FEASIBILITY STUDY FOR LOCATING ARCHAEOLOGICAL VILLAGE SITES BY SATELLITE REMOTE SENSING TECHNIQUES

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16. Abstract

The objective of this project was to determine the feasibility of detecting large Alaskan archaeological village sites by satellite remote sensing techniques. The approach used was to develop digital multispectral signatures of dominant surface categories including vegetation types, exposed soils and rock, hydrological patterns and known archaeological sites. ERTS scenes were then printed out digitally in a map-like array with a letter reflecting the most appropriate classification representing each picel.

During the first 6-months period, preliminary signatures were developed and tested. It was determined that there was a need to improve archaeological site identification by developing signatures for all naturally-occurring vegetation and surface conditions in the vicinity of the test area. These signatures were tested by means of comparison of computer signature printouts with NASA-supplied aerial photography.

Two large 512 by 512 picel signature printouts were prepared which, taken together included the entire test area. Archaeological site signatures were tagged, lake and waterways were outlined. Subjective criteria based on location were applied to the tagged signatures. Unlikely locations were eliminated while the remaining possible sites were compared with known sites identified by field expeditions and NASA-supplied aerial photography. Of twelve known sites along the middle Khotol River, five were identified as sites on the computer printout and several more possible sites were located. However, seven known sites were not properly identified.

It was concluded that it is nearly feasible to use ERTS data and the techniques developed here to locate large archaeological sites. Several suggestions are offered to improve the feasibility of this approach.

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PREFACE

1. Objective of Project: The objective of this project was to determine the feasibility of detecting large Alaskan archaeological village sites by satellite remote sensing techniques. The approach used was to develop digital multispectral signatures of dominant surface categories including vegetation types, exposed soils and rock, hydrological patterns and known archaeological sites. ERTS scenes were then printed out digitally in a map-like array with a letter reflecting the most appropriate classification representing each picel.

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   Two large 512 by 512 picel signature printouts were prepared which, taken together included the entire test area. Archaeological site signatures were tagged, lake and waterways were outlined. Subjective criteria based on location were applied to the tagged signatures. Unlikely locations were eliminated while the remaining possible sites were compared with known sites identified by field expeditions and NASA-supplied aerial photography. Of twelve known sites along the middle Khotol River, five were identified as sites on the computer printout and several more possible sites were located. However, seven known sites were not properly identified.

3. Conclusions: It was concluded that it is nearly feasible to use ERTS data and the techniques developed here to locate large archaeological sites. Several suggestions are offered to improve the feasibility of this approach.

4. Summary of Recommendations:

    1. Eliminate banding and striping in digital data. These effects arising from poor intercalibration among the six ERTS MSS photometers are particularly troublesome for signature analysis where signatures are closely defined.

    2. Use of scenes from other seasons. Shadow length could be shortened by using solstice data thereby possibly providing greater spectral resolution among signatures. Use of early spring data might enhance identification of sites due to early vigor of vegetation on archaeological sites.

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A. The Potential Value of Remote Sensing to Archaeology in Alaska

The initial reaction to a suggestion of using remote sensing satellite data to locate archaeologically interesting village sites might naturally be one of skepticism. However, certain features of Alaskan village sites make remote sensing a promising means of establishing such locations.

1) The sites are relatively large. The site of a former village is usually considerably larger than the village itself was at any given period in its history. A village may remain in the same general location for centuries, but activity areas and the situation of individual dwellings within a village tend to vary over time. This variation creates a fairly large area disturbed from the natural state of the surrounding countryside.

2) The sites are generally inaccessible by road. Village sites may be found in the tundra, along abandoned or present beach lines, or in the interior, along rivers and streams. Because of the inaccessibility of many parts of the state, and the subsequently great expense of making ground surveys, no systematic search for abandoned village sites has yet been undertaken. Sites that have been located were stumbled across by accident, or found by an investigator looking in a likely spot.

3) The area to be searched for potential sites is vast. Here the use of a remote sensing satellite is of special value. The cost of using aircraft for such a study is prohibitive--many times the amount for satellite data analysis.

4) The sites stand a good chance of being identified by remote sensing. Through time a village disturbs its environment. This disturbance ultimately leads to alteration of the relationships of various vegetable species growing within the perimeter of the site. In the past, multispectral scanning by satellite has proven useful in crop and crop disease identification. Therefore, this technique should also be capable of detecting variation in vegetation denoting the possibility of an abandoned village site.

5) The opportunity is timely. There is a general feeling in archaeology that more use should be made of remote sensing in site location, and that new techniques for doing this should be developed and tested. Supporting this opinion are remarks made by Elmer Harp, Jr. of the Department of Anthropology, Dartmouth College (1966).

"If archaeologists will exploit this kind of interpretation in depth, proceeding logically from the macro-levels of regional, natural topography toward the micro-levels of man's social and cultural activity, I am convinced that we

> can learn to read minimal signs of past human activity on the earth's surface. The most primitive and ancient traces may have been obscured, perhaps entirely obliterated, by physiographic processes, but short of drastic elimination, any cultural activity with social magnitude is likely to have altered the surficial environment and established a chain of unnatural effects that will long endure. And as long as these do persist, they will inevitably be reflected in remote sensing imagery. Ultimately, I suggest, we may penetrate to the stage of aboriginal, preliterate societies, perhaps even to pre-historic levels of Palaeolithic culture.
>
> These statements immediately suggest the need for experimentation in technical approaches, for the essential parameters of remote sensing in cultural analysis are unknown. We must determine optimum scales for varying conditions of environment and cultural stages, test the relative utility of different film emulsions, and check methods of remote sensing in the extra-visual bands of the electromagnetic spectrum."

One well-known characteristic of Alaskan archaeological sites has been the lush, tall grasses growing at these locations. It has generally been accepted that several reasons exist for this change in vegetational cover from the surrounding area: (1) disruption of the original flora, (2) ground disturbances, (3) increased soil nutrients, and (4) economic patterns of the occupants. The relative strength of these factors are determined by (5) the period of occupation and (6) the technological development of the site occupants.

The general remote sensing technique is to determine the spectral characteristics of solar radiation reflected from a known site and then search for other geographical locations with the same spectral characteristics. The remote sensing study, therefore, requires the use of a known archaeological site. There are several obvious requirements for this known site: (1) It should be free from recent disturbance as possible, (2) It should be in an area where there is a likelihood of finding other sites nearby, (3) It should be large enough to give every possibility of being detected by remote sensing techniques, and (4) The period of occupation should have ended sufficiently long ago that the vegetational cover is representative of sites not mentioned in recorded history.

One site which appeared to fill these requirements was "Old Fish Camp" on the Khotol River near Kaltag examined by Frederika DeLaguna (1947) in 1935. The DeLaguna report supplied much needed information regarding this site, but lacked much additional information necessary for the present study. In particular, specific information regarding the reasons listed above for vegetational change were required. One very important item was the acquisition of radiocarbon samples to give some indication of the period of occupancy.

In order to obtain the needed additional information, a two-man field party visited "Old Fish Camp" between July 1 and July 20, 1972. The following sections treat individually the factors responsible for vegetational change determined by this field trip and concludes with a brief summary of what has been learned about "Old Fish Camp" to date.

B. Results of Field Trip to Known Archaeological Sites in Vicinity of Kaltag, Alaska

Ideally, the field work described here should be performed after the remote sensing data is obtained. However, it appeared that this postponement would cause at least a two-year delay in the final analysis of data. Furthermore, it was necessary to visit the site before analysis of remote sensing data because the exact location of "Old Fish Camp" was not known: the location was indicated on early United States Geologic Survey sketches.

Although DeLaguna (1947) excavated a house pit at "Old Fish Camp", additional archaeological information beyond that which she reported was sought. Radiocarbon samples from both high and low levels were sought to give some indication of the period of occupancy, faunal remains were sought to indicate the economic patterns of the occupants and stratigraphy would give an indication of ground disturbance. Cultural objects taken together with those reported by DeLaguna would indicate the technological development of the occupants.

Hence, it was determined to visit the site before the remote sensing data was taken, determine the accurate location, and obtain the archaeological and biological evidence necessary to determine the parameters associated with the vegetation cover of the site at the same time. It was necessary then to obtain this data while disturbing the site as little as possible. Here, we will outline the technique used to accomplish this end.

Because some evidence exists to indicate the end of the occupation period, evidence indicating the beginning of site occupancy was sought. For this reason, we desired a shallow house pit indicating a longer period of abandonment than newer, deeper house pits. In addition, a house pit was sought which when excavated would alter the reflected solar radiation as little as possible. These requirements were met when a shallow house pit was found to the side of the main site which was located under several large overhanging willows. It has not been possible to detect this excavation on the aerial remote sensing data (photography).

As will be described later, it was necessary to collect soil and vegetational samples at intervals along a lateral and longitudinal transect of the site. It was soon discovered that the tall (over four feet) grass would not return to a vertical position once walked over. Hence, the transects were made with every effort to disturb the grass as little as possible. Where possible, the site was walked around to or from a transect station. Although a great deal of curiosity existed concerning various aspects of the site, these investigations were left to a later time when the vegetational cover could be disturbed without fear of destroying the reflected spectral characteristics unique to archaeological sites.

FACTORS RELATED TO THE PRESENT VEGETATIONAL COVER OF "OLD FISH CAMP"

1. Disruption of the Original Flora

There is extremely little direct archaeological evidence of the early alternation of the biotic community. It is assumed that disruption of the original flora consisted of removal or destruction of the trees in the area by activities related to the collection of wood for construction and other utilitarian purposes. In addition, there must have been considerable "tramping down" of the original flora. Indirect archaeological evidence was found that back dirt resulting from aboriginal excavations for the original dwellings as well as later refuse heaps were also agents in "smothering" the original flora. Fires may also have played a role in this initial disruption of the habitat.

Due to the nature of the sample, there is no well documented evidence of the first occupation of Old Fish Camp. Therefore, it is necessary to infer that the processes indicated by stratigraphic analysis of the upper levels, such as refuse heaps and house construction, occurred during earlier times as well. Direct archaeological evidence as to when and in what manner the site was originally disrupted is not available at this time.

2. Ground Disturbances

By far the greatest soil disturbances resulted from the numerous aboriginal house excavations. DeLaguna (1947) reported one house which was 18 x 17 feet with an entrance tunnel 15 feet long. This house was of exceptional size and DeLaguna believed that it was a Kashim, or men's house. Generally, the houses at "Old Fish Camp" range in size between 9 x 10 and 13 x 15 feet. DeLaguna also noted other disturbances which she described as being "from 2 or 3 feet square, up to holes 3 x 8 feet. ... They were probably used for storing salmon eggs or frozen meat."

The one house which was partially excavated in 1972 is illustrated in Figure 1. It was very unlike those mapped by DeLaguna for it was found to have been circular rather than rectangular. Because of the permafrost present at the site, it was impossible to complete the excavation of this house, However, all the structural material was exposed, mapped and photographed _in situ_.

Here the construction details of the house which was partially excavated are outlined. The house was approximately 3 meters in diameter with what appeared to be a sleeping platform along the northern wall (opposite the entrance). The platform consisted of undisturbed alluvial sands and exhibited what appeared to be retaining posts along its interior margin. The central living area was an aboriginally excavated area with the less deeply unexcavated bench rising above it. It possessed a centrally located hearth which was elevated above the floor level. An entrance tunnel approximately 3.1 meters long extended from the southeast corner and terminated in what was possibly a cold trap.

DeLaguna originally mapped over forty house pits and noted that many more were located in the willows and forested areas near the

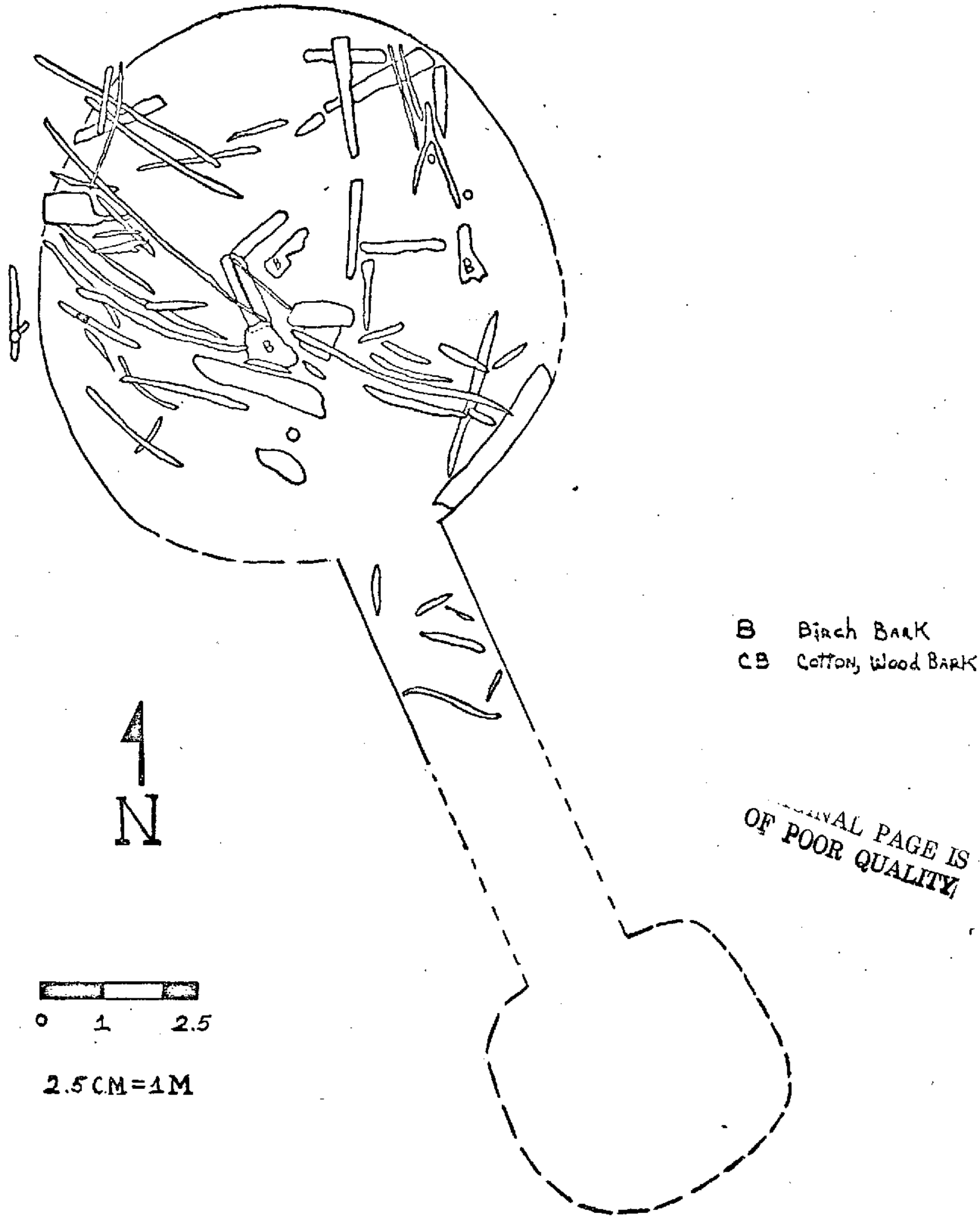

Figure 1. Map of Old Fish Camp house partially excavated in 1972.

site. It is not unreasonable to estimate that possibly one hundred house pits exist at the site, for the older house depressions are not well defined and are obscured by vegetation cover as well as aboriginal fill. The end result is therefore an extensive amount of ground disturbance from house construction alone. The innumerable cache pits as well as excavations for drying racks and the random digging of dogs as well as men increased the ground disturbance beyond that of house construction.

