AIRBORNE MULTISPECTRAL MAPPING OF THE INTERTIDAL ZONE OF SOUTHERN ALASKA

N.E.G. ROLLER, F.C. POLCYN

DECEMBER 1977

National Oceanic and Atmospheric Administration
Environmental Research Laboratories
Bering Sea-Gulf of Alaska Project Office
P.O. Box 1808
Juneau, Alaska 99802

Contract: 03-7-022-35208
COTR-Dr. Herbert E. Bruce

ENVIRONMENTAL
RESEARCH INSTITUTE OF MICHIGAN
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN
BOX 8618 • ANN ARBOR • MICHIGAN 48107

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.
130500-1-F

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Airborne Multispectral Mapping of the Intertidal Zone of Southern Alaska

5. Report Date
December 1977

6. Performing Organization Code

7. Author(s)
N.E.G. Roller and F.C. Polcyn

8. Performing Organization Report No.
130500-1-F

9. Performing Organization Name and Address
Environmental Research Institute of Michigan
Infrared and Optics Division
P.O. Box 8618
Ann Arbor, Michigan 48107

10. Work Unit No.

11. Contract or Grant No.
03-7-022-35208

12. Sponsoring Agency Name and Address
National Oceanic and Atmospheric Administration
Environmental Research Laboratories
Bering Sea-Gulf of Alaska Project Office

13. Type of Report and Period Covered
Final Report
August to December 1977

14. Sponsoring Agency Code

15. Supplementary Notes
Technical monitor for this contract was Dr. Herbert E. Bruce

16. Abstract

Multispectral analysis was performed on a data set collected by a low flying aircraft at three sites in the Gulf of Alaska, i.e., Zaikof Bay, Latouche Point and Cape Yakataga for the purpose of mapping intertidal algal communities.

Both supervised and unsupervised processing procedures were employed. It is possible to separate vegetation into broad spatial zones representing either species of algae or species associations or simply vegetation density classes. Clustering techniques represent the most effective way to extract training signatures. A minimum of four spectral bands is needed to achieve the recognition performance levels demonstrated in this study. Two channels in the visible (green and red), one in the near-infrared region (~1.0μm) and one in the thermal region were found most useful.

A hypothetical intertidal survey of 1200 miles of Alaska shoreline is outlined with summaries of data collection and processing costs given for the mission using optimum spectral bands.

17. Key Words
Remote Sensing
Algae
Multispectral
Gulf of Alaska
Intertidal

18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	105	

PREFACE

This report is submitted by the Environmental Research Institute of Michigan in fulfillment of the requirements specified in Contract 03-7-022-35208, under sponsorship of the National Oceanic and Atmospheric Administration, Environmental Research Laboratory. The Contracting Officer Technical Representative was Dr. Herbert E. Bruce, Bering Sea-Gulf of Alaska Project Manager. Principal Investigator was F.C. Polcyn. Data Processing and analysis was under the supervision of N.E.G. Roller.

The authors greatly appreciate the cooperation of personnel from the Bering Sea-Gulf of Alaska Project Office and from the Auke Bay Fisheries Laboratory, Auke Bay, Alaska for their support during the field data collection and their assistance in the "interactive data-processing" phase of this study.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0
INTRODUCTION

Our national need for adequate energy supplies necessitates the increased development of our natural resources. At the same time, sensitive biological communities that play valuable ecological roles must be protected.

To insure the protection of these delicate living resources, information is needed so that those communities which would be most easily and adversely affected by the results of energy development activities can be identified prior to impact. Accordingly, a goal of the Outer Continental Shelf Energy Assessment Program (OCSEAP) of the National Oceanic and Atmospheric Administration (NOAA) is to obtain current information about the location and composition of important littoral vegetation communities in the Gulf of Alaska, where development of gas and oil deposits is expected in the near future.

OCSEAP is under the direction of the Environmental Research Laboratories of NOAA and sponsored by the U.S. Department of Interior, Bureau of Land Management.

1.1 BACKGROUND

The environmental baseline data that must be collected consists of information about the distribution of the major littoral habitat types along the Alaskan coastline and the character and abundance of the vegetation within each habitat type. Currently, this data is collected by visual observation from light aircraft, a hazardous and difficult job.

After discussions with Dr. Herbert Bruce, Manager of the Bering Sea-Gulf of Alaska Project Office, Juneau, Alaska and Dr. Steven Zimmerman, a project was initiated in the summer of 1976 which had as its objective a demonstration of the potential of a passive airborne multispectral scanner and associated computer data processing for accomplishing this baseline coastal inventory task. Three sites were selected by Dr. Zimmerman and a coordinated overflight and ground investigation planned and executed in late June. The data collected on that mission was subsequently analyzed by the Environmental Research Institute of Michigan (ERIM) and a digital computer and special software used to map the type and distribution of algae found at the study sites.

The airborne data collection was accomplished using a twin-engined Cessna 310 carrying a 10-channel multispectral scanner that was installed in the aircraft at Anchorage, Alaska. Multispectral data was collected during low tide at the three study sites (1) Zaikof Bay, (2) Latouche Point, and (3) Cape Yakataga. The details of the overflight, the scanner and a catalog of the flight lines collected, altitudes, and headings were reported in the final report "Investigation of Intertidal Zone Mapping by Multispectral Scanner Techniques" 123200-1-F submitted in fulfillment of contract 03-6-022-35225. They are briefly reviewed in Chapter 3.0 of this report.

Processing of the data began at ERIM after converting the digital data, which was stored in high density form on magnetic tape during the aircraft mission, to computer compatible tape. An analysis of the multispectral signatures for the different types of algae was then performed.

There are a variety of procedures that are available to conduct such an analysis depending on the type and amount of information already known about the vegetation. First, if recognizable samples of each species can be located in the scene, spectral signatures can be calculated for each type and the scene can be classified according to well developed statistical criteria. Second, if no prior knowledge exists, computer programs exist to automatically group signal into clusters which can later be correlated to algae type after a classification map has been constructed.

For this analysis, a modified form of supervised classification was chosen. Dr. Zimmerman outlined the general boundaries of the major algal zones in the intertidal region on color aerial photographs.

Areas within each zone to be used as training sets were selected by inspection of signal differences on computer graymaps which resemble black and white air photos. Signatures were then calculated for the training sets which consisted of groups of pixels having a uniform appearance on the graymaps. The spectral signatures were then used to classify the remaining data. To display the classification results, color-coded terrain feature maps were made using ERIM's MIDAS computer with its color ink-jet printer. A computer map was made for each of the three sites and sent to Dr. Zimmerman and his staff. An inventory of the area of each algal type was also made by counting the number of individual picture elements (pixels) representing each algal type. The area of each pixel is known from the altitude of the aircraft and the angular size of the resolution element of the scanner.

Their initial reactions were favorable; the different algal zones appeared to have been correctly mapped. However, because the computer was able to distinguish differences within a zone as well as between zones, additional analysis efforts seemed warranted to determine the basis of these within class differences.

This initial processing effort (Phase I) used only visible and reflected infrared spectral data, whereas thermal infrared data was also available on tape, and its influence on recognition had not yet been analyzed.

Consequently a second processing effort (Phase II) was planned to look into these issues and was carried out at ERIM during a time convenient for Dr. Zimmerman and Ms Joyce Gnagy to be present. They both have personal knowledge of the study sites since they participated in the ground data collection phase which took place coincidently with the aircraft data collection. This report is designed to provide a description of the Phase II processing and a summary of the results obtained in both Phase I and Phase II.

1.2 OBJECTIVES

Under Dept. of Commerce Contract 03-7-022-35208, a Phase II effort was undertaken to complete this investigation of the use of airborne passive multispectral remote sensing techniques for surveying intertidal habitats. The purpose of this follow-on project was to provide a set of processed data from which several things could be learned: first, how accurately can different species of algae be mapped; second, what sensor operation/flight plan parameters have the most bearing on recognition performance; and, third, what computer processing technique is best in terms of combining acceptable recognition accuracy with low cost and good turn-around time? Then, on the basis of these findings determine the optimum method of airborne data collection and computer processing for operationally accomplishing the required coastline inventory task.

In August of 1977, Dr. Zimmerman and Ms Gnagy visited ERIM during which time the additional computer analysis of the data collected in June 1976 was undertaken. Their knowledge of the algal distribution at the study sites was used in the manual selection of training sets to derive spectral signatures. Cluster analysis of the data took place subsequent to their visit at ERIM. The results of these analyses appear in Chapters 4 and 5.

1.3 STUDY SITES

The character of the three study sites that were selected for this project provided the opportunity to observe different species of algae in different physical environments. The Zaikof Bay site on Montague Island represented a typical intertidal area with high algal species diversity, hilly topography and varying slopes. The intertidal area at Latouche Point has a gradual slope so that the algal zonation is relatively quite broad. The Cape Yakataga site is characterized by several large, nearly horizontal benches, each representing almost a mono-specific algal flora. Year to year environmental changes do, however, alter the extent and uniformity of the vegetation communities at each site.

A reference map showing the approximate location of the three study sites in the Gulf of Alaska is shown in Figure 1.

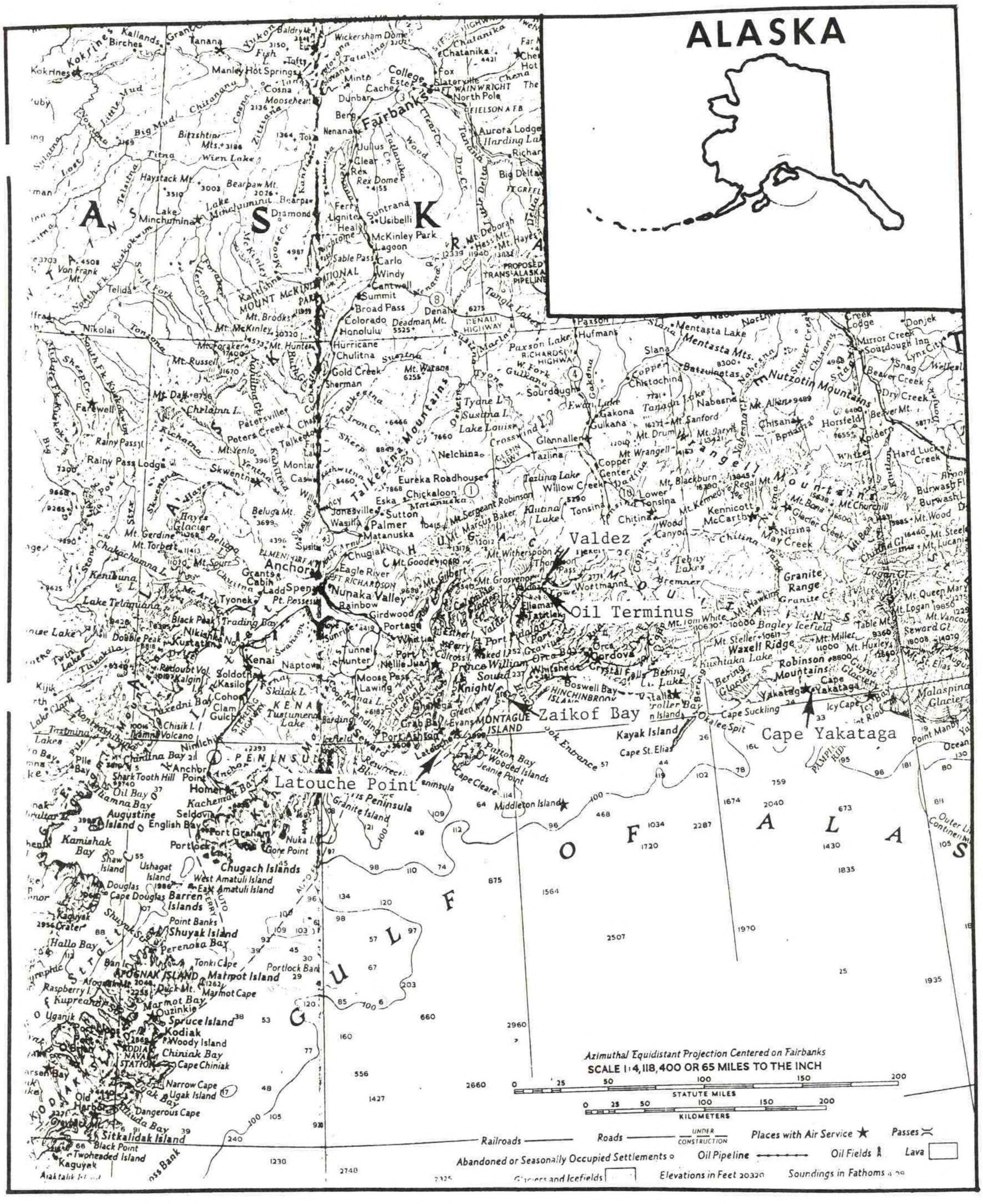


Figure 1. Location of Study Sites

2.0
APPROACH

In order to achieve the overall goal of this study, which is to determine the cost-effectiveness of computer-processed airborne multispectral scanner data for intertidal zone mapping in Alaska, a systematic investigation of sensor parameters and associated data processing strategies was undertaken. The advantage of this approach is that a set of boundary conditions are readily identified for each parameter and strategy, which, when considered together, define the most effective operational configuration of the remote sensing system under consideration. Another important benefit is that it permits using a very generalized data collection system, so that initially a wide range of alternative sensor configurations can be considered.

Based on specific experience gained in ERIM's related program of coastal zone macrophyte mapping the the Great Lakes (Wezernak, et.al., 1974; Tanis, 1977), along with our general knowledge of computer data processing techniques, three key information gaps were identified which we felt must be filled in by this study before it would be possible to specify an operational intertidal zone airborne MSS mapping system. In order of priority these three key information gaps were: (1) How much supporting biological field work is necessary, (2) what is the simplest scanner configuration that is effective, and (3) what should the role of the biologist be in the data processing? To answer these questions a three-level project design was developed, with each of the levels roughly corresponding to one of the previously identified information gaps and prioritized accordingly. This plan is outlined in Figure 2. The significance and nature of the three information gaps addressed by the individual levels of the study plan are discussed in the next three sections of the approach (Sections 2.1, 2.2 and 2.3). This background material is then followed by a brief discussion of the organization of the rest of the report (Section 2.5).

LEVEL I: Evaluate supervised and unsupervised methods of computer processing of airborne MSS data.

- compare supervised recognition results produced with and without ground truth.
- compare recognition results produced using both supervised and unsupervised methods.
- compare time and cost required for all three methods.

LEVEL II: Identification of optimum set and number of spectral bands

- On the basis of spectral signature analysis, identify the best reflected visible and near-infrared bands.
- compare recognition results to determine the relative performance of
    - a. reflected bands only
    - b. thermal band only
    - c. reflected bands plus thermal
- Insofar as possible determine the effect of data quality on band selection.

LEVEL III: Compare Interactive vs Batch modes of computer processing plus data displays

- compare the time and cost associated with each mode of data processing.
- compare ease of interpretation and analysis of various data displays.

FIGURE 2. Study Plan for Alaska Intertidal Zone Mapping Project.

2.1 LEVEL I: SUPERVISED VS. UNSUPERVISED PROCESSING

A major factor affecting the cost and speed of remote sensing data processing is the amount and type of human intervention required. If it is necessary for someone to analyze in detail the results of every step in the data-handling stream, and there are several steps, the processing of a single data set can quickly become both laborious and time-consuming. Matters are further complicated if interaction between field personnel located at a remote site is required with persons working at the data analysis center. These problems in one form or another have traditionally been associated with what is known as "supervised" data processing which emphasizes human selection of training sets for recognition processing. Basically this approach consists of humans trying to find pixels (picture elements) which represent characteristic samples of the spectral reflectance of the objects they wish to identify.

An alternative method of selecting training sets is to use a technique called "clustering" which is known as "unsupervised" recognition processing. Clustering is a multispectral data analysis technique which attempts to identify the inherent patterns of spectral reflectance observed in a given data set. The advantages of this approach are better signature separation, more complete filling of feature space and generally less time spent extracting signatures. Clustering is not a panacea, however, because even though it does identify the basic patterns of spectral reflectance that occur in a scene, these patterns may not be diagnostic of discrete scene classes. What is meant by this is that sometimes two dissimiliar materials, such as algae and trees, may have the same spectral reflectance, and although clustering can isolate this characteristic pattern, the computer cannot tell which material was responsible for producing it, and these two terrain features will be classified.

There are two primary advantages of unsupervised processing which may make it the more desirable approach to use for the application under consideration in this study: First, the amount of supporting field work required in the harsh and remote Alaska coastal environment would be greatly reduced. Secondly, the need for involvement of persons intimately familiar with the sites under study in the signature extracture process would be greatly lessened. Against these factors, however, we have to balance whether the cluster formation algorithms available are sensitive enough to isolate the spectral reflectances of the algal classes it is desirable to map. To assess the performance of clustering we decided to compare recognition results of cluster-generated maps against those produced using training sets picked with the help of extensive ground truth. This was done for two of the three study sites: Zaikof Bay and Cape Yakataga.

In addition to doing "pure" clustering it is also possible, if one is familiar enough with the principles of remote sensing and the target radiation interactions of neutral objects, to combine subjective training set selection with clustering. Using this approach, specialists cross-trained in both biology and remote sensing technology who have never been to the study area may be able to extract as much, if not more, information from a given data set as someone very familiar with the actual site yet only superficially familiar with remote sensing technology. This hypothesis was tested on the Zaikof Bay data set.

Our observations on the time required for implementation and the difficulties associated with each approach were derived from these processing tasks.

2.2 LEVEL II: IDENTIFICATION OF OPTIMUM SPECTRAL BANDS

The concept of a "spectral signature" is based on the observation that many natural materials exhibit a characteristic spectral signal pattern. The sources of this signal pattern are reflected and emitted radiation. Reflected radiation is that component of sunlight reflected by an object to the sensor; it ranges from .33 to 3 μm. Emitted radiation is heat energy and is given off by all objects; it is detectable in the far-infrared part of the spectrum, from 3μm to 30μm. The reflected portion of an object's spectral signature tends to be a more reliable basis for classification than the emitted portion. In large part this is because the processes that control reflection are linked to the basic composition and structure of the object which remains stable. For this reason, we can expect an inherent stability in the pattern of the reflected component of a material's spectral signature. Thus, under variable environmental conditions we would expect to be able to get as good, if not better, classification performance using fewer training sets, all other things being equal, by using only reflected data and avoiding the use of thermal data.

On the other hand, if environmental conditions are stable, the natural temperature variations between natural objects can be just as diagnostic as reflectance differences; for example, sunlight rocks are typically warmer than water and vegetation, and different types of vegetation - because of such factors as canopy structure - also may have characteristic temperatures.

To answer the question of how valuable thermal data is to the mapping of algae along the Alaskan coastline we elected to process a subset of the data in three different ways. First, map a study site using only reflected data, second, make a thermal map of the area and compare results with the reflected data, and finally, if the thermal data appears to add something, make a recognition map based on a combination of reflected and thermal data. The processing we implemented to achieve this objective consisted of:

Reflected Recognition Processing: Zaikof Bay, Latouche Island, Cape Yakataga.

Thermal Level-Slice Maps: Zaikof Bay, Latouche Island

Reflected/Emitted Recognition Processing: Cape Yakataga

2.3 LEVEL III: PROCESSING MODES AND DATA DISPLAYS

In recent years, following the overcoming of the initial obstacles of proving the feasibility of the multispectral scanner and signature recognition concepts as useful resource characterization and mapping tools, the emphasis in remote sensing technology has shifted toward achieving near-real time implementation of the classification process. The prime motivation for this thrust was to take advantage of the high through-put rate of computers thus making it possible to place decision-making information in the hands of managers in a useful time frame. Two concepts in the field of computer-design technology which are influencing how new computers are built and programmed that have emerged as a result of this emphasis are those of making future computers (1) interactive, and (2) user-oriented.

Interactive design characterizes the new third generation of computers. In practice, multiple operators talk via a teletype terminal with the central processing facility which carries on a diaglogue with each of them simultaneously while still dealing with their requests in a time-sharing mode. The result is that everyone feels as if he is personnally being taken care of at all times; as soon as a job is completed the operator receives the results and can begin another, permitting many tasks which must be done in sequence to be accomplished in a short time.

In contrast, the older, second generation computers operate in "batch-mode". In batch-mode operators submit jobs in a rigid format on punched cards. When several operators submit jobs at once the jobs are "qued" and processed sequentially by the computer. No one gets any results until all the jobs are finished and listed.

At first blush the special-purpose remote sensing interactive computer appears to be a vast improvement; and in many cases it is, particularly where the jobs to be done are not dependent upon completing a detailed analysis of the results of preceeding jobs before they can be started. The processing of remote sensing data is not as routine as many would like to believe, however, and it may be that batch mode computers are acceptable data processing units. This is important for a user to know, because processing costs are generally lower on these older units and many agencies could afford to make use of a multispectral software processing package stored in a centrally located general purpose computer that serviced other users as well.

We also felt an issue related to the interactive mode of computer processing that was worth examinating was the role of the biologist in data analysis. One school of thought in data processing emphasizes the direct involvement of the user in the data handling stream where this person(s) makes key decisions regarding the fine points of the actual data manipulation. In general this approach has proved successful compared to the early days of remote sensing when engineers with little biological background did most of the processing. Even so, at ERIM we have found that even better results can be obtained in most cases when data processing is conducted by a special type of individual who has been cross-trained at a high level in both remote sensing technology and biology. It may be that there is more to be gained in data processing by having a specially trained person involved rather than an exotic computer.

To provide some insight into this question of what type of individual is most effective at data processing (and thus learn how best the biologist can contribute to effective data processing), we conducted a comparison study. ERIM has both a user-oriented, interactive computer (MIDAS) and a batch mode general purpose computer (IBM 7094). To provide the performance benchmark for the interactive approach we processed one data set on MIDAS with biologists from NOAA's Auke Bay Laboratory who have visited the test sites supervising the processing. The performance benchmark for the batch mode processing under the direction of an ERIM remote sensing specialist/biologist was provided using the 7094 computer.

In our analysis of the results of this comparison we have not attempted to quantitatively prove that one approach is better than the other. Even if we had wanted to do so, the necessary ground truth was not available to us. Rather, what we have attempted to do is illustrate what types of tradeoffs are involved in going either way and what the user will get for the dollar he invests.

The final issue we have addressed in this study is that of optimum data displays. Remote sensing data often appears to the user as a bewildering array of statistics, images and oddly symbolized computer graphics. At ERIM we have made an effort to structure our software and output products into user-oriented formats that will improve communication, understanding and utility. Because these might go unnoticed without a basis for comparison, we have chosen to call them out and briefly describe them as representative of desirable elements of any operational remote sensing system that might be specified for intertidal analysis. In particular, the reader should note our use of EPLOT's and the ink-jet printer displays used to produce the color-coded recognition maps.

2.4 ORGANIZATION OF REPORT

An unusual feature of the work done for this project is that several of the individual data processing tasks, which make up the entire data processing effort, support more than one of the project's analysis programs. This poses a problem in report writing, because for logical presentation each analysis program should be described completely - beginning with data collection moving through data processing, continuing with analysis and finishing up with conclusions. Needless to say, for this project a report following these guidelines would consist largely of repetitions of data processing descriptions. To avoid such needless repetition, we have instead adopted the following plan: chapters 3.0 and 4.0, which deal with the technical details of data collection and data processing respectively, are organized in order of the chronological occurrence of the steps involved in the generation of the products. This makes it possible to present a complete and easy to follow discussion of the sequence of data handling associated with each data set. Chapters 5.0 and 6.0, which contain respectively the results and discussion and conclusions, are instead organized along the lines of the analyses programs, and as a result jump around somewhat in their treatment of the data sets as different questions related to the most feasible method of obtaining the desired results are addressed.

