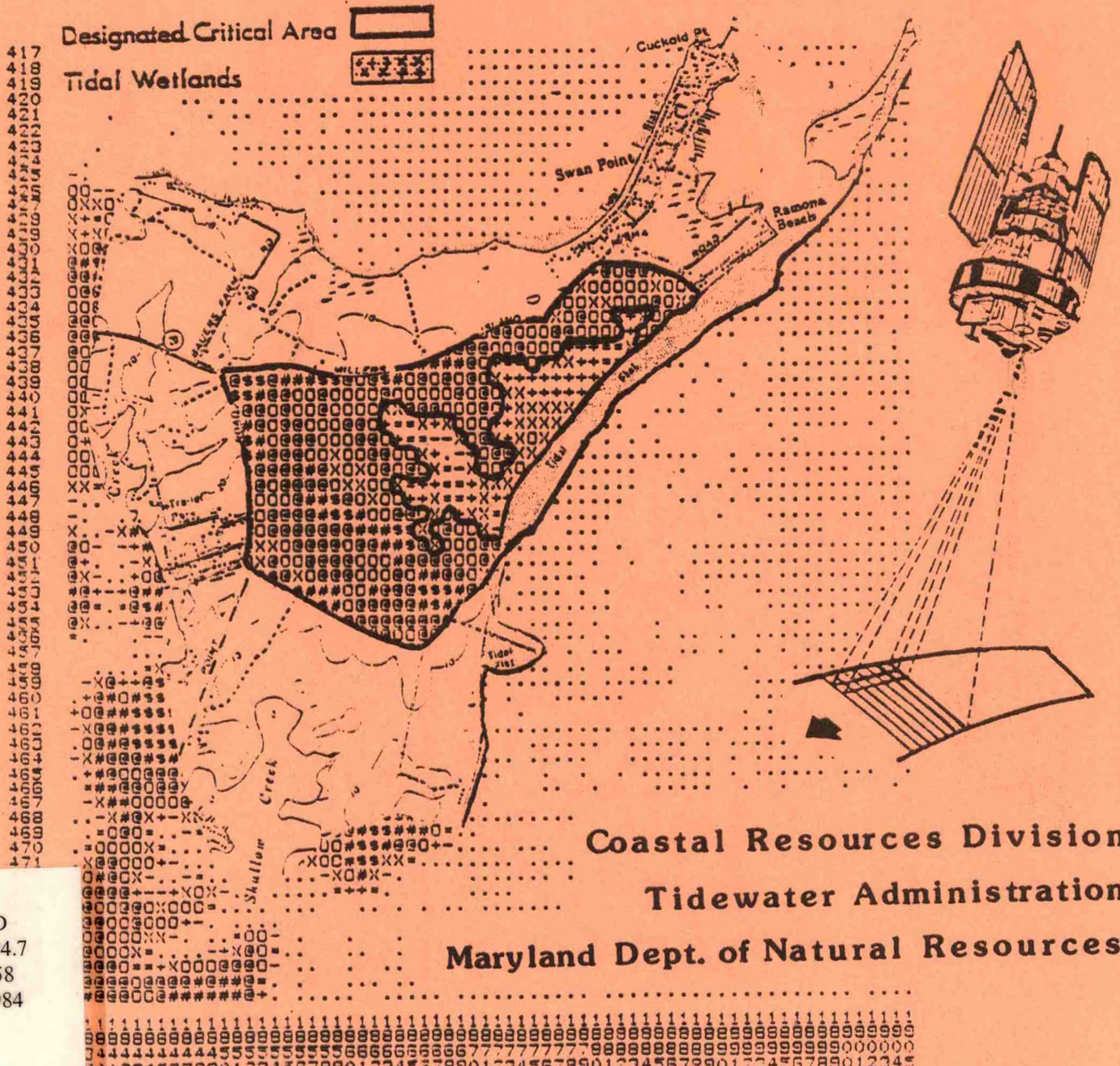
ENVIRONMENTAL MONITORING OF STATE CRITICAL AREAS:

AN EVALUATION OF LANDSAT SATELLITE IMAGERY AND OTHER TECHNIQUES

Chris Zabawa & K.-Peter Lade, Editors



Coastal Resources Division
Tidewater Administration
Maryland Dept. of Natural Resources

Maryland Coastal Zone Management Program

FINAL REPORT

JULY 1, 1984

ENVIRONMENTAL MONITORING OF STATE CRITICAL AREAS: AN EVALUATION OF LANDSAT SATELLITE IMAGERY AND OTHER TECHNIQUES

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T A B L E O F C O N T E N T S

Acknowledgements i

Executive summary iii

CHAPTER 1: INTRODUCTION

1.1 Purpose Of The Study 1

1.2 Contents Of This Report 1

1.3 Results 4

CHAPTER 2: THE CRITICAL AREAS PROGRAM

2.1 Legislative Mandate 11

2.2 General Management Goals 12

2.3 General Guidelines For Environmental Monitoring 16

CHAPTER 3: CLASSIFYING STATE CRITICAL AREAS

3.1 What Is Digital Image Processing? 24

3.2 Generating The LANDSAT Images 29

3.3 LANDSAT Digital Analysis Applied To Critical Areas 33

3.4 Comparison Of Remotely-sensed Data With Ground-truth Information 47

3.5 Accuracy Assessment 52

CHAPTER 4: CASE STUDIES

4.0 Introduction 55

4.1 Case I - The Nature Conservancy Choptank River Wetlands In Talbot And Caroline Counties 59

4.1.1 Background 59

4.1.2 Sources Of Information For The Resource Management Data Base 62

4.1.3 Evaluation Of Remote-Sensing Techniques . 63

4.2 Case II - THE ZEKIAH SWAMP IN CHARLES COUNTY . . 82

4.2.1 Background 82

4.2.2 Sources of Information For The Resource Management Data Base 84

4.2.3 Evaluation Of Remote-Sensing Techniques . 86

4.3 Case III - The Pocomoke River 104

4.3.1 Background 104

4.3.2 Sources of Information for the Resource Management Data Base 105

4.3.3 Evaluation of Remote-Sensing Techniques . 107

4.4 Case IV - Severn River Designated Critical Areas . 130

4.4.1 Background 130

4.4.2 Sources of Information for the Resource Management Data Base 133

4.4.3 Evaluation of Remote-Sensing Techniques . 134

4.5 Case V - Black Marsh 158

4.5.1 Background 158

4.5.2 Sources of Information for the Resource Management Data Base 158

4.5.3 Evaluation of Remote-Sensing Techniques . 160

CHAPTER 5: CONCLUSIONS 174

References Cited 181

Appendix A - Examples of LANDSAT Digitally Processed MSS Data For The First-Round Designated State Critical Areas A-1

Glossary B-1

Glossary of Acronyms B-7

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EXECUTIVE SUMMARY

Remote-sensing techniques, including the collecting and interpretation of aerial photography, and the digital processing of LANDSAT MSS data, can serve as a useful tool both for monitoring environmental characteristics in the First-Round Designated Areas of Critical State Concern, and for tracking land-use patterns and land-cover changes which may be the source of off-site impacts in First-Round Designated Critical Areas. This report presents results from a one-year cooperative study between Maryland DNR Coastal Resources Division and Salisbury State College to evaluate these techniques for environmental monitoring of Critical Areas. At the start of the project, the specific monitoring needs were identified by the Maryland Department of State Planning, which has principal authority for designating Critical Areas and for meeting management goals. The objective of the study was to determine which of these monitoring needs could be met by the application of LANDSAT data, which might be appropriately studied by including LANDSAT data with more traditional data sources such as on-site studies and aerial photography, and which could not be met through the application of digital analysis of LANDSAT multispectral data. A further objective was to determine whether existing computer technology available to state and local agencies could be successfully employed by natural resource investigators who did not possess training in computer applications.

The principal result of the study was that, for Class I and Class II sites (tidal and non-tidal wetlands) the LANDSAT satellite imagery can provide a reasonable discrimination of major vegetative types, tidal and non-tidal wetlands boundaries, and variations in sediment load. The continuous satellite coverage, available since 1972, is particularly well suited to accomplish such tasks as identifying trends in the transformation of tidal wetland to barren mudflat, succession of wetland types to forested/wetland types, extension of wetland cover into previously submerged areas, changes in the health and vigor of forest stands, and changing utilization of farmland. Gross changes in the landscape are readily recognized by LANDSAT, and where data are either not available or where retroactive study must be done, LANDSAT data provide a unique and vital tool. More detailed identification of vegetative types and comprehensive vegetative mapping could be achieved with the collection of suitable ground-truth information in the Class I and II areas, while general synoptic maps could be prepared without extensive effort by the investigator.

The LANDSAT technology also has several advantages over traditional air photo interpretation for establishing a resource management data base for Critical Areas. These are discussed in greater detail in Chapter 4 of this report. Foremost among these advantages is the form of the data. Digital values for both reflected visible light (red and green) and reflect near-infrared light can be manipulated by computer so that information about the area being investigated can be rapidly and accurately extracted. The data are uniformly available for the entire State and complete coverage is achieved over a three-day period, far more rapidly than could be achieved in any other way.

Other needs for monitoring are better suited to air photo interpretation. These include: identification of dumping of refuse, or cutting of individual trees, identifying frequency of visitation by cars or boats, identification of small scale (i.e. less than 1 acre) construction, sand and gravel pits, sediment buildup or soil erosion sites, and evidence of excessive runoff. With the inclusion of Thematic Mapper (TM) data in the future some of these needs might also be met with LANDSAT data analysis since the TM provides both higher resolution (1/4 acre as opposed to 1.1 acres) and additional spectral bands (6 bands in the visible and near-infrared range and one thermal band).

Finally, either air photo interpretation or LANDSAT satellite imagery would be suitable to monitoring land-use patterns and land-cover changes in the areas surrounding First-Round Designated Critical sites in any of the Four Class Types (I, II, III, or IV). Air photo interpretation methods are better suited to some needs, such as vegetative cover analysis in areas where vegetative types are heavily mixed, and in cases where data must be acquired under conditions not suitable for satellite data acquisition such as cloudy days. The latter is particularly relevant in attempting to determine the effects of runoff after storms.

Five case studies are separately investigated using a variety of digital analysis techniques. Areas include the Choptank River Wetlands, Zekiah Swamp, Pocomoke River, Severn River Areas, and Black Marsh. The results of these investigations show that LANDSAT data can serve as a significant source of data for analysis and as an appropriate means for monitoring most of the Critical Areas in the First-Round Designations. Further, the analysis process can be rapidly achieved in most cases to provide data sufficiently detailed to allow management to be formulated.

CHAPTER 1
INTRODUCTION

1.1 Purpose of the Study

Enabling legislation for the Maryland "Critical Areas Program", Article 88 C, requires the Maryland Department of State Planning (DSP) to designate Areas of Critical State Concern after consultation with and in consideration of recommendations submitted by local governments. In 1981, DSP published a Designation Report, which contains the first formal designations of Critical Areas. These first-round designations fall within four classes: tidal wetlands, non-tidal wetlands, rail service, and "special areas". The Designation Report also lists management goals specific to each site, and discusses the kinds of threat and problems to be expected in each impact area, and from off-site activities. Many of the impacts, resulting from changing land use or physical alterations of wetlands, will require some sort of ongoing environmental monitoring to assure that the legislative mandates are met for the First-Round Designated Critical Areas. This report evaluates remote-sensing methods for environmental monitoring of State Critical Areas.

1.2 Contents of This Report

Chapter 2 contains a discussion of the Critical Areas program. Separate sections are devoted to the legislative mandate, to the general management goals, and to a discussion of the general requirements for environmental monitoring. Chapter 2 also contains a series of maps, originally published in the 1981 DSP Designation Report, showing the First-Round Designated Critical Areas in each of the four initial generic classes (Class I - Tidal Wetlands; Class II - Non-Tidal Wetlands; Class III - Rail Service; Class IV - Special Areas).

Chapter 3 describes how digital analysis of LANDSAT satellite MSS data, a remote-sensing technique, is particularly suitable either for continual environmental monitoring or for identifying impacts to natural resources located within Critical Area site boundaries.

Chapter 4 presents several case studies where the results of the digital processing of LANDSAT data, used in combination with air photos, or on-site collection of ground-truth data, would fulfill the management goals specified in the DSP Critical Areas Designation Report for monitoring threats and problems at the site. The Critical Areas included in the case studies were selected in part so that they would constitute a reasonable sample of the diversity in size and nature of the Designated "Critical Areas". Additionally, the case studies illustrate the use of a number of different digital techniques falling into four major categories: (1) density slicing, (2) supervised classification, (3) unsupervised classification, and (4) special applications.

The aim of digital analysis (see Section 3.1) can vary considerably, depending on the accuracy of the results needed, the level of detail required, and the nature of the ground cover.

With these restrictions in mind, the investigators were asked to illustrate different approaches of analysis so that a reasonable evaluation could be made of both the level of effort required and the type of result achieved. In each case the aim was to establish a valid relationship between spectral response patterns recorded by the satellite sensors and different land cover types. Ground-truth, when available, as well as personal knowledge of the area was used to validate the classification results.