3. Increased Soil Nutrients

Unquestionably one of the most important agents responsible for the marked vegetation change between the archaeological site and the surrounding area is the increased nutrient value of the soil due to the deposition of cultural refuse. Table 1 illustrates a tabulation of the faunal remains recovered in 1972. The table illustrates that no one species dominates the sample and that there is insufficient representation of fragments and minimum number of individuals to evaluate the importance of each species.

In order to realistically discuss the minimum number of individuals in terms of meat represented, it would be necessary to sample the site in sufficient detail in order that all activity areas for butchering or bone processing could be located. Then an estimate of the element transport differential and degree of fragmentation and preservation could be made. The table does indicate, however, that the inhabitants of the site were exploiting several different ecosystems and had stratigically located themselves at an ecotone from which the individual ecosystems could be easily exploited.

Other factors also contribute to the change in the nutrient value. Although no coprolites were recovered, human as well as dog feces were most surely deposited. Birch bark for utilitarian purposes was also gathered in fairly large quantities and ash from fires is also incorporated in the midden debris.

TABLE 1

FAUNAL MATERIAL INVENTORY

	*M.N.I.	Total number of fragments	% of fragments
Large Fish	3	23	16.2
Medium Bird	2	22	15.5
Large Bird	1	1	.7
? Bear	1 ?	3 ?	2.1
Carnivore	1	1 skeleton	----
Rabbit	2	6	4.2
? Beaver	1 ?	3 ?	2.1
Muskrat	1	2	1.4
Small Mammal	---	18	12.7
Caribou	1	7	4.9
? Caribou	1 ?	6 ?	4.2
Large Mammal	---	16	11.3
Mussel (Anodonta)	1	2	1.4
Unidentified	---	33	23.2
Total	---	142 plus 1 skeleton	99.9

* Minimum number of individuals

In order to relate the nutrient value of the soil to the vegetation, two sampling transects were made across the site (see Figure 2). Both soil and vegetation samples were taken at 30 meter intervals. Unfortunately, the soil sample analysis is not yet compete. The vegetation samples along the transects are listed in Table 2. Conclusions relating soil nutrients and site vegetation will have to be made at a later date. It can be readily noted that grasses and herbacious plants dominate at the site proper and gradually give way to willows and other broad leaf species.

4. Period of Occupation

Analysis of the radiocarbon samples from the site is not complete and consequently a temporal sequence for the site has not been established. DeLaguna (1947) reported a glass bead from the site and therefore the site was not totally abandoned until sometime after the contact period. Loyens (1966) quotes Jetté as mentioning this site in passing in reference to a point on the Kaltag portage: "Loke-kayar-rota-na-te-tti-retton-ten: Place where the people of Lokekayar have or had their trail." Jetté adds, "when Lokekayar was permanently inhabited, its residents used to have a trail straight from their village, joining the Kaltag portage at this point." Loyens identifies Lokekayar as "Old Fish Camp".

In Kaltag today there is at least one old man who relates that there was a massacre at the village referred to here as "Old Fish Camp" with few, if any, survivors. This possibility will have

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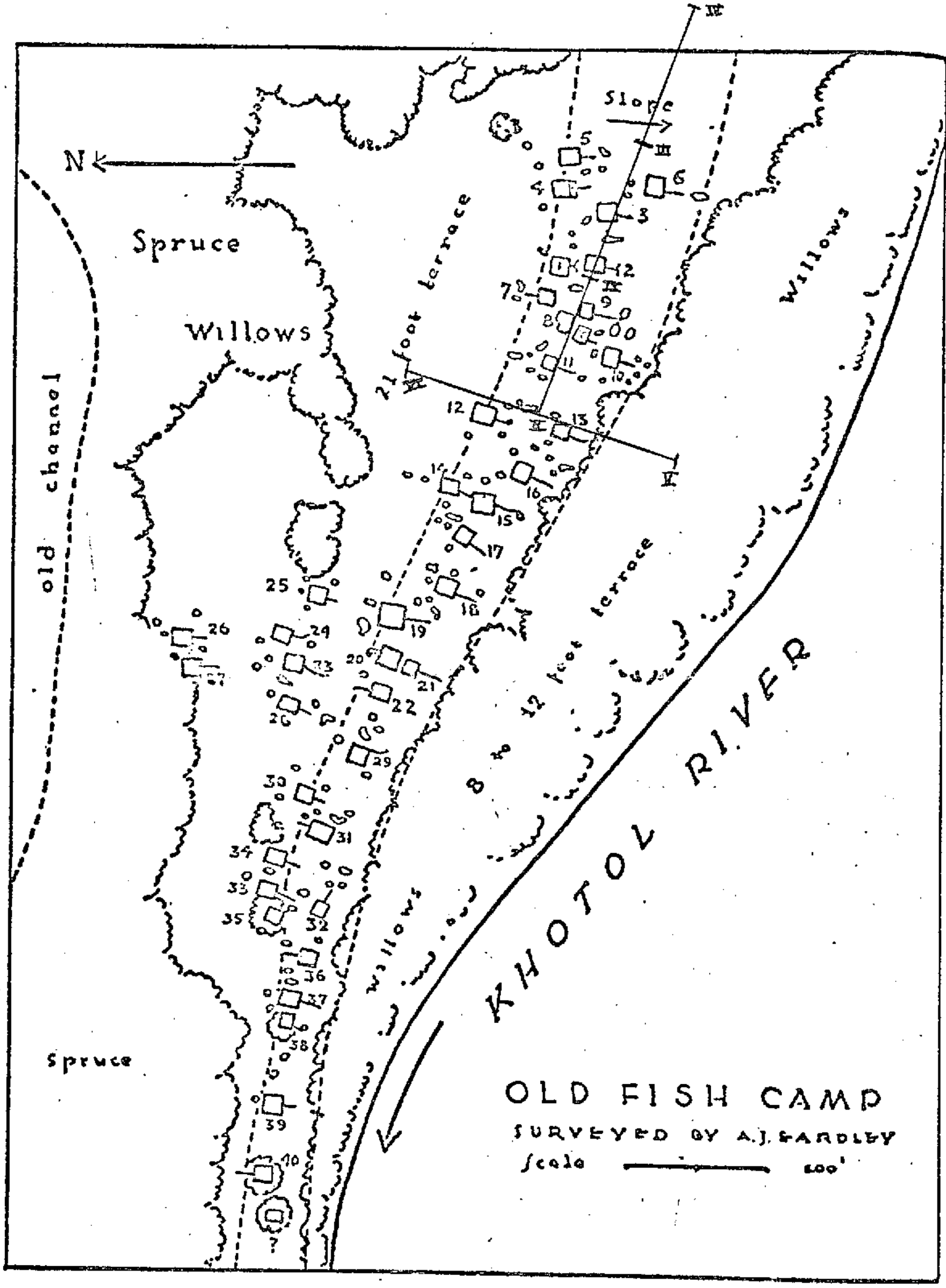

Figure 2. Map of Old Fish Camp (DeLaguna, 1947) showing 1972 sampling transects.

TABLE 2

VEGETATION INVENTORY TRANSECTS

Longitudinal Transects

Species	Station	I	II	III	IV
Polygonum alaskanum		15%	15%	0%	0%
Mertinsia paniculata		5	15	5	1
Calamagrostis canadensis		68	60	69	39
Echinopanax horridum		2	0	0	0
Rubus idaeus		2	2	3	5
Erysimum cheiranthoides		1	1	1	0
Galium boreale		2	2	1	2
Epilobium angustifolium		5	5	2	5
Salix		0	0	18	10
Thalictrum minus		0	0	1	0
Picea glauca		0	0	0	8
Betula		0	0	0	20
Equisetum arvense		0	0	0	10
Populus balsamifera		0	0	0	0

Lateral Transect

Species	Station	V	I	VI
Polygonum alaskanum		1	15	0
Mertinsia paniculata		5	5	10
Calamagrostis canadensis		2	68	55
Echinopanax horridum		0	2	0
Rubus idaeus		10	2	5
Erysimum cheiranthoides		0	1	2
Galium boreale		0	2	0
Epilobium angustifolium		1	5	2
Salix		40	0	10
Thalictrum minus		0	0	0
Picea glauca		3	0	10
Betula		0	0	5
Equisetum arvense		1	0	1
Populus balsamifera		37	0	0

to be investigated further. It does seem likely that permanent habitation ceased before 1850 but that the location may have been used as a camp for some time later.

A sample of ash from the central fire pit of the house was subjected to radiocarbon analysis. The age of the sample was found to be 490 $\pm$ 95 years. Hence, at this time we estimate that "Old Fish Camp" was occupied from at least some time before 1480 to around 1850 A.D.

5. Technological Development

Technological considerations are important when discussing the biomass harvest, ground disturbances, and subsistence patterns. This can be a limiting and regulating factor on the amount of food collected and thus on population size. The artifact inventory is listed in Table 3. A more thorough discussion of this inventory will be presented at a later date, although a few comments may be presented here. The good condition of the bone and wood artifacts argue for a fairly recent dating of the site while the typology, at least of the bone and slate points, may indicate an Eskimo influence if not an Eskimo habitation. So, too, does the pottery. However, the rolled birch bark, the birch bark baskets and the denticulate scraper are strong Athapaskan traits. This problem of Eskimo/Athapaskan identification is an important one which can only be solved by more excavation.

6. Economic Patterns of the Occupants

The name of the site, "Old Fish Camp", is somewhat misleading, for apparently it represents a much more permanent habitation site. The

TABLE 3

ARTIFACT INVENTORY

Bone Artifacts	No. of Specimens	Comments
A) Projectile Points	3	2 are fragments
B) Denticulate Scrapers	1	fragment
C) Bone Wedge	1	fragment
D) Adze Head	2	1 fragment
E) Knife Handle?	1	fragment
F) Worked Bone, "Scrap"	7	1 burned
G) Worked Antler, "Scrap"	2	
H) Unidentified	5	
Total	22	

Wood Artifacts	No. of Specimens	Comments
A) Worked Fragments	3	
B) Rolled Birch Bark	22	3 burned on one end
C) Complete Birch Bark Basket	1	
D) Birch Bark Basket Fragments	8	
E) Large Flat Pieces Birch Bark	3	
F) Structural Material (House)	86	
Total	145	

Ceramic Artifacts	No. of Specimens	Comments
A) Pot Shards	180	
Total	180	

Lithic Artifacts	No. of Specimens	Comments
A) Ground Slate Endblade	1	
B) Adze Blade?	1	fragment
C) Ground Slate Fragments	5	
D) Whet Stones	19	15 are fragments
E) Hammer Stone	1	
F) Obsidian Waste Flakes	7	
G) Quartz Waste Flake	1	
H) Geode	1	fragment
I) Fire Cracked Rock	228	
J) Stream Polished Pebbles	9	
Total	273	

TOTAL ARTIFACTS 598

numerous large semi-subterranean dwellings indicate a winter settlement of considerable size. The fact that fish remains constitute only 16.2% of the faunal remains also suggests that "Old Fish Camp" was anything but a fish camp. This is an important factor, for a seasonal occupation would limit the species represented in the deposits and dictate the type and form of ground disturbances.

II. DATA ACQUISITION

A. Oblique Hand-Held Aerial Photography

On July 8, 1972 an aerial reconnaissance of the "Old Fish Camp" area was made by light aircraft. This made possible a familiarization with the vicinity before detailed investigation on foot and by river boat. Many oblique color photographs were obtained by hand-held cameras. These photographs were found quite useful later when NASA-provided aerial photography was utilized to determine spectral signatures for vegetation: the oblique photography allowed an unambiguous identification of several vegetation types.

On August 5, 1974 the author had an opportunity to again overfly the study area in a light aircraft. This time oblique photos of likely locations of archaeological sites as determined from ERTS data were photographed.

B. Vertical-Incidence Multiband Photography

On July 25, 1972, just four days after the preliminary ground survey of the Kaltag-Nulato area had been completed, a NASA-provided aerial reconnaissance of the test areas was performed. The data collected included single band black and white photography, color photography, color infrared photography and two-band thermal imagery. The aircraft used was the NASA/NP3A. All products are vertical viewing angle. The color and color IR photography were the principal products used in determining vegetation types for signature development.

C. Spacecraft Data

1. Multispectral Imagery

On July 25, 1972 scene 1002-21315 was obtained containing Nulato and Kaltag. This scene was received during November, 1972 and found to be of high quality in all four spectral bands. The fact that this scene was obtained only two days after the aircraft data was obtained made it especially valuable since no seasonal changes could have taken place during the interval and the multi-spectral aircraft data could be used to best advantage. Hence on November 27, 1972 a retrospective order was placed for the digital tapes for scene 1002-21315.

2. Multispectral Digital Data

Digital tapes for scene 1002-21315 arrived in mid December, 1972, and were converted into computer compatible tapes for analysis purposes. This task was completed by the end of that month.

III. DATA HANDLING AND ANALYSIS

A. First Signature Attempt

1. Digital Signatures

Upon receipt of the MSS digital tapes, the data for each band was printed out as a mosaic of digits for the quarter of the scene containing the Nulato test site. After examination of the data for each band, it was determined not to use band 4 at that time. This decision was formed due to three factors:

(1) Position reference appeared to be different from the other three bands.

(2) Intercalibration among the 6 photometers appeared to be poor (with some scan lines reading intensity levels consistently higher or lower than their neighbors).

(3) Atmospheric scattering appeared to cause the least image definition in this band.

Hence, signature development was performed using only MSS bands 5, 6 and 7. In order to develop the first generation of signatures, the aircraft imagery and ground truth data gathered at the test area were used to determine which picels clearly represented various surface and vegetation types. The intensity levels of bands 5, 6 and 7 for several picels thought to represent the most significant surface features and vegetation types were noted. Based on the range of values in each band, the following preliminary signatures were identified:

TABLE 4

PRELIMINARY SIGNATURE IDENTIFICATION

Feature	Symbol	Band 5	Band 6	Band 7
Yukon river water (colored by glacial silt)	Y	18-30	omit	00-07
Stagnant lake (colored by vegetable matter)	L	00-10	omit	00-07

TABLE 4 (continued)

Feature	Symbol	Band 5	Band 6	Band 7
Khotol river water (combination of above)	S	11-17	omit	00-07
Grass	G	omit	32-45	18-40
Bare ground (mud)	B	omit	46-60	18-40
Willows and other broad leafed trees	W	7-11	18-25	11-14
Spruce trees	T	7-11	13-17	8-11
Possible archaeology site signatures on a scale of 1 through 8	A	9-11	26-31	15-17

The assignment of the numbers 1 - 8 for various archaeology site signatures reflected a rough estimate of probability of identification as a site. Roughly, the most probable is 8 and least probable, 1. Three known sites within the test area were used to determine the site signatures.

The picels of the 1/8th of the ERTS scene containing "Old Fish Camp" were subjected to a search for the above signatures. As a result, a computer printout was produced with the appropriate symbol occupying each identified picel. The printout magnifies the information contained on the ERTS 9 x 9" format to approximately 16 x 16' format and presents the MSS data with maximum resolution and grey scale range.

Although there was reasonable satisfaction with the results of the preliminary signature assignments and the printout of signatures, the following problems and possibilities concerning the signatures developed thus far were noted:

Water signatures: The three signatures developed for water aided greatly in the interpretation of data. However, at least two additional signatures could be developed.

Vegetation signatures: Generally, these were satisfactory. However, there were several possibilities for improvement. It was felt that it should be possible to differentiate further between types of trees. Several bare ground signatures could probably be identified (rock, sand, mud). It was also felt likely that a signature for old burn areas - now containing shrubs and berries - could be found.

Archaeological Site Signatures: While reasonably satisfied with our preliminary archaeological site signatures, we felt that there was ample opportunity for improvement. The archaeological sites used as training areas are typical of such sites in much of Alaska; the former habitation area has grown over with a combination of willows and grass. Both of these species appear to be unusually healthy and lush. It is presumed that the quality of these species results from an increase of nutrients and other factors related to long term habitation.

