination of wetland status among different observers in the field. It is beyond the scope of this project to delve deeply into the complex topic of wetlands identification, and the vegetation to wetlands correlation. Some information did "fall out" during the course of this project and is presented as food for thought.

The Soil Conservation Service map, previously described, was adopted as a reference in this study. It matched the field observations for both vegetation type and wetland status collected during the project. It also generally agreed with the DGGS wetlands map in the areas selected for reference test sites. In other words, three independent groups arrived at generally the same conclusions concerning wetland status of the polygon test sites used as reference data in this study.

The SCS map is really two maps contained on the same sheet. The primary map unit label is a vegetation identifier. Units which are considered wetland have an additional letter (W) at the end of the map unit label. The vegetation and wetland coding systems are contained in Appendix B of this report. Table II was compiled to look at the relationship between vegetation and wetland status of the reference data set. The separation of wetlands by vegetation type on this table is fairly clear. Herbaceous sedge meadows, shrubs and open black spruce forest classes are identified as wetland while upland forest classes are

TABLE II
SCS Vegetation vs Wetland Status

Reference Data Set

MAP LABEL	NAME	WETLAND	NON-WETLAND
2	Coniferous - black spruce-C*	3	3
4	black/white spruce-C		3
13	black/white spruce-O		1
14	bl.spruce/tamarack-O	4	
22	Deciduous - birch-C	1	4
23	aspen-C		4
24	birch/aspen-C		2
27	birch-O	1	
29	birch-woodland	1	
31	Mixed - spruce/birch-C		7
32	aspen/spruce-C		8
34	aspen/birch/spruce-C		6
36	spruce/birch-O	1	5
37	aspen/birch/spruce-O		3
37a	aspen/spruce-O		4
37c	birch/tamarack/spruce-O	3	
39	birch/tam./spruce-woodland	6	
40	Tall shrub - Closed	1	
50	Low shrub - Closed	2	
52	low willow	2	
53	dwarf birch/willow	1	
55	Low shrub - Open	5	
56	dwarf birch	1	
57	low willow	2	
58	dwarf birch/willow	1	
79	Herbaceous - wet sedge	12	
80	Aquatic - ponds/lakes	1	
81	floating/submerged veg	3	
82	emergent vegetation	4	
85	streams	1	
	TOTAL**	55	51
	PERCENT	52%	48%

* C - denotes closed canopy
O - denotes open canopy

** two polygons were split between vegetation types and discarded, leaving a total of 106 polygons associated with non-wetlands. Class 2, closed black spruce forest, is perhaps the most confusing, with the six units encountered split evenly between wetland and non-wetland categories. Note that the overall occurrence of reference sites is pretty evenly divided between wetlands and non-wetlands.

To further examine the relationship of vegetation type to wetland status this comparison was made for the entire study area. Table III is a listing for each map unit on the SCS map of the Fairbanks C-6 Quadrangle. Now the relationship between vegetation and wetlands is not so clear. The black spruce forest class (2) is indeed divided (49 units wetlands and 25 units non-wetlands). Other classes, primarily mixed forest types, are also split between wetland and non-wetland associations. While in general the trends seem to be the same as identified on Table II, there is more complexity on the landscape when viewed in its entirety. Assuming that the wetlands labels are correct, it appears that vegetation type alone fails to predict wetland status.

This data was tabulated by hand, late in the project. Unfortunately it would be very time consuming to manually track the units back to see where they occur spatially on the map. If this information is available in computerized format, it would be possible to display different map units to see the spatial relationship of these classes and potentially model the occurence of wetlands.