Chapter 5 presents the overall conclusions of the studies, and comments about the appropriateness of including LANDSAT data analysis in management programs. As will be seen, the cost-effectiveness of using LANDSAT data analysis is a major consideration in its use. In addition, the uniformity of the data, ease of manipulating the data by computer, and value of having access to an extensive data base spanning more than a decade are all major considerations in favor of further developing LANDSAT analysis and incorporating it into ongoing programs such as the Critical Areas Program.

1.3 Results

Table 1.1 contains a listing of the general guidelines prepared by the Maryland Department of State Planning for Critical Areas (Classes I, II, and IV) together with an identification of the strategy that is most appropriate for monitoring the Critical Area site. Several of the guidelines shown in the table are very site-specific, and will require actual on-site visits, or periodic low-altitude air photographs to document the existence of a threat caused by dumping, cutting of individual trees, excessive visitation, etc. However, some of the broader types of impacts can be addressed more efficiently with remote-sensing techniques, principally the use of LANDSAT satellite imagery and MSS digital data, which can also be more cost effective than actual on-site monitoring, or continual air photo reconnaissance.

The principal constraint to the use of the LANDSAT satellite technology when investigating very small areas (e.g. under 30 acres) is the limiting of resolution to 1.1 acre units. Some idea of the spatial resolution of this type of data can be seen in the photograph in Figure 1.1, where a 2-acre flag was unfurled on the Ellipse in front of the White House in Washington D.C. While the new LANDSAT-4 satellite currently in orbit has provided one-quarter acre resolution since 1982, existing LANDSAT coverage from 1972 to the present is at the 1.1 acre limit

Table 1.1

General Guidelines for Environmental Monitoring of Critical Areas (from Section 2.4)

	Air Photo Analysis	Landsat MSS Data	On-Site Sampling
o identify dumping of refuse or other debris	3	4	1
o monitor sediment movement/buildup	2	2	1
o recognize cutting of timber (both individual trees and timber stands)	3	3	1
o identify initial stages of construction on adjacent properties	3	3	1
o identify frequency of visitation by cars or boats	4	4	1
o monitor expansion of nearby activities, such as sand and gravel removal, farming, and drainage improvements	3	2	1
o identify evidence of excessive runoff into buffer zones or Critical Areas, including monitoring flooding of sites	3	3	1
o identify upstream erosion sites	2	3	1

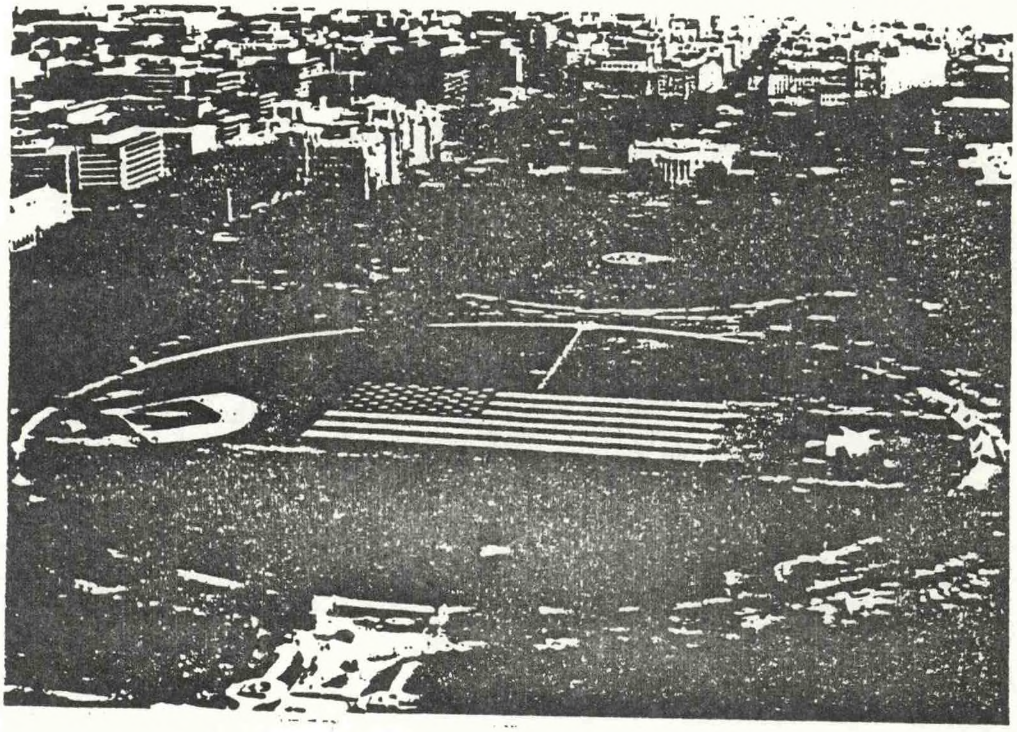
1 = the preferred recommended statagy

2 = a suitable strategy

3 = could be suitable under some circumstances

4 = not suitable

Figure 1.1



A two-acre flag, on the White House Ellipse, gives a visual impression of the limit of spatial resolution of the LANDSAT satellite data in 1.1 acre pixels. See Figures 3.4 and Appendix A for comparison with digitally processed images. Photo courtesy of the Washington Post, June 15, 1983. Used here with permission.

of resolution. Some idea of scale of resolution can be gained by scanning the computer processed images presented in Appendix A for many of the First Round Designations (Critical Areas I, II, and IV). Each print character is equivalent to one picture element ("pixel") of data and represents a 1.1 acre (60x80m) ground target. Tables 1.2a and 1.2b list the size of each First Round Critical Area (Class I, II, and IV) and the approximate numbers of LANDSAT pixels at the actual site, and within the adjacent impact area. For specific problems requiring more detailed ground coverage and resolution, direct air photo reconnaissance is the recommended strategy combined with actual on-site visits.

Although it is clear that LANDSAT multispectral data cannot replace other more traditional types of data, such as on-site investigation and aerial reconnaissance, there is no other data source available that provides so extensive and complete a data base as LANDSAT. The infrared data are particularly useful in such projects a wetlands delineation.

Finally, the results indicate that there are alternatives to the time-consuming process of "signature extraction". Since this is an important contribution of this report, the following brief discussion should help to orient the reader.

Supervised and unsupervised classifications are commonly used to derive "signatures", or spectral

Table 1.2a

First Round Designated Critical Areas - Tidal Wetlands

SITE	CSP DESIGNATION NUMBER Tidal Wetlands	NUMBER OF ACRES (*) Impact Area	Buffer Area	Total
Severn Run Tributaries	1	1,720	480	2,303
Jug Bay	2	N/A	567	5,153
Eagle Hill Bog	3	292	45	344
South River Headwaters	4	5,590	N/A	9,321
Round Bay Bog	5	N/A	10	33
Gunpowder Delta/Day's Cove	6	1,120	1,093	1,334
Zekiah Swamp	7	N/A	N/A	17,600†
Mattawoman Creek	8	N/A	N/A	6,000†
Big Marsh/Howell Point	9	N/A	717	870
Broad/Henson Creek Marsh	10	N/A	67	204
Piscataway Creek	11	N/A	N/A	2,450†
Chaptico Run	12	N/A	312	1,040
Killpack/Trent Hall Creeks	13	N/A	186	444
Pocomoke River	14	N/A	N/A	18,700†
Sullivan's Cove	15	10	8	26
Deep Pond/Beverly Beach	16	129	72	353
Black Marsh	17	N/A	510	520
Bush Creek Marsh	18	514	230	296
Church Creek Marsh	19	660	274	934
Otter Point Creek Marsh	20	1,610	728	922
Swan Creek Marsh	21	771	447	344

(*) These acreages are approximate, and were determined as part of this study by counting the 1.1 acre pixels within the Critical Area boundaries on processed LANDSAT MSS digital imagery. Examples of the imagery processed through the ASTEP computer programs (see Chapter 3) are included in Appendix A of this report.

(†) Acreages not computed. These acreages as published in "Areas of Critical State Concern: Designation Report", 1981.

(N/A) Indicates that acreage count is not applicable to this category.

Table 1.2b

First Round Designated Critical Areas - Non-Tidal Wetlands

SITE	OSP DESIGNATION NUMBER Non-Tidal Wetlands	NUMBER OF ACRES (*) Impact Area	Buffer Area	Total
Severn Run Tributaries	1	1,720	480	2,905
Jug Bay	2	N/A	567	5,153
Eagle Hill Bog	3	292	45	344
South River Headwaters	4	5,590	N/A	9,321
Round Bay Bog	5	N/A	10	38
Gunpowder Delta/Day's Cove	6	1,120	1,093	1,334
Zekiah Swamp	7	N/A	N/A	17,800 [$]
Mattawoman Creek	8	N/A	N/A	6,000 [$]
Big Marsh/Howell Point	9	N/A	717	870
Broad/Henson Creek Marsh	10	N/A	67	204
Piscataway Creek	11	N/A	N/A	2,450 [$]
Chaptico Run	12	N/A	312	1,040
Killpeck/Trent Hall Creeks	13	N/A	136	444
Pocomoke River	14	N/A	N/A	18,700 [$]
Fresh Pond/Angel's Bog	15	101	47	209
Battle Creek Cypress Swamp	16	N/A	210	113
Finzel (Cranberry) Swamp	17	N/A	N/A	107
Potomac Shoreline Marshes	18	N/A	N/A	435
Suitland Bog	19	N/A	N/A	25 [$]
	Special Areas Designation Number			
Pocomoke River	SA 1			18,700
Salisbury Paleochannel	SA 2			15,000

(*) These acreages are approximate, and were determined as part of this study by counting the 1.1 acre pixels within the Critical Area boundaries on processed LANDSAT MSS digital imagery. Examples of the imagery processed through the ASTEP computer programs (see Chapter 3) are included in Appendix A of this report.

($) Acreages not computed. These acreages as published in "Areas of Critical State Concern: Designation Report", 1981.

(N/A) Indicates that acreage count is not applicable to this category.

response curves, each representing a specific ground cover class. Ideally, a signature can be expressed as mean spectral values and an associated covariance matrix for all bands of LANDSAT data included in the analysis. Unfortunately, the spectral signature of a class is not necessarily unique, but usually shows variations depending on the conditions of measurement, variances in atmospheric scatter for reflected light measured by the sensor, differences in the amount of solar illumination, and the mix of objects on the ground.Furthermore, the development of signatures, especially for a supervised classification, requires expertise not likely to be found among nonspecialists. The results of classifications based on unsupervised techniques (e.g. clustering algorithms), density slicing, and special applications such as the use of various vegetative indexes can be seen in Chapter 4. These faster, and more readily learned, techniques may be compared to the signature-extraction method employed in the Zekiah Swamp case study.

Although successful in this study, it should be noted that most of the analysis required only wetland delineation. As suggested above, signature-extraction procedures may still be required if the level of detail is significant and a large number of ground cover types need to be extracted.

CHAPTER 2

THE CRITICAL AREAS PROGRAM

David Burke and Chris Zabawa

2.1 Legislative Mandate

The Maryland "Critical Areas" Program enabling legislations, Article 88C, requires the Maryland Department of State Planning (DSP) to designate Areas of Critical State Concern, after consultation with and in consideration of recommendations submitted by local governments. The legislation also empowers DSP to issue guidelines for use by local subdivisions in making Critical Areas recommendations. Guidelines are published in the Maryland Register on January 7, 1976, and were the product of an extensive cooperative effort between the Department of State Planning, other State agencies, local governments and special interest groups.

In 1979-1980, the Coastal Resources Division of the Department of Natural Resources reaffirmed its decision to use the Critical Areas Program to fulfill federal requirements for implementing a "Geographic Areas of Particular Concern Program" (GAPCP).

The Federal Coastal Zone Management Act requires each state participating in the program to designate GAPCP's within their jurisdiction. The Department of State Planning's Critical Areas Program has been acknowledged, by the federal government, as fulfilling the legislative intent of the Act. The Coastal Resources Division has assisted DSP with the development of their Critical Areas Program by providing financial support and preparing a report suggesting which generic classes of Critical Areas and which specific areas recommended by local governments, within the Maryland Coastal Zone, (Figure 2.1) should be given early consideration for designation.