In addition to identifying several known and potential archaeological sites, the preliminary archaeological site signature was printed out at several locations which are very likely not old habitation sites. We anticipated that this might occur and discussed the possibility in our proposal. At that time, we suggested that we might use the presence of a waterway as a selection criterion. While this is very likely valid, we felt that a great deal of improvement could be made upon development of a second generation of signatures including a more sophisticated approach to habitation site signature identification in particular.

2. Signature Improvement

By means of a Zoom Transfer Scope, we compared the digital printout with the NASA-provided aerial photography of the test area. We sought to improve vegetation signatures as well as archaeological site signatures. Not all archaeological site signatures appeared at reasonable locations on the printout. In this work, we attempted to change the signature definitions to eliminate these identifications and retain known sites. In order to do this, a 1290 picel area was analyzed by direct methods.

3. Semi-automatic Methods of Signature Identification

In conjunction with U of A ERTS project No. 1, we worked with the development of a computer program which lists the number of picels with each reflectance level for each band within a defined portion of an ERTS scene. This information aided us in definition of signatures and other analytical approaches. Shown here as Table 5 is a histogram printout of this information for bands 4 through 7 for first, the small area analyzed above, and second, for a large 512 by 512 picel area containing that area. The histograms are semi-logarithmic.

TABLE 5

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FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER     4 AND CHANNEL NUMBER    1.  DATE=06/05/73  TIME=22.28.50
AREA OF SCENE COUNTED IS FROM LINE 130 TO 159 AND PICEL 258 TO 300, CONTAINING A TOTAL OF    1290 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=FROM 1038-21301 LINE 1011, PICEL 1 REEL 2
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

                                ---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL ------------------------- 1 - 3 --

 LEVEL    NUMBER    PERCENT
  OR        OF        OF
 CLASS    PICELS    TOTAL    .1......5.........0.......0.........0.......0.........0.......0.........0.......0.........0...0.....
   13         2     0.15504 ****
   14        10     0.77519 *******************
   15       169    13.10077 **************************************
   16       332    25.73642 *****************************************
   17       225    17.44135 ***************************************
   18       262    20.31007 ****************************************
   19       251    19.45735 ****************************************
   20        38     2.94574 ************************
   43         1     0.07752 **
 TOTAL     1290   100.00000 ********************************************************

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER     4 AT 22.28.51.
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FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER     5 AND CHANNEL NUMBER    2.  DATE=06/05/73  TIME=22.29.06
AREA OF SCENE COUNTED IS FROM LINE 130 TO 159 AND PICEL 258 TO 300, CONTAINING A TOTAL OF    1290 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=FROM 1038-21301 LINE 1011, PICEL 1 REEL 2
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

                                ---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL ------------------------- 1 - 3 --

 LEVEL    NUMBER    PERCENT
  OR        OF        OF
 CLASS    PICELS    TOTAL    .1......5.........0.......0.........0.......0.........0.......0.........0.......0.........0...0.....
    7        11     0.85271 *******************
    8       101     7.82945 *************************************
    9       122     9.45736 *************************************
   10       222    17.20929 ****************************************
   11       331    25.65891 ******************************************
   12       320    24.80620 ******************************************
   13       121     9.37984 *************************************
   14        56     4.34108 ****************************
   15         6     0.46512 ************
 TOTAL     1290   100.00000 ********************************************************

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER     5 AT 22.29.08.
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Table 5. Histogram of bands 4-7 for small and large areas showing Frequency Distribution of reflected intensity levels.

TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER 6 AND CHANNEL NUMBER 3. DATE=06/05/73 TIME=22.29.23
AREA OF SCENE COUNTED IS FROM LINE 130 TO 159 AND PICEL 258 TO 300, CONTAINING A TOTAL OF 1290 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=FROM 1038-21301 LINE 1011, PICEL 1 REEL 2
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL ---------- 1 - 3 --

LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL
6	1	0.07752
7	10	0.77519
8	29	2.24806
9	20	1.55039
10	13	1.00775
11	13	1.00775
12	12	0.93023
13	11	0.85271
14	34	2.63566
15	13	1.00775
16	20	1.55039
17	60	4.65116
18	56	4.34109
19	32	2.48062
20	65	5.03876
21	71	5.50388
22	58	4.49612
23	107	8.29457
24	93	7.20930
25	67	5.19380
26	83	6.43411
27	33	2.55814
28	39	3.02326
29	31	2.40310
30	32	2.48062
31	18	1.39535
32	21	1.62791
33	9	0.69767
34	18	1.39535
35	11	0.85271
36	11	0.85271
37	12	0.93023
38	19	1.47287
39	22	1.70543
40	18	1.39535
41	18	1.39535
42	6	0.46512
43	19	1.47287
44	16	1.24031
45	21	1.62791
46	14	1.08527
47	12	0.93023
48	7	0.54264
49	1	0.07752
50	9	0.69767
51	2	0.15504
52	2	0.15504
53	1	0.07752
TOTAL	1290	100.00000

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER 6 AT 22.29.27.

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TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER 7 AND CHANNEL NUMBER 1. DATE=06/05/73 TIME=22.29.43
AREA OF SCENE COUNTED IS FROM LINE 130 TO 159 AND PICEL 258 TO 300, CONTAINING A TOTAL OF 1290 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=FROM 1038-21301 LINE 1011, PICEL 1 REEL 2
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL ------------------------ 1 - 3 --

LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL
0	1	0.07752
1	31	2.40310
2	32	2.48062
3	10	0.77519
4	16	1.24031
5	15	1.16279
6	17	1.31783
7	21	1.62791
8	48	3.72093
9	71	5.50388
10	54	4.18605
11	99	7.67441
12	128	9.92248
13	147	11.39535
14	119	9.22480
15	85	6.58914
16	56	4.34108
17	39	3.02326
18	33	2.55814
19	28	2.17054
20	20	1.55039
21	23	1.78294
22	27	2.09302
23	25	1.93798
24	25	1.93798
25	33	2.55814
26	20	1.55039
27	19	1.47287
28	15	1.16279
29	12	0.93023
30	15	1.16279
31	4	0.31008
32	2	0.15504
TOTAL	1290	100.00000

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER 7 AT 22.29.46.

EOF READ FROM INPUT TAPE IN PLACE OF ID RECORD. WILL REWIND AND CHECK FOR MORE CONTROL CARDS. PRESENT TIME=22.29.46.

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TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER 4 AND CHANNEL NUMBER 1. DATE=06/05/73 TIME=22.37.43
AREA OF SCENE COUNTED IS FROM LINE 1 TO 512 AND PICEL 1 TO 512, CONTAINING A TOTAL OF 262144 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=WHOLE SCENE FROM 1038-21301 REEL 2, LINE 1011, PICEL 1
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL ---------------------------- 1 - 3 --

LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL
6	9	0.00343
11	1	0.00038
12	93	0.03548
13	534	0.20370
14	4785	1.32533
15	46534	17.75131
16	85548	32.63397
17	41906	15.98587
18	38855	14.82201
19	19734	7.52792
20	3527	1.34544
21	322	0.12283
22	427	0.16289
23	280	0.10681
24	836	0.31891
25	1678	0.64011
26	8624	3.28979
27	7032	2.68250
28	649	0.24757
29	416	0.15869
30	168	0.06409
31	74	0.02823
32	33	0.01259
33	41	0.01564
34	2	0.00076
35	13	0.00496
36	1	0.00038
37	2	0.00076
43	1	0.00038
45	1	0.00038
47	1	0.00039
48	2	0.00076
59	1	0.00038
60	9	0.00343
70	1	0.00038
73	1	0.00038
74	1	0.00038
102	1	0.00038
104	1	0.00038
TOTAL	262144	100.00000

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER 4 AT 22.37.47.

TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER 5 AND CHANNEL NUMBER 2. DATE=06/05/73 TIME=22.39.47
AREA OF SCENE COUNTED IS FROM LINE 1 TO 512 AND PICEL 1 TO 512, CONTAINING A TOTAL OF 262144 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=WHOLE SCENE FROM 1038-21301 REEL 2, LINE 1011, PICEL 1
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL ---------- (scale: .1.....5.....10.....50.....100.....500.....1000.....5000.....10000.....50000.....100000.....130000)

LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL
2	2	0.00076
3	1	0.00038
5	44	0.01678
6	556	0.21210
7	5331	2.03362
8	29016	11.06873
9	38572	14.71405
10	50476	19.25507
11	43204	16.48102
12	41667	15.89470
13	21064	8.03528
14	8690	3.31497
15	2316	0.88348
16	752	0.28687
17	406	0.15488
18	340	0.12970
19	460	0.17548
20	266	0.10147
21	494	0.18845
22	3256	1.24207
23	2859	1.09062
24	9339	3.56255
25	2228	0.84991
26	516	0.19684
27	91	0.03471
28	41	0.01564
29	35	0.01335
30	48	0.01831
31	25	0.00954
32	12	0.00458
33	5	0.00191
34	4	0.00153
35	5	0.00191
36	1	0.00038
37	1	0.00038
39	2	0.00076
50	1	0.00038
51	1	0.00038
52	1	0.00038
56	3	0.00114
57	1	0.00038
59	2	0.00076
60	2	0.00076
61	1	0.00038
62	1	0.00038
66	1	0.00038
101	3	0.00114
105	1	0.00038
122	1	0.00038
TOTAL	262144	100.00000

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER 5 AT 22.39.51.

TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER 6 AND CHANNEL NUMBER 3. DATE=06/05/73 TIME=22.41.45
AREA OF SCENE COUNTED IS FROM LINE 1 TO 512 AND PICEL 1 TO 512, CONTAINING A TOTAL OF 262144 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=WHOLE SCENE FROM 1038-21301 REEL 2, LINE 1011, PICEL 1
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL ------------------------ 1 - 3 --

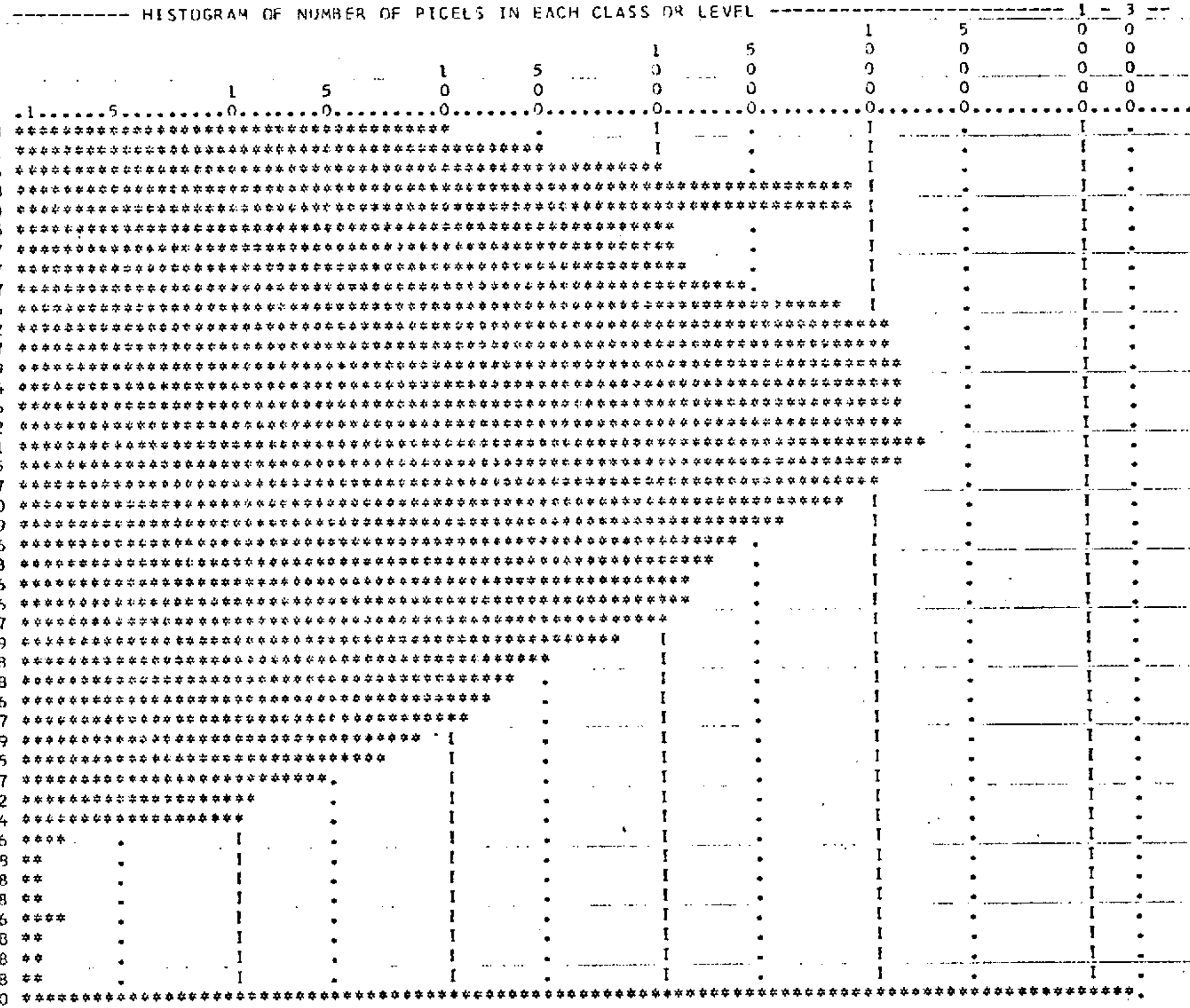
LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL
2	1	0.00038
3	6	0.00229
4	32	0.01221
5	112	0.04272
6	305	0.11635
7	578	0.22049
8	591	0.22545
9	595	0.22697
10	630	0.24033
11	741	0.28267
12	920	0.35095
13	1306	0.49820
14	2154	0.97169
15	4065	1.55067
16	5313	2.02675
17	16802	6.40945
18	15995	6.10161
19	11087	4.22935
20	15215	5.80406
21	13276	5.06439
22	10906	4.16031
23	19319	7.36961
24	16075	6.13213
25	13568	5.17573
26	25038	9.55124
27	9651	3.68156
28	22855	8.71849
29	12443	4.74663
30	10473	3.99513
31	9086	3.46603
32	4344	1.65710
33	3461	1.32027
34	2533	0.96626
35	2655	1.01280
36	1795	0.68474
37	1613	0.61531
38	1369	0.52223
39	1263	0.48180
40	896	0.34180
41	928	0.35400
42	248	0.09460
43	559	0.21324
44	355	0.13542
45	264	0.10071
46	205	0.07820
47	101	0.03853
48	130	0.04959
49	66	0.02518
50	83	0.03166
51	49	0.01869
52	35	0.01335
53	33	0.01259
54	10	0.00381
55	6	0.00229
57	1	0.00038
59	1	0.00038
82	1	0.00038
100	1	0.00038
105	1	0.00038
TOTAL	262144	100.00000

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER 6 AT 22.41.50.

TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER 7 AND CHANNEL NUMBER 1. DATE=06/05/73 TIME=22.43.48
AREA OF SCENE COUNTED IS FROM LINE 1 TO 512 AND PICEL 1 TO 512, CONTAINING A TOTAL OF 262144 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=WHOLE SCENE FROM 1038-21301 REEL 2, LINE 1011, PICEL 1
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL ----------



LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL
0	120	0.04578
1	512	0.19531
2	1200	0.45776
3	9294	3.54538
4	9239	3.52440
5	1951	0.74425
6	1653	0.63057
7	2117	0.80757
8	4961	1.89247
9	8847	3.37486
10	15557	5.93452
11	19845	7.57027
12	21425	8.17299
13	22642	8.63724
14	24670	9.41036
15	23215	8.85582
16	30107	11.48491
17	20866	7.95975
18	13520	5.15747
19	8915	3.40080
20	6104	2.32849
21	4438	1.69296
22	3258	1.24283
23	2069	0.78926
24	2042	0.77896
25	1205	0.45967
26	821	0.31319
27	503	0.19188
28	352	0.13428
29	283	0.10796
30	169	0.06447
31	87	0.03319
32	73	0.02785
33	45	0.01717
34	15	0.00572
35	14	0.00534
36	2	0.00076
37	1	0.00038
38	1	0.00038
39	1	0.00038
42	2	0.00076
46	1	0.00038
50	1	0.00038
56	1	0.00038
TOTAL	262144	100.00000

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER 7 AT 22.43.52.