Thus, those readers primarily interested in getting a quick picture of what we learned as a result of this study should concentrate on Chapter 5.0 and 6.0. On the other hand, readers more interested in the technical aspects of data collection and manipulation will find their interests addressed in Chapters 3.0 and 4.0.

3.0
AIRBORNE DATA COLLECTION AND DATA QUALITY

Acquisition of the airborne data used in this study took place on 27 and 28 June, 1976. Zaikof Bay and Latouche Island were overflown on the 27th and Cape Yakataga was covered on the 28th. The base of operation for the aircraft was Cordova, Alaska.

3.1 TIMING OF OVERFLIGHT

Data collection was achieved at all three sites within 1/2 hour of the occurrence of low tide and maximum sunlight on these dates. Tidal height was -1.9 ft. This is 1.4 ft. less than the yearly maximum low tide of -3.3 ft. which occurred approximately two weeks earlier. Scheduling data collection for such a combination of low tide and maximum sunlight hypothetically optimizes data collection by measuring the greatest exposure of the intertidal zone and the best illumination conditions.

3.2 ENVIRONMENTAL CONDITIONS

In spite of the considerable amount of advance planning by all parties concerned to insure an optimal data set, the environmental conditions that prevailed at the tidal low during the period for which the aircraft was available were for from optimum. Sky conditions on the 27th of June were dark and overcast at both Zaikof Bay and Latouche Island. On the following day the overcast was not as heavy as Cape Yakataga and some thin spots in the cloud cover improved illumination.

The effect of the poor illumination experienced at all three sites on data quality was to lower the signal-to-noise ratio. In effect, we are now dealing with a worst case situation instead of an optimum data set. Thus, the results of this project should be considered as a baseline for the worst performance that can be expected from an airborne multispectral mapping system, and that under better illumination conditions performance will be better.

A consequence of not collecting the data at maximum annual low tide is that there were considerable areas of wet sand and rock and tidepools at all three test sites which had appeared dry during the ground truthing activities that took place two weeks earlier. Since the presence of a layer of water over a material can significantly alter that material's spectral signature this condition caused problems in the classification of materials so affected. For a further discussion of the affects of this situation, see the discussion of the Zaikof Bay test site results in Chapter 4. Its implications are dealt with in Chapter 5.

3.3 SENSOR CONFIGURATION

Because of prior committments, ERIM's own airborne multispectral data collection system, consisting of a C-47 aircraft and the M-7 scanner, were not available for this project. Instead, a Bendix M2S scanner installed in a Cessna 310 owned by Walker Associates of Seattle, Washington was used.

The M2S scanner is a 12-channel system and 11 of the 12 channels were used to collect data in this project. The 12th channel was used to store electronic "housekeeping" data. The channel numbers and their associated bandpasses are listed in Table 1. The Instantaneous Field of View (IFOV) of the M2S is 2.5 milliradians, which means that at an altitude of 1000 feet above terrain the minimum area over which the scanner integrates received radiation is 2.5 ft. on a side, or 6.25 sq. ft. This, in effect, becomes the smallest size object that could be resolved.

3.4 DATA PRODUCTS

Five passes were flown over each test site at different altitudes and with varying combinations. The five combinations considered were:

1) a pass at 1000ft. AGL parallel to the shoreline.
2) a pass at 1500ft. AGL parallel to the shoreline.

TABLE 1. MULTISPECTRAL SCANNER CONFIGURATION FOR ALASKAN INTERTIDAL ZONE DATA COLLECTION, 26 and 27 June, 1976.

Channel		Spectral Band (λ_1-λ_2) (in μm)	Peak Wavelength(λ_c) (in μm)
1	Violet:	0.350 - 0.470	0.410
2	Blue:	0.415 - 0.515	0.465
3	Blue-green:	0.475 - 0.555	0.515
4	Green:	0.520 - 0.600	0.560
5	Yellow:	0.540 - 0.640	0.600
6	Orange:	0.600 - 0.680	0.640
7	Red:	0.640 - 0.720	0.680
8	NIR-1	0.680 - 0.760	0.720
9	NIR-2	0.725 - 0.905	0.815
10	NIR-3	0.925 - 1.105	1.015
11	thermal	8.000 -14.00	11.00
12		"Housekeeping Data"	*

3) a pass at 1000ft. AGL perpendicular to the shoreline.
4) a pass at 500 ft. AGL parallel to the shoreline.
5) a pass at 1000ft. parallel to the shoreline, but with the mirror rate reduced by a third.

For each pass, the scanner data was collected and stored on a high density digital tape (HDDT).

In addition to the MSS data, high resolution vertical aerial photography was collected using a 70mm Hasselblad camera and SO-397 ektachrome EF natural color film. Normally the camera was operated during pass one.

A complete flight log and the rationale for the different pass combinations is available in the companion study for this report (Polcyn et.al., 1977).

3.5 DATA QUALITY

Prior to beginning data processing a data quality check was performed. The purpose of this check was twofold. First, it provided insight into how the poor illumination conditions that existed during data collection affected the signal-to-noise ratio of the specific data sets to be processed. Secondly, it permitted us to find out if there had been any equipment malfunctions resulting in exceptionally poor quality data being recorded for a particular spectral band. The elimination of a channel with very poor data prior to recognition processing is desirable because the addition of noise to training sets seriously compromises the ability of the classifier to recognize what may be important spectral differences between materials.

The procedure used for analyzing data quality in this study involved assessments of both the dynamic range and noise properties of each spectral band. As defined for our purposes, dynamic range was the range of integers over which the data values representative of the variability to be encountered over the whole scene (data set) are distributed. This range was determined by histogramming a systematic 4% sample of the data values in each spectral band for a given data set.

When applied to the Cape Yakataga Data Set (Run 21) this procedure yielded the information shown in Table 2. Dynamic range varied significantly between channels, being as low as 33 integer values in channel 8 and as large as 222 in channel 2.

A measure of "system noise" was obtained from the standard deviation of a spectral signature extracted from a water area of uniform appearance and temperature. The resulting rms fluctuations observed in the signal level for each channel are listed in column 4.

By dividing the dynamic range for each channel (column 3) by the corresponding rms noise fluctuation (column 4), a ratio of signal-to-noise (S/N) for the MSS system used in this study was calculated (column 5). This quantity indicates the number of quantum contrast levels available in each channel and provides a relative means of ranking channels according to their ability to distinguish between objects of different reflectivity. The figures in column 5 show one channel with (relatively speaking)a very good S/N ratio, five channels with generally better S/N ratios, and five channels with generally poorer S/N ratios. This relationship is diagrammed in Figure 3. Fortunately, all three important spectral categories of radiation (near-infrared, visible and thermal) are represented in two visible channels, the thermal channel, another visible channel, and finally another near-infrared channel.

Only channel one (channel 1) had a S/N ratio so poor we felt it should be excluded from further consideration. Thus, all further processing of the Cape Yakataga data set was carried out using only channels 2-11.

It also appears that the illumination conditions that prevailed at Cape Yakataga during data collection did not greatly affect data quality in an adverse fashion. This conclusion is based on a comparison of the S/N ratios observed for the Cape Yakataga data with those obtained using the same type of scanner to collect data on a bright, sunny day over a

TABLE 2. DATA QUALITY FOR CAPE YAKATAGA (RUN 21)

1 Sensor(tape) channel	2 Spectral Band μm (50% response points)	3 Dynamic Range* (data values)	4 Noise (RMS signal fluctuations for a uniform target)	5 Signal to Noise Ratio	6 Data Quality Ranking
1	Violet 0.350-0.470	0-85/86	8.60	9.9	11
2	Blue 0.415-0.515	34-255/222	8.27	26.84	9
3	Blue-green 0.475-0.555	35-166/132	3.73	35.39	7
4	Green 0.520-0.600	32-112/81	1.89	42.86	5
5	Yellow 0.540-0.640	25-79/55	1.09	50.46	2
6	Orange 0.600-0.680	25-67/43	0.86	50.00	3
7	Red 0.640-0.720	25-61/37	1.25	29.60	8
8	NIR-1 0.680-0.760	26-58/33	0.78	42.31	6
9	NIR-2 0.725-0.905	18-91/74	1.07	69.16	1
10	NIR-3 0.925-1.105	17-83/67	2.97	22.56	10
11	Thermal 8.00-13.0	49-102/54	1.16	46.55	4

*Range over which 96% of the pixels are distributed

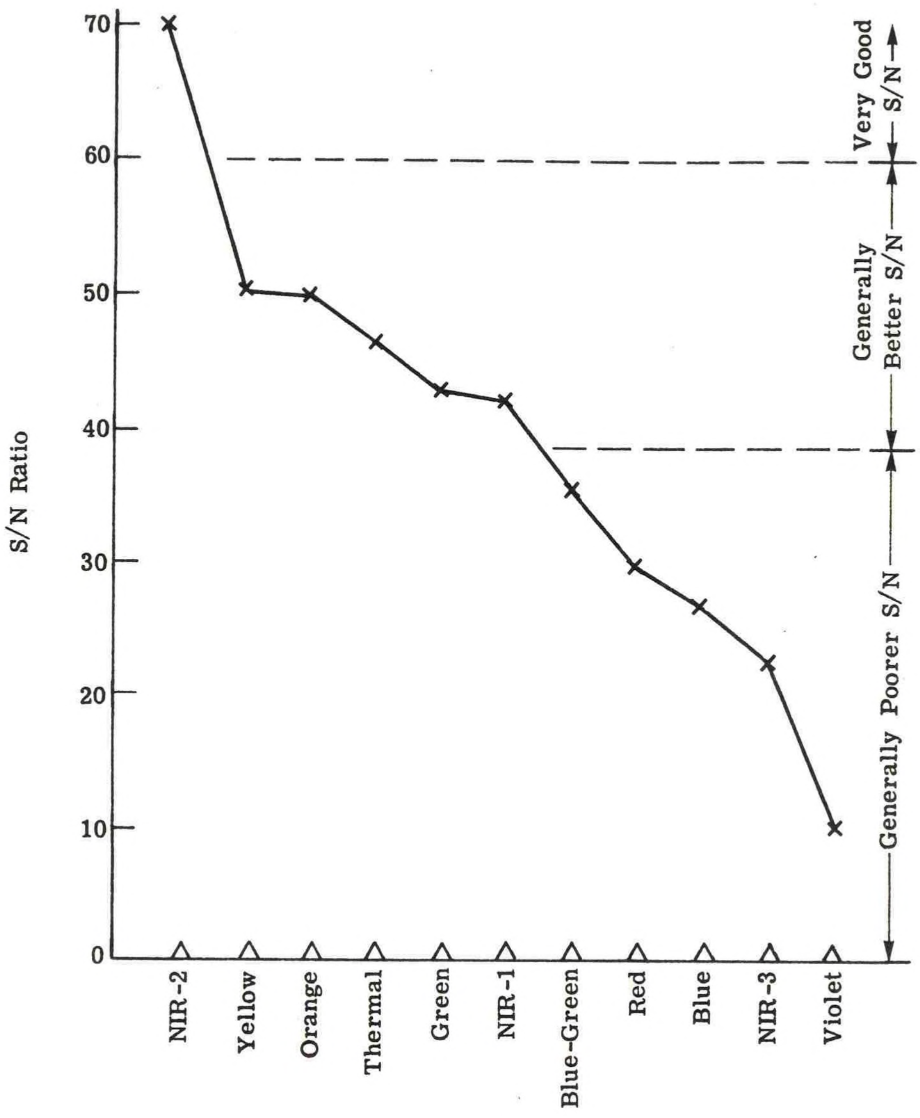


FIGURE 3. SIGNAL-TO-NOISE RATIOS FOR CAPE YAKATAGA (RUN 21) DATA SET.

Texas forestry study site (Sadowski and Sarno, 1976). The S/N ratios obtained for the two data sets are basically similar.

3.6 SCAN ANGLE EFFECT ANALYSIS

Because aircraft multispectral scanners are capable of collecting data over a large range of view angles (± 60° from nadir in the case of the M2S scanner), scene radiance values as recorded by the detectors can include a systematic variation associated with the scan angle. This variation is typically due to the scattering and attenuating influences of the atmosphere as path length from sensor to ground varies with scan angle (Turner, 1974). The bidirectional reflectance properties of the objects in the scene are another major cause (Suits, 1972).

To determine the magnitude of scan angle effects in the Yakataga data set an average scan line was computed for the end of the run over a uniform area of water. The average scan line contained average signal values for 70 divisions across the scene, each of which had been calculated by averaging 10 adjacent resolution elements over 51 successive scan lines. The effect of averaging 510 resolution elements into each of the divisions in effect smooths out any high frequency variations associated with system noise in order that gross radiance changes associated with scan angle can be observed more clearly.

Figure 4 shows the shape of the average scan line computed for three of the 10 channels considered. The portion of the scene included in the calculations is just off the tip of Cape Yakataga at the end of Run 21. This area was selected because at this point the scene is composed entirely of a single material -- water. It is desirable to make such calculations over uniform areas to reduce the possibility of signal variances being due to the intrinsic reflectional differences between different materials and not scan angle, in which we are interested.

It is evident from inspection of the curves that scan angle effects do occur in this data set at both ends of the scan line, at less than point 50 and beyond point 600. The explanation for the asymmetrical

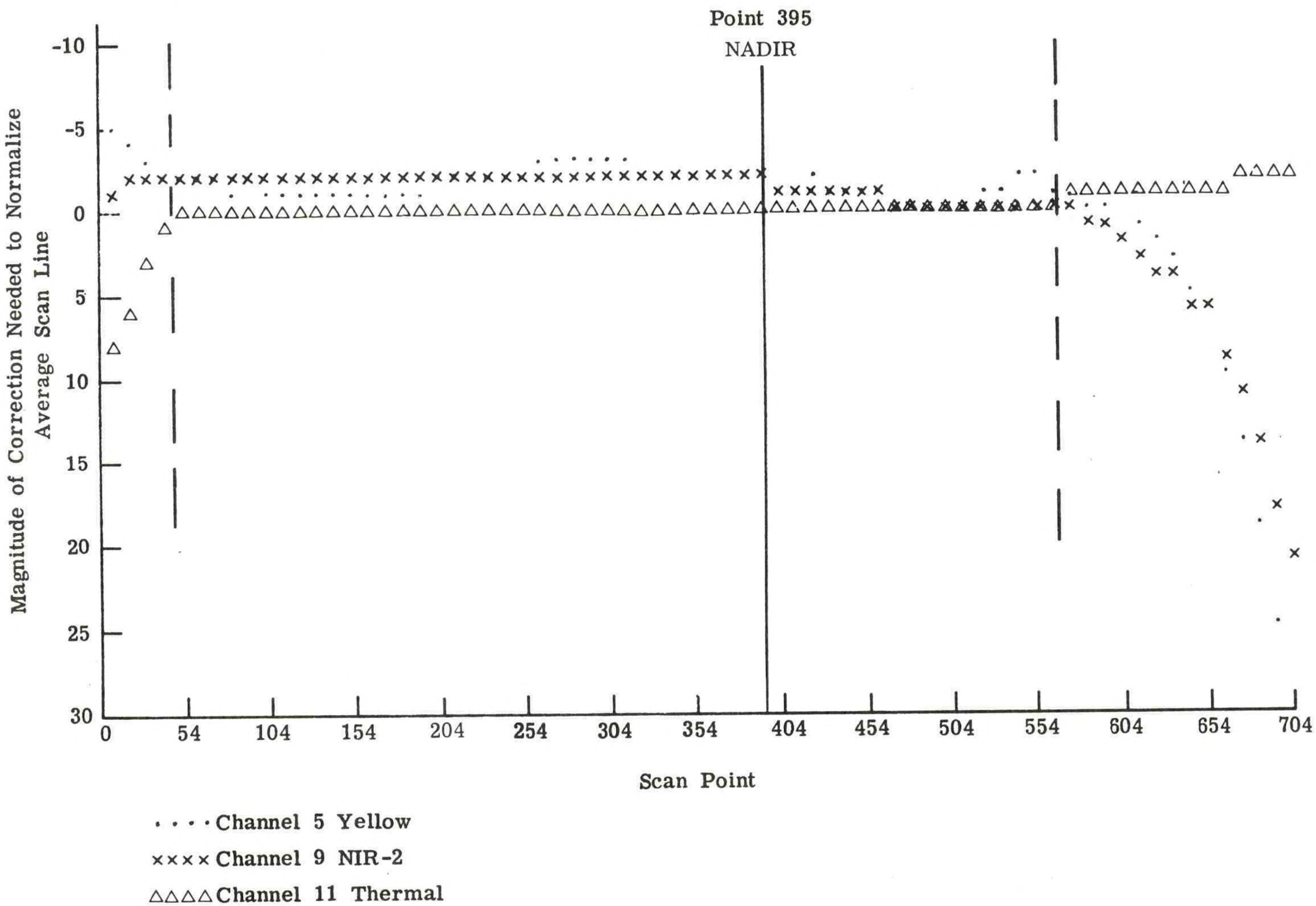
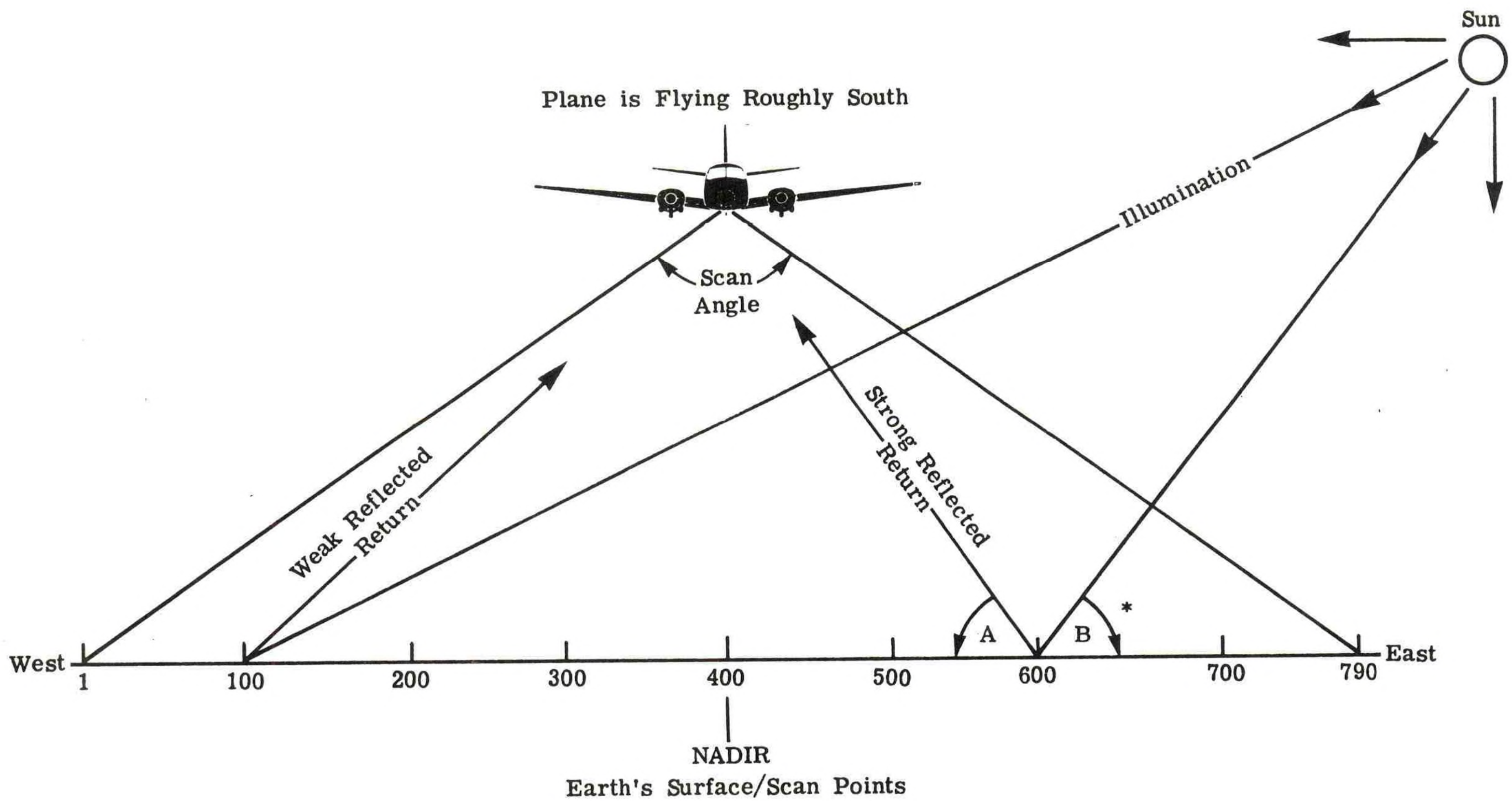


FIGURE 4. SHAPE OF THE AVERAGE SCAN LINE OVER WATER FOR SELECTED CHANNELS.

slope of the curves about the nadir point most likely has to do with the location of the sun's position relative to the sensor. Since the data were collected early in the morning, on one side of the scanline the sun's illumination comes from behind the sensor, while on the other side illumination is toward the sensor, as shown in Figure 5. This would account for what appears to be specular reflection from the water in channels 5 and 9 beyond point 600, on the west side of the run. The thermal channel shows a strong angle effect on the east side of the scan line, which may indicate the presence of a cooler current in this area.

If one wished to a priori minimize the possibility of sun angle effects in multispectral data, it is possible to do so by orienting the flight line either directly toward or away from the sun. This has the effect of making the entire scan line perpendicular to the direction of illumination. Any radiance variations that do occur will then be symmetrical, and if they are large enough to need to be removed a simple parobolic function can be used to correct the data.

For the Cape Yakataga data set we did not feel that it was necessary to correct the data beyond avoiding the edges of the scan lines. Thus, in subsequent recognition processing of this data set we concentrated on the scene area between points 60 and beyond 600. The procedures involved in the recognition processing of data for all three study sets is discussed in the next chapter.



*Where ∠A=∠B Specular Reflectance Will Result from Calm Water

FIGURE 5. DIAGRAM OF SUN-SENSOR GEOMETRY FOR CAPE YAKATAGA DATA SET.

4.0

COMPUTER DATA PROCESSING

There are three logical ways in which the computer work for this project can be described: first, on the basis of chronology; second, on the basis of processing techniques used; and third, on the basis of study sites. Of these three approaches the first, chronology, is of least significance technically, but should be included to show how the project progressed and at what stage different individuals were involved. It will be dispensed with briefly at the end of the introductory material to the present chapter. Between the remaining two approaches we have chosen to use thestudy sites as the basic framework around which to organize our discussion, treating the specific data processing techniques applied to the different data sets as the subheadings. The advantage of this organization is that comparison of the results produced by the different techniques can be discussed sequentially with regard to the same data set. This makes it possible to avoid the "apples and oranges" confusion that might result if we tried to compare the results of two processing techniques applied to different study sites. A summary of the processing and results that are discussed in this chapter is contained in Figure 6 which also serves as a useful overview of the material that will be covered.