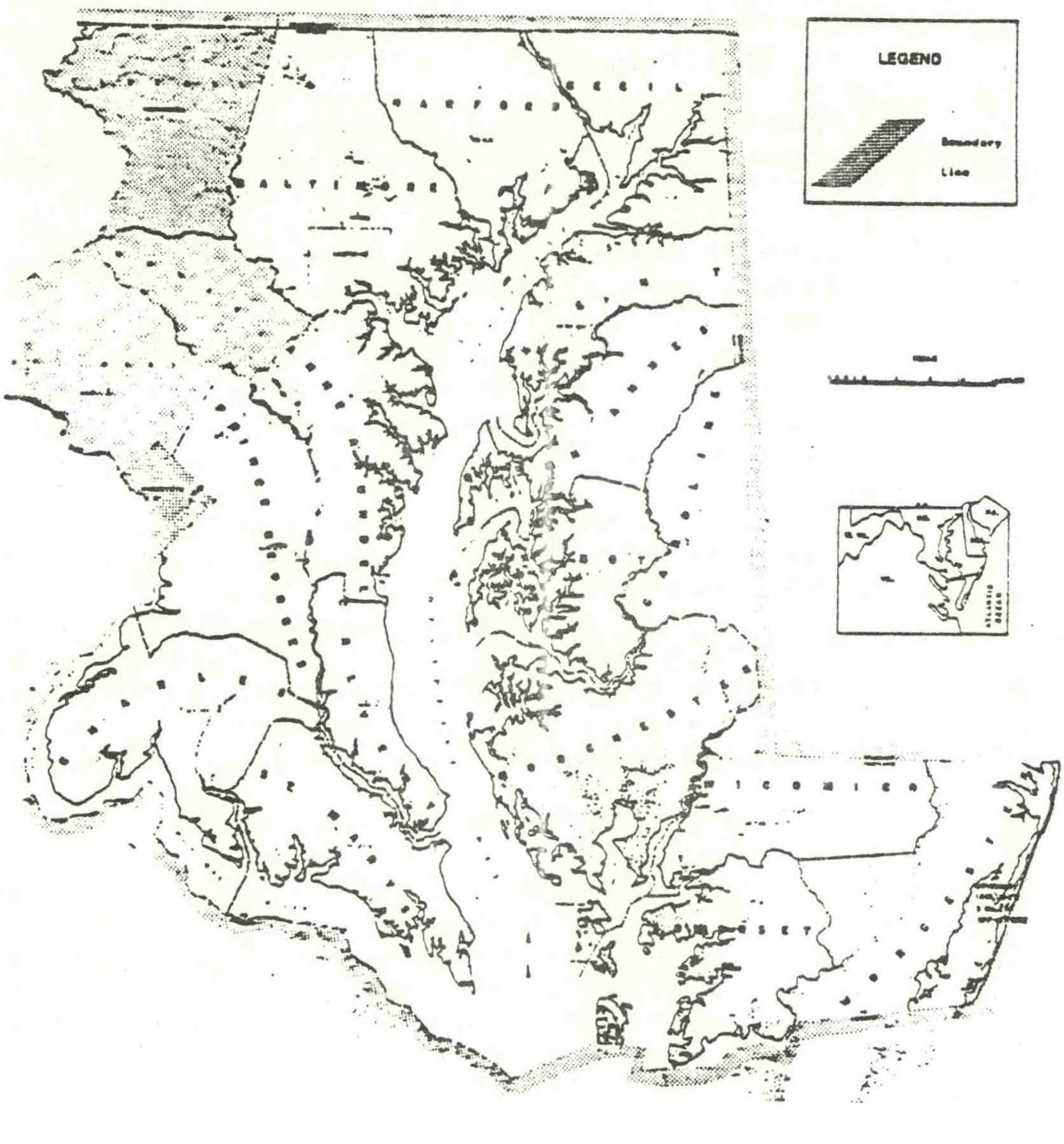
In January, 1981, the Maryland Department of State Planning published the Areas of Critical State Concern: Designation Report which contains the first formal designation of Areas of Critical State Concern. These first-round designations fall within four classes: tidal wetlands, non-tidal wetlands, protection and enhancement of rail service, and "special areas". Separate sections of the Designation Report are devoted to site descriptions, ownership patterns, planning and zoning, threats and problems, and management goals specific to each site.

2.2 General Management Goals

The 1981 Department of State Planning Areas of Critical State Concern: Designation Report states (p. ix) that: "Critical Areas, designated as part of the State Development Plan, are accorded special status and will receive special attention. It is intended that State and local governments should care for these areas and their actions

<u>Figure 2.1</u>

Maryland Coastal Zone Management Program Boundary



Reprinted from: <u>State of Maryland Coastal Management Program and Final Impact Statement</u>, published by the U.S. Dept. of Commerce, NOAA (Office of Coastal Zone Management) (1980).

should reflect a major commitment toward these resources and the continuing program." The Designation Report goes on to list specific actions which can be taken by DSP to ensure appropriate management of Designated Critical Areas:

1. Intervene in administrative, judicial, or other proceedings concerning land use, development, or construction in order to gain proper management of Critical Areas;

2. Prepare model zoning, subdivision and other regulatory provisions to aid in management of Critical Areas;

3. Conduct State Clearing House Project Reviews to assure consistency with management and other aspects of Critical Areas;

4. Make capital improvements decisions that will avoid, to the extent possible, or mitigate detrimental impacts on Critical Areas;

5. Provide technical assistance to State and local agencies to aid in Critical Area identification and management;

6. Give high priority in the administration of planning grant assistance programs to substate jurisdictions that will enhance and implement the Critical Area program.

7. At the same time local governments are similarly required to:
   a. adopt designated sites in local comprehensive plans;
   b. annually review the impacts of local zoning decisions on designated sites;
   c. develop new generic classes within which more sites can be recommended for Critical Areas designation.

For those generic classes included in the first-round of Critical Areas designations, the anticipated results of the Critical Areas Program can be summarized as follows:

Class I - Tidal Wetlands - The general goal is to protect against physical impacts that can adversely affect wetlands.

Class II - Non-tidal wetlands - The general goal is to protect against physical impacts that adversely affect wetlands, to inventory more fully the non-tidal wetlands, and then to emphasize existing programs which can be used for management of these areas, since they are not regulated under the State's Tidal Wetlands Program.

Class III - Rail Service Areas - The goal is to protect and carefully plan for the future use of 15 designated rail lines throughout the State of Maryland that are in a state of disuse, abandoned, or required to connect Maryland with the rail networks of adjacent states.

Class IV - Special Areas - Two special areas were included in the 1981 Designation Report: Pocomoke River and Salisbury Paleochannel, which do not fit into any of the other First-Round generic classes. The goal for the Pocomoke River is to develop a comprehensive coordinated policy oriented towards development pressures throughout the watershed, towards channelization projects to aid drainage, and towards land-clearing and land-filling activities. The goal for the Salisbury Paleochannel, a fragile underground source of groundwater, is to define its spatial extent and production capacity across the Delmarva Peninsula, and to develop a comprehensive plan to protect against over-appropriation of the stored water supplies, and contamination from incompatible land uses in the area above its known limits.

The following sections of this report contain a discussion and evaluation of techniques for environmental monitoring of the Class I and Class II Designated Critical Areas described above. Some discussion is also devoted to the Pocomoke River watershed (Class IV Critical Area). The Rail Service Areas were not included in the scope of investigations for this report; however, the interested reader will be able to understand from the following chapters how the remote-sensing techniques which are part of the LANDSAT satellite technology can be applied to the monitoring of impacts where appropriate in the Designated Rail Service Areas.

Figures 2.2-2.4 contain location maps and listings of the areas which were identified as part of the First-Round Designation of Critical Areas found within Maryland's Coastal Zone boundary (Figure 2.1).

2.3 General Guidelines For Environmental Monitoring

To test the utility of using LANDSAT for "environmental monitoring", the Department of State Planning was asked to specify which physical activities within or adjacent to a Critical Area should resource managers be able to identify to effectively monitor the environment.

The following list, formulated by DSP, represents those specific activities, which it is thought would be useful to identify or monitor, in the ongoing management of Critical Areas.

- Identify dumping of refuse or other debris.
- Monitor sediment movement/buildup.
- Recognize cutting of timber (both individual trees

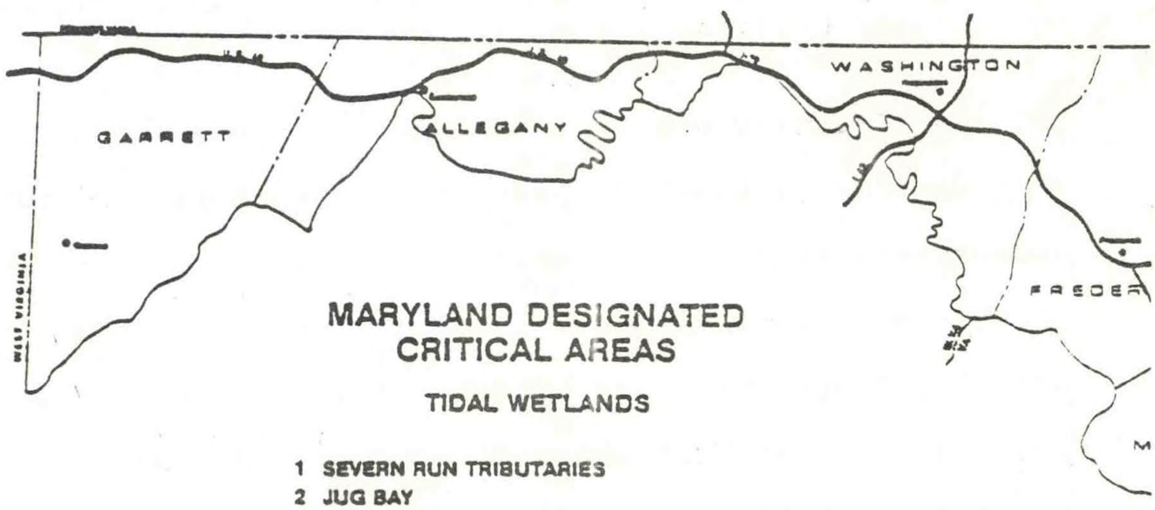
and timber stands).

- Identify clearing of areas.
- Identify initial states of construction on adjacent properties.
- Identify frequency of visitation by cars or boats.
- Monitor expansion of nearby activities, such as sand and gravel removal, farming, drainage improvements.
- Identify evidence of excessive runoff into buffer or Critical Areas, including monitoring flooding of sites.
- Identify upstream erosion of sites.

Obviously, some of these requirements for monitoring necessitate site visits, while others could be monitored using remote sensing data from LANDSAT satellites or aerial photography. The capabilities of digital data collected by the Multispectral Scanner (MSS) on board the LANDSAT satellites are discussed in the following chapters of this report vis-a-vis aerial photography as a suitable methodology for evaluating the management interests listed above. The general conclusions regarding the best methods for evaluating any of the above management interests are listed in Table 1.1, in Chapter 1 of this report.

Figure 2.2

Map of Class 1 - Designated Critical Area Sites
(Tidal Wetlands)



1 SEVERN RUN TRIBUTARIES
2 JUG BAY
3 EAGLE HILL BOG
4 SOUTH RIVER HEADWATERS
5 ROUND BAY BOG
6 GUNPOWDER DELTA MARSH/DAY'S COVE
7 ZEKIAH SWAMP
8 MATTAWOMAN CREEK
9 BIG MARSH/HOWELL POINT
10 BROAD/HENSON CREEK MARSH
11 PISCATAWAY CREEK
12 CHAPTICO RUN
13 KILLPECK/TRENT HALL CREEKS
14 POCOMOKE RIVER
15 SULLIVAN'S COVE MARSH
16 DEEP POND/BEVERLY BEACH
17 BLACK MARSH
18 BUSH CREEK MARSH
19 CHURCH CREEK MARSH
20 OTTER POINT CREEK MARSH
21 SWAN CREEK MARSH

Prepared by
MARYLAND DEPARTMENT OF STATE PLANNING
January, 1981

Figure 2.2

Map of Class I - Designated Critical Area Sites
(Tidal Wetlands)