EOF READ FROM INPUT TAPE IN PLACE OF ID RECORD. WILL REWIND AND CHECK FOR MORE CONTROL CARDS. PRESENT TIME=22.43.52.

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Inspection of the histograms for band 4 (CDU file number 4 on the printout) shows that for the small area (1290 picels) there are only seven significant intensity levels while for the larger 512 by 512 (262, 144 picel) area, there are from three to four times as many intensity levels represented. More significantly, for the small area no signature domains appear obvious while for the larger area, there are two groupings of intensity levels which appear to represent dominant features. Further, note that the small histogram agrees with the upper portion of the large area histogram--even to the point that intensity level 16 appears most frequently. However, there is no correlation between the lower portion of these histograms. There is a large range of intensity levels represented on the large area histogram not indicated on the small area histogram. This indicates that the area was not homogeneous and that band 4 is more useful for signatures than one may have thought on the basis of the small area histogram. Examination of the large area histogram shows an unusual number of picels with intensity level 60. It remains to be seen whether this is significant or the result of statistics. Similarly, the histograms for bands 5, 6 and 7 were compared.

B. Second Signature Attempt

1. Approach to Problem

a. General

It was determined to develop a second generation of signatures for as many surface features and vegetation types as possible. The relationship of archaeological site signatures to other vegetation signatures could be accurately determined and hopefully the range of signatures used for archaeological sites could be decreased while retaining those signatures with the greatest likelihood of being archaeological sites.

b. Technique

A Zoom Transfer Scope was used to superimpose picel-by-picel intensity level printouts with NASA-provided aerial photography of the test area. The intensity levels in all bands were then transferred to a picel map ruled into squares sufficiently large to write these numbers and a notation of the vegetation type or types found in the area on the ground represented by that picel.

Next, correlation scatter plots in band 5 vs. band 7 and band 6 vs. band 7 were prepared. The scatter plots were approximately 4 x 4 ft. square and ruled into squares so that for each intensity-level combination there was room to note the number of picels with that combination and the vegetation types in that picel as recognized from aerial photography and ground truth.

These scatter plots were then overlaid with tracing paper and the general domains of each recognizably distinct signature delineated. The signatures thus determined were then used to produce a new thematic computer printout of the test area.

2. Results

a. Signature Development

Figure 3 shows the plots of generalized signature domains described in the previous section. The meaning of the symbols, and intensity level

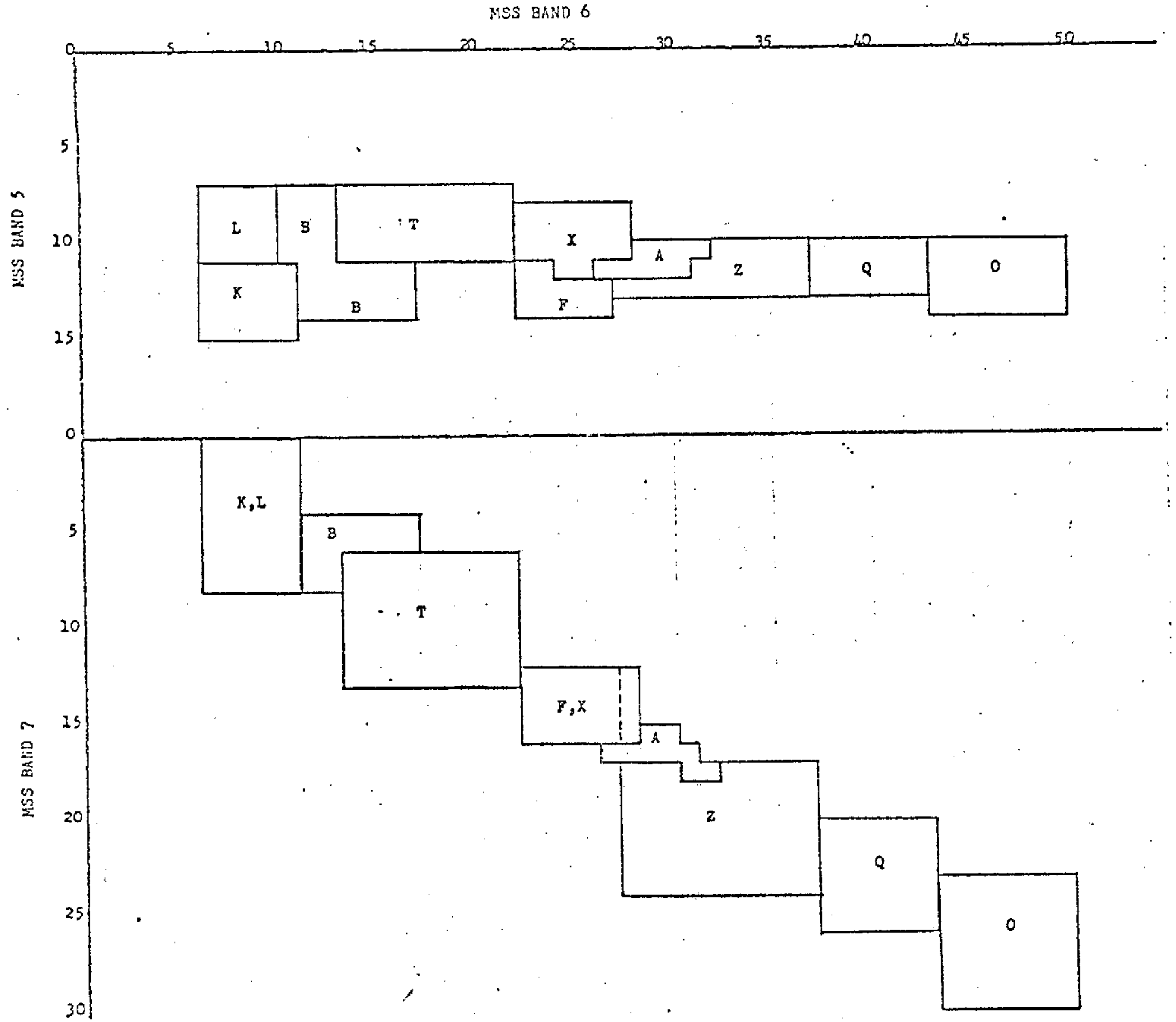

Figure 3. Two-dimensional projections of 3-dimensional signature domains. Considering digital reflectence levels in MSS bands 5, 6 and 7 as coordinant magnitudes, the idealized domains of each identifiable signature have been delineated. These two projections may be considered as a "top" and "side" view of a series of 3-dimensional domains. All picels with the combinations of intensity levels in each domain are identified on signature plots by the letter shown on that domain.

range for each signature are given in Table 6. As the table shows, most of the signatures developed are for mixtures of vegetations and surface features. This is because in this test area rarely are pure vegetation types or surface features found in the area of a single picel. Indeed, the archaeological sites themselves consist of a mixture of vegetation types.

b. Signature Printout

Figures 4 and 5 show identical portions of ERTS scene 1002-21315 signature printouts. Figure 4 shows the printout performed on the basis of the preliminary signatures, while Figure 5 is a printout based on the new signatures. The new printout has been shaded according to vegetation types. The following paragraphs contain a discussion of the newly-developed signatures.

i. <u>water course signatures</u>

The major change here was to identify a signature for the bank of the Khotol River and sloughs. Formerly the Khotol River signature was given a rather broad range of definition with the result that picels containing both the Khotol and a significant fraction of riverbank were registered as "K". Here, we have narrowed down the range of definition so that only picels located in the center of the Khotol River are represented by "K" and picels located on its bank are represented by "B". Note that generally the "Bank" signature is represented on one side of the river or the other.

ii. <u>vegetation signatures</u>

As can be readily seen, the new printout contains signature symbols for more vegetation type identifications than the old. Further, almost

```
SSSS      6557            WWWW                    W
TLLSSSSSSSSSSSSSSSSSSSS  WWWWW 75                  W
WWWWW WSSSSLL TTTTTLSSSSS WW
SSSSSSSSI  75WW  WWWWTWW SSSSWWW
LLLLLL WW WWW W8GWWTLTWWLSSTWW  5         W  W  W
 WWWWWWWWWWW   WGGWWW WTWWSSSW                   W
WWWWWWWWWW     WW GWW7G8 L  SSW
WWWWWWWWWW8GGGG  GGWW6G TTTTSS 8WWW        WW W5
WWWW8GG3     GGG WGGWW GG TT SSSWW       W
W5GG  GGGG GGGG GGWWWGGWWTTTSST         W
GGGGGGGGGGGGGGGGG8G7WWW8 W8 T SSSWWWW
GGGGGGGBGGGGGGGGGGWWWW7  57TTTTSSW
GGGGGGGGGGGGGGGGG WWWW  W8W T SS WW          5W
8GGGGGGGGGGGGGGGGG8WW W86WG8TTWSSTWW         WTT
G8 GGGGBB88GGGGG   WWWW5 7 8    SSSW        WTT
GGG GG5T GGBBGGG W    WWW5GGT TSSSW        WTT W
BGGGGG1L2GWGBBGG8WW8 WWW GWWWTSSSWW        WLTWW
BBBBBG6 T 8 BBBG WW5 WWW 8W WTSS W       WLT
GBBBBGGG 8GGGBGGW     B   W WW5 TSS            85W
BBBBBBGGGGGGGGGGG3W 63 W WL 7 TWSSW  WWW 7WW
  GGBBGGGGGGGGGGGWW88 WTW 8WT    SS     5W   W
G GBGGGGGBGG BGGW G6W W GW WTWSS        WWWW
TW GBGGGBBG 8BGGW8G8W W     TT SS      W
TTTT GBBBBBG BB W G WWWWWTTWWSSS                8
6      WGGGG  GB8W8G  WW WWW SSSW     W     67 W
WGGG6W TTWW6 GGG T WW W688WSSST WWTLT WWWWW
GGGGGG    TT WWW6LTWWSSSSSSSSL WWWLLW    W   W
8GGGGGG  TLTTT  TTTSSSSSLLTTWWW WWWW
W53GGGG  TT  TTTSSSLT    WW    W8 WW        WWW
 GG    B GWWWWTTSSSTTWWT   WWWW G
```

Figure 4. Printout of preliminary vegetation signatures in the vicinity of Old Fish Camp. Signatures were derived for slough (of the Yukon River) (S), willows (W), large trees (T), grass (G), bare ground (B), and probability of archaeological site (1-8). The archaeological site probability is greatest for an "8" signature. Information is from a portion of ERTS scene 1002-21315.

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Figure 5. Printout of second generation signatures described in text. Here archaeological site probability is inversely proportional to magnitude of numbers 1-7. Groupings of similar signatures have been indicated by shading. Improvement over signature classifications illustrated in Figure 4 include recognition of combinations of vegetation types and identification of greater number of distinct signatures. The quantity of picels with possible archaeological site identification has been drastically reduced.

TABLE 6

SYMBOL	CLASSIFICATION
1-7	Signature characteristic of former (archaeological) habitation sites, probability inversely proportional to number
K	Khotol Slough (slough of Yukon with additional drainage)
L	Lake
Y	Yukon River
P	Stands of predominately large spruce
T	Large trees (combinations of spruce, birch and aspen)
B	Bank of slough (average of slough and vegetation)
F	Vegetation characteristic of old burn (scrub trees, grass, berries)
X	Combination of mainly small black spruce and some willow and grass
Z	Combination of willows, grass and bare ground
Q	Combination of water puddles, wet bare ground and grass
O	Largely bare grass
+	Submerged sand bar
*	Sand bar
.	Average of general vegetation, sandy bare ground and water

none of these new signatures are for a pure vegetative type. Here we will discuss each of these new signatures.

P Stands of predominately large spruce trees. Picels printed out with a "P" are shaded darkest of Figure 3. These are generally trees of sufficient size to be considered of potential commercial value. Comparison with NASA-provided aerial photography shows this signature to be reasonably accurate (see discussion of "T").

T Large trees (combinations of spruce, birch and aspen). Although not shown in Figure 3, band 4 was found to have utility in differentiating between T and P signatures. This differentiation is reasonably good with its greatest deficiency being that band 4 is subject to relatively poor intercalibration among the MSS detectors. As a result, there appears to be some error introduced into the T/P decision.

X Combination of mainly spruce with some willow and grass. Note that this signature is differentiated from the "F" signature only through band 5. The vegetation type represented here is much lower in height than that represented by "T" or "P". The spruce combination is often black spruce which is generally smaller than white spruce.

F Vegetation characteristic of old burn. The area to the right of the Khotol River was the site of a forest fire in 1958. As characteristic of many fires in interior Alaska, there were many pockets of unburned trees within the area of the fire. The area that burned is now moderately lush with scrub spruce, and many low-lying berry plants and grasses. Although the vegetation in "X" and "F" picels are moderately distinct, as noted above, a spectral distinction can only be made in band 5. With this close distinction it might be expected that many picels would be mislabeled, and indeed one can find "F" signatures on the left hand side of the Khotol River where it is unlikely there has been a fire in recent times. However, it is still possible that "F" vegetation type can be found on this side of the river. Moreover, it is interesting to note that there are relatively large areas of contiguous "X" picels and also relatively large areas of contiguous "F" picels. This result indicates that the distinction between these two signatures is reasonably accurate and significant.

A Signatures characteristic of former habitation sites. This group of signatures (numbers 1 through 7 on the printout) is discussed in detail under the next subsection heading. Here we wish to point out that the signatures for known sites lie within a moderately close range (see Figure 3). The vegetation on these sites generally consists of unusually vigorous grasses and willow. The unusually healthy state of these plants results from fertilization, soil mixing and aeration resulting from former habitation activities.

Z Combination of willows, grass and bare ground. This vegetation type is characteristic of much low-lying wet ground and is often interspersed with patches of mud. The mud patches are probably maintained in part by the grazing activities of moose. The tendency toward mud patches is one feature which generally helps distinguish "Z" picels from "A" picels. However, the distinction is not complete as evidenced by several patches of 6's, a lower probability archaeological site signature. These patches of 6's should very likely be Z's.

Q Combination of water puddles, wet bare ground (mud) and grass. Picels with this signature have been shaded slightly darker than the picels with "O" signatures. Note that the Q's often align themselves in rather long strings. There are several former river channels in this area which now consist of lineated low-lying areas.

O Largely grass. There is no clear line of distinction between this signature and "Q". However the choice made appears to have differentiated between two surface conditions in that Q's and O's are not randomly distributed with respect to each other but rather appear in separate groups. Comparison with aerial photography generally bears out the distinction made.

'. Average of general vegetation and sandy bare ground. This signature was found to represent picels located along riverbanks and other areas where moderate expanses of dry sandy soil with perhaps some vegetation occurred.

iii. <u>archaeological site signatures</u>

1-4, signatures of known archaeological sites. The locations of these signatures determine the boundaries of the signature volume labeled "A" in Figure 3. Any picel represented by these numbers has the same combination of reflectance levels as a known archaeological site. There is the possibility however, that the banding effects mentioned earlier are at least partly responsible for the identification of some picels as 1, 2, 3 or 4 simply because there are variations of the average intensity level on the order of one unit among the six detectors monitoring each MSS band.