V. CONCLUSIONS

The objective of this project was to make a reconnaissance map of the wetlands using computer-aided analysis of Landsat MSS

TABLE III
SCS Vegetation vs Wetland Status

Entire Study Area

MAP LABEL	NAME	WETLAND	NON-WETLAND
2	Coniferous - black spruce-C	49	25
3	white spruce-C		2
4	black/white spruce-C	20	48
5	bl.spruce/tamarack-C	12	6
11	black spruce-O	59	13
13	black/white spruce-O	3	11
14	bl.spruce/tamarack-O	60	7
14a	tamarack-O	2	
16	black spruce-woodland	4	
18	black/white spruce-WL	2	
19	tamarack-woodland	5	
21	Deciduous - balsam poplar-C	1	1
22	birch-C	1	42
23	aspen-C	1	20
24	birch/aspen-C		23
26	balsam poplar-O	4	
27	birch-O	6	25
28	aspen-O		14
29	birch-woodland	15	4
31	Mixed - spruce/birch-C	8	80
32	aspen/spruce-C	1	41
33	poplar/spruce-C	2	
34	aspen/birch/spruce-C	1	43
34a	birch/tamarack/spruce-C	1	2
36	spruce/birch-O	23	61
37	aspen/birch/spruce-O	20	49
37a	aspen/spruce-O	1	22
37b	aspen/spruce/tamarack-O	1	1
37c	birch/tamarack/spruce-O	47	14
39	birch/tamarack/spruce-woodland	17	
40	Tall shrub - Closed	2	
41	willow	1	
45	Tall shrub - Open	22	1
46	willow	1	
48	shrub birch	1	
50	Low shrub - Closed	69	3
51	dwarf birch	20	
52	low willow	9	
53	dwarf birch/willow	15	
55	Low shrub - Open	60	4
56	dwarf birch	19	
57	low willow	3	3
58	dwarf birch/willow	19	2
60	low alder/willow	3	
70	Tall Grass	1	
79	Herbaceous - wet sedge	78	
80	Aquatic - ponds/lakes	10	
81	floating/submerged veg	8	
82	emergent vegetation	50	
85	streams	4	
	TOTAL	761	567
	PERCENT	57%	43%

data. A number of techniques were used. The modified supervised classification of the summer MSS data showed substantial improvement over a simpler, unsupervised procedure. Neither approach would have been successful without image stratification of the classification results.

Single band winter MSS data provides information concerning the location of low, open wetland areas. The selection of winter imagery for computer analysis is extremely important because of the potential for dust plumes and terrain shadows to obscure important image details.

Combination of information from the summer classification and winter wetlands mask didn't dramatically improve the amount of detail on the wetlands map. In the opinion of the author the combination of multiple data sources is an important technique for future computer-aided mapping from satellite remote sensing data. It does appear that separation between vegetation types cannot be adequately made by spectral differences alone. Increase in spectral and spatial resolution won't necessarily improve classification results. A recent study in the Northeast United States compared MSS and Thematic Mapper Simulator data and found no significant gain in overall classification performance for wetland mapping (Dottavio & Dottavio, 1984).

The use of vegetation as an indicator of wetlands is an area which requires further investigation. Interior Alaska tends to be vegetated, making it difficult to directly observe soil and surface hydrology. The spatial relationships between vegetation types and wetland status depicted on the SCS map offer one way to study this relationship, and attempt to model the occurrence of wetlands to other landscape parameters.

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APPENDIX A

Alaska Department of Natural Resources
Division of Geological And Geophysical Surveys

Wetland Mapping Descriptions
for the Nenana Agricultural Area

WETLANDS MAP OF NENANA AGRICULTURAL AREA, ALASKA

by

Alaska Division of Geological and Geophysical Surveys
April 15, 1981

Wetlands are habitats dominated to varying degrees by water. In these areas the water table is at, near, or above the land surface long enough each year to influence the types of plants growing or soils developed on that surface (Cowardin and others, 1977). As a result of frequent flooding, vegetation may even be lacking or soils undeveloped. Wetlands comprise highly productive habitats for wildlife, especially waterfowl and fish, as well as important sources of surface water for domestic and commercial uses, popular recreation areas, and navigatable waterways.

These maps illustrate the types and extents of wetlands in the six quadrangles enclosing the Nenana Agricultural Area. The overlays were prepared by DGGS personnel experienced in interpreting false-color and black-and-white aerial photographs and are keyed to 1:31,680-scale orthophoto base maps. The scale of the photographs used during the interpretation is 1:65,000. Each wetland class is interpreted from several indicators, including landform, vegetation, and photo color. The user is cautioned that these wetlands maps are not based on water-level records and have not been verified by field observations. Therefore, the maps are subject to revision pending field verification. Water conditions attributed to each class are extrapolated from known conditions elsewhere in interior Alaska and may also be revised as a result of detailed field observations.