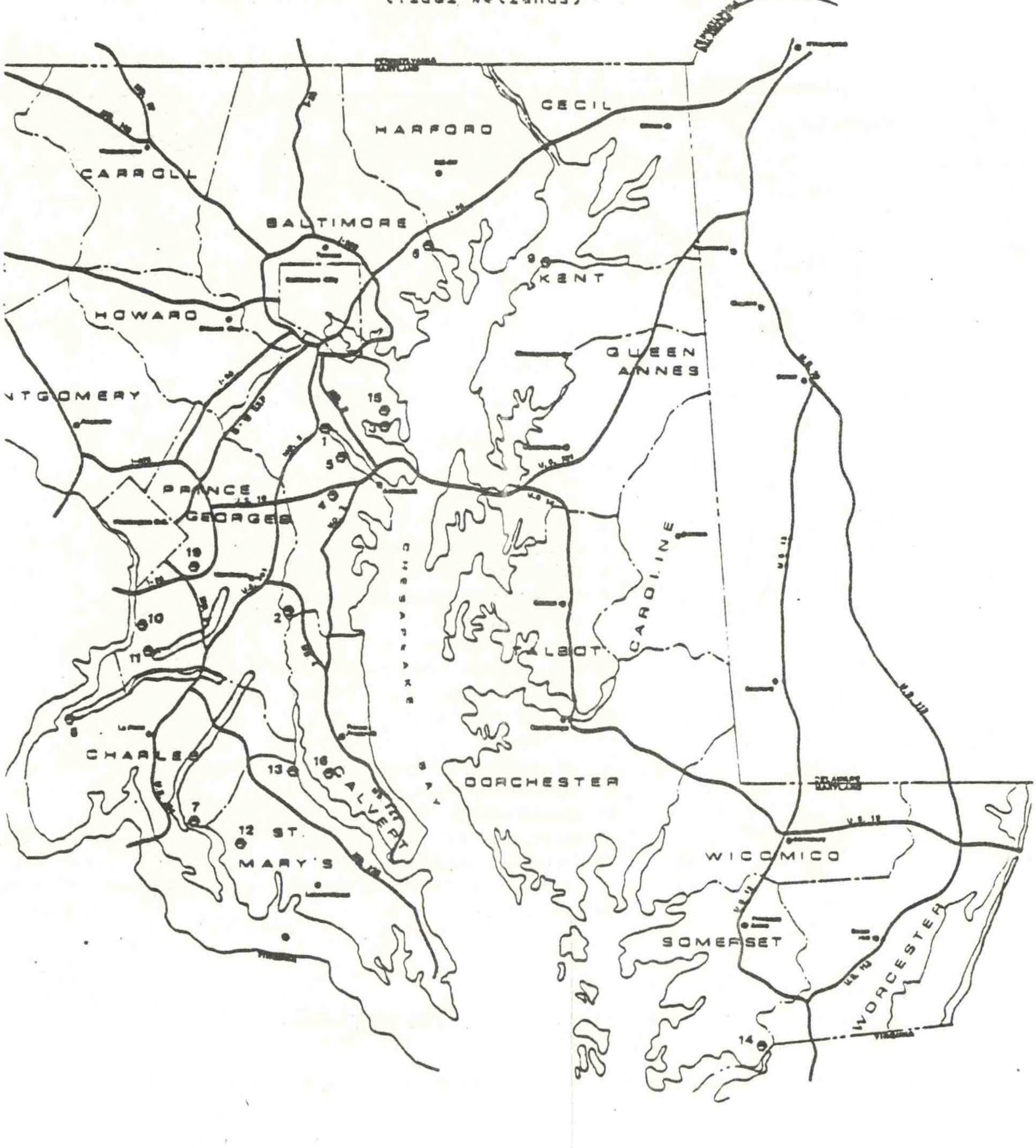


Figure 2.3

Map of Class II - Designated Critical Area Sites
(Non-Tidal Wetlands)

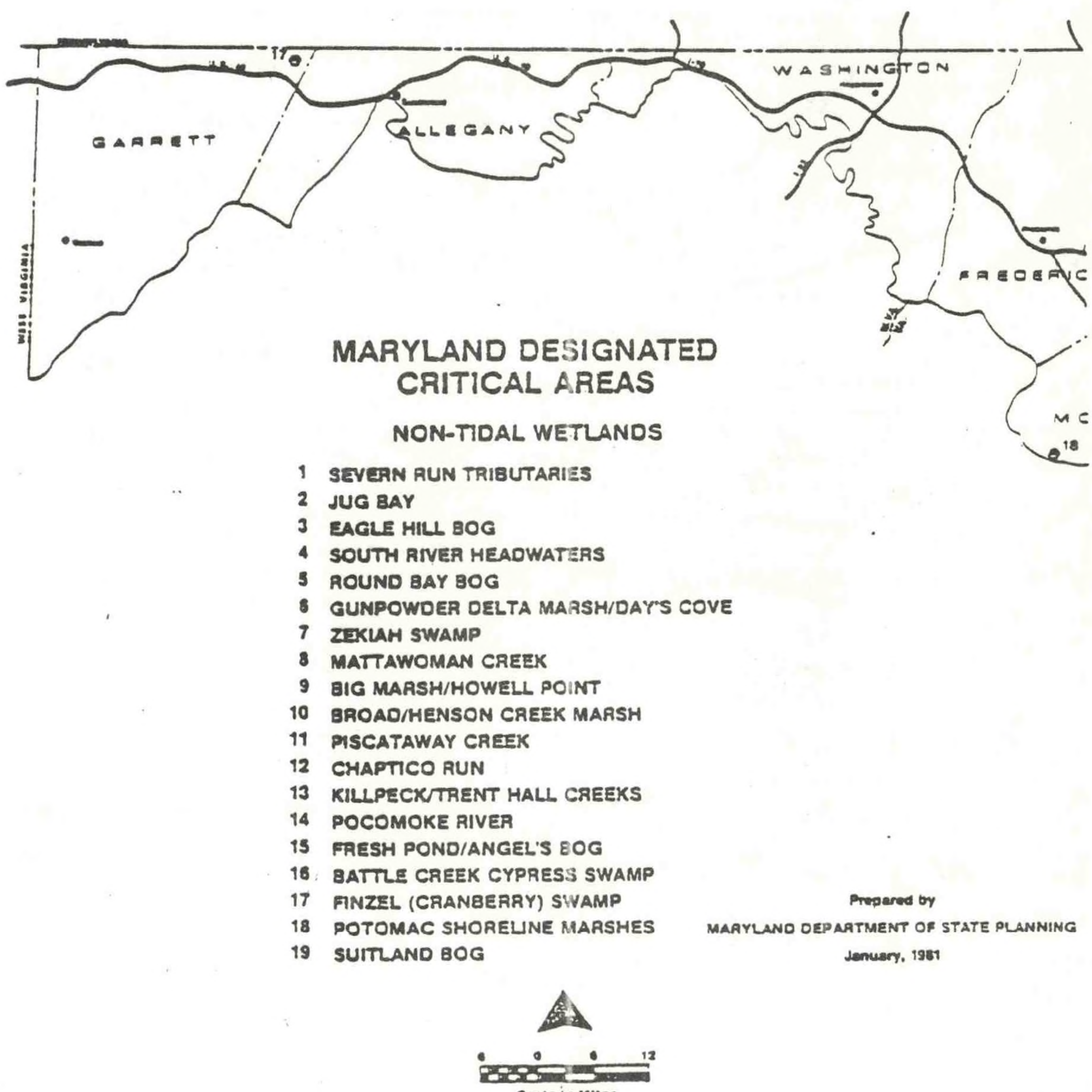


Figure 2.3

Map of Class II - Designated Critical Area Sites
(Non-Tidal Wetlands)

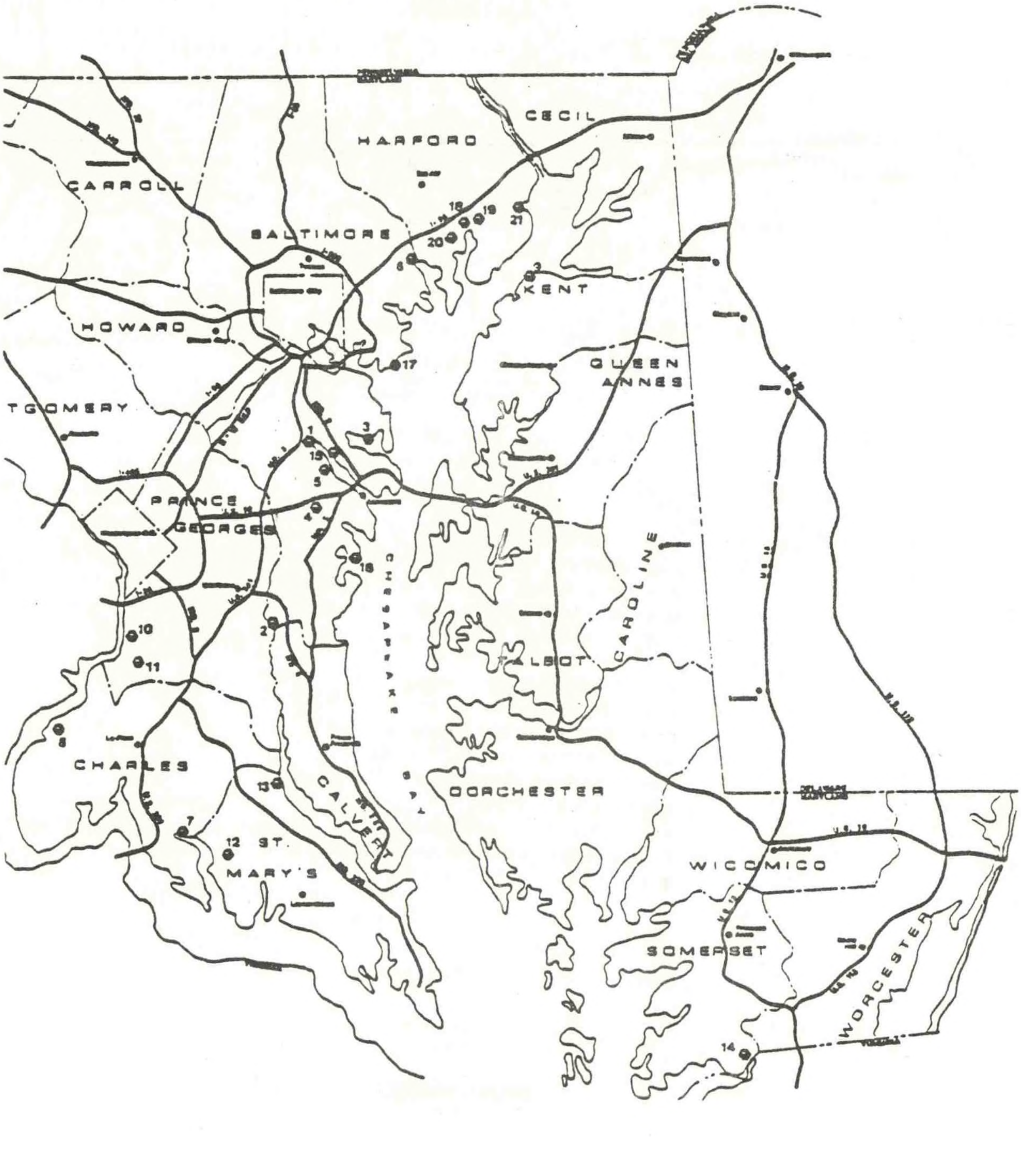


Figure 2.4

Map of Class III & IV - Designated Critical Area Sites
(Abandoned Railroad Rights of Way & "Special Areas)"