Returning now to the chronology of the project, the sequence of events associated with this project and the principal participants are outlined below:

When	What	Where	Who
early June, 1976	Ground truth collection	Study Sites, Alaska	Zimmerman, Gnagy et al
late June, 1976	Airborne data collection	Study Sites, Alaska	Polcyn, Stewart

I. SUPERVISED RECOGNITION PROCESSING
   A. REFLECTED RADIATION STUDIES
      1. 9 channels/no ground truth/7094 computer*
      2. 4 channels/interactive mode/MIDAS computer°
   B. THERMAL RADIATION STUDY
II. UNSUPERVISED RECOGNITION PROCESSING
   A. REFLECTED RADIATION STUDY°
   B. REFLECTED AND THERMAL STUDY°

	I.A.1. 9 channels/no ground truth/7094 computer*	I.A.2. 4 channels/interactive mode/MIDAS computer°	I.B. THERMAL RADIATION STUDY	II.A. REFLECTED RADIATION STUDY°	II.B. REFLECTED AND THERMAL STUDY°
ZAIKOF BAY	X	X	X	X	
LATOUCHE POINT	X	X	X		
CAPE YAKATAGA	X	X			X

*indicates phase I processing: June, 1976-March 1977

°indicates phase II processing: April 1977-December 1977

Figure 6 . Summary of Computer Data Processing Accomplished for each study site.

August, 1977	Phase I processing; Supervised, reflected radiation 9 channel, 7094 maps	ERIM, Ann Arbor	Lyzenga, Marinello
September, 1977	Phase I results sent to Sponsor for analysis	Alaska	Bruce, Zimmerman
April, 1977	Interim Report, describing Phase I progress	ERIM, Ann Arbor	Polcyn, Lyzenga
August, 1977	Beginning of Phase II processing; Supervised 4 channel, interactive mode/MIDAS maps	ERIM, Ann Arbor	Zimmerman, Gnagy, Roller, Marinello
September, 1977	Paper given at Symposium		Zimmerman, Gnagy
October, 1977	Completion of Phase II Processing: Supervised thermal maps, and unsupervised reflected and reflected and thermal 4 channel, 7094 maps	ERIM, Ann Arbor	Roller
December, 1977	Writing of Final Report	ERIM, Ann Arbor	Roller, Polcyn

Before beginning the discussion of the specific data processing for the first study site, a brief description will be given of the preliminary data reformatting steps involved in getting the data ready to process. These steps were common to all three study sites. By discussing them here we can avoid repeating the description of reformatting as each of three study sites in turn is discussed.

The data collected by the scanner is recorded in the aircraft in high density digital form on a magnetic tape (HDDT). The HDDT must then be converted into a computer compatible tape (CCT). Once a CCT is produced it must then be reformatted into a form that is acceptable by the software that is being used to analyze the data. The 7-track ERIM format CCT's used for this project were prepared using the University of Michigan's Amdahl 470 computer facility. A total of nine data sets were converted: four over Zaikof Bay (Runs 4-7); three over Latouche Point (Runs 9, 10, and 12); one over Cape Yakataga (Run 21); and, one of the calibration panels at Cordova Airfield (Run 15). In the rest of this chapter the specific processing techniques are described that were applied to the data sets for each study site.

4.1 ZAIKOF BAY

All of the processing for the Zaikof Bay study site was performed using data collected during Run 7. Run 7 was the low altitude run (400 ft AGL) flown parallel to the shoreline. Two airphotos of the study site are shown in Figure 7.

4.1.1 SUPERVISED RECOGNITION PROCESSING

Three kinds of supervised recognition processing were applied to Run 7 data. The first kind of recognition processing was done during Phase I. It was accomplished using nine channels of reflected radiation and the 7094 computer by ERIM analysts using just the air photos to guide training set selection (no ground truth). The second kind of supervised processing of Zaikof Bay data was accomplished in Phase II. Here NOAA Auke Bay Fisheries Laboratory personnel helped prepare recognition maps in an interactive mode using the MIDAS computer and four channels of reflected radiation. The third kind of supervised processing involved analyzing the information content of the thermal band and consisted of level-slicing techniques.

4.1.1.1 REFLECTED RADIATION STUDIES

In Phase I and the interactive mode processing of Phase II, it was decided not to include the thermal channel in the

a. Low-Oblique photo taken 14 June 1976

b. Vertical photo taken 27 June 1976

FIGURE 7. AIR PHOTOS OF ZAIKOF BAY STUDY SITE

recognition processing. The reason for this decision was that thermal data is closely coupled to ambient environmental conditions, and the results obtained using it -- either good or bad -- might not be representative of what can be done under normal conditions or repeatable. Results based on reflected radiation would represent a measure of performance based on the fundamental properties of the materials imaged, and hence should be repeatable and serve as a useful, conservative guide to the specification of an operational survey system.

In the first reflected radiation study all nine channels of useful visible and near-infrared data were processed using the 7094 computer. In the second study the four channels that were found best (i.e., those channels that were most valuable for spectrally discriminating between training sets) in study one were used. The second study was limited to four channels because it was done on the MIDAS computer whose classifier was designed to accept no more than four channels of input data. For Landsat data analysis and most aircraft multispectral data processing this now has been shown to be adequate.

Study 1: Nine Channels of Reflected Radiation/No Ground Truth/ 7094 Computer

The selection of training sets for this study was made by ERIM analysts from air photos of the study site annotated by Dr. Zimmerman, who headed the ground truth effort. Line and point numbers for each training set were obtained from training sets drawn on graymaps of channel 9 (NIR-2). Training set locations were determined by first roughly localizing them on the graymap using the annotated photography and then fine "tuning" the location of their boundaries by matching them up with zones of contrast observable in the graymap. In this way training sets were established for five types of material, including algae, rock, water, grass and trees. For algae, six training sets in all were used.

Classification of the data was performed on the 7094 computer using all nine available visible and near-infrared spectral bands. The recognition results are shown in the map in Figure 8.

This map was sent to Dr. Zimmerman for evaluation in September, 1976.

Study 2: Four Channel/Interactive Mode/MIDAS Computer

In August, 1977 Dr. Zimmerman and Mrs. Gnagy visited the ERIM facility in Ann Arbor to learn more about digital computer data processing techniques as applied to multispectral remote sensing data. While they were here they assisted in actual data processing on the MIDAS computer.

The MIDAS computer is designed for interactive data processing, in which the computer prompts the operator with several alternatives and the operator then chooses what he wishes to do, with the option to repeat a step until he is satisfied with the results.

In the Phase I processing we felt our most serious limitation was inadequate knowledge of the study site which made training set selection difficult and potentially inaccurate. For example, the ERIM analysts were able to identify seven distinct contrast zones where we knew algae occurred, but Dr. Zimmerman later informed us he felt only four basic species associations were present. Presumably, we were mistaking horizontal vegetation density classes with the species associations for additional types.

To avoid misplacing training sets and take advantage of Dr. Zimmerman's first-hand knowledge of the study, it was decided that he should pick the training sets. This was done in the following manner: A single band image similar to a graymap was produced on a television monitor screen that is part of MIDAS. A cursor was then moved to points which were used to designate the corners of a polygon which enclosed the area to be used as a training set. As the corners were identified, the computer automatically drew in the connecting side of the polygon. When the polygon was completed the training set characterization statistics used in the classification process were generated. These statistics include the mean and standard deviation for each channel.

FIGURE 8. LEGEND

algae	light red olive brown dark green light green orange light purple	rock	dark grey black	grass: trees: water: unclassified:	yellow light orange blue white

Scene: 1,554, 1, 1, 790, L

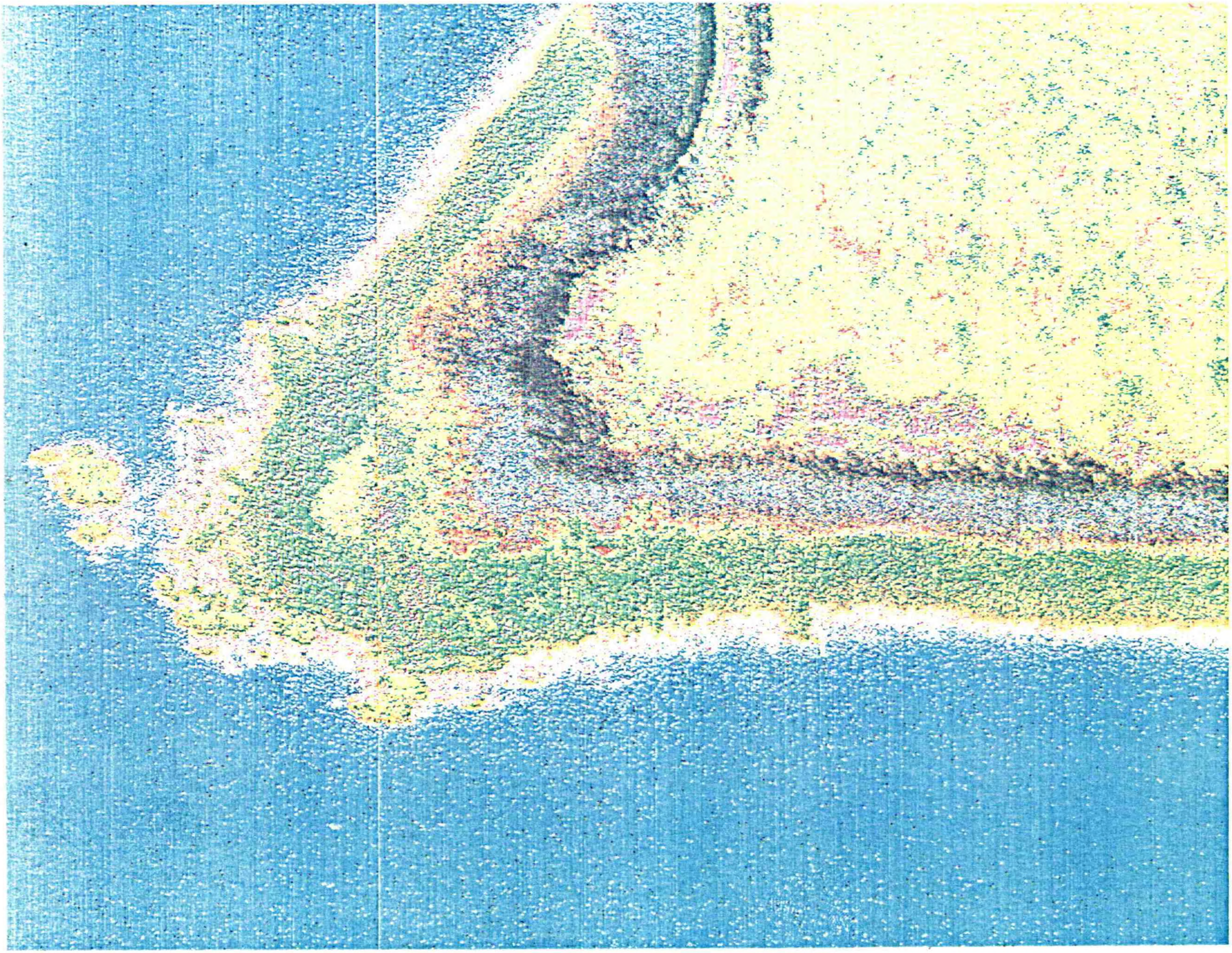


FIGURE 8. SUPERVISED RECOGNITION MAP OF ZAIKOF BAY: 9 CHANNELS OF REFLECTED RADIATION/NO GROUND TRUTH/7094 COMPUTER

Upon completion of training set selection, the data was immediately classified. The MIDAS recognition processor uses the maximum-likelihood decision rule with a priori probabilities. Use of this rule assumes the things you want to recognize are characterized by multi-model Guassian multivariate distributions. The variables in this case being the different signal levels in the various spectral bands.

As indicated in the title of this sub-section, only four channels of data were used. The reason for this is that the classifier of MIDAS was only designed to handle a maximum of four input channels. Thus, we had to select only four channels for further processing from the nine used in the preceeding study.

To make this selection we used the results of the Phase I processing to guide our choice. We did this by using the statistics of the training sets selected in Phase I as input to a computer program called ALCHAN. ALCHAN was written to statistically find the best subset of channels by searching through all possible subsets. "Best" in this case means minimizing an average pairwise linear approximation of the probability of misclassification.

ALCHAN was run three times using the three sets of Phase I signatures from the three study sites. The results are listed in Table 3.

TABLE 3
FOUR CHANNEL SUBSET SELECTION FOR
SUPERVISED PROCESSING BY STUDY SITE

Study Site	Best Combination of Channels
1. Zaikof Bay	9, 8, 4, 6
2. Latouche Point	9, 4, 8, 10
3. Cape Yakataga	9, 5, 8, 4

Channels 9, 8, and 4 were unanimously selected on the basis of all three study sites. For the fourth channel, a three way tie existed between channels 6, 10, and 5. Channel 5 was ultimately selected because it placed higher in usefulness (second in contrast to fourth for channels

6 and 10) and it had a better signal-to-noise ratio. Thus, for all four channel processing except the unsupervised work the input data was:

TABLE 4

SUBSET OF CHANNELS SELECTED FOR PHASE II REFLECTED RADIATION STUDIES

Channel	Spectral Band	
9	0.725-0.905	NIR-2
8	0.680-0.760	NIR-1
5	0.540-0.640	yellow
4	0.520-0.600	green

Dr. Zimmerman selected seven training sets and then the data set was classified. The results are shown in the recognition map in Figure 9. A copy of this map accompanied Dr. Zimmerman when he left Ann Arbor.

4.1.1.2 THERMAL RECOGNITION STUDY

Chronologically, this study was carried out <u>after</u> the unsupervised recognition processing of the Zaikof Bay data set described next. Yet, because the technique used is a supervised one, it is included here. The technique is a simple one and it is called level-slicing. It consists of color coding ranges of values in a single channel of data to make a map-like image.

In the case of the thermal band we examined the spatial distribution of pixels with the same temperature and were able to construct the map shown in Figure 10 by grouping together objects with similar temperatures. Although boundaries between some scene classes are not as clear as in the proceeding maps, one thing that stands out totally unambiguously in this map is the zone of rock rubble that occurs between the shoreline and the vegetated uplands.

FIGURE 9. LEGEND

Algae

alario:	red	water:	blue
ulva:	green	rock:	black
Fucus:	gold	trees:	yellow
Mixed:	orange	unclassified:	white

Scene: 1,550,1,1,790,1

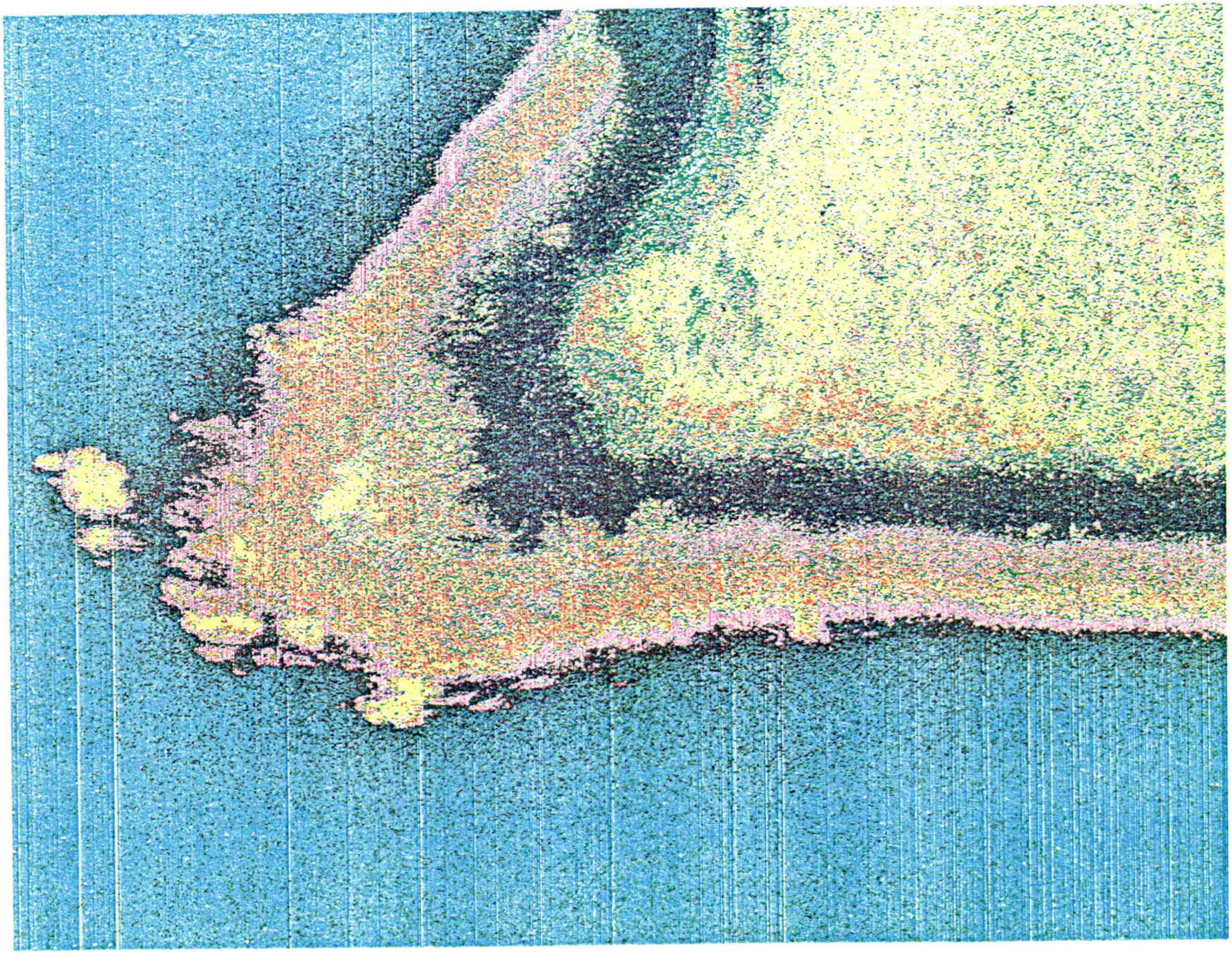
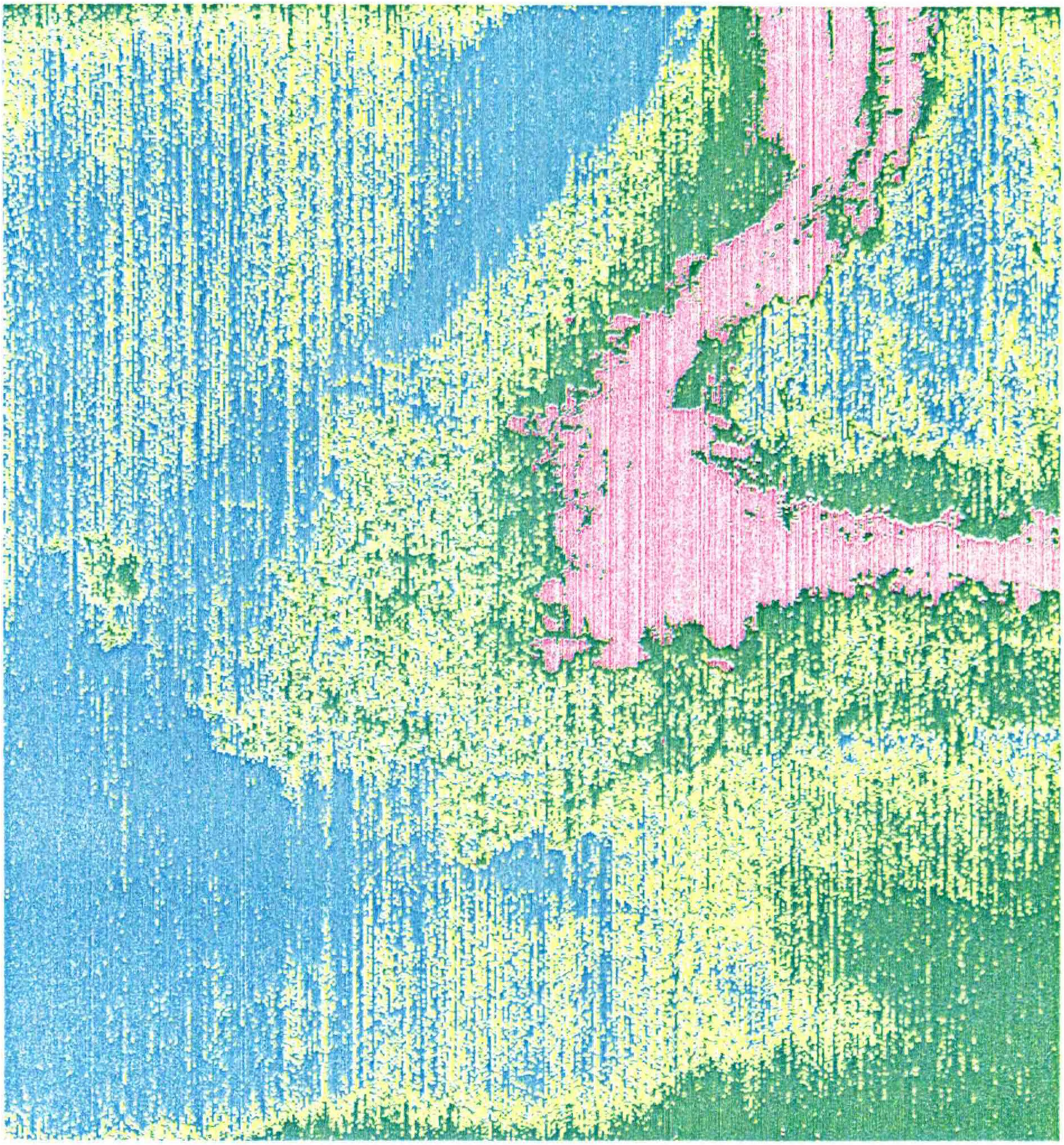


FIGURE 9. SUPERVISED RECOGNITION MAP OF ZAIKOF BAY: FOUR CHANNELS OF REFLECTED RADIATION/INTERACTIVE MODE/MIDAS COMPUTER.



LEGEND

Very cool: blue warm: green

cool: yellow Very warm: red

Scene: 1,400,1,1,790,1

FIGURE 10. THERMAL CONTOURING OF ZAIKOF BAY

4.1.2 UNSUPERVISED PROCESSING: FOUR CHANNELS OF REFLECTED RADIATION 7094 COMPUTER

This study actually took place in parallel with the interactive mode processing involving Dr. Zimmerman and the MIDAS computer. Its purpose was to provide a comparison of unsupervised and supervised techniques on the same data set. Training sets for the unsupervised recognition processing were obtained by "clustering". A brief description of clustering is contained in Section 2.1.