PRELIMINARY LEGEND

Symbol	Description
R	RIVERINE---All wetlands and permanent-water habitats contained within stream channels that are bounded by uplands or by wetlands dominated by trees, shrubs, persistent emergent plants, nonaquatic mosses or lichens; water is usually, but not always, flowing.
Rb	UNCONSOLIDATED OR ROCK BOTTOM---All rivers and other streams permanently containing water; characterized by water and aquatic grasses and mosses.
Rs	UNCONSOLIDATED SHORE---Frequently flooded active flood plains and linear phases of inactive flood plains (Weber and Péwé, 1961, 1970) between average and highest flood levels; mostly barren, but where vegetated characterized by <u>Equisetum</u>, carices, willows, small spruce, and uncommon alder.

Re EMERGENT RIVERINE---Seasonally to semipermanently flooded modified linear and coalescent flood-plain phases (Weber and Péwé, 1961, 1970); vegetated by *Equisetum*, willow shrubs, dense alder clumps, small balsam poplar, shrub birch, and ground cover of *Sphagnum* moss up to 12 in. thick.

P PALUSTRINE---Ponds, marshes, swamps, bogs, and fens not affected by wave action or wind and stream erosion, except during flooding, and dominated by trees, shrubs, persistent emergent plants, and nonaquatic mosses or lichens; may occur in isolated, small thermokarst basins or on slopes, especially in areas underlain by permafrost; bounded by uplands and streams, but not lakes; may comprise very slow-flowing segments of stream courses.

Pe EMERGENT PALUSTRINE---Seasonally flooded and permanently or semipermanently saturated bogs, fens, tundra, and herbaceous wetlands not bounded by lakes.

Ps SCRUB/SHRUB PALUSTRINE---Temporarily flooded phases of abandoned flood plains vegetated by numerous to dense, low shrubs of birch and willows and by scattered black spruce, larch, and birch trees less than 20 ft tall and by clumps of these small trees, all growing on boggy ground.

Pf FOREST PALUSTRINE---Temporarily flooded phases of abandoned flood plains vegetated by numerous to dense black spruce, birch, and larch trees more than 20 ft tall and growing on boggy ground.

L LACUSTRINE---Wetlands and permanent open-water habitats situated in topographic depressions or dammed stream channels and commonly affected by wave action; bounded by uplands and palustrine habitats; lacking trees, shrubs, persistent emergent plants, and nonaquatic mosses or lichens.

Lw LIMNETIC LACUSTRINE---All permanent lakes and ponds; vegetated by hydrophytic plants such as aquatic mosses and grasses, pond and water lilies, reeds, rushes, and floating organic mats.

Ls LITTORAL LACUSTRINE---Seasonally or semipermanently flooded, generally treeless, peaty and grassy lake and pond margins between low and high water levels.

U UPLAND---Well-drained surfaces very rarely or never flooded and saturated only for short periods of time; vegetated by deciduous, mixed deciduous and coniferous, and coniferous forest/woodland.