5-7, signatures approximate to those of known archaeological sites. Considering the intensity levels in bands 5, 6 and 7 to define an ordinary orthogonal 3-space. Signatures 1 through 4 define the outline of a 3-dimensional solid. This solid has been subdivided into three smaller volumes labeled 5, 6 and 7. The ordering sequence being determined by a subjective judgment was based on the relative proximity to signatures of known sites.

Of the 262,144 picels examined in this portion of ERTS scene 1038-21301, a total of 7,890 or just under 3% were classified as 1 through 3. The most frequent classification was "6" with 4,243 or 1.6% of all picels. It is not believed that these are unreasonably high percentages. Further interpretation of the probability of a picel with a classification of 1 through 7 actually being an archaeological site will depend on its position relative to other classified picels. For instance, the life style of peoples in this area was directly linked to fishing and water transportation. Hence identified picels at any distance from water courses can be ignored. This additional decision-making process will greatly reduce the number of possible locations of archaeological sites.

C. Detailed Analysis of Second Generation Signatures

Since our data analysis plan calls for printing our digital signatures for a portion of an ERTS scene, it is very important that the signatures developed be applicable without modification to a wide geographical area within each scene, if not throughout the whole scene. In terms of archaeological village sites which have a very narrowly-defined signature range this could be a significant problem.

Therefore, before using the digital printout as an inventory of possible archaeological village sites, the printout should be tested at selected locations to determine whether or not signatures of well-known features are being correctly identified. One could then infer that the site signatures are remaining correct also.

This was done and the results were found satisfactory. One example of this test is illustrated in Figure 6. This figure consists of a two-frame mosaic of aerial photographs and the corresponding portion of our digital signature printout. The signature symbols were defined in Table 6.

The area illustrated here contains the present-day village of Kaltag, located on the west bank of the Yukon River just below the top of the photograph. The village and its airstrip have been outlined by rectangles on the printout. It is interesting to note that because there were no present-day habitation sites in the signature training area, no signatures were developed for that kind of feature. Consequently, the Kaltag area is largely blank on the printout. Three signatures can be found within the village area: the dot (˙) signature standing for an average of general vegetation, sandy bare ground and water (in that order), the "F" signature standing for vegetation characteristic of a burned area (approx. 15 years before), and a "7" signature representing vegetation characteristic of an archaeological site.

Aerial photograph (top) and digital printout of ERTS signatures (bottom) of small 1x2 1/2 mile area including Kaltag, Alaska. Aerial photographs obtained from 5,000 feet. ERTS data obtained from altitude of 500 miles. Digital tape of ERTS scene 1038-21301, covering area 110 miles square, was utilized for printout. Signatures displayed here were obtained through analysis of training area fifteen miles distant.

The occurrence of the dot within the village should be expected; there are large expanses of bare ground (paths, roads, dog tie-down areas, wood-chopping areas, etc.) and other areas of grass including some sod roofs. The two "F" picels within the village and the large area of "F" picels to the west probably result from a fire adjacent to the village within the historic past. The archaeological signature within and those adjacent to the village very likely do not indicate old habitation sites but rather vegetation characteristic of modification of soil conditions due to nearby human occupation (fertilization, etc.). That is, the conditions responsible for development of archaeological site signatures probably apply at least in part in areas adjacent to present day villages.

Across the Yukon River from Kaltag, a slough of the Yukon can be seen which meanders first east, then south, then east with a small gooseneck to the north and finally north. The presence of Yukon River water in the slough is demonstated by the occasional "Y" signature found along its course. One should note that in order for a picel to be labeled with a "Y" signature, it must be fortuitously located squarely within the banks of the slough. Otherwise spectral averaging will occur with the result that the reflectance levels measured correspond to a different signature, or more likely to no defined signature at all. This result can be seen between the "Y"'s. The "B" signature which was developed to define the bank of a slough with different spectral characteristics than the Yukon River, was still close enough to define the bank of the slough in some places. More importantly, however, the "B" signature traced this slough of Yukon River water after it became so narrow that spectral averaging took place in all picels containing it. This is an added utility of that signature not anticipated.

The banks of slough such as this one are usually elevated due to deposition of material during flooding. Very often this elevated area contains large spruce and birch trees. This phenomena is particularly well illustrated here on the east side of the south-going portion of the slough. Note the band of "T" and "P" signatures paralleling this portion of the slough.

Blank areas generally contain vegetation not found in the training area. At this point signatures for these unidentified areas could be determined. Of particular note is the blank area just north (above) of the gooseneck of the slough. Examination of the aerial photograph shows this area to contain vegetation considerably different in appearance from any other in the photograph with the possible exception of that found in some portions of the dried-up ox-bow lakes between the Yukon River and the south-going part of the slough. This vegetation is probably a stand of large willows.

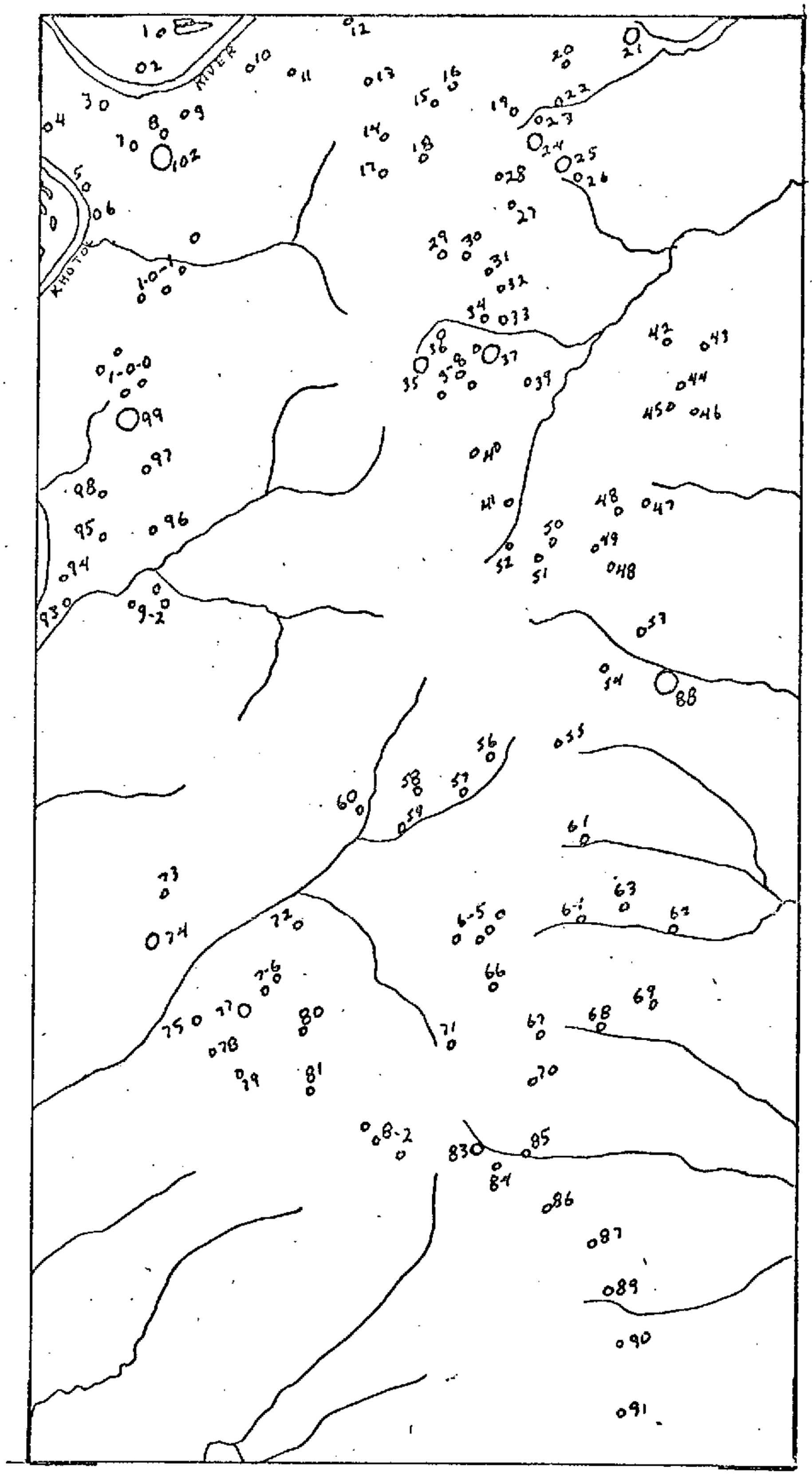
Along the east bank of the Yukon River can be found a number of picels represented by archaeological village site signatures. One should recall that a "1" is the most probable and a "7" the least probable site signature. Three areas of relatively high average site probability have been delineated on the printout. When Schwatka surveyed the Yukon River in 1887, he indicated the village of "Khaltag" at approximately this location. This identification has not been field-checked.

Thus it was concluded that the signatures developed are valid over a wide geographical area. The distance between the area used here to test signature validity and the training area where the signatures were developed is approximately fifteen miles.

IV. RESULTS: COMPARISON OF AERIAL PHOTOGRAPHY WITH SIGNATURE PRINTOUT

Following verification of signature identification the locations of the three most probable archaeological site signatures for an area approximately fifteen by thirty miles were transferred from the printout to transparent overlays on USGS 1:63,360 maps. The major features of the USGS maps were added to these overlays. These overlays, reduced to page size, are shown here as Figure 7. For convenience the potential archaeological sites have been given an identifying number.

Each numbered possible site was located on the NASA-provided color and color infrared photography and examined in terms of the likelihood that it was an archaeological site. A great many of the potential sites were eliminated from consideration by this process. Usually, one of two major factors was involved: either the potential site was located far from a waterway, or it was very low-lying. The first selection factor is justified on the basis that the aboriginal life style called for village location near a watercourse sufficiently large for navigation by canoe. The second selection factor is justified on



NULATO (A-5)

Figure 7a. Xerox reduction of 1:63,360 map overlay showing locations of archaeological site signatures in the Kaltag, Alaska area.

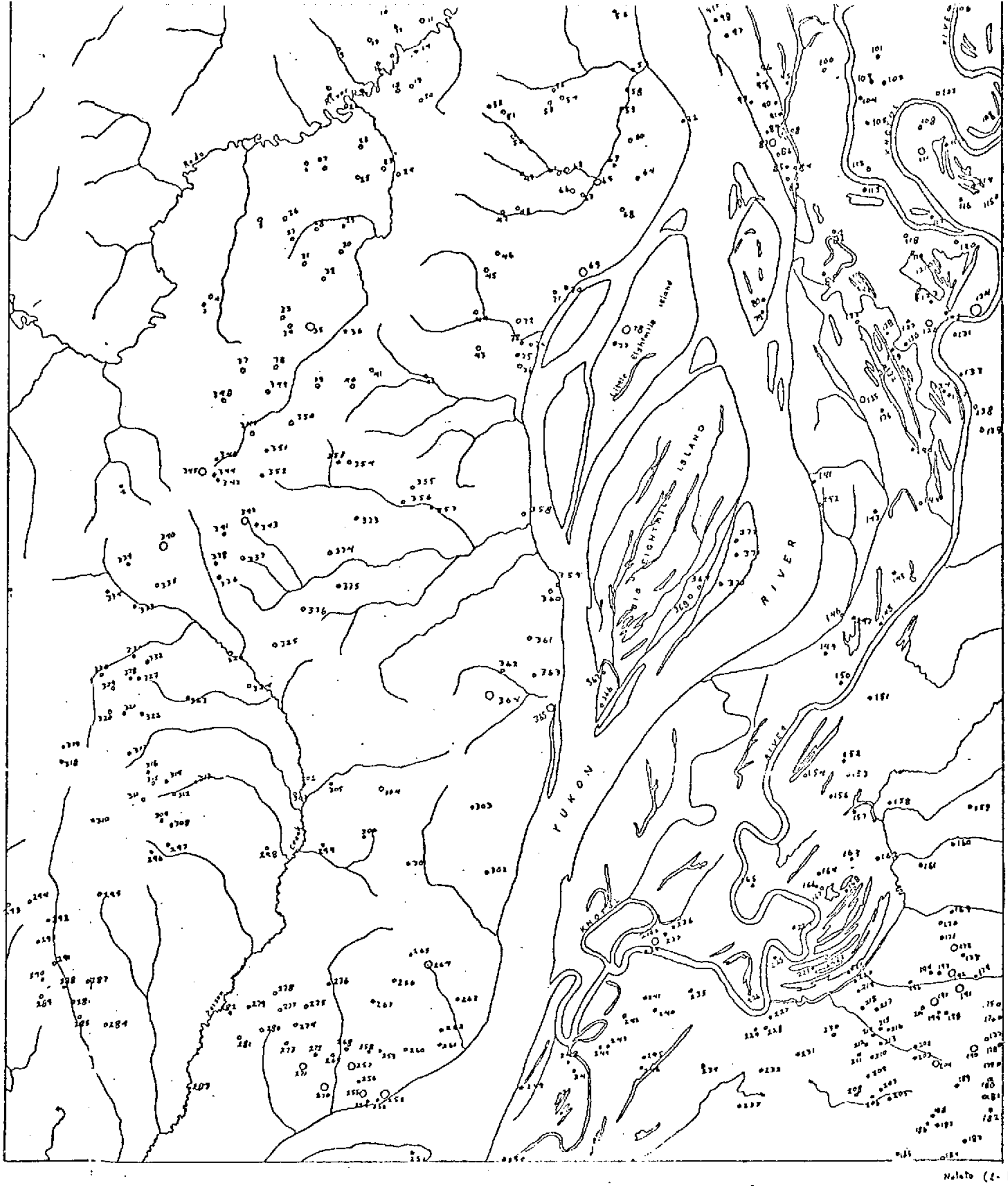


Figure 7b. Xerox reduction of 1:63,360 map overlay showing locations of archaeological site signatures in the Kaltag, Alaska area.