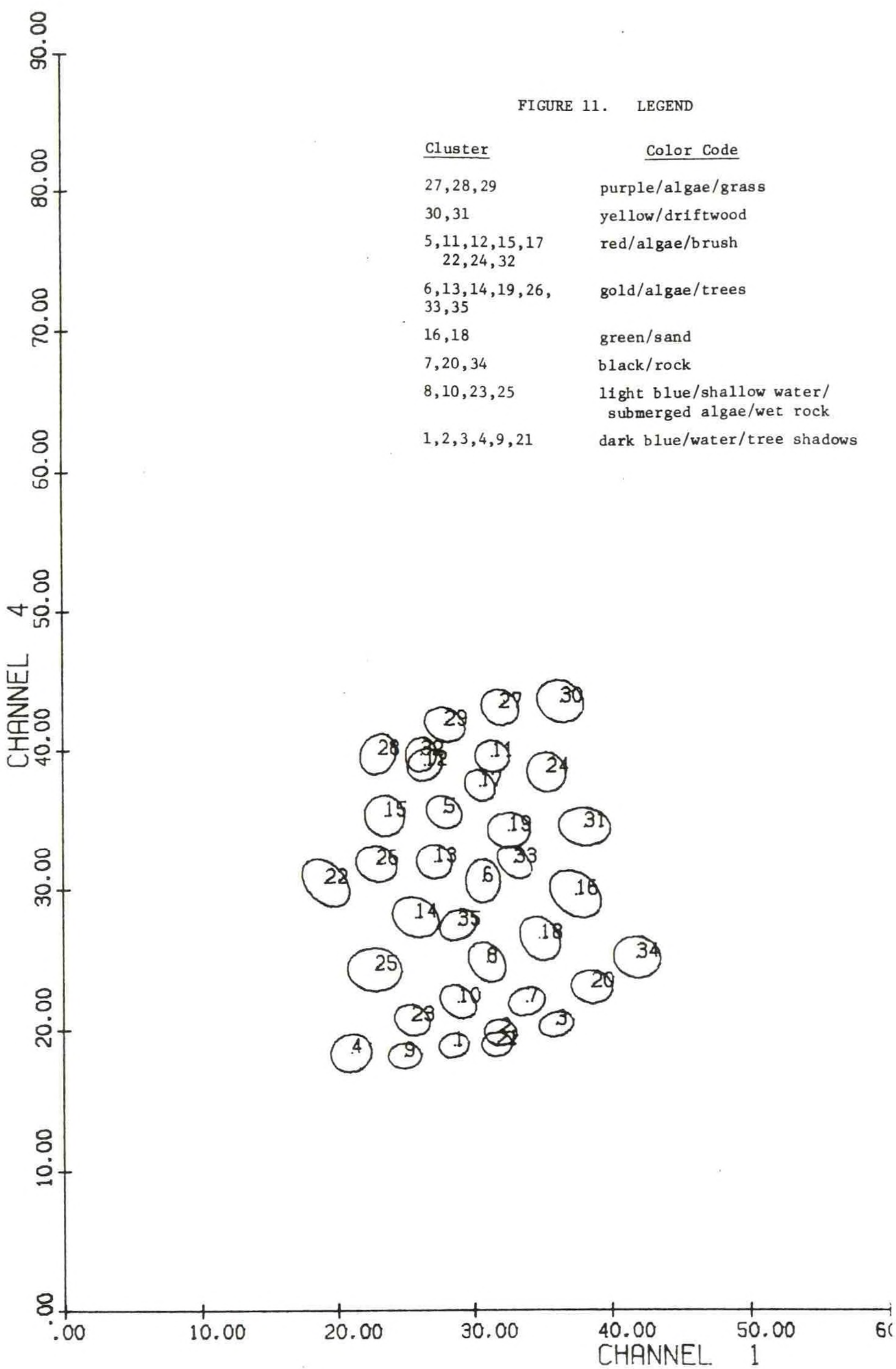
The clustering algorithm identified 35 unique spectral signatures. Using these signatures the data was then classified using the 7094 computer.

Before a map could be produced, however, it was necessary to color code the clusters. To aid in properly assigning colors to clusters we analyzed EPLOTS and video displays of the candidate color combinations on the MIDAS video display unit. EPLOT's are a two dimensional representation of the chi-square distribution of the training set signatures. The EPLOT for the Zaikof Bay clustering output is shown in Figure 11. The colors by which the clusters in the EPLOT are coded correspond to the colors assigned to the pixels classified as belonging to that cluster in the recognition map output.

The recognition map itself is shown in Figure 12. In many ways this map appears to be the best overall representation of the Zaikof Bay study site. The implications of this will be dealt with in Chapter 5.0. We now turn to the processing of the Latouche Point data set.

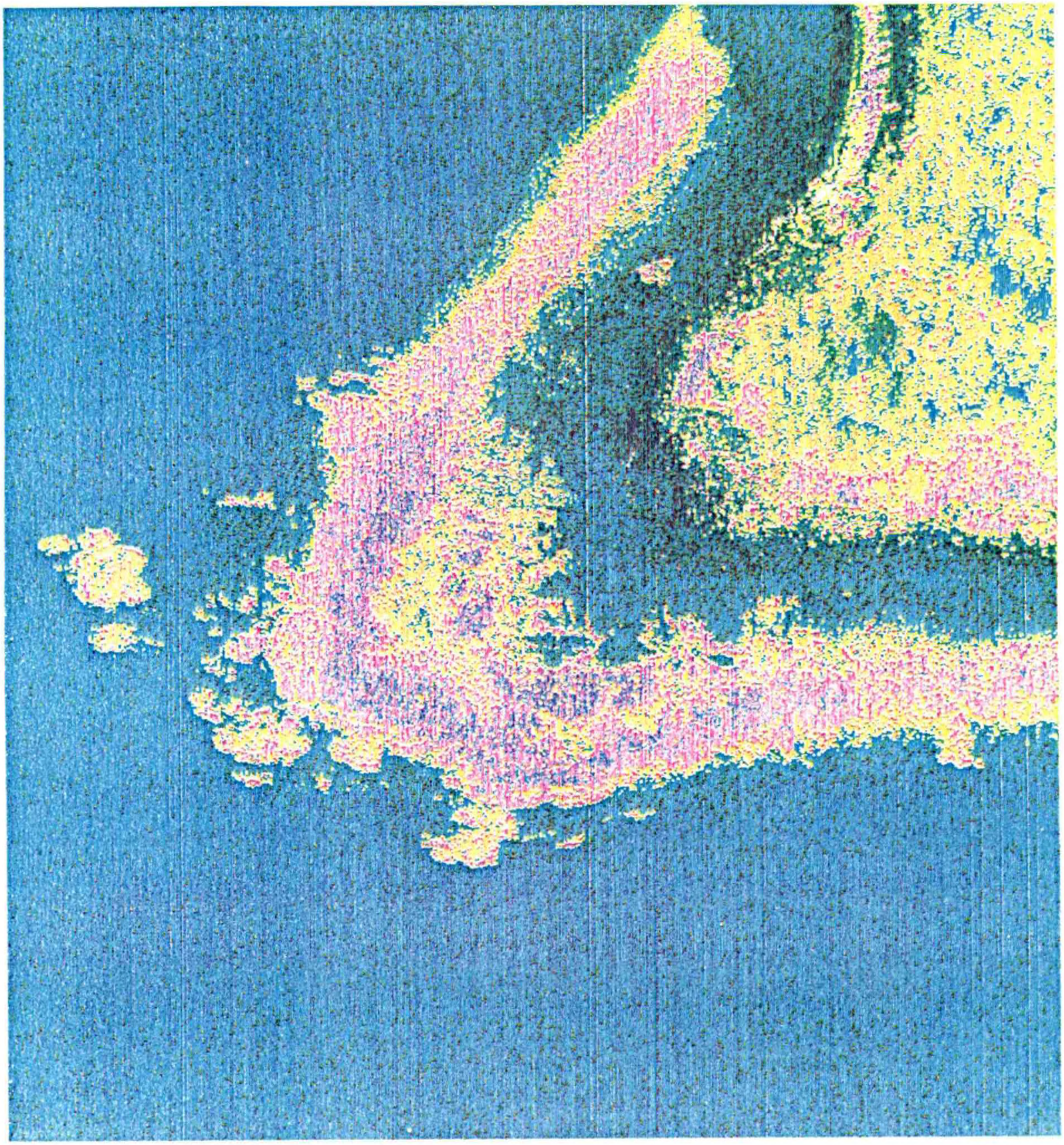
4.2 LATOUCHE POINT

The processing for the Latouche Point study site was performed on the data collected during Run 9. Run 9 was made at 1,000 ft AGL parallel to the beach. A vertical airphoto of the study site is shown in Figure 13.



Cluster	Color Code
27,28,29	purple/algae/grass
30,31	yellow/driftwood
5,11,12,15,17 22,24,32	red/algae/brush
6,13,14,19,26, 33,35	gold/algae/trees
16,18	green/sand
7,20,34	black/rock
8,10,23,25	light blue/shallow water/ submerged algae/wet rock
1,2,3,4,9,21	dark blue/water/tree shadows

FIGURE 11. EPLOT OF CLUSTERING-DERIVED TRAINING SETS USED IN UNSUPERVISED RECOGNITION PROCESSING OF THE ZAIKOF BAY DATA SET.



LEGEND

water/tree shadows
shallow-water/submegent algae/wet rock: light blue
algae/trees: gold
algae/bush/red
algae/grass/purple
sand: green
rock: black
driftwood: yellow and white

Scene 1,400,1,1,790,1

FIGURE 12. UNSUPERVISED RECOGNITION MAP OF ZAIKOF BAY: FOUR CHANNELS OF REFLECTED RADIATION/CLUSTERING/7094 COMPUTER

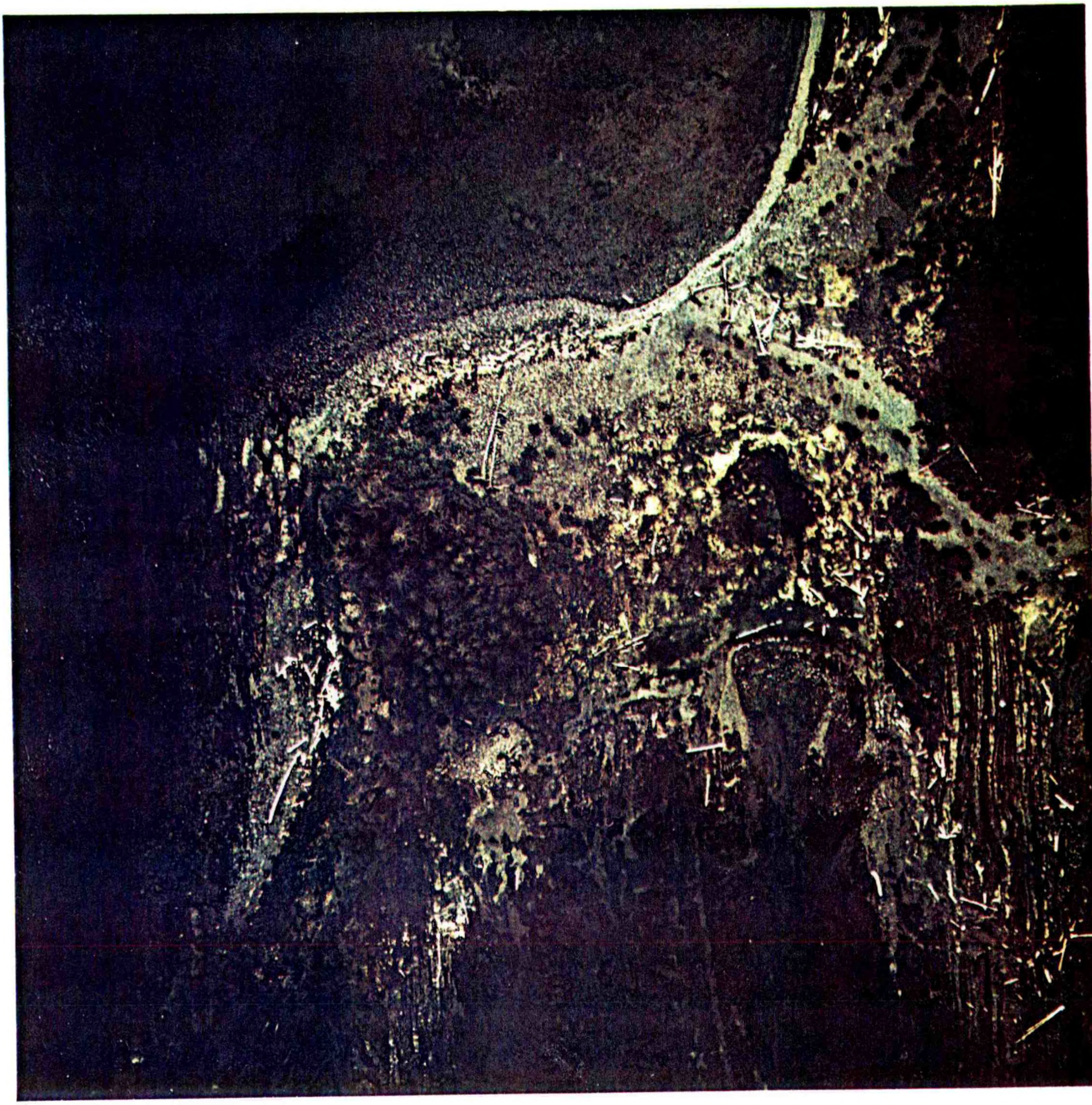


FIGURE 13. VERTICAL AERIAL PHOTOGRAPH OF LATOUCHE ISLAND STUDY SITE COLLECTED 27 JUNE 1976.

4.2.1 REFLECTED RADIATION STUDIES

The Latouche Point data set was processed at the same time as the Zaikof Bay data set with regard to reflected radiation studies.

4.2.1.1 STUDY 1: NINE CHANNELS OF REFLECTED RADIATION/NO GROUND TRUTH/7094 COMPUTER

The training set selection procedure used by ERIM analysts for this study was the same as that employed in the Phase I Zaikof Bay data processing; for a description of it refer to Section 4.1.1.1, Study 1. The only difference between this study and the Zaikof Bay study is that no annotated photos were available for Latouche Point.

The results of the classification made using the 7094 computer are shown in the map presented in Figure 14. This map was sent to Dr. Zimmerman along with the Phase I Zaikof Bay Map in September, 1976.

4.2.1.2 STUDY 2: FOUR CHANNELS OF REFLECTED RADIATION/INTERACTIVE MODE/MIDAS COMPUTER

The interactive processing of the Latouche Point data set was similar to that described for the Zaikof Bay data set in Section 4.1.1.1 Study 2, only in this case, Mrs. Gnagy did the training set selection.

The results of the MIDAS classification are shown in Figure 15. A legend was developed for this map at the time it was prepared. Unfortunately Dr. Zimmerman took it with him when he left at the end of his visit and no copy of it exists at ERIM.

4.2.2 THERMAL RADIATION STUDY

The thermal level-slice map produced for Latouche Island is shown in Figure 16. Two things it immediately aids the viewer in doing are (1) locating the boundary between deep water/submergent algae and (2) separating the dry sand, rocks, and gravel from vegetation. No unsupervised processing of the Latouche Point data set was attempted.

FIGURE 14. LEGEND

Algae:

1 light red
2 olive brown
3 dark green
4 light green
5 dark orange
6 violet
7 dark red
8 light blue
9 black

water: blue
trees: light orange
grass: yellow
rock: grey
unclassified: white

Scene: 1,600,1,1,531,1

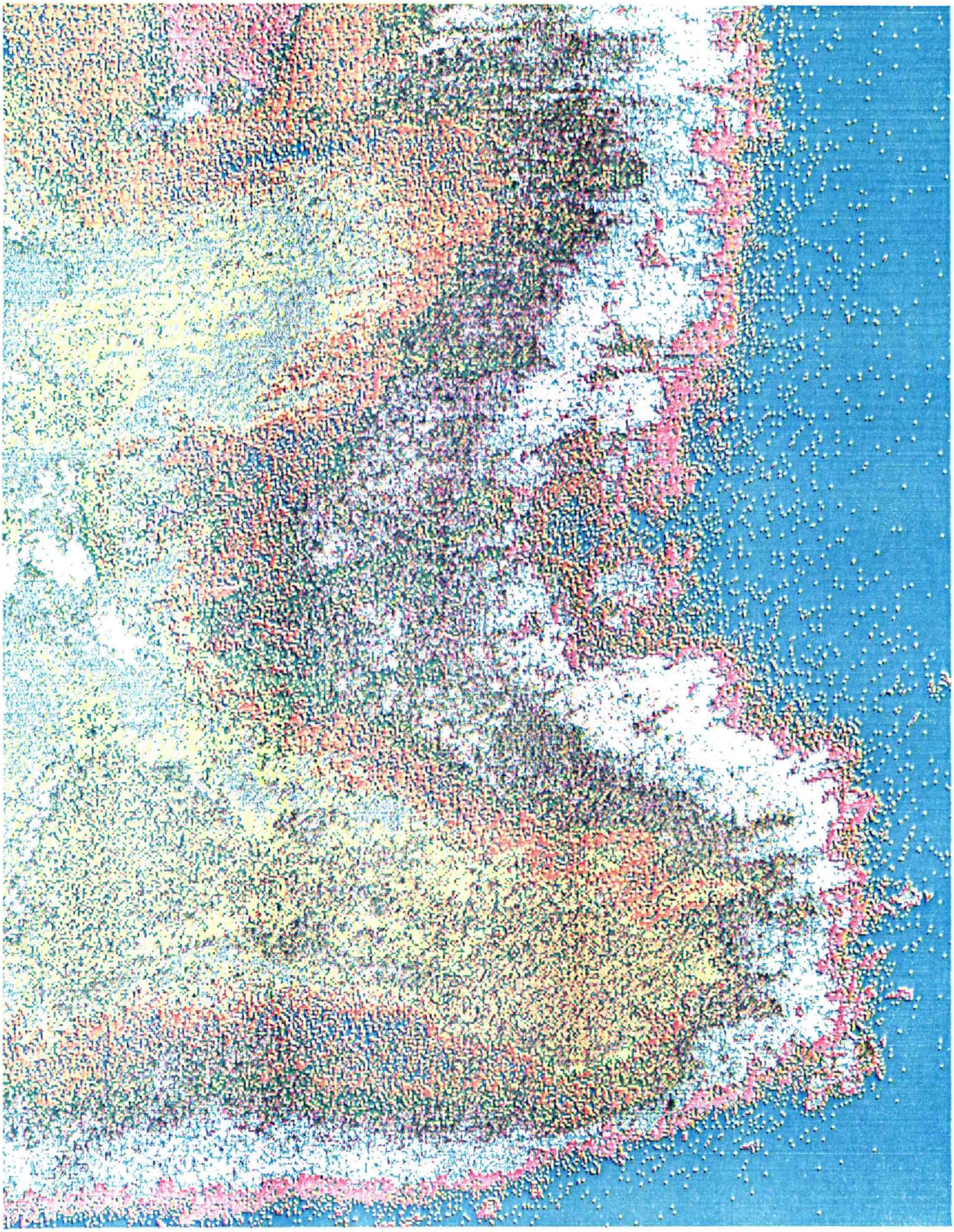


FIGURE 14. SUPERVISED RECOGNITION MAP OF LATOUCHE ISLAND: 9 CHANNELS OF REFLECTED RADIATION/NO GROUND TRUTH/7094 COMPUTER

FIGURE 15. SUPERVISED RECOGNITION MAP OF LATOUCHE ISLAND: 4 CHANNELS OF REFLECTED RADIATION/INTERACTIVE MODE/MIDAS COMPUTER

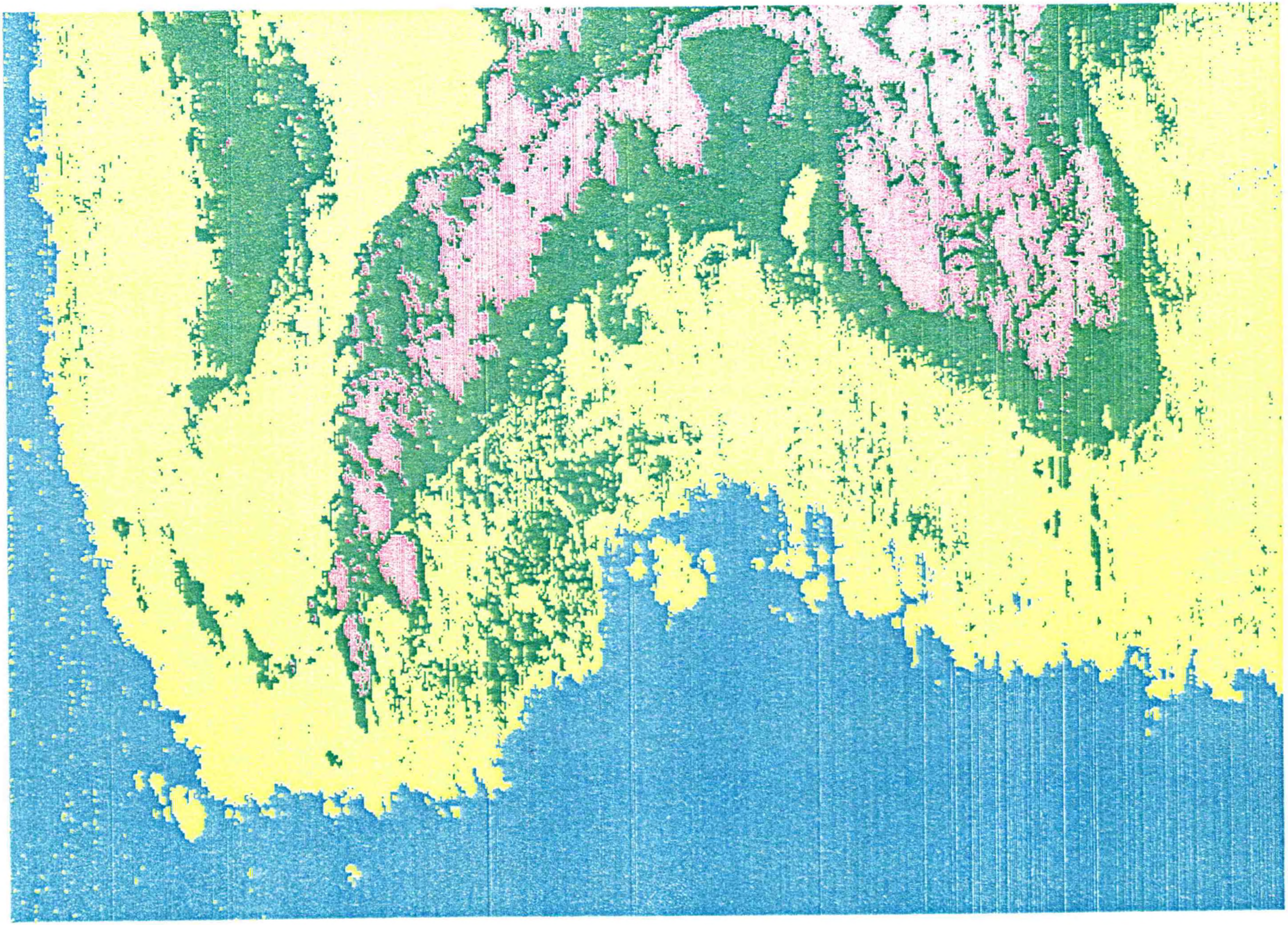


FIGURE 16. THERMAL CONTOURING OF LATOUCHE POINT

Blue: very cool, Yellow: cool, Green: warm, Red: very warm

4.3 CAPE YAKATAGA

The processing for the Cape Yakataga study site was done using the MSS data collected during Run 21. Run 21 was flown at 1,000 ft AGL parallel to the shoreline. A photo of the central portion of the study site is shown in Figure 17.

4.3.1 REFLECTED RADIATION STUDIES

The Cape Yakataga data set was processed as part of the Phase I effort, and it was intended to further process it on both the MIDAS and 7094 computer during Phase II. These plans were not fully realized, however, as explained below in Section 4.3.1.2 under Study 2.

4.3.1.1 STUDY 1: NINE CHANNELS OF REFLECTED RADIATION/NO GROUND TRUTH/7094 COMPUTER

A map was made for Cape Yakataga by the same method used to make the study 1 maps of Zaikof Bay and Latouche Point (Section 4.2.1.1). It is shown in Figure 18.