SYMBOLS

⁓ Approximate contact

? Questionable occurrence

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APPENDIX B

USDA Soil Conservation Service

Vegetation and Wetlands Mapping Categories for the Totchaket Area

TOTCHAKET VEGETATION MAPPING UNITS

Level I	Level II	Level III	Level IV
Forest	Conifer Forest	(1) Closed Conifer Forest	(2) Black Spruce (3) White Spruce (4) Black Spruce-White Spruce (5) Black Spruce-Tamarack
		(10) Open Conifer Forest	(11) Black Spruce (12) White Spruce (13) Black Spruce-White Spruce (14) Black Spruce-Tamarack (14a) Tamarack
		(15) Woodland Conifer	(16) Black Spruce (17) White Spruce (18) Black Spruce-White Spruce (19) Tamarack
	Deciduous Forest	(20) Closed Deciduous Forest	(21) Balsam Poplar (22) Paper Birch (23) Aspen (24) Birch-Aspen
		(25) Open Deciduous	(26) Balsam Poplar (27) Paper Birch (28) Aspen
		Woodland Deciduous	(29) Paper Birch
	Mixed Conifer Deciduous Forest	(30) Closed Mixed Forest	(31) Spruce-Birch (32) Aspen-Spruce (33) Poplar-Spruce (34) Aspen-Birch-Spruce (34a) Birch-Tamarack-Spruce
		(35) Open Mixed Forest	(36) Spruce-Birch (37) Aspen-Birch-Spruce (37a) Aspen-Spruce (37b) Aspen-Spruce-Tamarack (37c) Birch-Tamarack-Spruce (37d) Poplar-Spruce
		(38) Woodland Mixed Forest	(39) Birch-Tamarack-Spruce (39a) Aspen-Tamarack-Spruce

Level I	Level II	Level III	Level IV
Shrubland	Tall Shrub	(40) Closed Tall Shrub	(41) Willow
			(42) Alder
			(43) Shrub birch
			(44) Alder-Willow
		(45) Open Tall Shrub	(46) Willow
			(47) Alder
			(48) Shrub birch
			(49) Alder-Willow
	Low Shrub	(50) Closed Low Shrub	(51) Dwarf Birch
			(52) Low Willow
			(53) Dwarf Birch-Willow
		(55) Open Low Shrub	(56) Dwarf Birch
			(57) Low Willow
			(58) Dwarf Birch-Willow
			(59) Low Alder
			(60) Low Alder-Willow
			(61) Sheperdia-Dryas
			(62) Dwarf Birch-Sphagnum
			(63) Mixed Shrub-Sphagnum
Herbaceous	(70) Tall Grass	(71) Bluejoint	
		(72) Bluejoint-Herb	
		(73) Bluejoint-Shrub	
		(74) Herbs	
	(75) Midgrass	(76) Dry mid-grass	
		(77) Mesic mid-grass	
	(78) Sedgegrass	(79) Wet Sedge-grass	
Aquatic	Freshwater	(80) Ponds and Lakes	(81) Floating and submerged vegetation
			(82) Emergent vegetation
		(85) Streams	(86) Floating and submerged vegetation
			(87) Emergent vegetation
		(90) Para-riverine	

*
Species classes

conifer forest 75% total tree cover from coniferous species
deciduous forest 75% of tree cover in deciduous tree species
mixed stand-neither conifers or deciduous species have clear dominance; both contribute 25% to 75% of total canopy cover

**
Canopy classes

Crown cover was used to indicate the relative differences in canopy classes
Closed Forest-60% to 100% forest canopy cover
Open Forest-25% to 60% forest canopy cover
Woodland Forest-10% to 25% forest canopy cover

***
Size Classes

R - Reproduction <5" D.B.H. (Diameter Breast High) coniferous and deciduous species
P - Pole 5" D.B.H.-9' coniferous species
5" D.B.H.-11" D.B.H. deciduous species
S - Sawtimber >9" D.B.H. coniferous species
>11" D.B.H. deciduous species

BR - Burned Recently

W - Wetland

NOTE: R size class is all trees under 5 inches dbh, not just regeneration.

NOTE: Size class reflects the size of the majority of the dominate species in a polygon

NATIONAL WETLAND INVENTORY CONVERSION TABLE FOR TOTCHAKET AREA

All polygons on the aerial photographs with a label ending in "W" are wetland according to the U.S. Fish and Wildlife Service. The number code at the beginning of each label is the key to converting the SCS vegetation type to the FWS wetland classification code. Many of the codes on the photographs have additional letters between the number code and the wetland modifier (e.g. 19RW, 11PW and 15BRW). These additional letters do not affect the conversion of the SCS vegetation types to the FWS wetland types.

Several of the codes on this list include letters (e.g. 14a, 37c, and 80L). In these cases the first letter following the numerical code does affect the conversion.