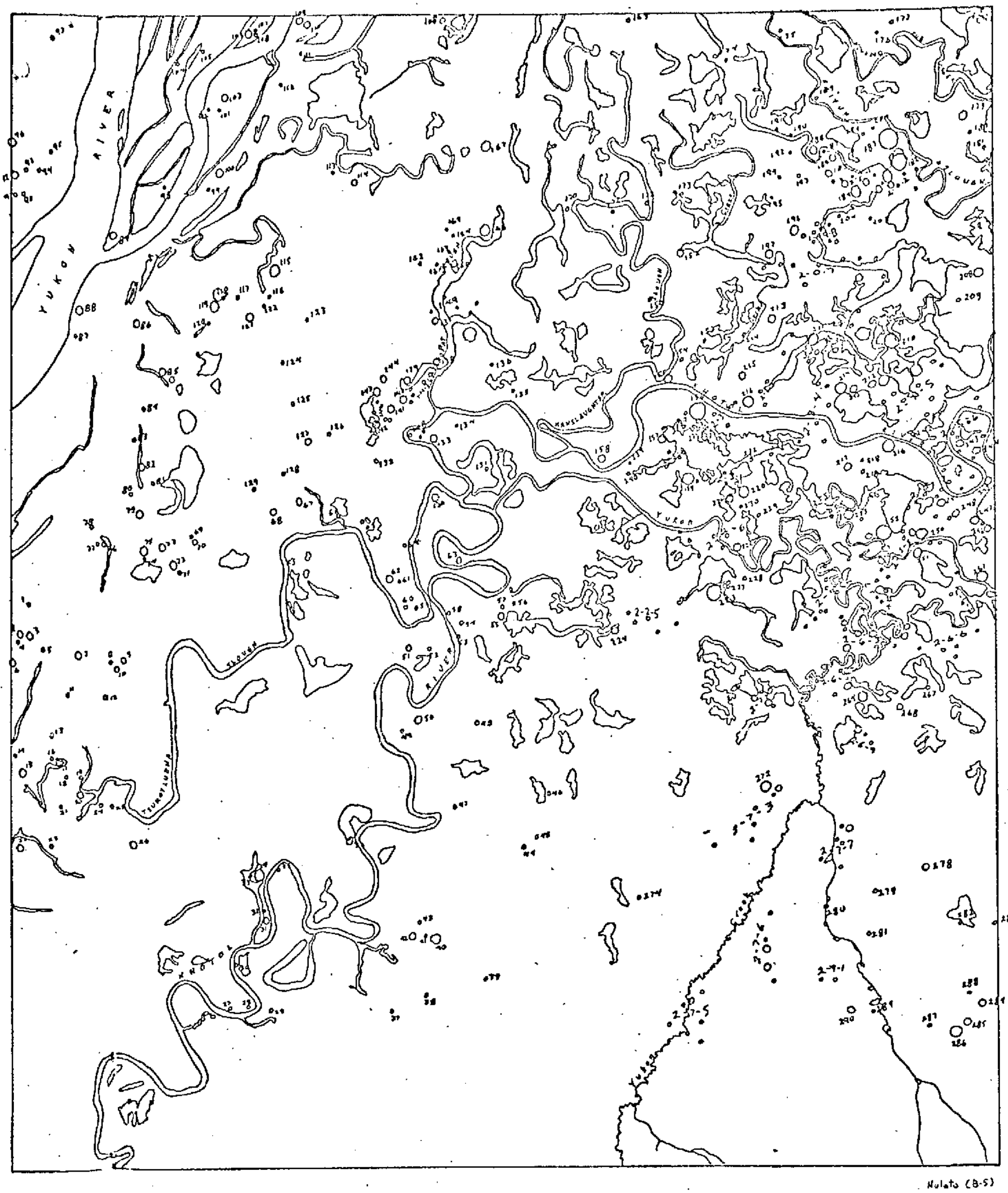
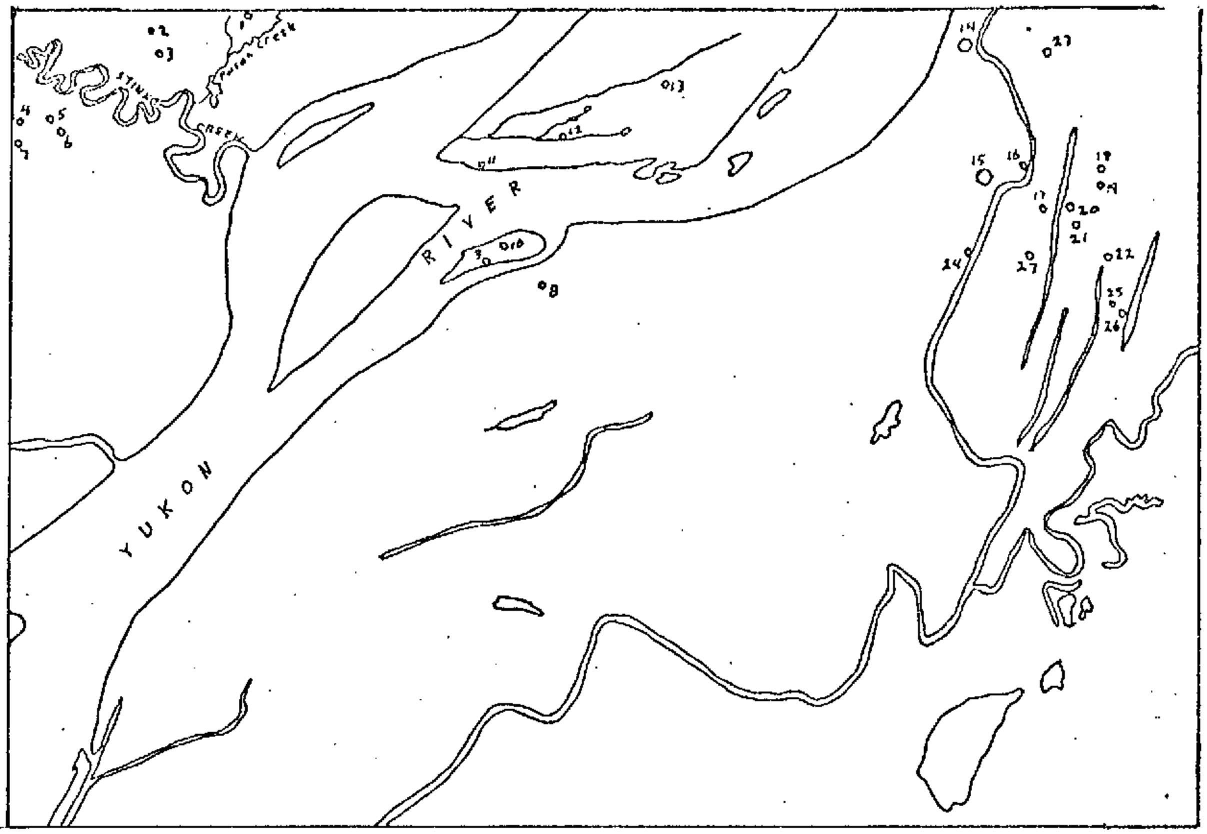


Figure 7c. Xerox reduction of 1:63,360 map overlay showing archaeological site signature locations near Kaltag, Alaska.



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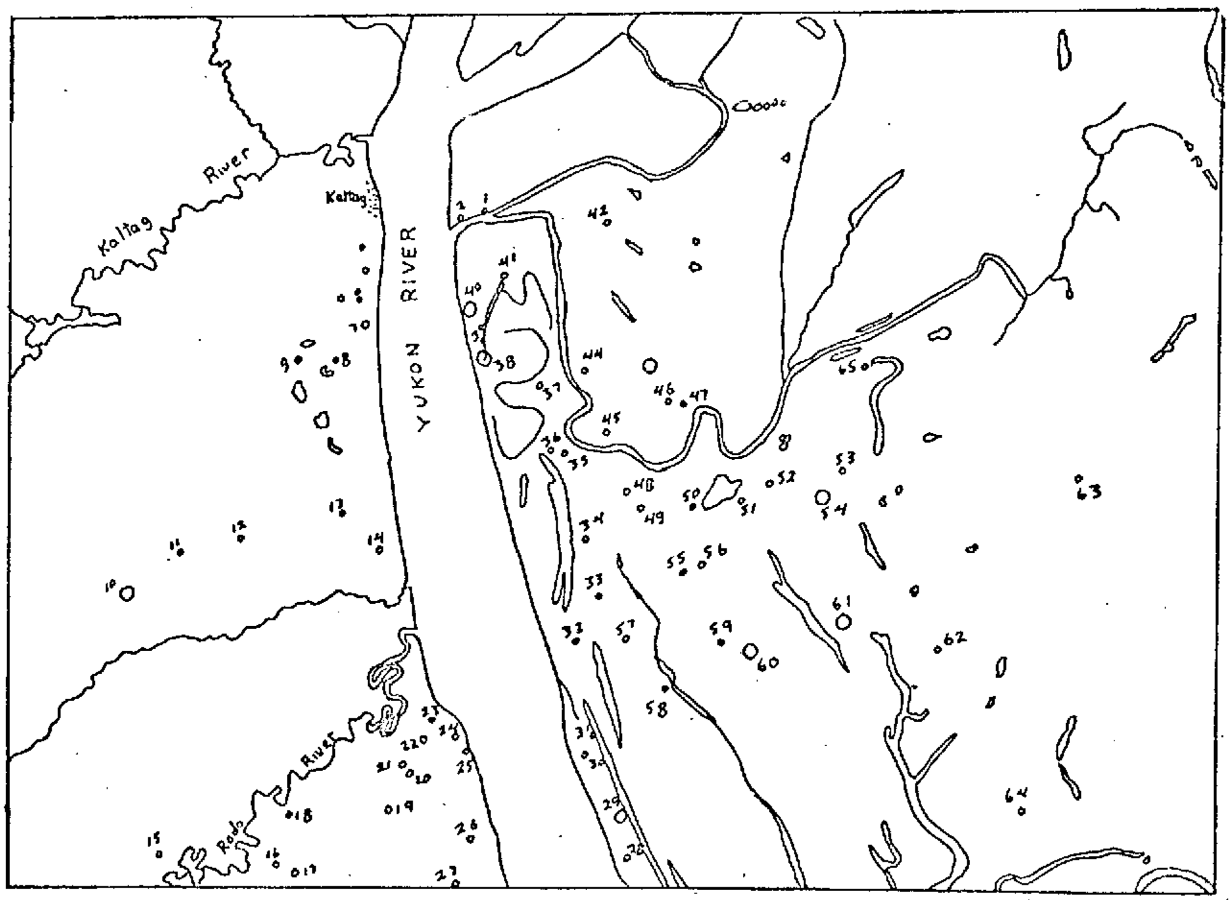

NULATO B-6

Figure 7d. Xerox reduction of 1:63,360 map overlays showing the locations of archaeological site signatures in the Kaltag, Alaska area.

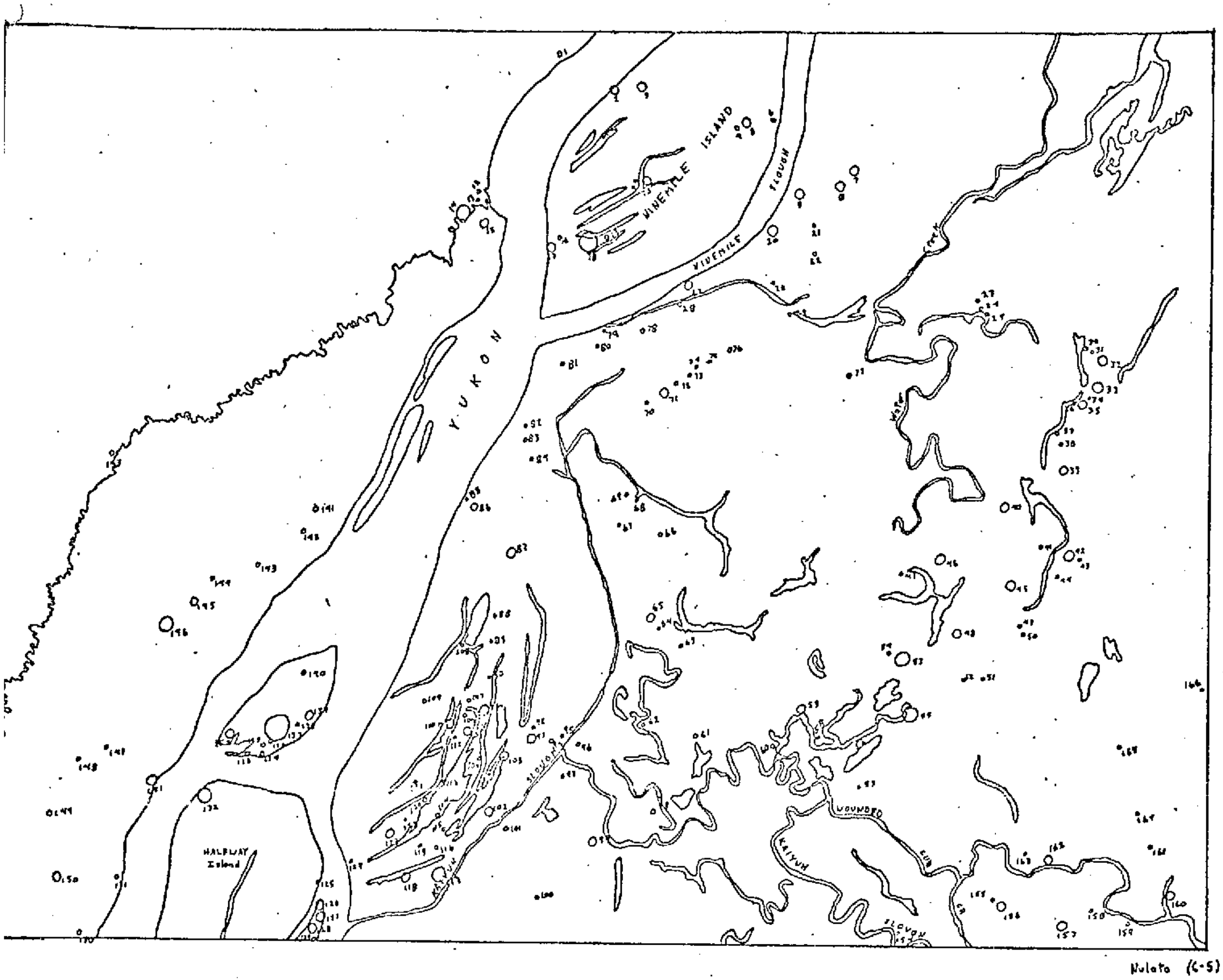

Figure 7e. Xerox reduction of 1:63,360 map overlay showing the locations of archaeological site signatures near Kaltag, Alaska.

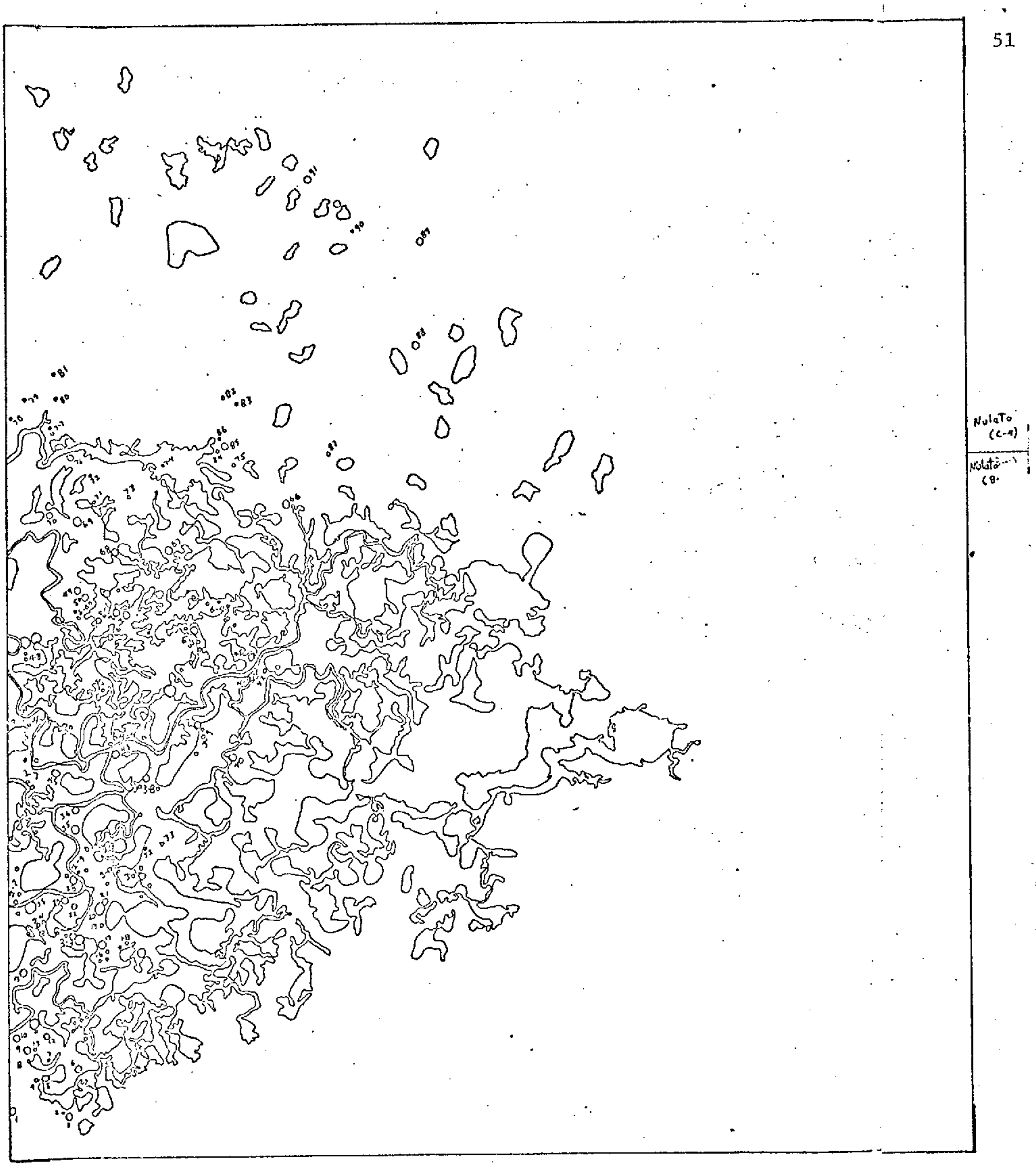

Figure 7f. Xerox reduction of 1:63,360 map overlay showing the location of archaeological site signatures in the Kaltag, Alaska area.

the basis that sites are found on well-drained, relatively high ground. The semi-subterranean houses constructed by the residents were largely responsible for this requirement.