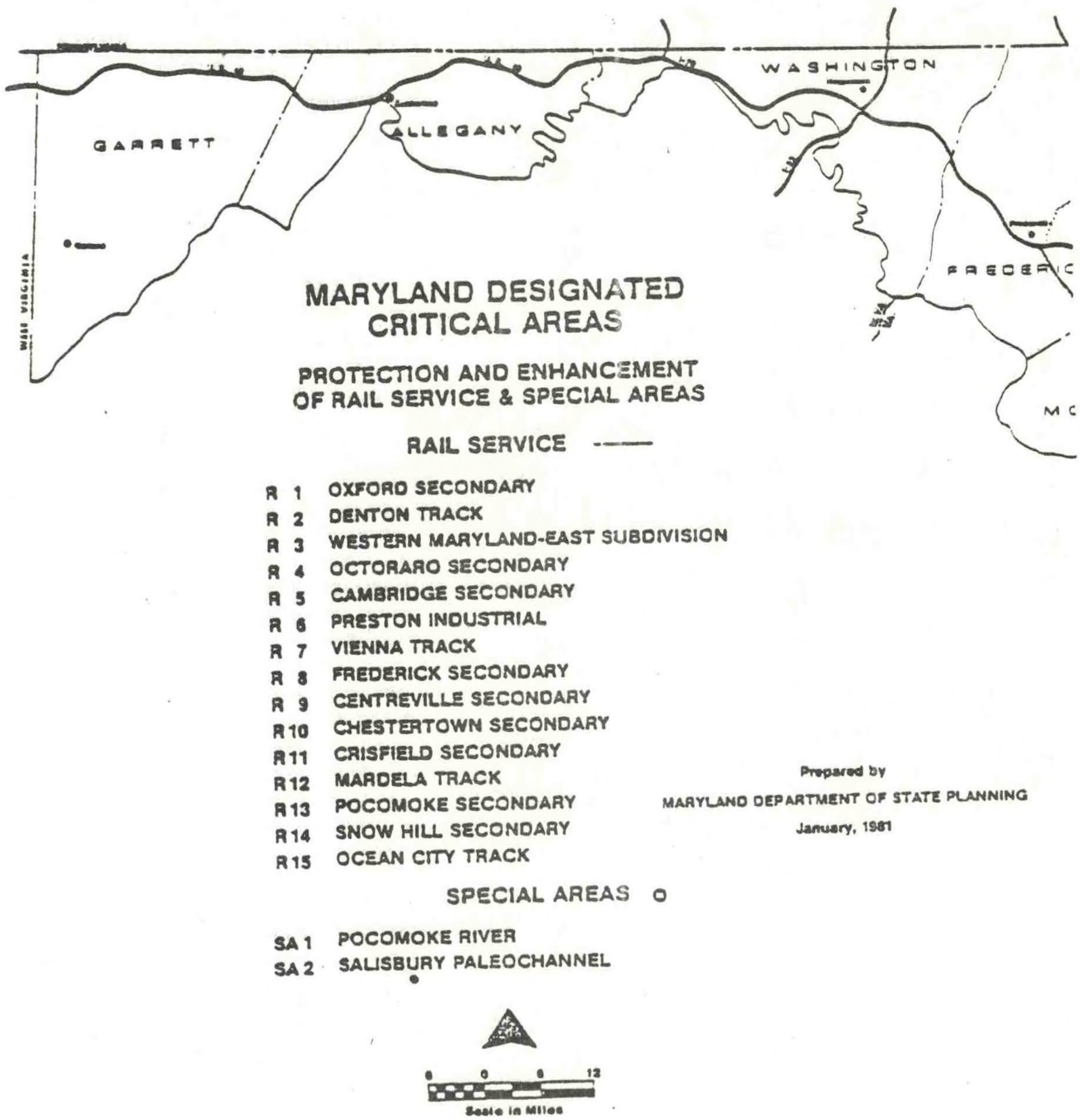
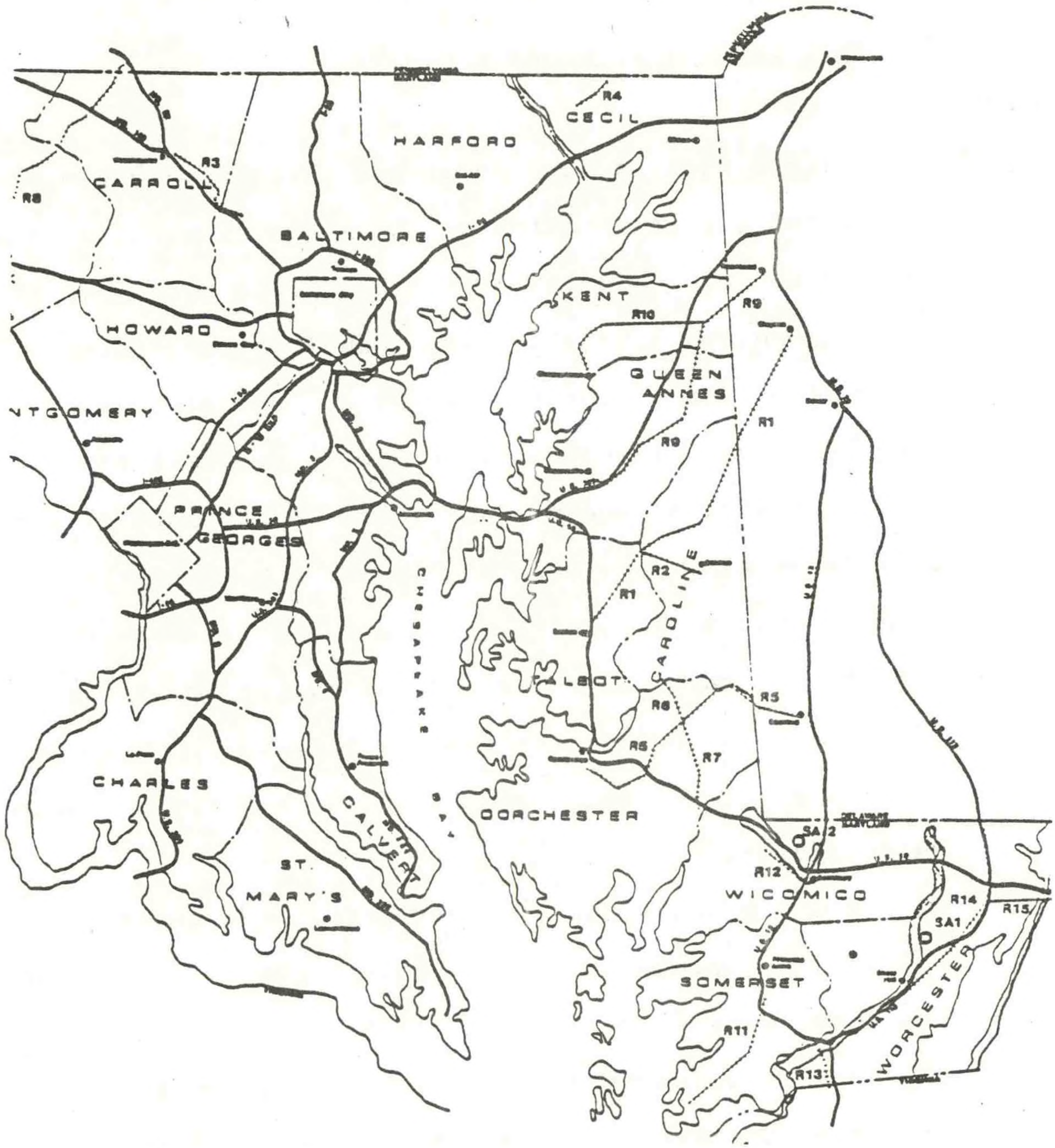


Figure 2.4

Map of Class III & IV - Designated Critical Area Sites
(Abandoned Railroad Rights of Way & "Special Areas)



CHAPTER 3

LANDSAT TECHNIQUES FOR CLASSIFYING STATE CRITICAL AREAS

K.-Peter Lade and David A. Block

3.1 What is Digital Image Processing?

Remote sensing techniques are collectively concerned with obtaining information about various aspects of the earth's surface by collecting data from a distance. The most common means of acquiring these data are optical photography and electronic scanning. In both cases various platforms are employed, including aircraft and satellites. Scanners, whether active as in the case of radar, or passive as in the case of LANDSAT's multispectral scanner system, typically produce a digital record rather than an optical one. This digital record is in the form of a matrix of numbers so that each column in each row is given a value for each spectral band in which the scanner is recording.

A photo image can be constructed from these spectral reflectance values by replacing each number with a dot. The tonal density of the dots is varied in accordance with the numeric value--the higher the value, the darker the dot; the resulting picture resembles a newspaper photo or a television image. Thus,by processing scanner data into photo products, the principles of aerial photo interpretation may be applied to digital data.

With the aid of a computer it is possible to employ powerful statistical techniques to directly manipulate digital data. This not only overcomes some of the weaknesses inherent in photo interpretation such as interpreter subjectivity, limited ability to discriminate among a large number of tonal gradations, and difficulty in producing reproducible quantitative measures, but also permits the reliable integration of digital data with other data sources.

From the time that LANDSAT multispectral data were first collected the tendency has been to rely increasingly on computer analysis and less on traditional photo interpretation of a processed image. The result is that it has become possible to explore the full spatial and spectral resolution of vast quantities of data and to integrate those data with an ever-increasing variety of statistical models and management strategies.

The first LANDSAT satellite was launched by NASA in 1972; and since then three more satellites have been placed into orbit to provide an uninterrupted stream of remotely-sensed data. LANDSAT data take the form of digital measurements of reflected energy in four different portions of the electromagnetic spectrum (see Table 3.1). One set of these measurements of reflected energy is recorded by a multispectral scanner (MSS) for each 1.1

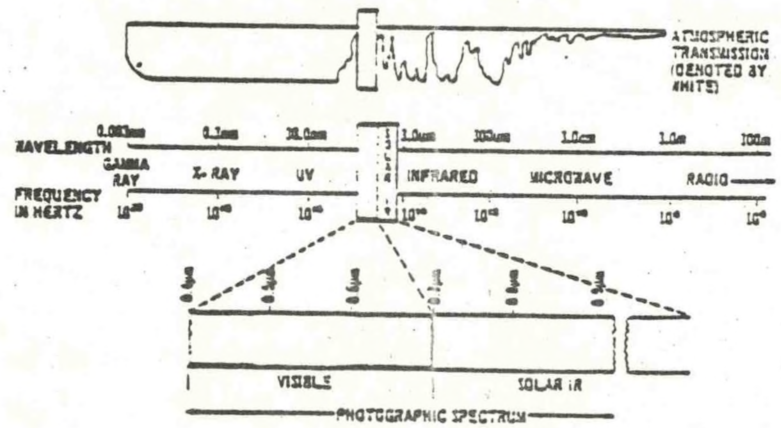
acre parcel of a scene. (A typical scene covers 8,464,000 acres, or 13,225 square miles). Figure 3.1 shows how LANDSAT data collected from Maryland or adjacent states appear on one of four possible scenes (Path:Row 15/33, 16/33/ 17/33 and 18/33) on orbits over the eastern U.S. Data from any orbit is transmitted back to earth from the LANDSAT satellites as a series of discrete values depicting the amount of reflected energy from every 1.1 acre portion (pixel) in the scene for each of the four bands listed in Table 3.1. These data are then processed at ground facilities into images which resemble photographs of the earth's surface taken from outer space. One such representative photograph is shown in Figure 3.2. Processed LANDSAT images are sold over the counter, along with the raw data stored on computer compatible tapes (CCT's), and can be ordered by State agencies or other appropriate institutions from the U.S.G.S. EROS Data Center in much the same way as topographic maps are purchased through the mail (Watkins, 1979).

Since different types of land cover reflect different amounts of sunlight in different portions of the electromagnetic spectrum, the computer processing of the digital light reflectance values collected by the LANDSAT satellites can provide remotely-sensed impressions of the earth's surface that have many unique qualities apart from simple aerial photography. In addition, the LANDSAT digital data offer several advantages over air photo

Table 3.1

The electromagnetic spectrum with the visible range and reflected (solar infrared) range shown in detail.

ELECTROMAGNETIC SPECTRUM



The four bands in the LANDSAT MSS which are useful for earth resource identification are:

Band 4: The green band, between 0.5 and 0.6 micrometers. This band is most useful for identifying sediment-laden water and delineates areas of shallow water, shoals, and reefs.

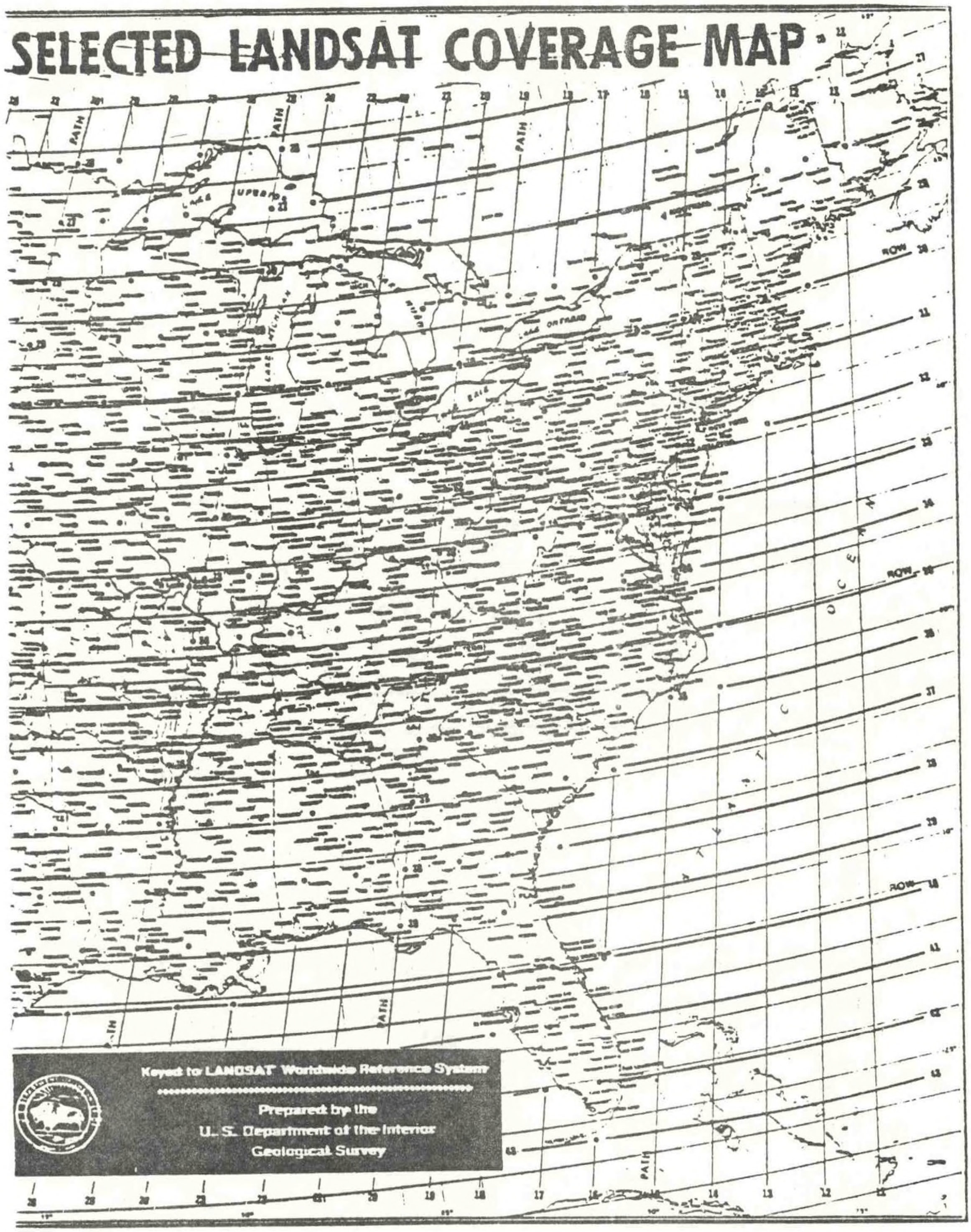
Band 5: The red band, between 0.6 and 0.7 micrometers. This band is most useful for identifying man-made cultural features such as urban and rural settlements.