SCS CODE	VEGETATION TYPE	NWI CODE
1W	Closed Conifer Forest	PFO4B
2W	Black Spruce	PFO4B
3W	White Spruce	PFO4B
4W	Black Spruce-White Spruce	PFO4B
5W	Black Spruce-Tamarack	PFO4/2B
10W	Open Conifer Forest	PFO4B
11W	Black Spruce	PFO4B
12W	White Spruce	PFO4B
13W	Black Spruce-White Spruce	PFO4B
14W	Black Spruce-Tamarack	PFO4/2B
14aW	Tamarack	PFO2B
15W	Woodland Conifer	PSS1B
16W	Black Spruce	PSS1B
17W	White Spruce	PSS1B
18W	Black Spruce-White Spruce	PSS1B
19W	Tamarack	PSS1B
20W	Closed Deciduous Forest	PFO1A
21W	Balsam Poplar	PFO1A
22W	Paper Birch	PFO1A
23W	Aspen	PFO1A
24W	Birch-Aspen	PFO1A
25W	Open Deciduous	PFO1A
26W	Balsam Poplar	PFO1A
27W	Paper Birch	PFO1A
28W	Aspen	PFO1A
29W	Paper Birch	PSS1A
30W	Closed Mixed Forest	PFO1/4B
31W	Spruce-Birch	PFO4/1B
32W	Aspen-Spruce	PFO1/4B
33W	Poplar-Spruce	PFO1/4B
34W	Aspen-Birch-Spruce	PFO1/4B
34aW	Birch-Tamarack-Spruce	PFO1/2B

35W	Open Mixed Forest	
36W	Spruce-Birch	PFO4/1B
37W	Aspen-Birch-Spruce	PFO1/4B
37aW	Aspen-Spruce	PFO1/4B
37bW	Aspen-Spruce-Tamarack	PFO1/4B
37cW	Birch-Tamarack-Spruce	PFO1/2B
37dW	Poplar-Spruce	PFO1/4B
38W	Woodland Mixed Forest	PSS1B
39W	Birch-Tamarack-Spruce	PSS1B
39aW	Aspen-Tamarack-Spruce	PSS1B
40W	Closed Tall Shrub	PSS1A
41W	Willow	PSS1A
42W	Alder	PSS1A
43W	Shrub birch	PSS1A
44W	Alder-Willow	PSS1A
45W	Open Tall Shrub	PSS1A
46W	Willow	PSS1A
47W	Alder	PSS1A
48W	Shrub birch	PSS1B
49W	Alder-Willow	PSS1A
50W	Closed Low Shrub	PSS1B
51W	Dwarf Birch	PSS1B
52W	Low Willow	PSS1B
53W	Dwarf Birch-Willow	PSS1B
55W	Open Low Shrub	PSS1B
56W	Dwarf Birch	PSS1B
57W	Low Willow	PSS1B
58W	Dwarf Birch-Willow	PSS1B
59W	Low Alder	PSS1C
60W	Low Alder-Willow	PSS1C
61W	Sheperdia-Dryas	PSS1A
62W	Dwarf Birch-Sphagnum	PSS1B
63W	Mixed Shrub-Sphagnum	PSS1B
70W	Tall Grass	PEM1A
71W	Bluejoint	PEM1A
72W	Bluejoint-Herb	PEM1A
73W	Bluejoint-Shrub	PEM1A
74W	Herbs	PEM1A
75W	Midgrass	PEM1A
76W	Dry midgrass	PEM1A
77W	Mesic midgrass	PEM1A
78W	Sedgegrass	PEM1C
79W	Wet Sedgegrass	PEM1F

80W	Ponds	POWH
80LW	Lakes	L1OWH
81W	Floating and submerged vegetation-ponds	PAB4H
81LW	Floating and submerged vegetation-lakes	L2AB4H
82W	Emergent vegetation	PEM1H
85W	Streams	R3OWH
86W	Floating and submerged vegetation-streams	R3AB4H
87W	Emergent vegetation	PEM1H
90W	Para-riverine	R3FLC