Table 7 lists by index number the possible site and some comments regarding its suitability as a site.

Thus only 19 of the 379 locations identified on the printout were selected as possible archaeological sites by examination of aerial photography. This represents a 2% ratio. On the other hand, approximately 300 of the potential sites on the printout could be eliminated from consideration on the basis of their location without use of aerial photography. This would yield a 25% ratio of ERTS-identified sites considered possible archaeological sites based on aerial photography.

In the previous section, we compared the number of archaeological sites located by means of ERTS digitally processed data with the number of those sites remaining for consideration after examination of high quality aerial photography of the same area. The best result that can be achieved is that approximately 25% of the sites determined by analysis of ERTS data would be selected by means of aircraft data. This is only after the ERTS-selected sites have been transferred to topographic maps so that sites considered unsuitable because of their unfavorable locations could be eliminated.

Of the twelve sites described by DeLaguna (1947) along the middle of the Khotol River (e.g. not along its tributaries), five were identified as sites on the computer printout. For example Figure 8 shows a vertical

TABLE 7

Index	Map	Comments
3	Nulato (A-5)	close to waterway, clearing
6	Nulato (A-5)	on bank of waterway in clearing
30	Nulato (B-5)	high ground next to stream bank, clearing in trees
32	Nulato (B-5)	located next to river, looks possible
46	Nulato (B-4)	some possibility, a bit low but good location
112	Nulato (A-6)	high ground between two waterways, clearing in trees
117	Nulato (A-6)	near waterway
120	Nulato (A-6)	near waterway, clearing in trees
124	Nulato (A-6)	known site, "Old Fish Camp"
130	Nulato (A-6)	clearing in trees, texture could be house pits
138	Nulato (A-6)	high ground, base of hill on waterway
139	Nulato (A-6)	situated in clearing at base of hill
142	Nulato (A-6)	situated on edge of river
155	Nulato (B-5)	good location, high ground
158	Nulato (B-5)	possible from appearance
222	Nulato (B-5)	high ground next to waterway
226	Nulato (B-5)	high ground next to waterway
236	Nulato (A-6)	texture could be house pits
248	Nulato (A-6)	possible, from appearance

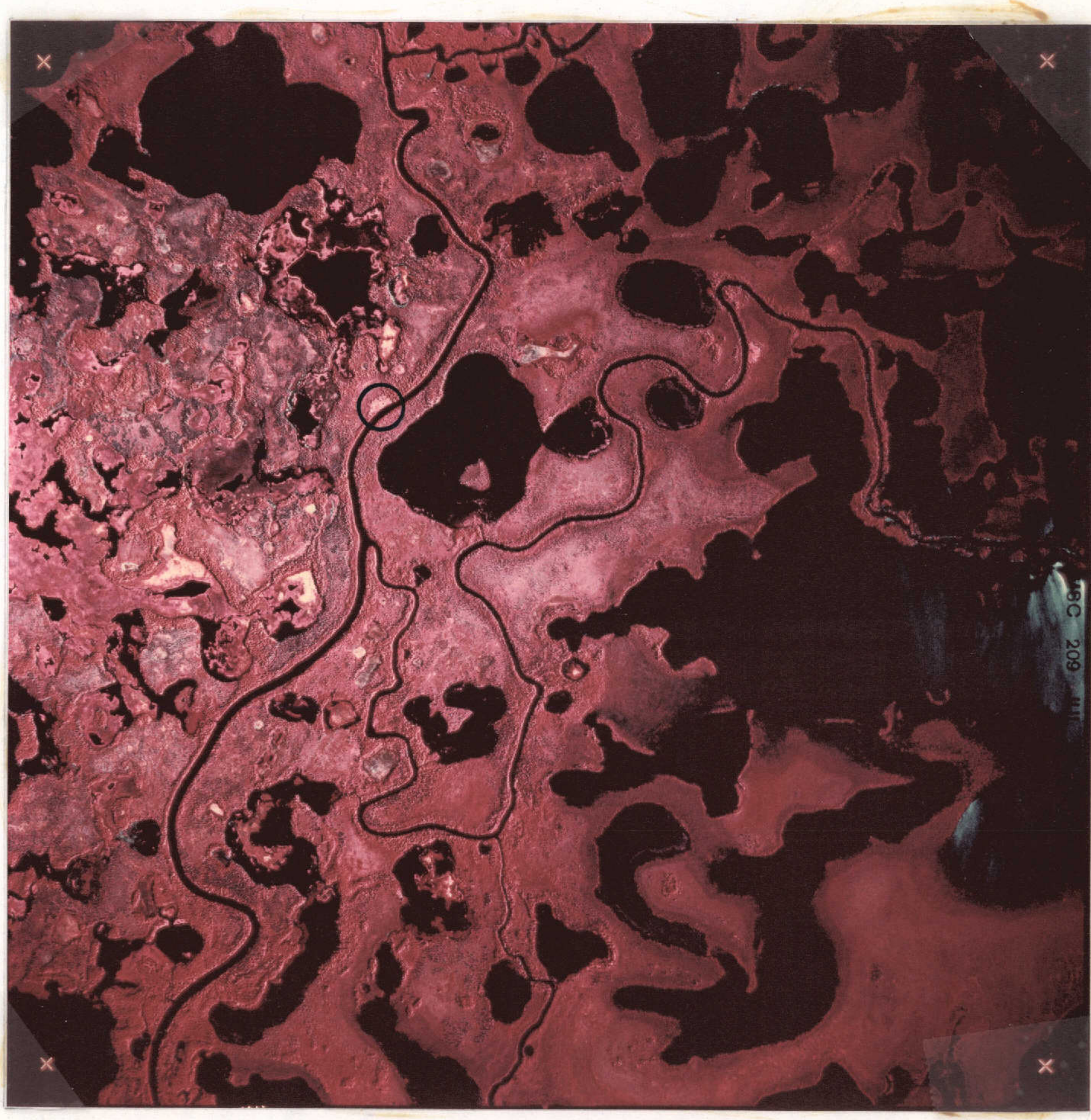

Figure 8. Aerial photograph of archaeological site named "The Mouth of Cottonwood Creek"

aerial photo of the site named "The mouth of Cottonwood Creek". Figure 9 shows the corresponding portion of the computer printout for this area. The site was identified as a "4" signature.

As mentioned previously, several potential sites were identified which were not identified by DeLaguna. One of these is shown in Figures 10 and 11 where a vertical aerial photograph and corresponding portion of the digital printout show a very likely former village site located on a narrow neck of land between the Khotol Slough and a former length of the slough which has now become a long lake entering the Khotol Slough approximately two miles from this location. If this is an archaeological village site, it may have been obscured from DeLaguna's view by trees growing on the Khotol Slough side.

On the other hand, it is likely that not all potential large archaeological sites were identified. Half of the sites found by DeLaguna were not identified on the printout. While it could be argued that some of these are small, at least one large site, circled on Figure 12 was not identified. Figure 13 shows a portion of the printout for this area. This is the site identified as "Latskokat" by DeLaguna. Note that the signatures in this area are spectrally close to archaeological site signatures.

In several instances that a known site was not recognized, a blank appeared on the printout where an archaeological site signature should have appeared. In these cases, the combination of intensity levels was located at a position near the volume occupied by archaeological site signatures on Figure 3.

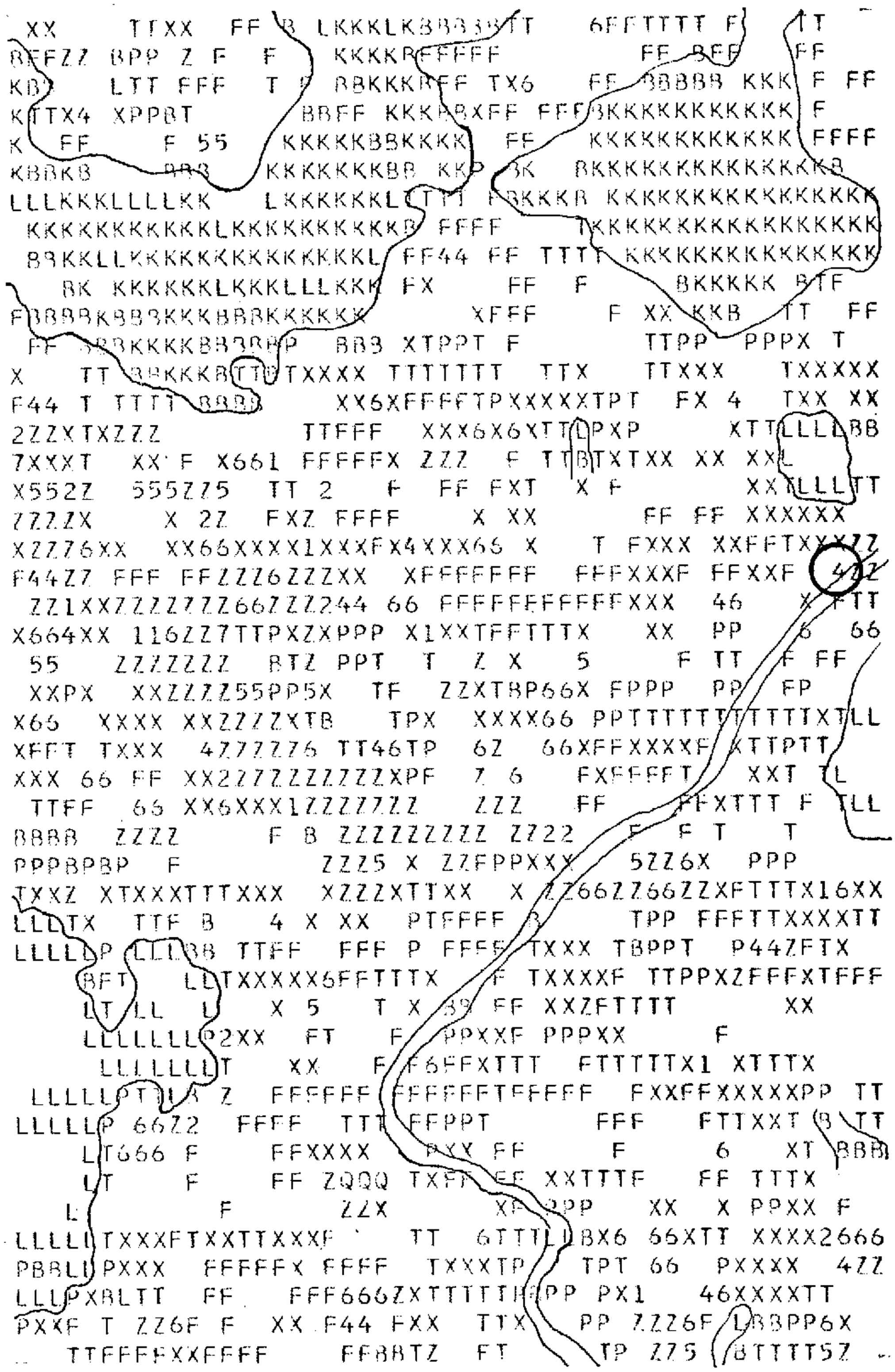

Figure 9. Portion of signature printout containing archaeological site: "The Mouth of Cottonwood Creek"

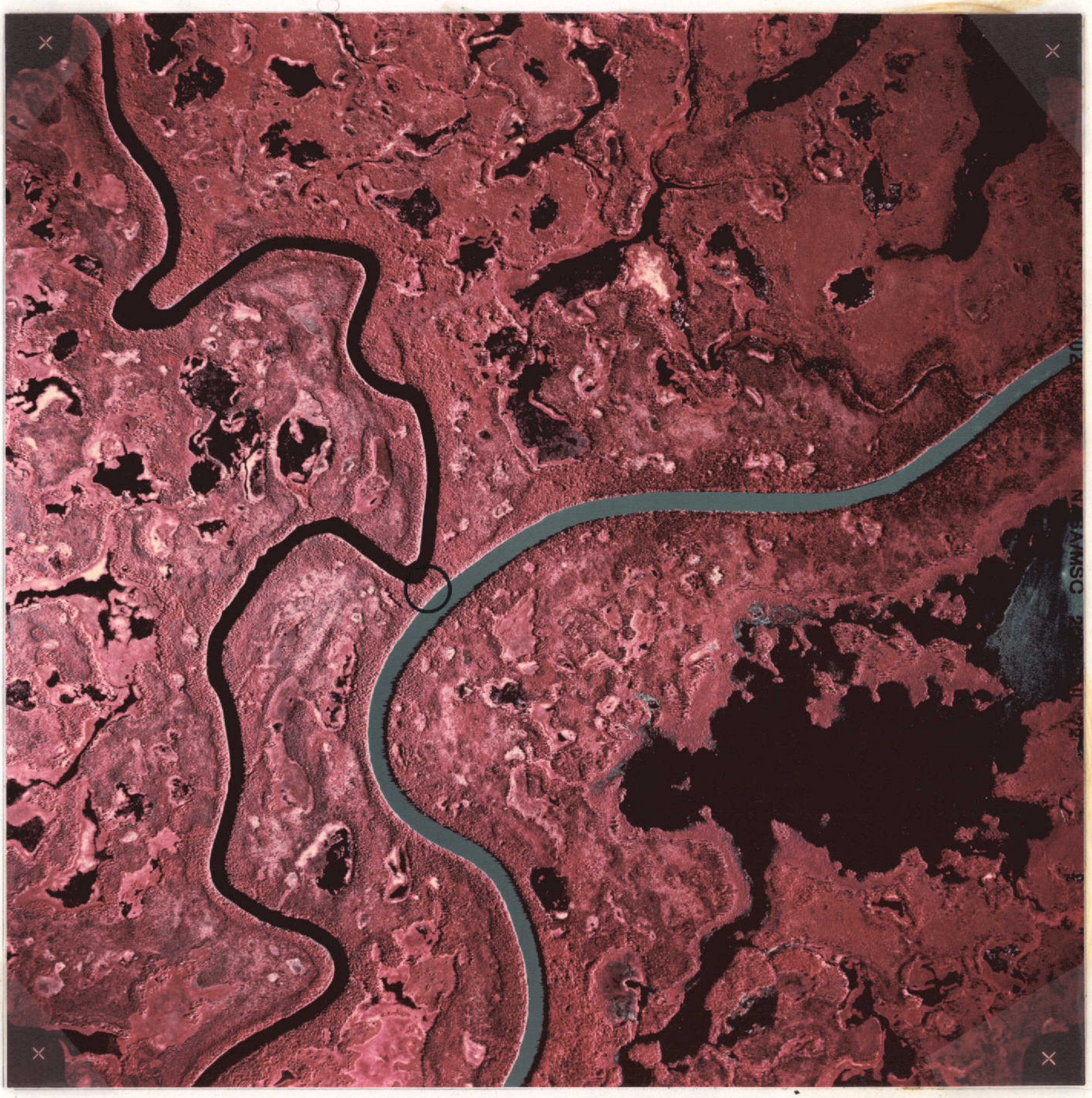

Figure 10. Aerial photograph of location of possible archaeological site identified by ERTS