4.3.1.2 STUDY 2: FOUR CHANNELS OF REFLECTED RADIATION/INTERACTIVE MODE/MIDAS COMPUTER

An interesting situation developed when we attempted to interactively process this data set. The distribution of the algal communities at Cape Yakataga is uneven and often occurs in very narrow linear patches running along rock outcrops and beach ridges. Thus, locating training sets was very difficult. Furthermore, it was hard to produce graymaps on the MIDAS video console which exhibited contrasts similar to those seen in the air photos. It was finally concluded that manual training set selection could not be done well enough for this data set to justify spending the time and money required to complete recognition processing, and further supervised analysis was dropped.

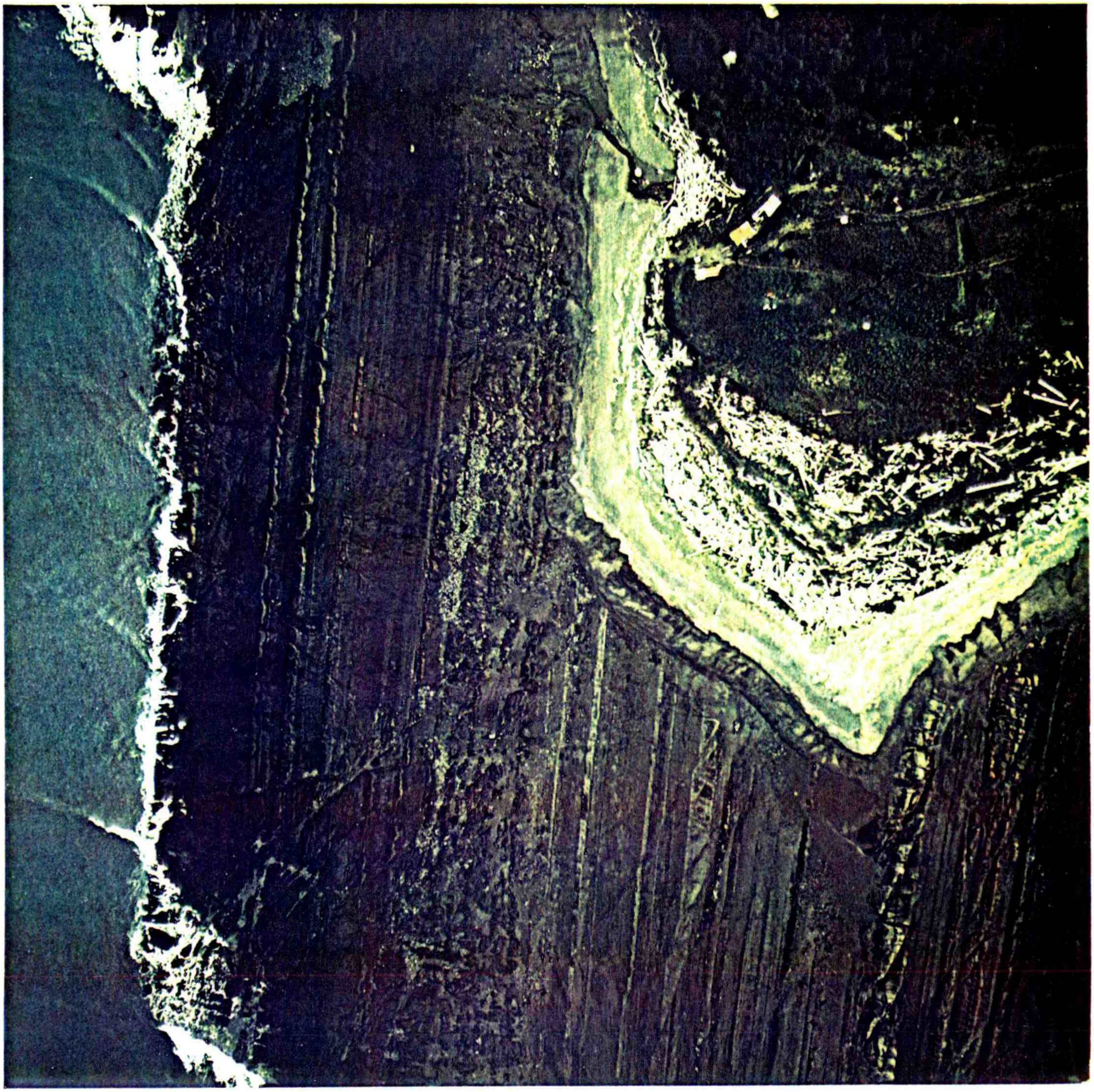


FIGURE 17. VERTICAL AIR PHOTO OF CENTRAL PORTION OF CAPE YAKATAGA STUDY SITE.

FIGURE 18. LEGEND

Algae

1: light red
2: olive brown
3: dark green
4: light green
5: dark orange
6: violet
7: dark red
8: grey
9: black

Rock

1: light blue
2: light orange

water: blue
grass: yellow
unclassified: white

Scene: 400,1000,1,185,615,1

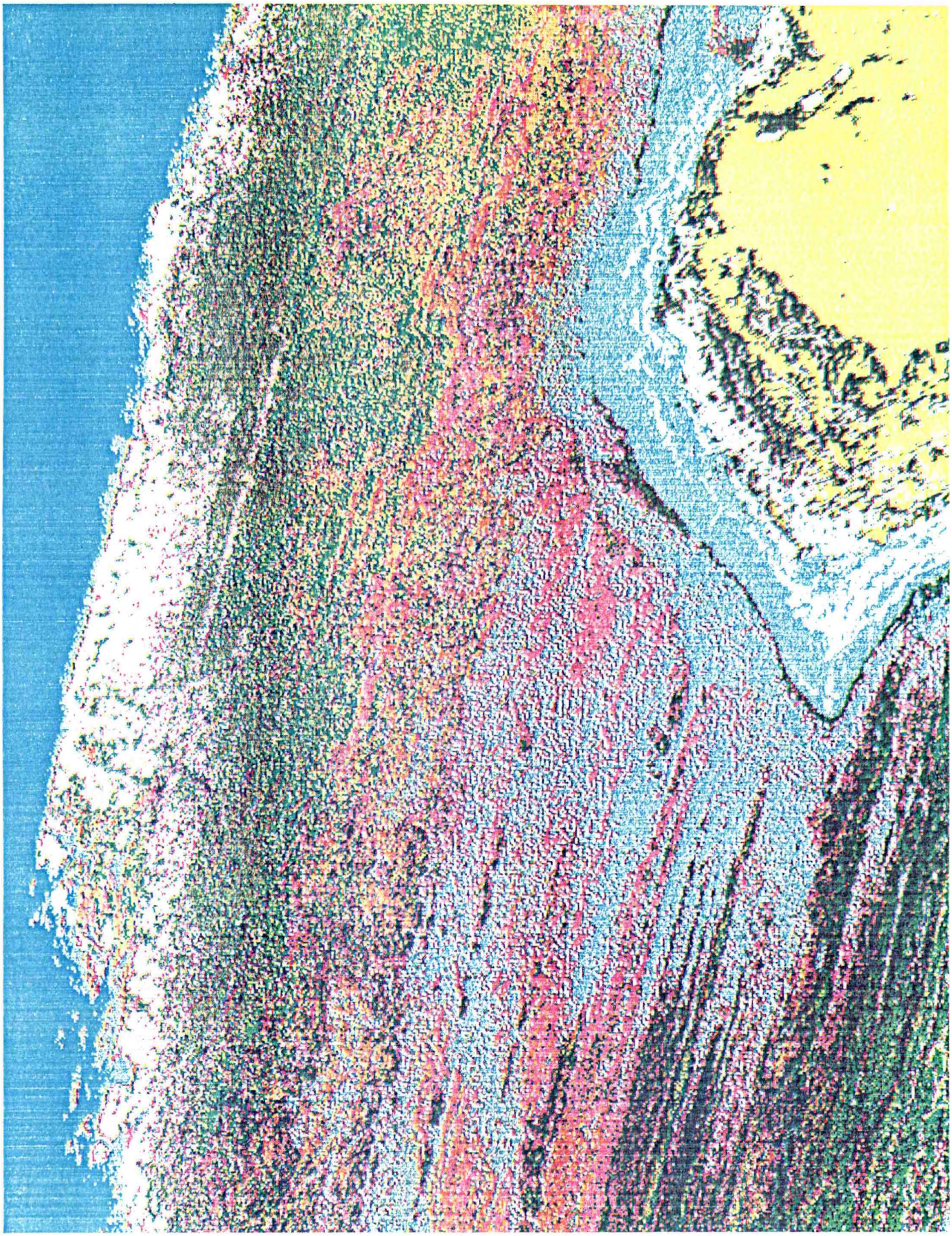


FIGURE 18. SUPERVISED RECOGNITION MAP OF CAPE YAKATAGA: NINE CHANNELS OF REFLECTED RADIATION/NO GROUND TRUTH/7094 COMPUTER.

4.3.2 UNSUPERVISED RECOGNITION PROCESSING: REFLECTED AND THERMAL RADIATION STUDY

The processing described in this section was chronologically the last to be done. It was inspired partly by the apparent improvement in the scene class separation that could be achieved by including the thermal band. For completeness we initially considered using all the reflected bands, even those that had not been used since Phase I. Thus, we began this study with 10 channels of data.

The same general approach to training set selection via clustering used for Zaikof Bay (Section 4.1.2) was used here; the only difference being that this time the clusters were based on eight channels of data and not four. We had to reduce the initial 10 channels in this study to eight because that is what the clustering algorithm was set up to handle. Based on their poor signal-to-noise ratios (Table 2) channels two and ten were eliminated before clustering. In operation, the algorithm produced 26 clusters. To find out which channels were most useful in describing the clusters, and hence best as a basis for data classification, we ran ALCHAN on the cluster signatures. The results showed that it took only four channels to essentially do as well as could be done. The four channels selected are listed in Table 5.

TABLE 5

FOUR CHANNEL SUBSET SELECTED FOR UNSUPERVISED PROCESSING

Channel	Spectral Band
3	0.475-0.555 blue-green
5	0.540-0.640 yellow
9	0.725-0.905 NIR-2
11	8.0-13.0 Thermal

Significantly, two of the channels (five and nine) are those that were selected for the four channel supervised processing subset. Channel three is a newcomer and so is the thermal band, but the latter was expected to be useful. An EPLOT for the clusters is shown in Figure 19.

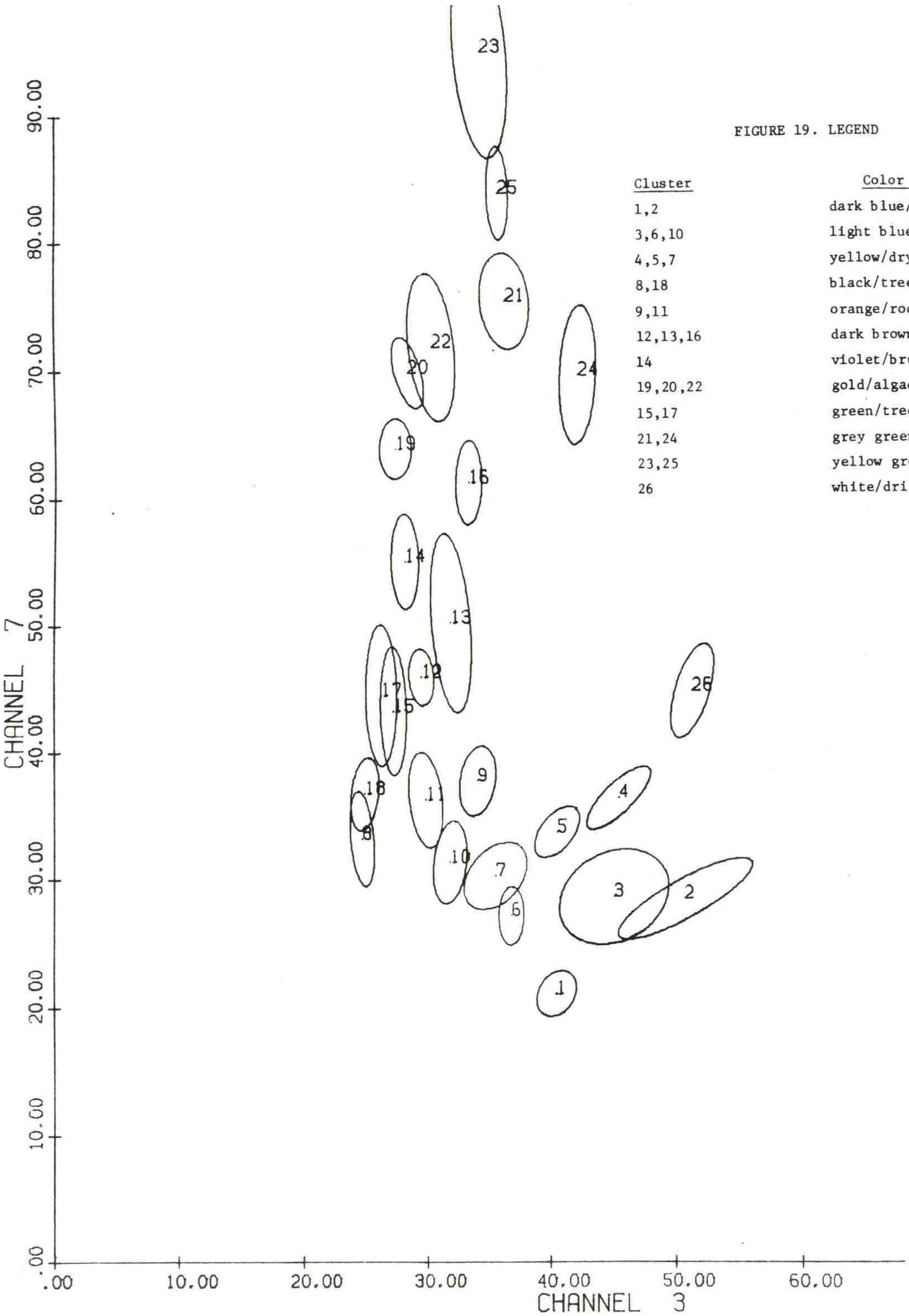


FIGURE 19. LEGEND

Cluster	Color Code
1,2	dark blue/water
3,6,10	light blue/shallow water/wet sand
4,5,7	yellow/dry sand
8,18	black/tree shadows
9,11	orange/rock-fucus
12,13,16	dark brown/algae (Rhodymenia)
14	violet/brush/algae (Rhodymenia)
19,20,22	gold/algae (alaria)
15,17	green/trees/algae (Rhodymenia)
21,24	grey green/driftwood/grass
23,25	yellow green/grass
26	white/driftwood

FIGURE 19. EPLOT OF CLUSTERING-DERIVED TRAINING SETS USED IN UNSUPERVISED RECOGNITION PROCESSING OF CAPE YAKATAGA DATA SET

The color codes assigned to the clusters are those used in the recognition map. A map of the entire study site is shown in Figure 20. An enlargement of the central portion is shown in Figure 21.

Just how good this map is will be discussed in the next chapter.

LEGEND

water: dark blue
shallow water/wet sand: light blue
dry sand: yellow
tree shadows: black
rock-fucus: orange
algae (Rhodymenia): dark brown
brush/algae (Rhodymenia): violet
algae (alaria): gold
trees/algae (Rhodymenia): green
driftwood/grass: grey-green
grass: yellow green
driftwood: white

Scene: 1,1500,1,1,790,1

FIGURE 20. UNSUPERVISED RECOGNITION MAP OF CAPE YAKATAGA: REFLECTED AND THERMAL RADIATION

FIGURE 21. LEGEND

water: dark blue
shallow water/wet sand: light blue
dry sand: yellow
tree shadows: black
rock-fucus: orange
algae (Rhodymenia): dark brown
brush/algae (Rhodymenia): violet
algae (alaria): gold
trees/algae (Rhodymenia): green
driftwood/grass: grey-green
grass: yellow green
driftwood: white

Scene: 400,1000,1,185,615,1

FIGURE 21. ENLARGEMENT OF CENTRAL PORTION OF CAPE YAKATAGA UNSUPERVISED RECOGNITION MAP

5.0
RESULTS AND DISCUSSION

The material in this chapter of the report is organized like that in the Approach (Chapter 2.0), and addresses the specific tasks listed in Figure 2.

5.1 SUPERVISED VS NONSUPERVISED PROCESSING

During the course of this project seven recognition maps were produced: three for Zaikof Bay, and two each for Latouche Point and Cape Yakataga. Of these seven maps, five were produced by supervised processing and two using unsupervised methods. With regard to the supervised maps, three of them were generated on the basis of little to no ground truth, while two of them were produced with the aid of local experts. These products form the basis of the results and analysis in the next few sections. First, we will evaluate the difference ground truth makes in supervised processing. Then we will compare the performance differences between the supervised methods in general and the unsupervised technique. Following that we will examine the tradeoffs in terms of time and cost between the two approaches.

5.1.1 GROUND TRUTH REQUIREMENTS

For this analysis we will be comparing two sets of products, each set consisting of two supervised recognition maps. The first set covers the Zaikof Bay Test Site (Figures 8 and 9) and the other covers Latouche Point (Figures 14 and 15).

Beginning with the Zaikof Bay maps, perhaps the first thing one notices is that water recognition is better for the "no ground truth" map. Water recognition is something we want to discount immediately as being seriously affected by a lack of ground truth. Most likely the better water recognition of Figure 8 is due to the information contained in the additional spectral bands used in its preparation.

We do not, however, think this is true of other differences we have noted. For example, the land/water boundary is better in Figure 9. Quite possibly Dr. Zimmerman's intimate knowledge of the width of the first algal zone helped him place his training set for this type more accurately. Dr. Zimmerman's knowledge presumably also helped him accurately locate the training set for the Mixed Zone, which was not recognized (and presumably not even trained for) in Figure 8.

Figure 9 is not perfect, however, because the Mixed Zone is confused with brush. A further observation we make at this point is that Figure 9 appears more "grainy", i.e., the algal species recognition (with the exception of Alaria) is quite interspersed and does not exhibit as clearly the zonation apparent in Figure 8 or for that matter in Figure 7. Which map is a truer representation of the ground we at ERIM do not know, but our opinion is that reality actually lies somewhere between the two.

One further thing we should like to point out here is that the further away from the shoreline or tree line that Dr. Zimmerman tried to pick training sets, the harder he found it to accurately locate himself in the video graymap. This experience points out the fact that even the best ground truth may be hard to apply to remote sensing data and a big ground truth effort is no guarantee of fool-proof processing. In general, however, we feel that the local experience of the ground truth team did contribute to a better map in the case of the Zaikof Bay study site.

The complexity of the Latouche Point study site makes it very difficult to reach even qualitative conclusions. The only obvious difference between the no ground truth map (Figure 14) and the Interactive Mode map (Figure 15) is that deep water appears better recognized in Figure 14, probably for the same reason it does in Figure 8, the Zaikof Bay set. Many of the major patterns (not necessarily coded in the same colors) in both maps (Figure 14 and Figure 8) appear to represent similar vegetation zones. Thus, we would not be suprised to learn that the accuracies of both maps are similar, so for this study site we may have an example of where having good truth did not necessarily improve recognition performance.

5.1.2 RECOGNITION PERFORMANCE EVALUATION

For comparing the results of supervised and unsupervised recognition processing we again have two sets of maps. These map sets cover Zaikof Bay and Cape Yakataga. For Zaikof Bay there are three maps (Figures 8, 9, and 12) and for Cape Yakataga there are two maps (Figures 18 and 20).

One's initial reaction to Figure 12 of Zaikof Bay is that it appears "cleaner" than the other two maps. There are several reasons for this: the first is that the shoreline is more accurately represented here by the light blue/gold interface than in the other two maps. This can be verified by closely inspecting the vertical airphoto in Figure 7. The submergent zone that appears as pink in Figure 8 is light blue in Figure 12, but is poorly defined in black in Figure 9. On the other hand, the inland rock zone was not well recognized (Figure 12). A band of dark blue appears in the center of the rock zone in Figure 12 (look closely!) indicating some confusion with deep water. This confusion does not occur in Figure 9 and only to a limited degree in Figure 8. The fact that a lot of light blue occurs in Figure 12 does not indicate serious error and is in fact nearly the same situation that exists in Figure 9, where the shallow water zone is similarly mapped in the same color as part of the rock area. The only difference is the color coding, and the association one makes with the colors used.

Grass recognition in Figures 9 and 12 appears similar and better than that in Figure 8. Brush recognition, however, looks similar in Figure 8 and Figure 12, which both look better than Figure 9. Sand recognition also looks about the same in Figures 12 and 8 and in both cases less "grainy" than Figure 9. Individual driftwood logs can be spotted in both Figures 12 and 9, but the clearest representation of the large pile of driftwood in the right side of the scene appears in Figure 12.

With regard to the accuracy of the algal zone mapping, it appears that Figure 12 combines the best features of both Figure 8 and 9. The Alaria Zone (red) of Figure 9 is the light blue of Figure 12. The Fucus Zone of Figure 9 (yellow) is better defined and appears more cohesive, as it probably is on the ground, in Figure 12 (gold); and the same is true of the Ulva (green) and Mixed (orange) zones of Figure 9 which probably correspond with the pink and violet zones respectively of Figure 12. Another major benefit shared by both Figure 8 and Figure 12 is the better definition of beach topography. The many rock ridges, boulders, fissures, etc., that help to orient one's self clearly stand out in Figure 12. Thus, for the Zaikof Bay data set it appears, on a qualitative basis, that clustering, i.e., the unsupervised approach, produced results as good if not better than the supervised methods.

An examination of the unsupervised recognition map of the entire Cape Yakataga study site (Figure 20) and a comparison of the enlarged supervised and unsupervised maps (Figures 18 and 21, respectively) of its central portion lead to essentially the same conclusions. Overall, the clustering technique has again resulted in a "cleaner" map, and a map with more apparent topographic and geomorphic detail. Comparison of the spatial occurrence of the cluster recognition results shown in Figure 21 with air photos annotated by Ms Gnagy on which she roughly outlined the areas where the most common type of algae occur on the study site, has tempted us to tentatively apply the names seen in the legend to the color classes indicated. Shoreline detail also appears more accurate in Figure 21 than Figure 18, compared with the photo in Figure 17.

The one major difference between the two maps is the percentage of the littoral zone that is classified as algae. Figure 18 has much more of its center portion designated as algae. What has apparently occurred, is that in the absence of ground truth, different colors of sand have been mistaken for algae and training sets established to recognize these "zones" as well. Renaming the "algae classes" that occur in this zone as sand and color coding them accordingly would probably produce a map more similar to Figure 21. For example, consider what Figure 8 would look like if the dark red, light orange, dark orange and gray algae classes were coded light blue like the Rock 1 class. The result would be a fairly homogenous central map portion like that of Figure 21.

So, for Cape Yakataga, as with Zaikof Bay, it appears that unsupervised recognition techniques have produced better results. We expect that quantitative evaluation of recognition accuracy will bear this conclusion out, and look forward to hearing the results of such analyses which we expect the sponsor will undertake.

5.1.3 TIME AND COST CONSIDERATIONS

Representative time and cost statistics for what it would take to do a given remote sensing inventory project operationally are among the most difficult figures to obtain in a research environment. This project is no exception. Simply using the expenditures and schedules experienced during the course of the project would hardly be fair. Neither do we want to ignore what we learned and simply extrapolate from commercial operations that bear a faint resemblance to the Alaska survey situation. In order to be totally responsive to the sponsor's needs it is necessary to use elements of both approaches, and this is what we have done.

In the following discussion we have used the schedules, difficulties experienced, and results obtained from the present project, but in a relative sense, to look at the time, staff, and supporting resources required to conduct the type of airborne survey evaluated in this study, while cost data has generally been derived from actual operational survey projects with similar instrumentation and flight plan specifications and data processing methods.