Band 6: The near-infrared band, between 0.7 and 0.8 micrometers. This band is most useful for identifying vegetation, landforms, and the boundary between land and water.

Band 7: The near-infrared band, between 0.8 and 1.1 micrometers. This provides the best penetration of atmospheric haze and also emphasizes vegetation and landforms.

Figure 3.1

LANDSAT Satellite Coverage Map for the Eastern United States



Source: EROS Data Center, Sioux Falls, South Dakota interpretation as a method for monitoring natural resources in designated Critical Areas, and impacts on these areas from activities on adjacent lands.

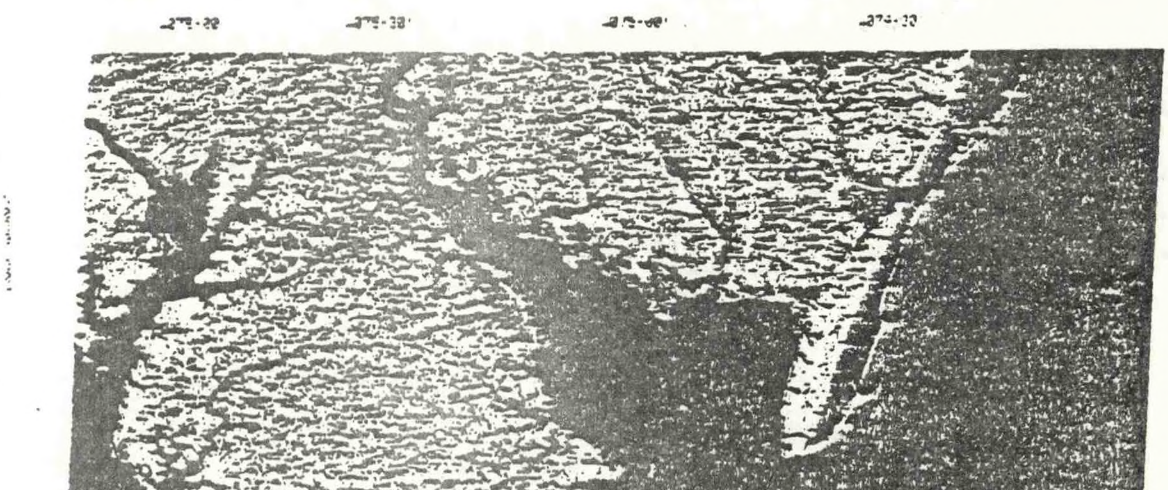
These advantages include:

- sequential coverage every eighteen days; with added value of ten years worth of data that have accumulated since 1972
- infrared images reveal many earth features more clearly than simple aerial color photography
- mechanical processing of each 1.1 acre eliminates "operator error" common from scene to scene or from study-to-study in conventional air photo methods.

3.2 Generating The LANDSAT Images

Once the computerized LANDSAT data and matching photographs have been procured from the U.S.G.S. EROS Data Center, these data need to be processed by a computer to produce meaningful results. Researchers at the State Universities and Colleges of Maryland employ a software package termed ASTEP (Algorithm Simulation and Testing Evaluation Program) to access and process LANDSAT satellite imagery. The steps, or routines, which the ASTEP computer programs accomplish have been previously described in a DNR report User's Guide to LANDSAT Satellite Imagery for Studying Natural Resources in Maryland (Blades, et. al., 1982) together with a sample demonstration of the digital processing methodology for a satellite scene of Maryland's Ocean Coast, including Fenwick Island (Town of Ocean City), Ocean City Inlet and Assateague

Figure 3.2



LANDSAT photo of Band 4 on December 24, 1975. Scene 15/33 (Path/Row), centered on Dover, Delaware, includes portions of Maryland's Eastern Shore and Ocean Coast.

Island.

Due to satellite motion and earth rotation, LANDSAT maps tend to be inherently distorted. If the total size of the area being studied is relatively small (e.g less than 2500 acres) it may be possible to ignore the distortion. However in attempting to register a computer-generated LANDSAT map to such standard base maps as the 7.5 minute USGS topo quad sheets, the distortion is sufficient enough to make comparisons difficult.

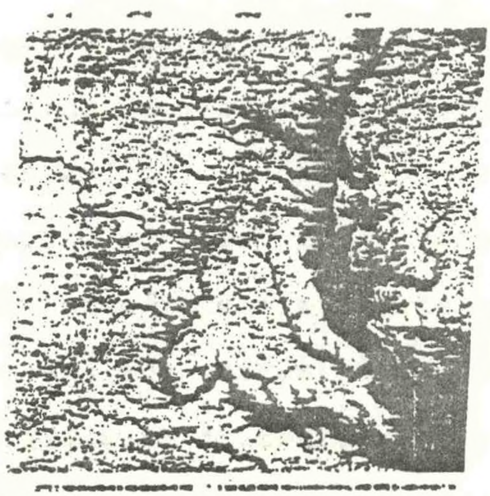
There are several solutions to this dilemma. The easiest remedy employs a zoom transfer scope-- an optical device that permits one to optically overlay two images. Although this is probably the most rapid means by which close registration may be achieved there are a number of disadvantages to using a zoom transfer scope: the instrument is costly and requires a moderate amount of skill to be used successfully; the results are one-time and cannot be used as input into further analyses; once registration is achieved, the merged data must either be photographed or redrawn by hand. These limitations were judged sufficiently severe that after an initial trial, further use of the zoom transfer scope was not attempted in this study.

A second solution utilizes a standard resampling algorithm for resampling the data so that it nearly approximates some standard base map. The ASTEP programs include a routine for deskewing and rescaling the data. For small areas (less than 500 acres) this routine is

Table 3.2

CCT List

Salisbury State College/DNR Cooperative Project



Path/Row 16/33	Path/Row 15/33
11 Oct. 72	10 Oct. 72
2 June 73	30 Aug. 73
8 July 73	24 Dec. 75
17 Apr. 75	5 Aug. 76
30 June 78	23 Aug. 76
16 July 80	9 Apr. 78
1 Nov. 80	11 June 78
	27 June 80
	31 Oct. 80
	29 Sept. 81

adequate for many purposes including numerical analysis and comparison with ground-truth data. Larger areas, however, require better registration of the LANDSAT data to a base map, and are easier to work with if the entire scene is rotated to a north-south axis.

A third solution involves reforming the LANDSAT image by resampling the original data according to a regression equation that fits the distorted image of the LANDSAT scene to a selected base map, such as a topo quad sheet. This latter solution has the advantage that the resampled data may then be statistically analyzed repetitively. The greatest difficulty lies in defining appropriate ground-control points on both the LANDSAT digital map and the base map so that the development of a successful regression equation can occur. The success of such an equation is measurable in terms of the variation between the actual and predicted error rates in relocating the ground-control points by virtue of the equation.

All three approaches were used in assessing each of the Critical Areas and are discussed in further detail in the following section.

3.3 LANDSAT Digital Analysis Applied To Critical Areas

To be effective, any management strategy designed for Maryland's Designated Critical Areas requires a continuing source of information concerning the physical impacts likely to affect each of the Areas. Although on-site inspection of each Critical Area would undoubtedly be most desirable, such an effort conducted on a regular and continuing basis would not be economically feasible. Ideally, one should seek a long record of observations, uniform for each of the Critical Areas, that takes into account a variety of impacts on each of the Critical Areas. By combining records extending into the past with designs for projecting them into the future through continued monitoring, it would be possible to design and test meaningful management strategies.

Fortunately, as a result of the LANDSAT program, we have available such data, in digital form, accessible to planners and managers. Several of the needs listed on page 16-17 for evaluation of environmental conditions in Designated Critical Areas are well suited to the application of remote-sensing techniques either for continual monitoring or for identification of impacts on those natural resources located within the site boundaries. For the Class I and Class II First-Round Designations (Tidal and Non-tidal wetlands), the site boundaries are shown in Appendix A (Figures A.1-A.25), on a series of LANDSAT maps corresponding to those published in the 1981 Designation Report prepared by the Maryland Department of State Planning.

In order to assess the merits of using LANDSAT data to analyze Critical Areas in Maryland, a preliminary investigation was carried out on the following sites:

1. Eagle Hill Bog (320 acres), Site TN3
2. Round Bay Bog (90 acres), Site TN5
3. Gunpowder Delta Marsh/Day's Cove (1350 acres), Site TN6
4. Big Marsh/Howell Point (850 acres), Site TN9
5. Broad/Henson Creek Marsh (200 acres), Site TN10
6. Chaptico Run (1050 acres), Site TN12
7. Killpeck/Trent Hall Creek (450 acres), Site TN13
8. Sullivan's Cove Marsh (20 acres), Site T15
9. Deep Pond/Beverly Beach (350 acres), Site T16
10. Black Marsh (500 acres), Site T17
11. Bush Creek Marsh (300 acres), Site T18
12. Church Creek Marsh (300 acres), Site T19
13. Otter Point Creek Marsh (900 acres), Site T20
14. Swan Creek Marsh (325 acres), Site T21
15. Fresh Pond/Angel's Bog (200 acres), Site N15
16. Battle Creek Cypress Swamp (125 acres), Site N16
17. Suitland Bog (25 acres), Site N19

These sites were the smallest in acreage of the tidal and non-tidal Critical Areas in Maryland's Coastal Zone. It was felt that by preprocessing these data, tentative judgments could be made concerning the quality and appropriateness of using satellite data to analyze all Critical Areas. Taking into account problems that appeared at this early stage, a more intensive and systematic approach could then be implemented.

The initial analysis included the following steps in computer processing of the digital data:

1. Extracting the "windows" containing the areas of interest from the Computer Compatible Tape received from the EROS Data Center.

2. Executing "density slicing" and "uniformity" computer programs to display the spectral data in computer map form for each site.

3. conducting unsupervised classifications of the spectral data for selected sites using a clustering algorithm.

4. Identifying seasonal variation in the spectral characteristics of natural features (ponds, tidal wetlands, non-tidal wetlands, mudflats, etc.).

The mapping results appear in Appendix A, (Figures A.1-A.25). A number of points were revealed concerning spectral analysis of Critical Areas using remotely sensed data.

First, it is important to examine several different LANDSAT scenes for any particular Critical Area, because different features will be identifiable at different times of the year. For example, Big Marsh/Howell Point (Site TN9) is easier to delineate on Spring rather than on Summer LANDSAT scenes because vegetation does not mask the zone of saturated soil, which can be readily identified by the ASTEP programs. Accordingly, one task yet to be thoroughly addressed is to find other sites in the Maryland coastal zone where quantitative measurements of soil moisture have been gathered, and to use these data to determine the actual levels of soil moisture represented by the remotely sensed LANDSAT data for the Critical Areas. Further multitemporal investigations will then identify whether soil moisture conditions in Critical Areas have been constant from 1972-1981, or whether measurable changes have taken place over and above "normal" seasonal fluctuations.

Second, there are three important physical characteristics which will largely determine the suitability of any particular Critical Area for remotely sensed spectral data analysis:

1. Size of the area.
2. Contrast (differences in spectral characteristics , between a particular site and its surroundings).
3. Shape of the area.

The size of an area is particularly important because small areas of only a few acres are represented on a computer printout by too few pixels to be analyzed quantitatively. On the other hand, small Critical Areas can be discerned if they display a sharp contrast with their surroundings. For example, Fresh Pond/Angel's Bog (Site N15) contains a twelve acre pond which can be easily recognized by the LANDSAT data because it contrasts sharply with the surrounding landscape (see Figures 3.3 and 3.4).

Finally, the shape of an area needs to be considered when evaluating LANDSAT's utility for environmental monitoring. Large linear areas such as the narrow wetlands of Mattawoman Creek (Site TN8; 6000 acres), the Severn Run Tributaries (Site TN1; 3000 acres), and Piscataway Creek (Site TN11; 2450 acres) are more difficult to delineate than other Critical Areas which may be much smaller but which are not as narrow (see Figures 3.5 through 3.10).