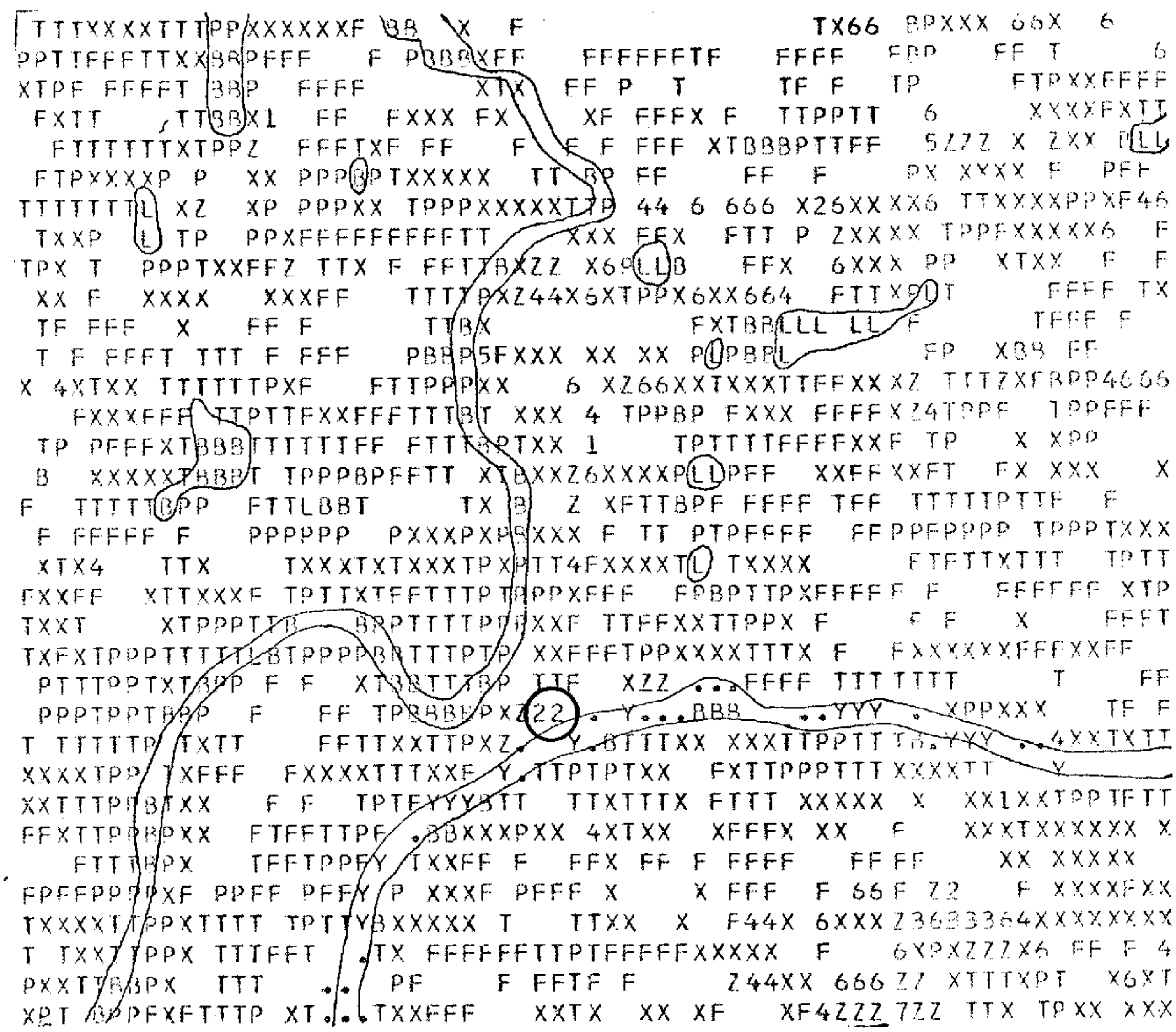

Figure 11. Portion of signature printout showing ERTS-identified possible archaeological site

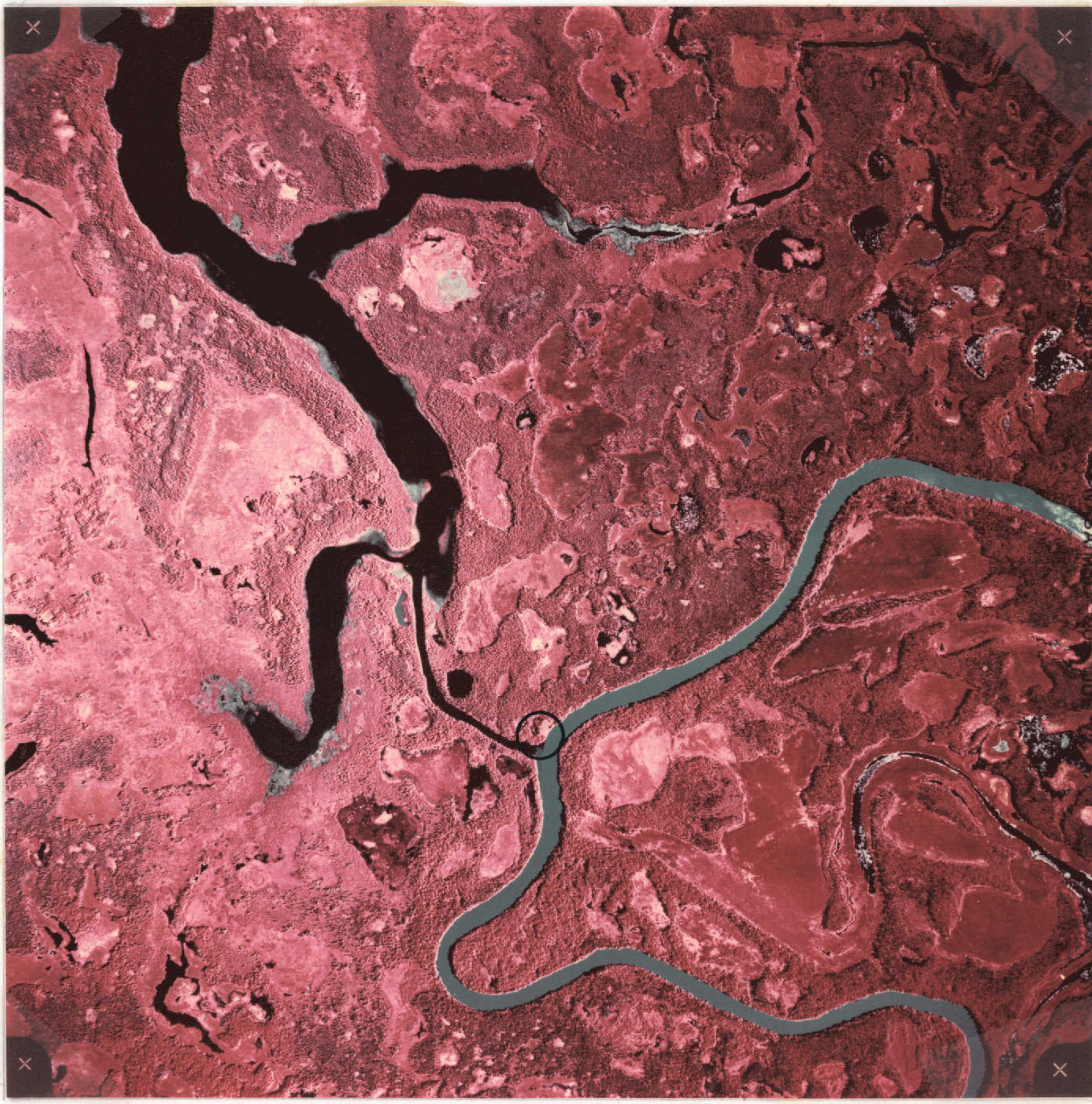

Figure 12. Aerial photograph of large archaeological site not identified on signature printout

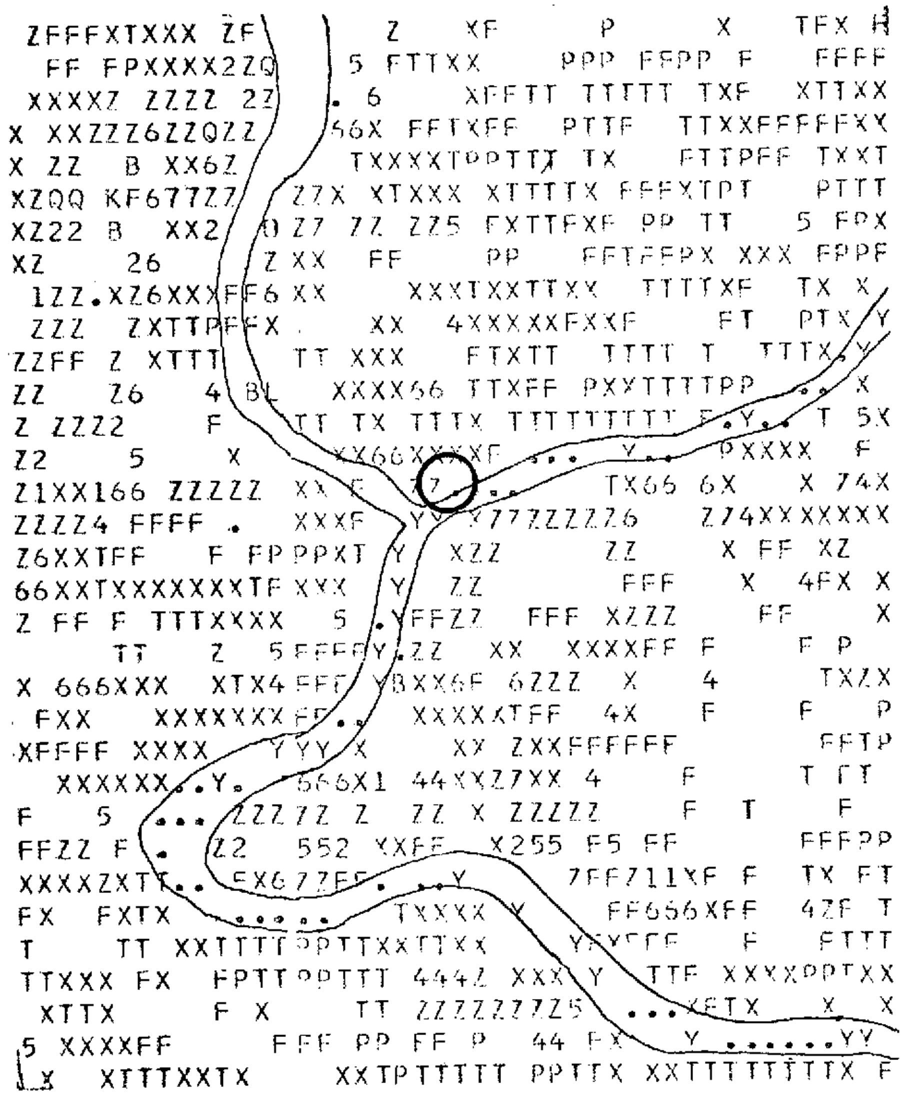

Figure 13. Portion of signature printout showing signatures in area of large archaeological site not identified on printout

V. CONCLUSIONS: THE FEASIBILITY OF MAPPING LARGE ARCHAEOLOGICAL VILLAGE SITES BY MEANS OF ERTS-1 DATA

The results described in the previous section are encouraging, but as has been pointed out, considerable interpretation of data is required to achieve anything approaching useful data. The signatures 1, 2, 3 and 4 are each combinations of one intensity level in each of bands 5, 6, and 7; yet, with this rigid distinction, over three hundred potential sites with these signatures were found in the test area of approximately 450 square miles. Unlikely sites were discriminated on the basis of location to reduce the number of potential sites to a reasonable quantity.

Even then, examination of aerial photography showed that many of the potential sites were very likely not archaeological sites. Finally, not all known sites of sufficient size to be identified were actually identified on the digital printout.

Our conclusion is that it is nearly feasible to use ERTS data to identify large archaeological village sites, and that actual feasibility could possibly be achieved using the techniques described in the next section.

VI. RECOMMENDATIONS FOR ADDITIONAL TECHNIQUES TO MAKE POSSIBLE IDENTIFICATION OF LARGE ALASKAN ARCHAEOLOGICAL VILLAGE SITES BY MEANS OF ERTS-1 DATA

A. Elimination of banding and striping in digital data

These effects are readily seen on ERTS images and digital printouts of single bands. They result from poor intercalibration among the six photometers used for each band. The result is particularly troublesome for signature analysis like that used here where signatures are closely defined. In the previous section it was reported that in some cases known sites were represented by blanks on the digital printout resulting from a combination of intensity levels for that picel which lay outside the domain of defined signatures.

The intercalibration problem could be corrected manually or by means of computer program. Although completed too late to be used by this project, University of Alaska ERTS project No. 1 did construct a computer program for this purpose. However, it appears that the intercalibration ratios actually change within a few kilometers with the result that the program is only of limited utility. In our particular case we could compute intercalibration ratios using intensity levels measured from the Yukon River.

B. Use of scenes from other seasons

1. sun-angle considerations

The scene used was considered to be of high value because it was obtained very soon after the aerial photography was acquired. Hence, the latter could be used for interpretation of the former.

Although the scene used was obtained in late August, because of the high latitude of Alaska, shadows are quite long. Since almost all former village sites occur in clearings in the forest, they are partly covered by shadows which obviously play a role in determining their signature. Data taken near the summer solstice would possess minimum ambiguity due to this effect. This data was not available to us until after the major portion of the work had been completed.

2. seasonal variations in vegetation

We reported earlier that many of the potential sites identified on the computer printout were easily rejected on the basis of examination of the vertical aerial photography. Generally this was because it could be seen that these areas were low-lying and not well-drained. Although by mid-August these two types of areas have similar spectral characteristics, it may well be that in early June the vegetation in the well-drained areas will become active before vegetation in the low-lying areas because these areas remain cold from melt waters. ERTS digital data from this time period may offer stronger archaeological site signatures than any other season.

VII. OTHER APPLICATIONS OF RESULTS

The method of processing ERTS digital data used here involved producing a general vegetation map. This method is considered valid for generally level topography and could be used for detailed vegetation mapping under these conditions.

An immediate application of this technique would be a detailed forest inventory along Alaska's major rivers. These forested areas are generally flat and because timber along the rivers is accessible, they are of potential commercial value.

To date, a region-wide timber inventory has been made but no data exists on designated areas. In one or two small regions of interior

Alaska timber inventories have been made at considerable cost by analysis of aerial photography. Although not as precise as photographic techniques, the ERTS technique is probably on the order of one order of magnitude cheaper.

VIII. INTEREST BY AGENCIES

We have not yet actively sought funding by other agencies. However, we did receive a request for a proposal from the National Park Service. A proposal was submitted for funding using FY 1973 EROS allocations. As the letter attached as Appendix A details, the work was originally one of 9 proposals selected for funding and was deleted when available funds limited Park Service EROS activities to three of the nine projects.

IX. FUTURE ACTIVITIES

We feel we were fortunate that NASA should support the seemingly risky activity of determining the feasibility of locating archaeological sites by use of ERTS-1 data. The results seem to us to indicate that this method is nearly feasible. We have suggested additional techniques which may make ERTS a practical archaeological tool.

We plan to propose to other funding agencies to carry this work further based on these results.

LIST OF PUBLICATIONS

1. Remote Sensing of Alaskan Archaeological Village Sites - I A Preliminary Report, Presented at the 23rd Alaskan Science Conference, Fairbanks, Alaska, 1972. (Published in Preprint form)

2. Remote Sensing of Alaskan Archaeological Village Sites - II Digital Analysis of ERTS Data, Presented at the 24th Alaskan Science Conference, Fairbanks, Alaska, 1973.

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