A logical place to begin cost analysis is with data collection. To provide a basis on which to determine costs a hypothetical survey project was postulated. In this hypothetical project we planned to accomplish all the necessary flying, including transit time, within one month. Transit time of the aircraft to and from Alaska and to get on station for each data collection run is estimated to require 60 flight hours. Forty hours of data collection was budgeted in, which, since 30 flight miles of data can be collected in one hour, means that 1200 miles of data can be collected. If we assume 10 days for travel to and from Alaska, the aircraft will be on station for 21 days. If we further assume that weather conditions are suitable, for data collection one of three days (cloudfree tables; ASP, 1968), then seven days are available for flying in which to use the 40 data collection hours. This works out to an average mission length of six hours, during which both scanner data and color photography (70 mm) are collected.

In developing the cost figures for data collection we have done it two ways. In Mode I we have figured expenses on the basis of commercial rates we encountered during the data collection phase of this project. In Mode 2 we have figured costs on what we think it would cost if ERIM collected the data using its own aircraft and scanner. These figures are broken down in Table 6 and followed by an explanation of how they were derived.

TABLE 6

Mode 1: Lease a commercial scanner and install it in a rental plane

Mode 2: ERIM's M-8 scanner in an ERIM aircraft

Category	Mode 1 Cost	Mode 2 Cost
Labor	7,000	34,000
Travel	7,000	14,000
Materials	4,000	4,000
Aircraft	25,000	14,000 (POL)
Scanner	53,000	0
TOTALS	96,000	66,000

Breakdown of Expenses

Labor:

Mode 1: salary and overhead of technician for one month

Mode 2: salary and overhead for a five-man crew for one month; one crew chief, two pilots, one technician, one scanner operator

Travel:

Mode 1: airline ticket and per diem of technician and pilot: \$80 day x 30 days x two persons = \$6,000 x two x \$500/ticket = \$7,000

Mode 2: per diem of five-man crew for one month and two commercial airline tickets

Materials:

Mode 1: HDDT's, film, liquid nitrogen, camera rental, miscellaneous

Mode 2: same as above except for camera rental

Aircraft:

Mode 1: Rental of commercial aircraft (e.g., twin-engine Cessna 301) @ $250/hr x 100 hrs for 30 days = $25,000

Mode 2: The only cost associated with the use of an ERIM aircraft is for gas, oil, lubrication and maintenance. The figure quoted is for 100 hours of operation.

Scanner:

Mode 1: This figure reflects the rental cost $1,000/day and installation cost $5,000 of a commercial scanner such as a Bendix M^2S unit.

Mode 2: There is no charge for use of the ERIM-8 scanner beyond personnel and aircraft expenses covered earlier.

Based on the above data a data collection cost per flight line mile can be calculated for each mode of operation. These figures are:

Mode 1: $80/flight line mile

Mode 2: $55/flight line mile

On the basis of costs alone, it appears that Mode 2, having ERIM collect data, is preferable. Another point worth mentioning at this time is that ERIM scanner data has traditionally been the finest multi-spectral data routinely collected. Furthermore, the spectral bands in the ERIM scanner are located differently from those in other multispectral systems, based on many years of research in terrain analysis, and we feel they represent the optimum set-up for vegetation mapping.

If it was decided to go the Mode 1 commercial route, this is one place a government agency potentially could save money by using a government-owned aircraft and flight crew.

Data collection is only one side of the coin, however, before any decisions can be made the data has to be processed, maps made, and information extracted from them. These steps comprise the data processing effort of our hypothetical survey project. For the sponsor to be able to evaluate the consequences of their alternatives in terms of cost as well as performance we felt it was necessary to provide scenarios representing the main approaches to handling the data processing. On the basis of the results of this project and our experience, we identified three possible scenarios for handling the volume of data collected in this hypothetical project. These are:

Scenario 1: Supervised digital recognition processing

Scenario 2: Unsupervised digital recognition processing

Scenario 3: Unsupervised digital recognition processing on MIDAS

Each of these three scenarios will be discussed in turn and then a cost comparison and summary made.

Before we turn to discussion of the individual scenarios, however, let us make a few more assumptions about the nature of the hypothetical survey project. First, processing all the data digitally is unreasonable. We are talking about 1200 data miles, with 2100 scan lines per mile and 800 points across each line. This amounts to more than 1.68 million pixels per mile or a total of over two billion pixels of data x the number of channels collected. This is the equivalent of 266 Landsat frames. To avoid the expense of digitally processing all of this data we recommend the following approach in which all the data is utilized but processing costs are greatly reduced.

In most environmental surveys it turns out that only a fraction of all the data collected is ever used in decision making. Sampling is one reason for this, data collection problems are another, often only a few sites are actually found to be of interest, and so on. We feel this could well be the case with our hypothetical project. We have thus assumed that we really only need to digitally process only 1/6 of the total data set or 200 data miles. The next question that logically arises is which 200 miles? We feel that candidate sites for digital processing can be effectively selected on the basis of visual analysis of analog playback of all the data.

Analog playback is an electronic process whereby a channel of scanner data is electronically modulated in the form of a CRT pulse and recorded on film as a 70 mm filmstrip (see Figure 22). The result is a strip of imagery resembling aerial photography.

Then, biologists, using this imagery, vertical photography, maps and local knowledge of the area, can zero in on those sketches of shoreline which they feel appear to contain sensitive algae communities about which they want more information.

The description of the three scenarios for digitally processing 200 flightline miles is as follows.

SCENARIO 1: Supervised Digital Recognition Processing

This type of processing is the most conventional form of remote sensing data processing. The general steps in the sequence are diagrammed in Figure 23.

A brief description of the supporting processing for each step, plus the cost and time required to finish it, are furnished in the following breakdown and keyed to Figure 23. Computer costs are based on the rates associated with the University of Michigan's Amdahl 470/V6, a large modern general purpose time-sharing digital computer. The costs presented for each step, however, reflect the entire cost for each step, including salary and wages, overhead and computer costs. ERIM's corporate cost structure was used as a general guideline for figuring personnel expenses.

Step 1: The purpose of this step is to produce a 70 mm filmstrip image of one channel of data

Cost $2,500 Time Required: 2 weeks

Step 2: The purpose of this step is to select a subset of 200 miles of data from the original 1200 miles. This would probably require two to three persons at the GS-12 level from the sponsoring agency to be involved.

Cost: borne by the agency Time required: 3 weeks

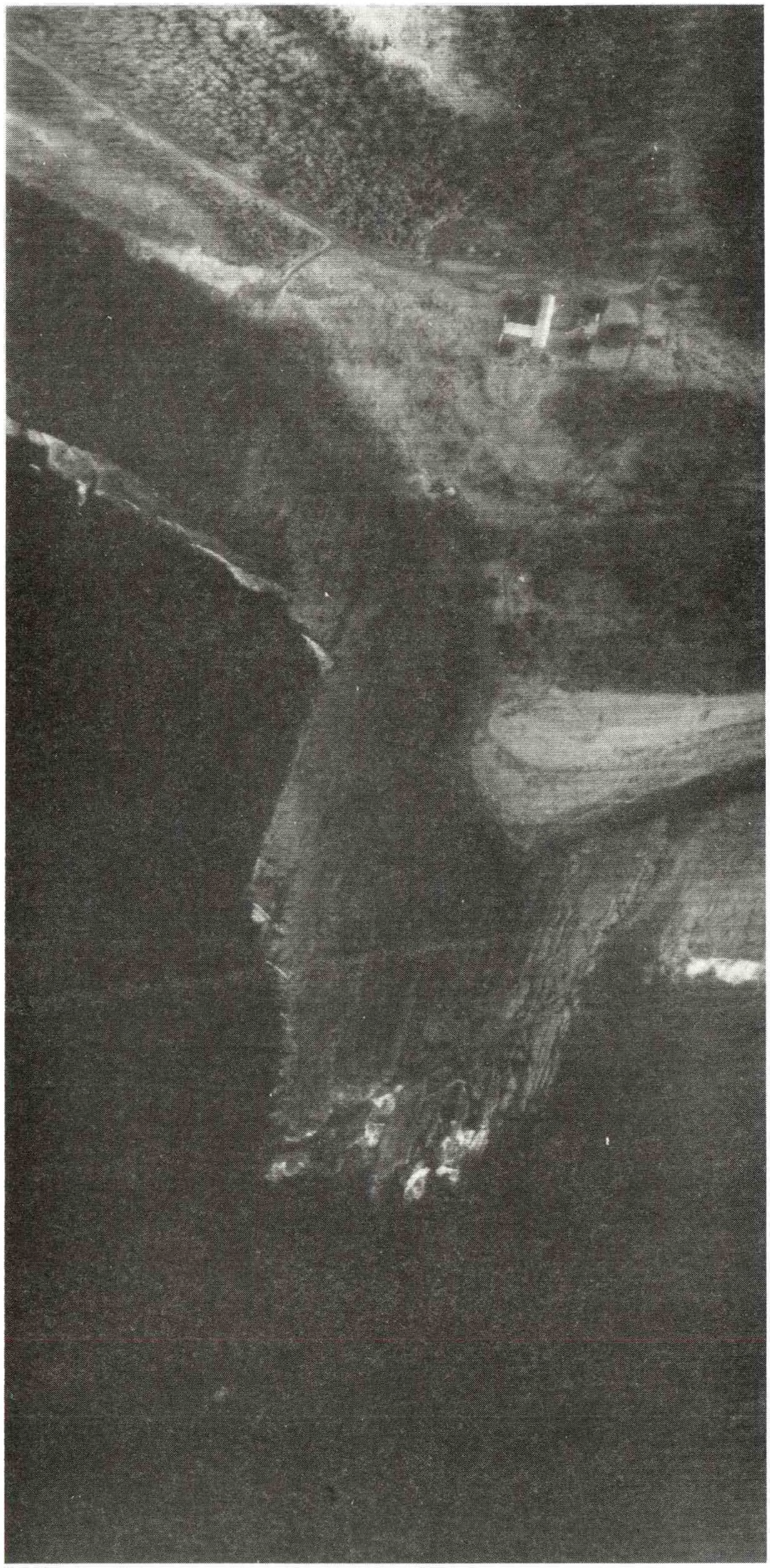
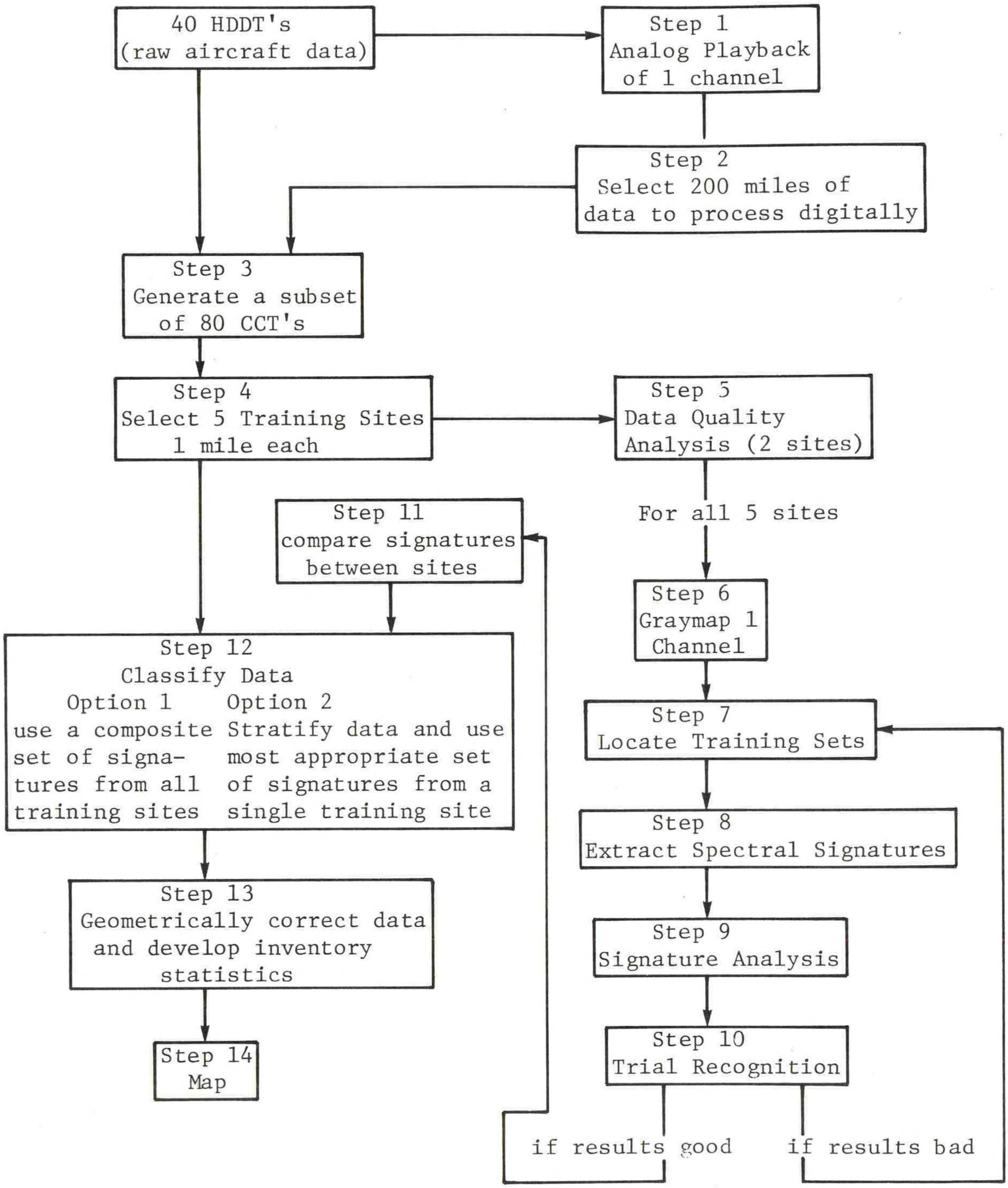


FIGURE 22. 70mm FILMSTRIP ANALOG PLAYBACK OF RUN 21, CAPE YAKATAGA, CHANNEL 9.

FIGURE 23: Scenario 1: Supervised Digital Recognition Processing



Step 3: The purpose of this step is to generate a set of tapes that can be read by the general purpose computer

Cost: $12,000 Time Required: 2 weeks

Step 4: In this step five study sites are selected which contain representative samples of the biological communities it is desired to inventory. It could be done concurrently with step 2 by the same persons.

Step 5: This step would be done for only two of the five study sites, selection could be based on the best and worst environmental conditions and/or sensor performance.

Cost: $1,250 Time Required: 1 week

Steps 6, 7, 8: These steps represent training the computer and would be done for all five sites.

Cost: $2,500 Time Required: 2 weeks

Step 9, 10: This step would involve classifying a portion of each study site and evaluating the results.

Cost: $4,500 Time Required: 3 weeks

Note: for each repeat of steps 6-10 an additional $500/study site is required.

Step 11: The purpose of this analysis is to see how similar the signatures of the different sites are; things to look at are unique signatures; signatures that can be combined; whether the signatures can be transformed for better recognition performance using signature extension techniques; etc.

Cost: $1,250 Time Required: 1 week

Step 12: Classification would be done in small batches over a two week period using a maximum likelihood decision rule: about four miles a day could fit in.

Cost: $18,000 Time Required: 4 weeks

Step 13: The purpose of this step is to remove scan angle effects and standardize the ground as represented by each pixel.
Cost: $5,500 Time Required: 2 weeks

Step 14: The maps would be made on the Ink-Jet printer. It would be dedicated to the project 1/2 time.
Cost: $6,500 Time Required: 2 weeks

Materials: 80 CCT's, 13 DIVA Disks, other supplies
Cost: $3,500

Additional Time required for travel, communications, etc.: 2 weeks

Grand Totals: Cost: $57,000 Time Required: 6 months

On a per mile basis the data processing cost for Scenario 1 is $285.00

SCENARIO 2: UNSUPERVISED DIGITAL RECOGNITION PROCESSING

This scenario is essentially similar to scenario one except for the manner in which training sets are selected. Instead of manually identifying areas of representative materials and extracting signatures from these locations, clustering is used to locate samples of spectrally similar materials. All other assumptions are the same. Where the description of the purpose or work involved in a step is similar to Scenario 1 it is indicated. See Figure 24.

Step 1: See Scenario 1, Step 1
Cost: $2,500 Time Required: 2 weeks

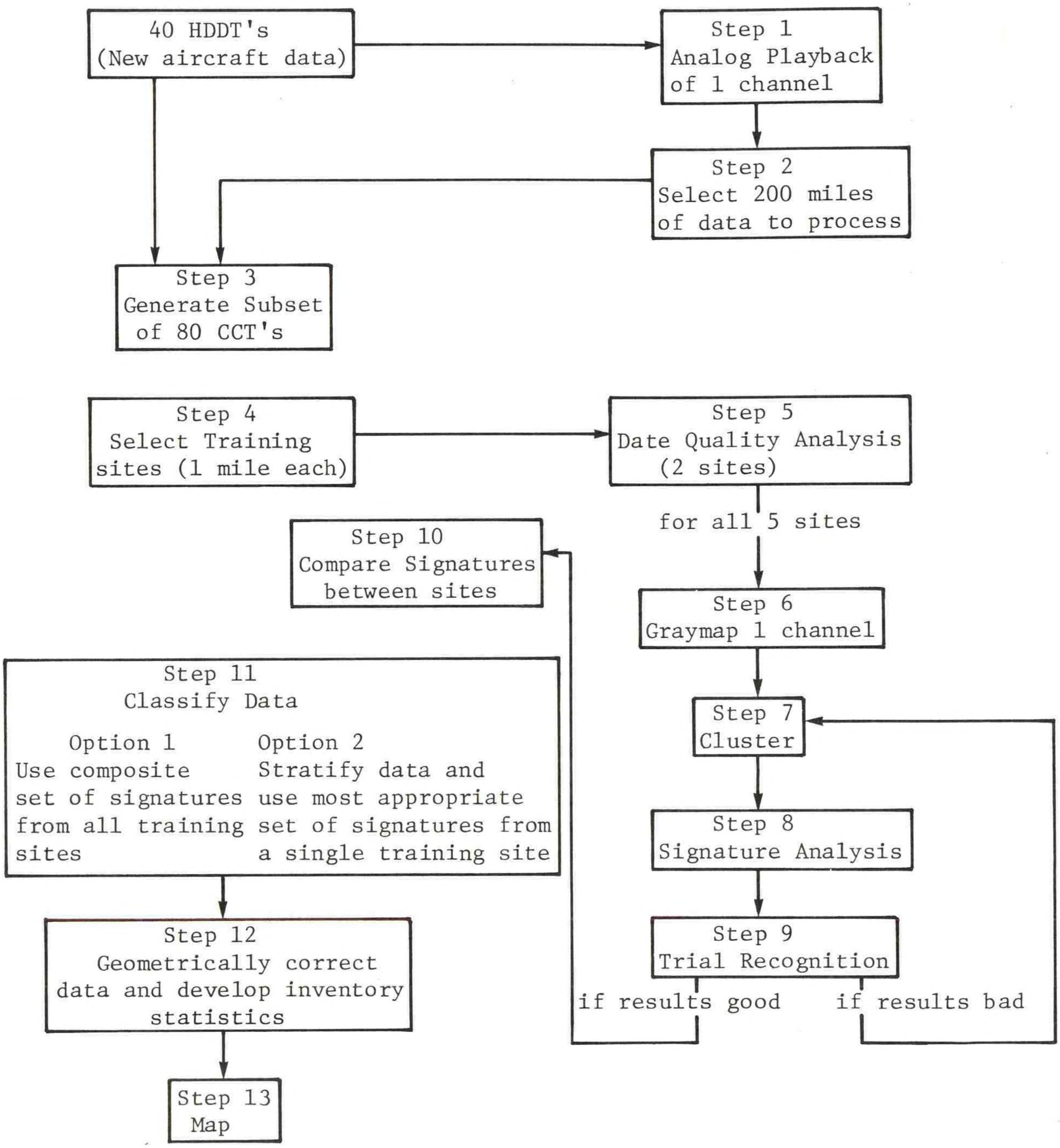
Step 2: See Scenario 1, Step 2
Cost: borne by the sponsoring agency
Time Required: 3 weeks

Step 3: See Scenario 1, Step 3
Cost: $12,000 Time Required: 2 weeks

Step 4: See Scenario 1, Step 4

Step 5: See Scenario 1, Step 5

FIGURE 24: Scenario 2: Unsupervised Digital Recognition Processing



Step 6, 7: The purpose of these steps is to generate training set statistics based on the inherent spectral properties of the data.

Cost: $3,000 Time Required: 2 weeks

Steps 8, 9: See Scenario 1, Steps 9, 10

Cost: $4,500 Time Required: 3 weeks

Step 10: See Scenario 1, Step 11

Cost: $1,250 Time Required: 1 week

Step 11: See Scenario 1, Step 12

Cost: $18,000 Time Required: 4 weeks

Step 12: See Scenario 1, Step 13

Cost: $5,500 Time Required: 2 weeks

Step 13: See Scenario 1, Step 14

Cost: $6,500 Time Required: 2 weeks

Materials: $3,000

Additional Time Requirements: 2 weeks

GRAND TOTALS: Cost: $57,500 Time Required: 6 months

On a per mile basis, the data processing cost for Scenario 2 is $287.50.