Figure 3.3

Reference Map for Unsupervised LANDSAT Classification
of Fresh Pond/Angel's Bog (Site N15)

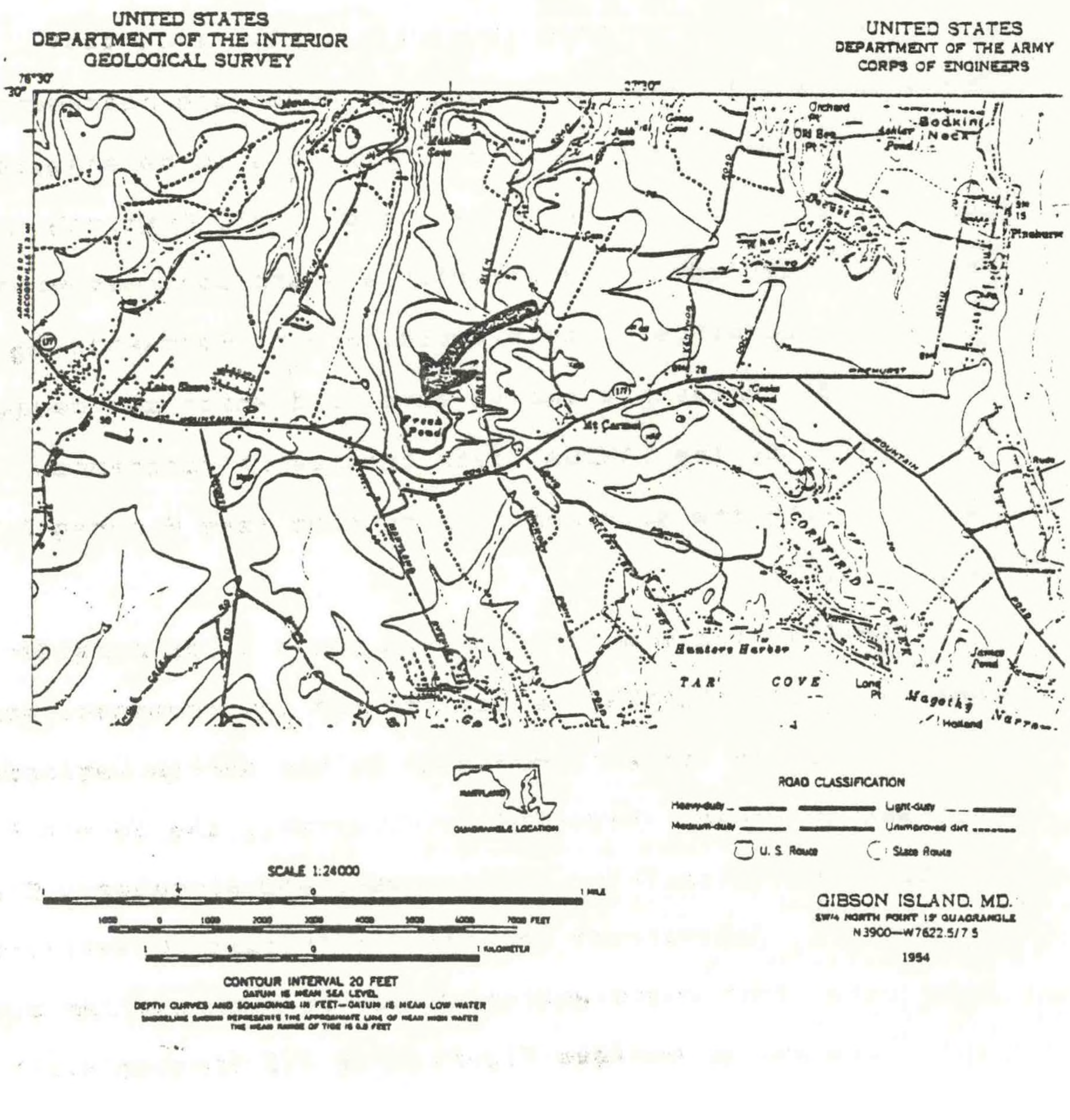


Figure 3.4

Computer Printout of Unsupervised LANDSAT Classification
of Fresh Pond/Angel's Bog (Site N15)

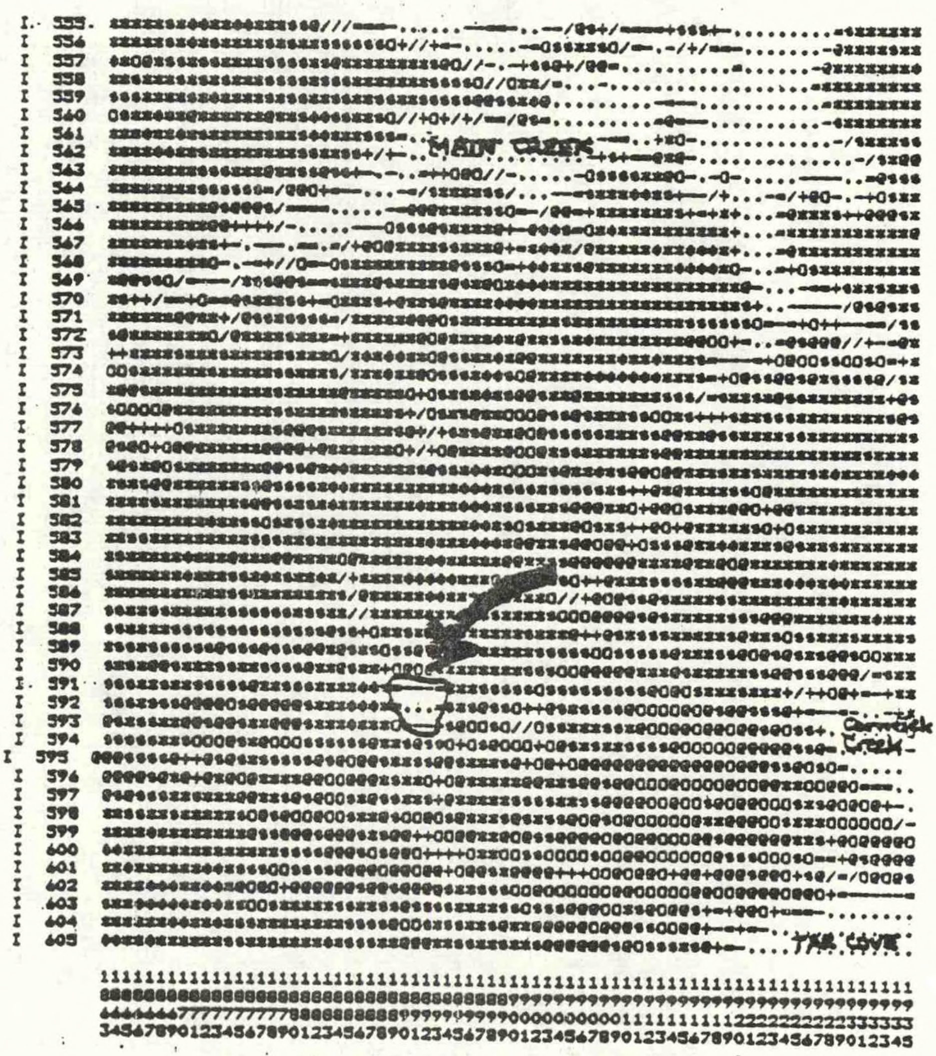
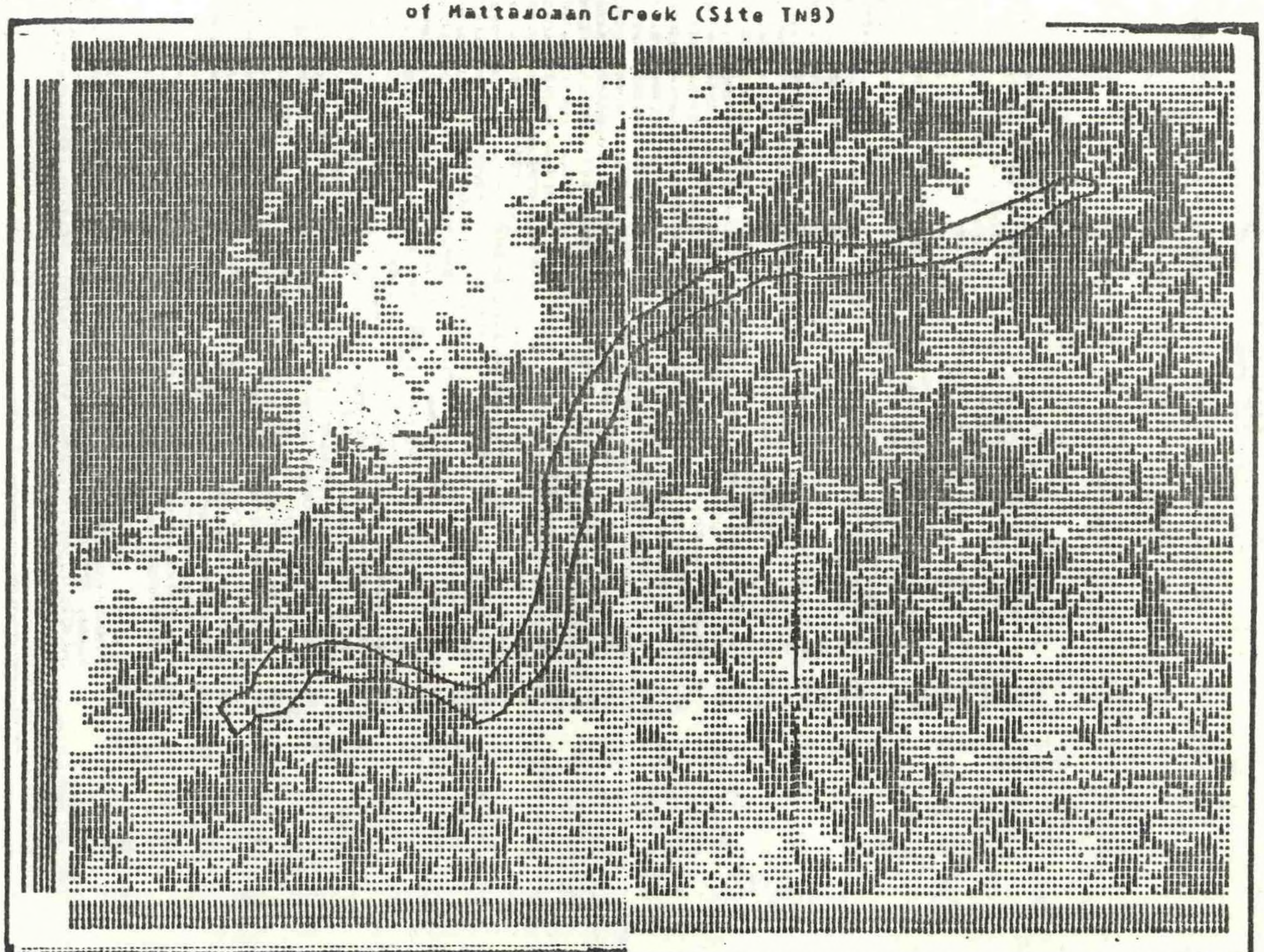


Figure 3.5

Computer Printout of Unsupervised LANDSAT Classification of Mattawoman Creek (Site TN8)