SCENARIO 3: UNSUPERVISED DIGITAL RECOGNITION PROCESSING ON MIDAS

The latter part of Scenario 3 (Step 8-14) is radically different from Scenarios 1 and 2 because instead of being accomplished on a time-shared, general purpose, digital computer, they are performed on a dedicated, high-speed, special purpose computer developed specifically to handle large volumes of remote sensing data. The individual steps with their associated cost and time required are described below: (See Figure 25)

Step 1: See Scenario 1, Step 1

Cost: $2,500 Time Required: 2 weeks

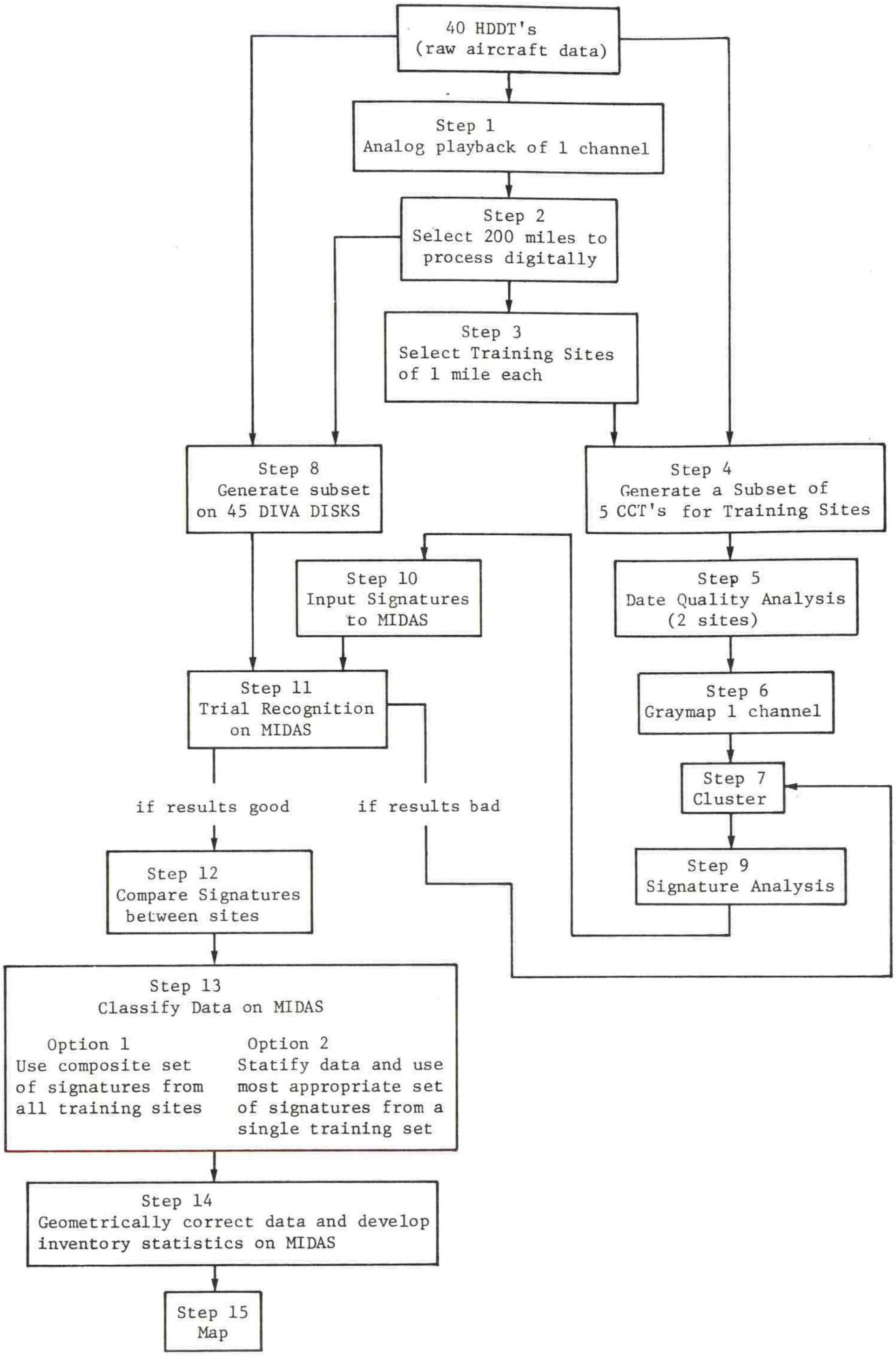


FIGURE 25: Scenario 3: Unsupervised Digital Processing on MIDAS

Step 2: See Scenario 1, Step 2

Cost: borne by sponsoring agency

Time Required: 2 weeks

Step 3: See Scenario 1, Step 4

Step 4: See Scenario 1, Step 3

Cost: $750 Time Required: 1 week

Step 5: See Scenario 1, Step 5

Cost: $1,250 Time Required: 1 week

Step 6,7: See Scenario 2, Steps 6, 7

Cost: $3,000 Time Required: 2 weeks

Step 8: 200 miles of the total 1,200 mile data set are loaded onto DIVA Disks via MIDAS for rapid access

Cost: $8,700 Time Required: 2 weeks

Steps 9, 10, 11: The purpose of this step is to determine if accurate enough recognition is being achieved by classifying a small portion of each of these study sites and evaluating recognition performance. $3,000 of the cost and 2 weeks of the time shown for software development to enable signature input to MIDAS via punched cards.

Cost: $6,000 Time Required: 4 weeks

Step 12: See Scenario 1, Step 11

Cost: $1,250 Time Required: 1 week

Step 13: On the MIDAS Computer one disk of data (11.25 flight miles) can be classified in 30 minutes.

Cost: $3,700 Time Required: 1 week

Step 14: The purpose of this step is to remove scan angle effects and standardize the ground area represented by each pixel before generating the inventory statistics. $3,000 and two weeks of software development support are figured into the logistics of this step.

Cost: $5,000 Time Required: 3 weeks

Step 15: The maps will be made on the ink-jet printer attached to MIDAS. MIDAS will be dedicated 1/2 time. The cost is substantially low for this step in this scenario because the data is already loaded on the DIVA Disks.

Cost: $4,500 Time Required: 1 week

Materials: 57 DIVA Disks, 5 + CCT's, other supplies Cost: $8,000

Additional Time Required: 2 weeks

Grand Totals: Cost: $44,650 Time Required: 5.5 months

On a per mile basis, the data processing cost associated with Scenario 3 is $222.80.

SUMMARY

In this section of the report we have covered a lot of material and this summary of it should be helpful in putting it all in perspective.

Figure 26 graphically presents the costs associated with performing the hypothetical inventory task we proposed. On the basis of these figures it is clear that data processing is the most expensive aspect of multispectral remote sensing. It is also clear that various data collection and processing alternatives can result in substantial savings in cost. Interestingly enough, in the case of this hypothetical project, it turns out that the recommended approach (ERIM data collection and clustering) can be done for the least expense.

FIGURE 26. SUMMARY OF COST DATA FOR HYPOTHETICAL MULTISPECTRAL SURVEY OF ALASKAN COASTLINE.

Data Collection	Data Processing	Project Cost/ Digitally Processed Flightline Mile	Total Project* Cost	Rank
MODE 1-$80/FL Mile	Scenario 1-$285.00/mi	$365.00	$153,000	5
	Scenario 2- 287.50/mi	$367.50	$153,500	6
	Scenario 3- 222.80/mi	$302.80	$140,560	4
MODE 2-$55/FL Mile	Scenario 1-$285.00/mi	$340.00	$123,000	2
	Scenario 2-$287.50/mi	$342.50	$123,500	3
	Scenario 3-$222.80/mi	$277.80	$110,650	1

*The total project is considered to be a survey of 1200 miles of Alaskan coastline with 1200 miles of the data mapped in analog form and 200 miles inventoried with digital processing techniques.

5.2 OPTIMUM SENSOR SYSTEM PARAMETERS

In order of presentation we discuss the following topics in this section of the report: 1) The spectral bands most useful in this study, 2) performance differences between reflected bands and thermal band, and 3) the effect of data quality on the results of this analysis.

The question of what are the optimum spectral bands for a multispectral scanner is a complicated one. Any selection represents a compromise involving many factors, such as detector sensitivity, sun illumination, atmospheric transmittance, and reflectance characteristics of the target, etc. In the past ERIM has performed many studies aimed at finding the ideal compromise as part of the research and design work supporting its own sensor development programs. For general vegetation analysis the following spectral band requirements were identified (Lowe, et al., 1973):

TABLE 7

OPTIMUM SPECTRAL BANDS FOR VEGETATION ANALYSIS

Band	$\lambda_1 - \lambda_2$ (μm)	Sensitivity
1	.42-.47	1% reflectance
2	.62-.68	
3	.69-.75	
4	1.0 -1.4	
5	1.5 -1.8	
6	2.0 -2.6	
7	8.3 -9.3	1°K
8	10.5 -12.5	

The findings of this work shows up in the design of ERIM's latest scanners system, the M-7 and M-8 (see Figure 27). Many of the bands of the M-7 and M-8 scanners coincide exactly with the theoretical optimum, others do not. The reason some bands are shifted is because of their importance for other applications, such as geologic or marine resource

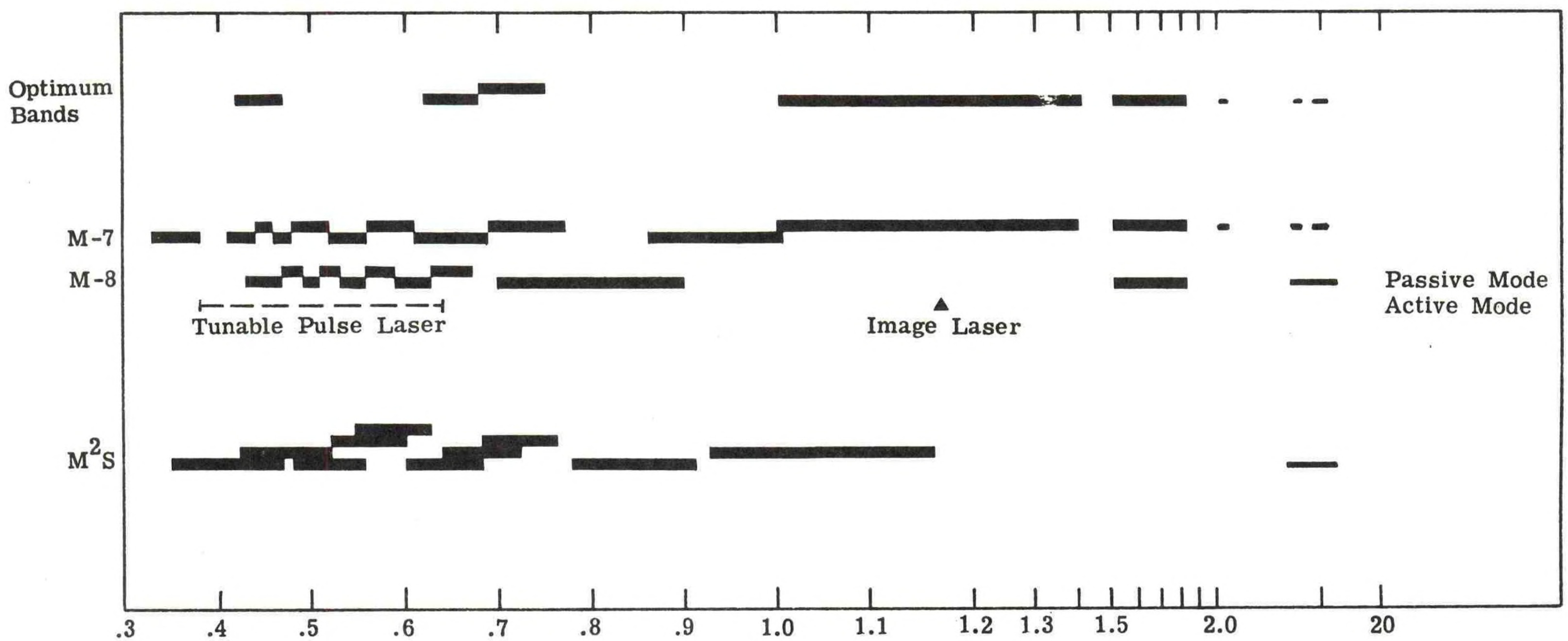


FIGURE 27. COMPARISON OF OPTIMUM SPECTRAL BANDS FOR VEGETATION ANALYSIS WITH THOSE OF THE M-7, M-8, AND M^2S SCANNERS.

inventories. For comparison the M^2S scanner spectral bands are shown.

In general, the ERIM scanners have narrower spectral bands which do not overlap. In the M-8 scanner we also have two "active" bands; by this we mean two spectral bands that detect radiation reflected from terrain that was illuminated by two lasers which are part of the scanner system. The development of the "active" scanner promises to be a major breakthrough in multispectral remote sensing applications and it is unfortunate we did not have the opportunity to use it in this study. In contrast, the M^2S scanner bands are wider and overlap more. All three sensors have adequate spectral coverage for vegetation mapping.

Although it doesn't cost significantly more to collect many bands of data, when it comes to data processing, every additional channel substantially increases computer time. Thus, we want to minimize the number of spectral bands of data we analyze. By the same token, the bands we use should be the ones which offer the greatest potential for spectral discrimination between scene classes.

One way of determining which channels to use is to compare the probability of misclassification between the spectral signatures of various scene classes using different combinations of channels. This was done twice in this study: once at the beginning of Phase II, to identify a subset of channels (See Table 3) to use on MIDAS, and again, for the Cape Yakataga unsupervised recognition processing (See Table 4). In the first case, only reflected channels were considered; in the second case, the thermal band was also considered.

The results of these analyses tell us two things. First, that very little improvement in expected classification accuracy is gained using more than four channels of data (See Figure 28); and, second, that all three major, spectral regions (visible, NIR and thermal IR) are important in the discrimination of the materials that make up the coastal Alaska environment.

In Figure 29 curves showing the relative signal in each channel from

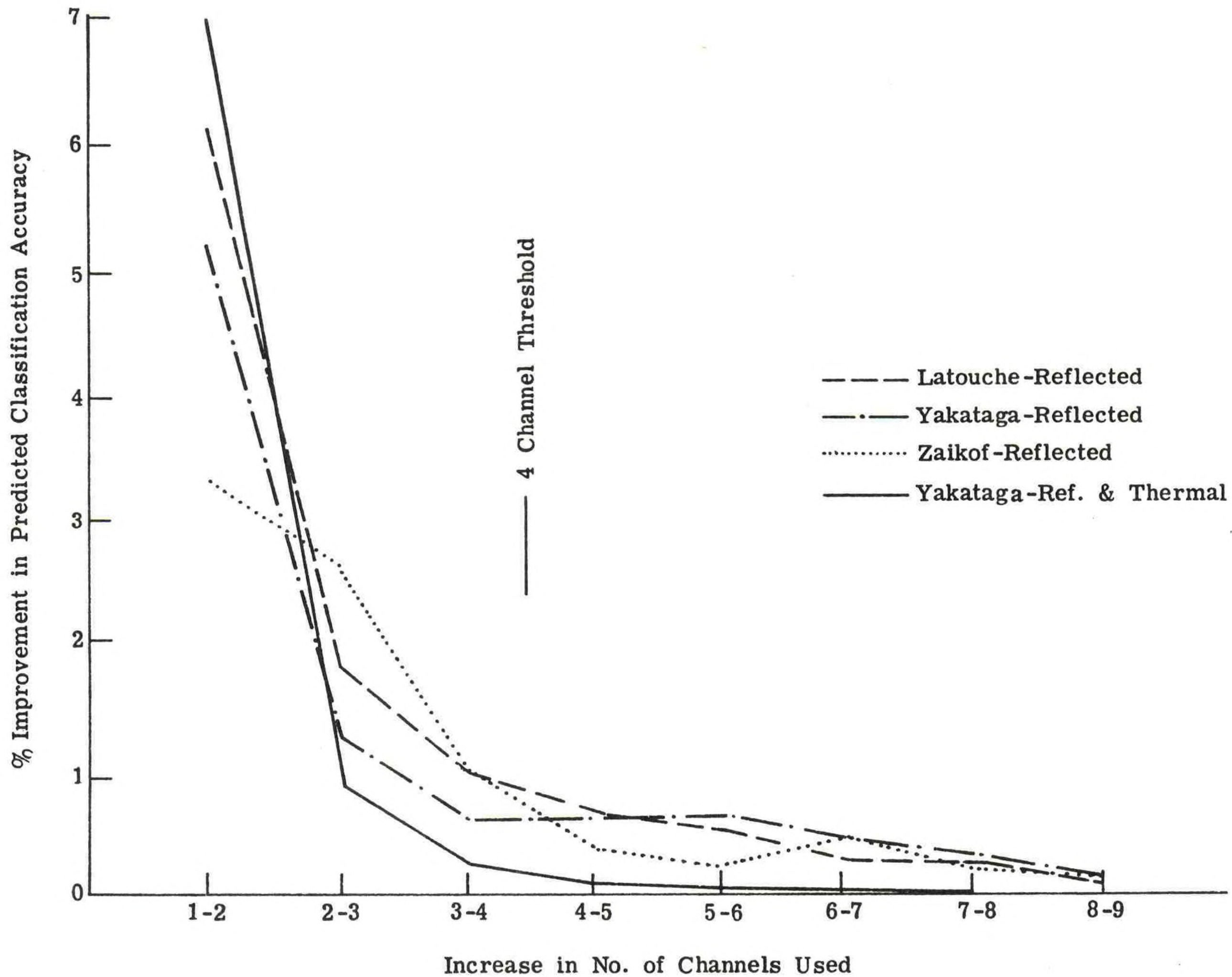


FIGURE 28. EXPECTED RECOGNITION PERFORMANCE INCREASE AS A FUNCTION OF ADDING SPECTRAL BANDS.

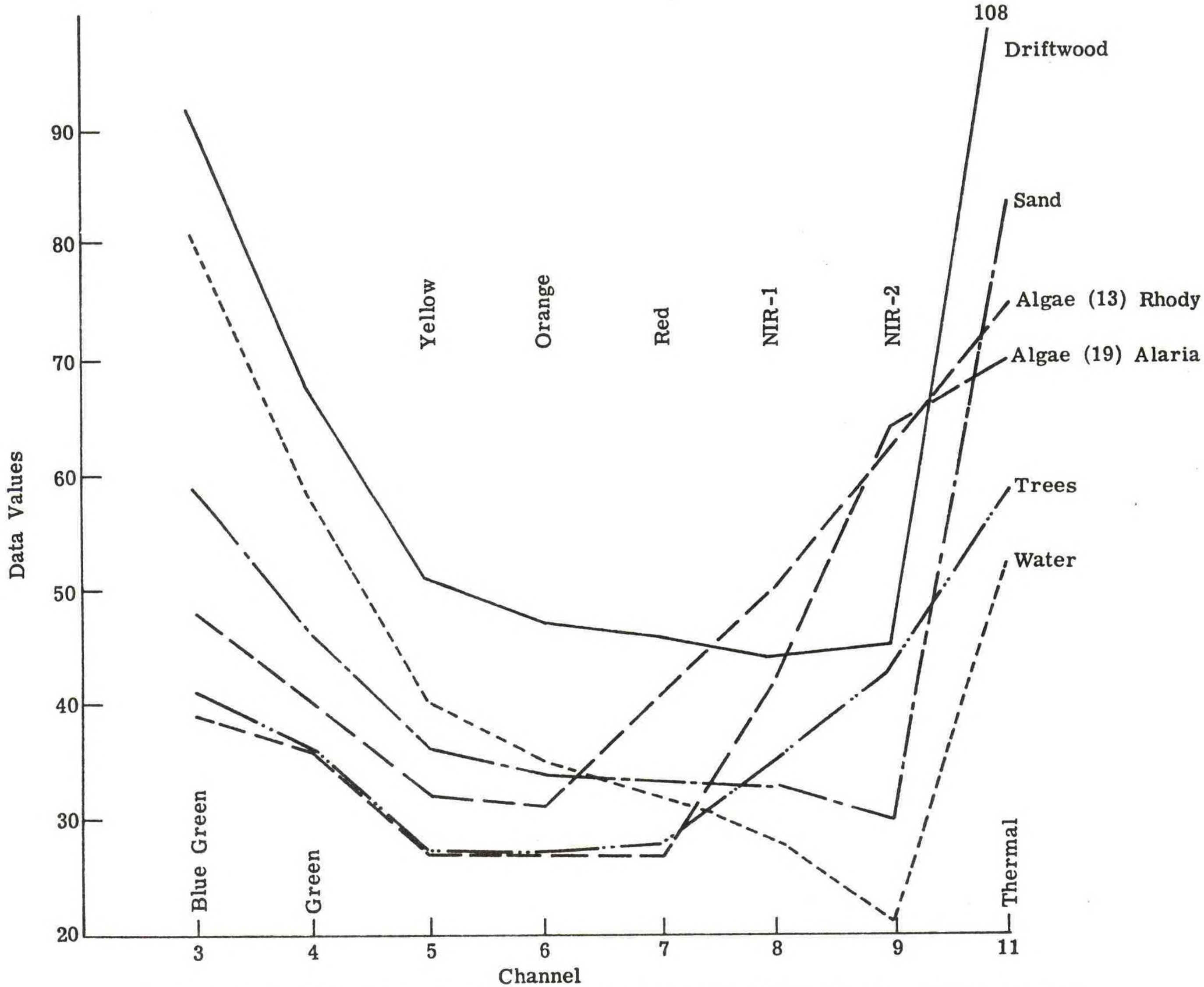


FIGURE 29. REPRESENTATIVE SPECTRAL SIGNATURES USED IN THE UNSUPERVISED CLASSIFICATION OF CAPE YAKATAGA.

representative scene classes illustrate the basis for our conclusions regarding the optimum number and placement of channels for discrimination. Beginning in the visible portion of the spectrum (channels 3-7) we see that non-living things are bright, compared to vegetation which is generally less reflective. One exception to this rule is the higher red reflectance of one of the algae signatures. This anomaly could be due to several things, contamination of the algae signature by a bright rock background, or perhaps the algae contains pigments especially reflective in this region (i.e., this may be the signature of a red or brown species of algae).

In the near-infrared region (channels 8 and 9) everything behaves as expected: the vegetation reflects highly, minerals reflect intermediate and water falls off to nearly zero reflectance. Out in the thermal region the non-living things show the effects of solar heating most dramatically, while the two types of vegetation display differential rates of transpiration. Water is, of course, the coolest thing in the scene. To summarize the reflectance patterns just described we have used the simple technique shown in Table 8.

TABLE 8

SIMPLIFIED SPECTRAL SIGNATURES OF COMMON MATERIALS FOUND IN THE CAPE YAKATAGA DATA SET

Material	Visible	Near-Infrared	Thermal
Driftwood	H*	M	H
Sand	M	L	M - H
Algae	L	M - H	M
Trees	L	M	M - L
Water	H	L	L

* Average Signal Response

H= High M= Moderate L= Low

With these reflectance relationships in mind, now is a good time to explain some differences in apparent recognition performance between some of the maps. Starting with Zaikof Bay, one thing we had trouble with there is recognition of the bare rock zone. Why we would have trouble with this is unclear when we look at Figure 7, because the rock is bright and we would expect it to have a relatively high reflectance in the visible and near-infrared regions. Yet, in the recognition maps (Figures 8, 9 and 12) the rock zone is confused to varying degrees with water. One possible explanation for this is that when data collection occurred two weeks after the photo was taken, the tide was not as low, and perhaps the rock zone was not completely dry; maybe even tidepools were present. (See Fig. 7). The signal received by the scanner from this region would then be a composition of dark rock and shallow water reflectance. This, in fact, is the type of reflectance signal we found to be characteristic for much of this area. Inclusion of the thermal band would eliminate this confusion because the heating effect of the sun would cause even the tidepools to be warmer than the ocean water.

Another thing we noticed was that actually a range of signatures was required to totally map each scene class. For example, to map a simple material like sand, it required training samples of wet sand and dry sand, coarse sand and fine sand, light colored sand and dark colored sand, and all the combinations of these that exist. The same is true of water. Classified as water are such diverse spectral conditions as deep water, shallow water, surf, tidepools and small streams. The existence of such a range of conditions, it should be obvious, place a considerable burden on those who choose to use supervised training set selection. It means a training set must be located for each and every condition exhibited by a scene class if the computer is to be adequately trained. In contrast, this is largely done automatically by clustering, and represents one of the major advantages of the unsupervised recognition processing approach.

With regard to the specific spectral bands that were found most useful in this study we can make the following remarks. Among the reflected bands, we found the single most useful band to be the second near infrared channel; the second most useful band was the green channel; then came the first near-infrared band, followed in fourth position by the yellow band. In the single study in which the thermal band was considered, it replaced the first near-infrared band as the third most useful channel. In summary then, for this study, we found the usefulness of channels to be the following:

TABLE 9

OPTIMUM SPECTRAL BANDS FOR ALASKA COASTLINE INVENTORY

Utility Rating	Spectral Region(m)		Channel No.	S/N
1	NIR-2	0.725-0.915	9	1
2	green	0.520-0.600	4	5
3	thermal	or NIR-1	8, 11	6, 4
4	yellow	8.14, 0.680- 0.760 0.540-0.640	5	2

Another factor that will seriously influence the usefulness of a given channel for spectral discrimination is its S/N ratio. It is thus not surprising that the channels selected are those with very high S/N ratios, as indicated by the relative ratings included in the table above taken from Table 2. The question of S/N may explain why the red band was not selected as a useful channel, as one might expect; the red band had one of the worst S/N ratios of any of the channels.

Briefly, then, it appears that if one had a scanner with only four spectral bands, it would be possible to achieve the performance levels achieved in this study if they (1) had good S/N ratios, and (2) were placed so that there were two in the visible part of the spectrum (one green and one orange or red), one in the near-infrared part of the spectrum (centered around 1.0 μm) and one in the thermal region.

5.3 EVALUATION OF DATA PROCESSING SYSTEMS AND DATA DISPLAYS

In this section, first we identify the important characteristics of a data processing system that make it either well-suited or ill-suited to handling a large data reduction task like the one posed by the hypothetical inventory task described earlier; then, we look at the role of the biologist in the total scheme of data processing and discuss how to best use the talents of such an individual; finally, we examine different types of data and information displays in an effort to find out what is the best way to get maximum information transfer.

5.3.1 BATCH MODE VS INTERACTIVE MODE

The enormity of the hypothetical coastal survey proposed in Section 5.1.3 does not really hit home until one actually calculates the amount of data that will be processed, and compares it to what is routinely done. For example, the amount of data we considered processing digitally (200 flight lines miles) is equivalent (on a number of channels x pixels basis) to 45 frames of Landsat data. Since Landsat was launched in 1973, probably fewer than 800 frames have been digitally processed.

The next thing that hits one, as the data processing is costed out, is that it is simple data transport that takes all the time and costs all the money; every time one does an operation on the data either 80 CCT's or 45 Discs must be loaded and unloaded. The time actually spent processing the data by the computer is trivial in comparison. Furthermore, it takes so long to move the data on a general purpose, time-sharing computer that the load must be spread out over a period of days to keep other users happy. As a result, the question of which computer can do calculations becomes almost irrelevant. The real question is: who has a cheap computer!? Of course, fast <u>and</u> cheap is the most desirable type of computer.

When it comes to choosing between batch mode or interactive mode for processing there appears to be no significant advantage to either system, except in the area of visual displays which we will discuss later. Typically an analyst runs a job, gets the results and then goes away to scratch his head and think about what to do next. Rarely is the next step immediately obvious, so the ability to interact instantaneous with the computer is of little value.

A more important characteristic of a data processing system that should be considered is the state of its software. All software should be compatible and error checking routines should be standard. This will prevent something happening during data processing that will result in an unreadable tape or loss of data. The software should also be designed to keep track of data in terms of scenes, channels, multiple-reels and completed operations, to reduce the analyst's bookkeeping requirements. Of course, full documentation of all program variables and algorithms should be considered essential. Suprisingly, few such software systems exist for multispectral data processing.

5.3.2 THE ROLE OF THE BIOLOGIST

In our opinion the person best qualified to supervise the processing of remote sensing data is an individual cross-trained in three different fields. In order of decreasing emphasis, these are: radiation-physics and computer technology. Neither an engineer nor a pure biologist will do as good a job as such an individual, all other things being equal. This is not to say that we think the biologist plays an insignificant role; quite the contrary. Actually, the biologist has the most important role; i.e., defining the project's purpose and objectives. But once these are done, the overall technical effort should be placed under the direction of a remote sensing specialist. Then, during the course of a project, the biologist can be called on only as his (or her) expertise is required. Such occasions would logically be (1) during ground truth acquisition; (2) during signature analysis; and (3) during recognition performance evaluation. The biologist's first-hand knowledge of the site and conditions is indispensable to doing a good job of these operations, but to be used most effectively it must be properly coordinated and directed.

For example, not just any data must be gathered during ground truthing, certain kinds of information are essential to good data processing. For example, in addition to species of vegetation, it is desirable to know foliage shape, leaf area index, leaf orientation, background color, background composition, the amount of shadow in the canopy, slope and aspect of the substrate and illumination conditions during overflight.

Similarly when it comes time to analyze signatures modeling the bidirectional reflectance conditions which provided the signals under analysis, it takes someone familiar with target-radiation interactions. Without a good understanding of vegetation canopy reflectance, interpreting spectral signatures would simply be a hit-or-miss affair, and the consequences of poor results too costly to allow this risk.

Finally, it is essential that the biologist be involved in determining the accuracy of classification that has been performed. The main reason for this is to convince the biologist that the results are good and can be relied on. Similarly, he will know first-hand the limitations of the results. This familiarity is essential in providing the biologist with enough confidence in the product to insure that it will be useful for decision making.

In brief, then, we visualize the role of the biologist as a changing one during the course of a project. Initially, the biologist identifies the task and specifies what results are needed. Then the remote sensing specialist designs the project and supervises its progress, including directing the biologist in ground truth acquisition and utilizing his knowledge in signature analysis. In these latter functions the biologist fulfills a service role. Finally, near completion of the project, after the remote sensing specialist and the biologist have jointly assessed performance results, the biologists' role changes again to that of the user of the results, making decisions on the basis of what has been learned.

5.3.3 DATA DISPLAYS

The one area of computer processing of remote sensing data where the interactive mode is desirable is in the production of maps, whether for computer training or recognition. The ability to generate maps quickly and cheaply is a great asset. Furthermore, these maps should have several characteristics. For example, the pixel size should be small enough to produce photo-like images, so that the eye can integrate large enough areas to identify important patterns. The value assigned each pixel (either recognition class or signal brightness) should be able to be made discrete, e.g., by the use of a color or symbol. Specific pixels should also be georeferenceable.

In this study, two data display modes were used: the alpha numeric type graymap made by computer lineprinters, and the color maps made by ERIM's ink jet printer. In all situations but one, the ink jet maps are a superior product. This one case was the identifying line and print numbers of training set pixels; the ink jet maps do not have rulers printed out in their borders like line printer maps do. This problem can be circumvented by using a electronic cursor to pick out the corners of the training sets on a CRT image of the map, but this is sometimes inconvenient. Nevertheless, we think ink jet color maps are a major breakthrough in remote sensing data display for both analysis purposes and final products.

The ability to make such maps quickly in the signature analysis phase of a project is a real time-saving advantage and undoubtedly improves the quality of the analysis. Subjective anlaysis so often depends on identifying subtle things which in turn are only brought out by effective display, resulting from sequential refinement. This process of "zeroing in" on the identification of the subtle patterns in a scene that are needed to accurately locate training sets or evaluate accuracy should not be underestimated in its importance. It is the only way good training sets can be manually located, and without good training sets it is impossible to get good recognition.

The other type of data display that is normally associated with remote sensing data is statistics. For this type of project the statistics we are interested in is the ground area of the scene covered by each scene class. Producing such statistics from remote sensing data is the forte of a computer and the bane of humans.

Conceptually, the process is simple: Because remote sensing data collection geometry is known, we can assign to each pixel the area it represents on the ground. Then, after classification, when we know what scene class each pixel belongs to, we simply tally the number of pixels in each class and multiply this figure by the area each pixel represents. The result is the ground area of the scene occupied by each scene class.

The procedure for calculating such statistics with airborne MSS data involves only one additional step: geometric rectification. In this step we correct for the fact that pixel size varies along the scanline as the scanner looks out to the side (see Figure 30). In uncorrected scanner data, pixel size at nadir is nominally 2.5 ft.sq. At the edge of a scanline, the IFOV is roughly 4 ft. square. Obviously then in uncorrected data, a pixel of a given scene class at the edge of a scan line does not represent the same relative proportion of the scene as a pixel of the same scene class at nadir. To equalize pixel size is a simple matter, however, and a cosine function is applied across a scan line, which in effect compresses pixels at the edges of the scan line until they are the same size as those at the nadir. Now, once all

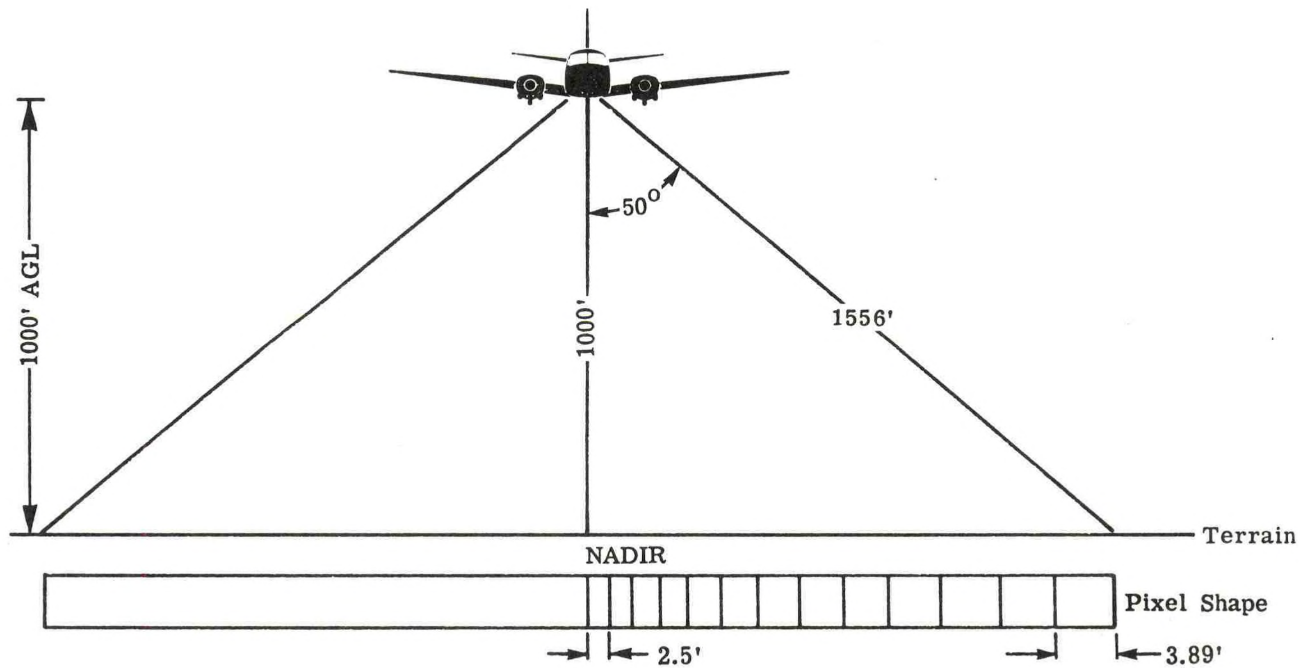


FIGURE 30. SCAN ANGLE GEOMETRY OF AIRCRAFT MSS DATA.

the pixels are the same size, it is a simple matter to tally up their number by scene class and multiply by the area factor to get the desired inventory statistics.

To illustrate this principle the statistics associated with the maps for the Phase I processing are included in Appendix B.

In the following chapter we summarize the conclusions arrived at based on the analyses discussed in this chapter.

6.0
CONCLUSIONS

The following conclusions have been reached on the basis of the work undertaken during the course of the project:

- o It is possible to identify vegetation in the intertidal zone from other scene classes (e.g., water, sand, rock, and driftwood).
- o It appears possible to further separate vegetation into broad spatial zones representing either species of algae or species associations, or simply vegetation density classes (which may correlate with species groups).
- o It is possible to collect useable data under overcast illumination conditions.
- o Clustering techniques represent the most effective way to extract training signatures.
- o A minimum of four spectral bands is needed to achieve the recognition performance levels demonstrated in this study.
- o Optimum spectral bands include two channels in the visible part of the spectrum (green and red), one in the near-infrared region (near 1.0μm) and one in the thermal region.
- o Special purpose computers designed specifically to handle remote sensing data can reduce processing costs.
- o Concise visual displays of results are essential for signature analysis, recognition performance evaluation, and final products.
- o Optimum project design and implementation are best left to a specialist trained in remote sensing data handling and reduction with a strong background in biology and radiation-physics.

7.0
RECOMMENDATIONS

We have two types of recommendations. Type 1 relates to improving classification accuracy. Type 2 relates to reducing cost.

Type 1 Recommendations

If recognition accuracies prove to be lower than desired, more sophisticated newly developed training set selection techniques would be evaluated:

- test clustering techniques which employ spatial relationships between pixels as well as spectral characteristics.
- Test classification rules that base recognition on the spectral characteristics of surrounding pixels in addition to individual pixels.

Type 2 Recommendations

These deal with finding ways to reduce the costs associated with data collection and processing:

- Evaluate the possibilities of mapping some areas at coarser spatial resolution. If you fly higher you can cover more ground faster, and there are less pixels to process. This gives a first stage sample of the distribution.
- Evaluate the use of finer spatial data collected on a sampled basis supported by ground measurements to provide classification accuracies for the multistage survey.

REFERENCES

1. C.T. Wezernak, D.R. Lyzenga, and F.C. Polcyn, 1974. Cladophora Distribution on Lake Ontario (IFYGL). EPA-660/3-74-028 National Environmental Research Center, USEPA, Corvallis, Oregon.

2. Tanis, F.,(in press)

3. Polcyn, F.C., D.R. Lyzenga and E.I. Marinello. 1977. Investigation of Intertidal Zone Mapping by Multispectral Scanner Techniques, ERIM Report No. 123200-1-F.

4. Sadowski, F. and J. Sarno. 1976. Forest Classification Accuracy as Influenced by Multispectral Scanner Spatial Resolution. ERIM Report 109600-71-F.

5. American Society of Photogrammetry. 1968. Manual of Color Photography. Chuck Falls, Virginia.

6. R.E. Turner, Radiative Transfer in Real Atmospheres, Report No. 190100-24-T, Environmental Research Institute of Michigan, Ann Arbor, Michigan, July 1974.

7. G.H. Suits, The Calculation of the Directional Reflectance of a Vegetative Canopy, Remote Sensing of Environment, Vol. 2, 1972, pp. 117-125.

APPENDIX A

The four sheet flight log contained in this appendix describes the data acquisition sequence for this project. Five passes were flown at each of the three study sites, Zaikof Bay, Latouche Island and Cape Yakataga. Scanner data was collected on every pass, but natural color photography (Kodak SO-397) was collected only once per sequence, except at Cape Yakataga where coverage was obtained during all 500 ft. altitude overpasses.

As part of a calibration procedure for the scanner data, overpasses were also made of a set of these panels of known reflectance 40 ft. x 20 ft. in size. This data can now be used as a reference for calculating the minimum percent reflectance that the scanner could detect under the illumination conditions and instrument configuration that prevailed during data collection. The panel overflights were made at the Cordova airfield on June 26th.

M^2S FLIGHT LOG

DATE 6-9-76, 6-26-76, 6-27-76, 6-28-76

OPERATOR Haeske

A/C N41WA

FLIGHT NO. ______ MISSION ID. ERIM / Alaska TAPE NO. 1 FILM TYPE(S) SO-397

FILTER(S) Hase 500/5.6

CAMERA(S) Hassalblad

PILOT Byers

CO-PILOT ______

RECORDER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SCANNER	1	2	3	4	5	6	7	8	9	10	11			
CAL HIGH											070			
CAL LOW											233 296			

070 = 35°C
233 = 10°C
296 = 5°C

PAGE 1 OF 4

RUN	LINE ID	T.O.T.	RUN TIME Min	G.S.	A.G.L.	MAG. HDG.	ACCUM COUNT	FRAME COUNT	IV	S/S	DIAL SET	MISSION NOTES
1		1020	2.0	180	1.3K	160				70	668	Test Flight 6-9-76 Bremerton, Wash.
2		1245	1.0	140	2.5K	210				70	668	VHF TX During Run Test Flight 6-26-76 Anchorage, Ak.
3	1	0708	.38	140	1.5K	195	0 / 7	7	6	70	668	6-27-76 WX-Very Overcast & Dark Zaikof Bay
4	2	0712	.45	100	1K	195				70	668	Thermal May Be Clipping Negative
5	3	0715	.50	100	1K	195	17		5	50	450	
6	4	0720	.40	100	1K	120	23		5	70	668	
7	5	0723	.40	90	400	195				70	668	
8	1	0745	.50	150	1.5K	120	32		6	70	668	Latouche Low Black Body 296
9	2	0750	1.00	100	1K	120				70	668	
10	3	0753	1.00	100	1K	120				50	450	
11	4	0756	.45	100	1K	010	42		5	70	668	
12	5	0759	1.00	100	400	120				70	663	
13		0809	.50	100	1K	030	47		5	70	668	Needle

M^2S FLIGHT LOG

(cont'd)

DATE 6-27-76, 6-28-76

OPERATOR Haeske

FLIGHT NO. ______ MISSION ID. ERIM/ Alaska TAPE NO. 1 FILM TYPE(S) SO-397

FILTER(S) Hase

CAMERA(S) Hassalblad

PILOT Byers

CO-PILOT ______

PAGE 2 OF 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RECORDER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SCANNER	1	2	3	4	5	6	7	8	9	10	11	-	-	-
CAL HIGH											070			
CAL LOW											296			

RUN	LINE ID	T.O.T.	RUN TIME	G.S.	A.G.L.	MAG. HDG.	ACCUM COUNT	FRAME COUNT	IV	S/S	DIAL SET	MISSION NOTES
14	1	0845	.40	130	1.5K	090	8		6	70	668	6-27-76 Panels on Gravel at Cordova Airport
15	2	0848	.40	100	1K	090				70	668	
16	3	0850	.40	100	1K	090	14		?	50	450	
17	4	0852	.40	100	1K	180				70	668	
18	5	0855	.40	100	400	090				70	668	
19	1	0800	.45	120	1.5K	170	8		6	70	668	WX-Overcast Some Thin Spots Cape Yakataga Gyro Caged
20	1	0804	.50	120	1.5K	165				70	668	
21	2	0808	.50	200	1K	165				70	668	
22	3	0811	.50	100	1K	165				50	450	
23	4	0815	.50	100	1K	075	17		5	70	668	
24	4	0818	.50	100	1K	255				70	668	Opposite Direction Same as above Closer to Shore
25	5	0821	.50	100	400	165	26			70	668	Manual Pictures
26		1410	1.15	100	1K	285	000 / 19			70	668	Nochek Gyro Caged
27		1413	1.05	100	1K	285				70	668	Nochek Same As Above Uncaged

M^2S FLIGHT LOG
(cont'd)

DATE 6-28-76 | OPERATOR Haeske

FLIGHT NO. ______ MISSION ID. ERIM/ Alaska TAPE NO. 1 & 2 FILM TYPE(S) SO-397

FILTER(S) Hase

CAMERA(S) Hassalblad

PILOT Byers

CO-PILOT ______

PAGE 3 OF 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RECORDER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SCANNER	1	2	3	4	5	6	7	8	9	10	11			
CAL HIGH											070			
CAL LOW											296			

RUN	LINE ID	T.O.T.	RUN TIME	G.S.	A.G.L.	MAG. HDG.	ACCUM COUNT	FRAME COUNT	IV	S/S	DIAL SET	MISSION NOTES
28		1415	.45	100	1K	240	27		5	70	668	Made Extra Run Over Rocks 9 Pictures Porpoise Rocks 6-28-76
29		1425	.45	100	1K	210	36 / 37		5	70	668	Sun Glint Seal Rocks
30		1427	.30	100	1K	190	43		5	70	668	Sun Glint Seal Rocks
31		1430	.30	100	1K	010	50		5	70	668	Sun Glint Small Rocks
32		1432	.30		400	190	56		5	70	668	Sun Gline Seal Rocks
33		1449	.55	130	1.5K	040	60		6	70	668	Wooded Isle
34		1453	1.05	130	1.5K	040	74		6	70	668	Wooded Isle
35		1455	.30	100	1K	070	79		6	70	668	Fish Isle
36		1509	.30	100	1K	190	87		6	70	668	Needle
37		1511	.30	100	400	010	90		6	70	668	Needle
38		1646	2.45	170	10K	210				35	250	Start Tape #2 Montaque to Green is Whale △ , High Alt.
39		1700	2.30	100	1K	030				70	668	Green to Montique Whale △ , Line #1
40		1703	4.54	100	1K	280				70	668	Montique to Seal is #2
41		1709	4.54	100	1K	140						Seal to Green is #3 Sun Glint

M²S FLIGHT LOG

(cont'd)

DATE 6-28-76 OPERATOR Haeske

FLIGHT NO. ______ MISSION ID. ERIM / Alaska TAPE NO. 2 FILM TYPE(S) SO-397

FILTER(S) Hase

CAMERA(S) Hassalblad

PILOT Byers

PAGE 4 OF 4 CO-PILOT ______

RECORDER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SCANNER	1	2	3	4	5	6	7	8	9	10	11			
CAL HIGH											070			
CAL LOW											297			

RUN	LINE ID	T.O.T.	RUN TIME	G.S.	A.G.L.	MAG. HDG.	ACCUM COUNT	FRAME COUNT	IV	S/S	DIAL SET	MISSION NOTES
42	1	1735	.30	150	1.5K	090		2		70	668	Manual Pictures Panels
43	2	1739	.40	100	1K	090				70	668	
44	3	1741	.40	100	1K	090				35	250	
45	4	1746	.30	100	1K	180				70	568	
46	5	1749	.30	100	400	090		3		70	668	Manual Pictures

APPENDIX B

The statistics presented here were generated automatically by computer for the Phase I processing results. They accompany the indicated maps.

ZAIKOF BAY
Run 7
Map: Figure 8

LEVEL	SCENE CLASS	COLOR	NUMBER OF PIXELS	AREA (m^2)
1	Algae 1A	light red	2259	4489
2	Algae 2A	olive brown	23439	4666
3	Algae 3A	dark green	11482	2287
4	Algae 4A	light green	24534	4885
5	Algae 5A	orange	15720	3130
6	Rock 1A	dark gray		
7	Rock 2A	black		
8	Grass	yellow		
9	Trees	light orange		
10	Algae 6A	light purple	21131	4207
11	Water	blue		
255	Unclassified	white		

The average pixel = 2.14 ft^2 or $0.20 m^2$

TOTAL AREA

pixels = 437,660 @ 0.20 m^2/pixel

Total Area = 8.7^{1nd}

LATOUCHE ISLAND

Run 9

Map: Figure 14

LEVEL	SCENE CLASS	COLOR	NUMBER OF PIXELS	AREA (m^2)
1	Algae 1C	light red	22258	12304
2	Algae 2C	olive brown	15987	8837
3	Algae 3C	dark green	14251	7878
4	Algae 4C	light green	10693	5911
5	Algae 5C	dark orange	36872	20382
6	Algae 6C	violet	8864	4900
7	Algae 7C	dark red	16939	9363
8	Algae 8c	light blue	18407	10175
9	Algae 9C	black	12237	6764
10	Water	blue		
11	Trees	light orange		
12	Grass	yellow		
13	Rock	gray		
255	Unclassified	white		

The average pixel = 5.95 $ft.^2$ or $0.55m^2$

TOTAL AREA

pixels = 300,600 @ $0.55m^2$/pixel

Total Area = 16.6 lnd

CAPE YAKATAGA

Run 21

Map: Figure 18

LEVEL	SCENE CLASS	COLOR	NUMBER OF PIXELS	AREA (m^2)
1	Algae 1B	light red	15761	8712
2	Algae 2B	olive brown	14389	7954
3	Algae 3B	dark green	5862	3240
4	Algae 4B	light green	18402	10172
5	Algae 5B	dark orange	9828	5433
6	Algae 6B	violet	12380	6843
7	Algae 7B	dark red	33773	18669
8	Rock 1B	gray		
9	Algae 8B	black	43470	24029
10	Rock 2B	light blue		
11	Algae 9B	light orange	18238	10081
12	Water	blue		
13	Grass	yellow		
255	Unclassified	white		

The average pixel = 5.95 $ft.^2$ or 0.55 m^2

TOTAL AREA

pixels = 259,201 @ .55 m^2/pixel

Total Area = 14.3 2nd