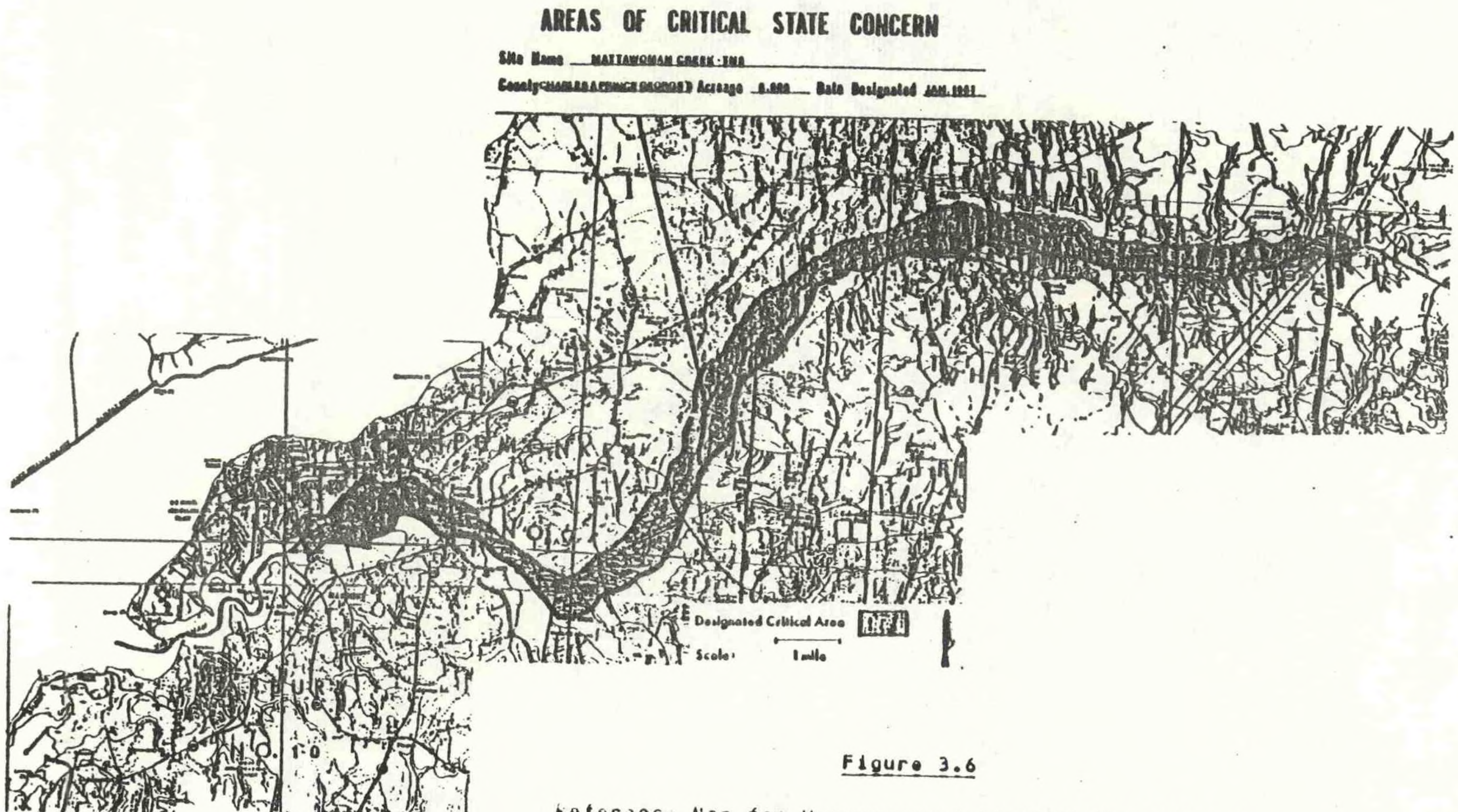
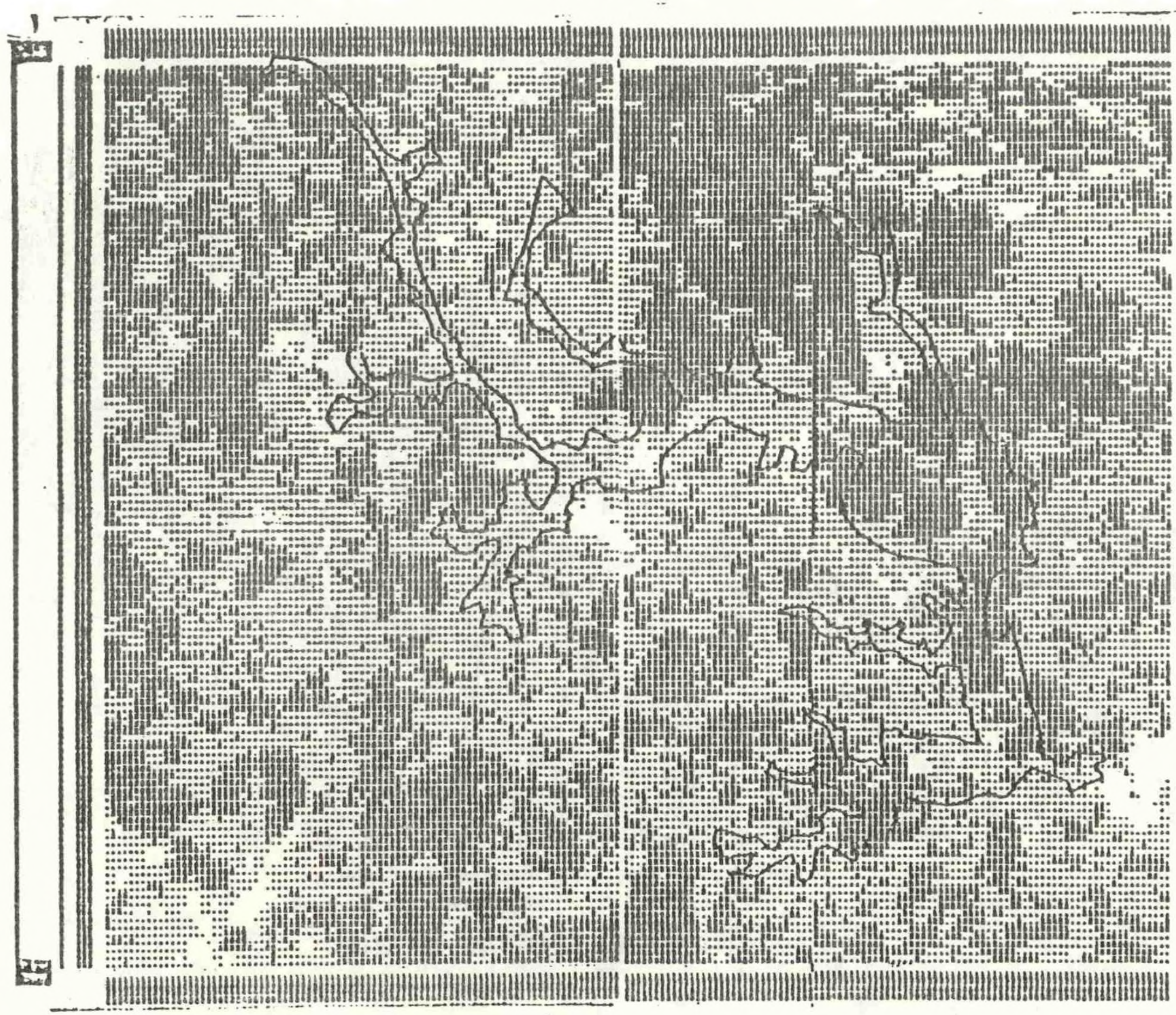


Figure 3.6

Reference Map for Unsupervised LANDSAT Classification of Mattawoman Creek (Site TNA)

Figure 3.7



Computer Printout of Unsupervised LANDSAT Classification
of Severn Run Tributaries (Site TM1)

Figure 3.8

Reference Map for Unsupervised LANDSAT Classification
of Severn Run Tributaries (Site TN1)

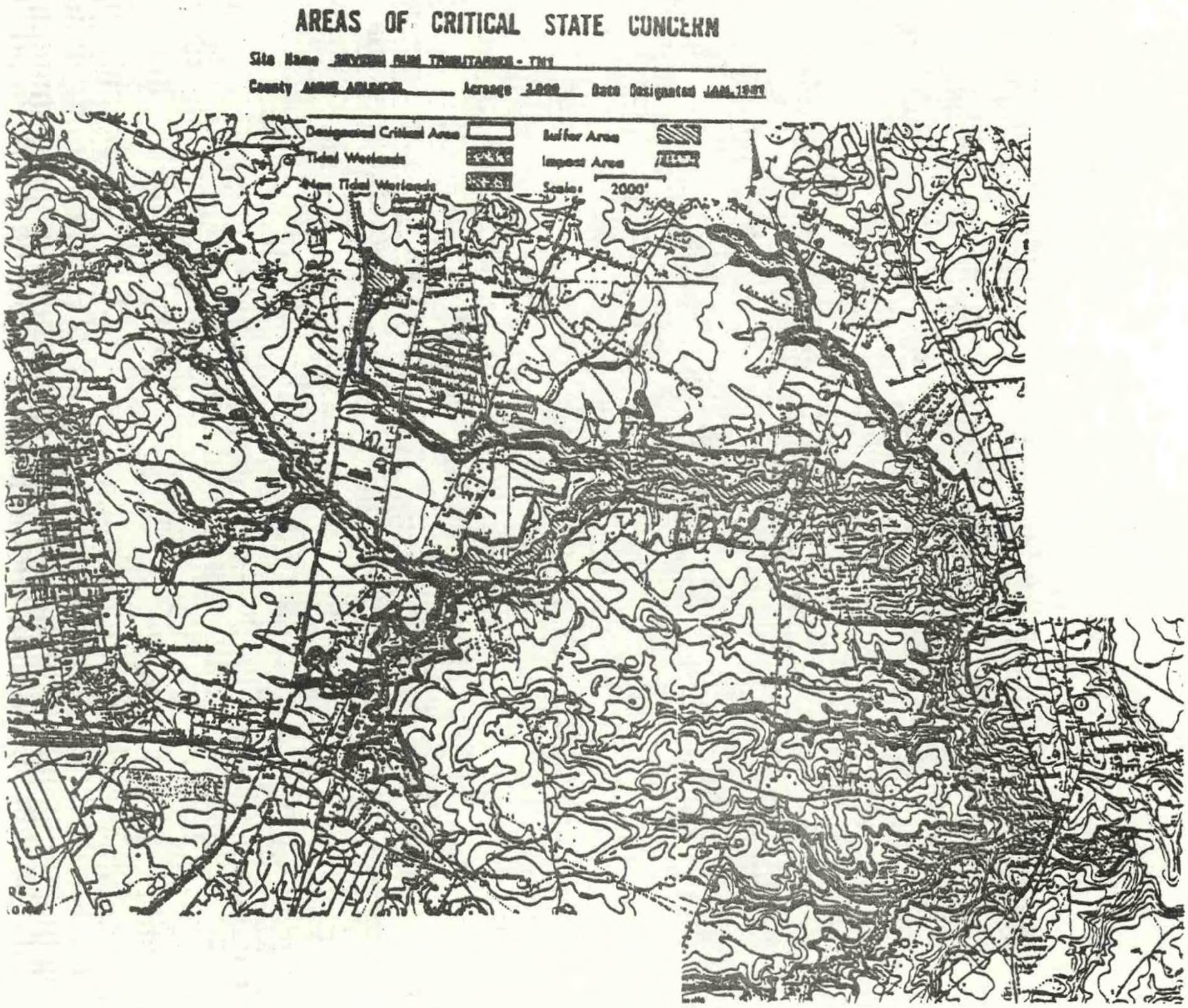


Figure 3.9

Computer Printout of Unsupervised LANDSAT Classification
of Piscataway Creek (Site TN11)

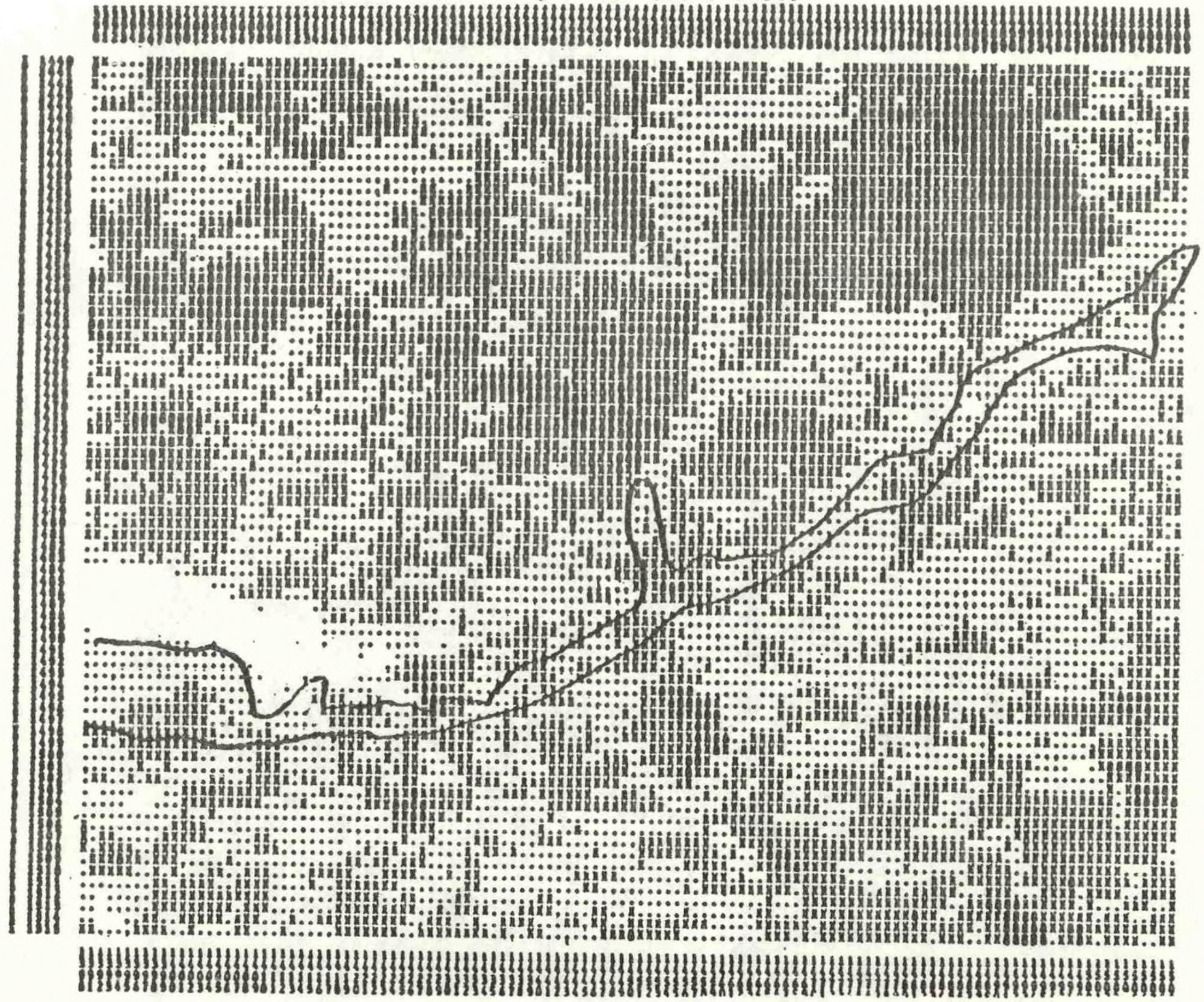
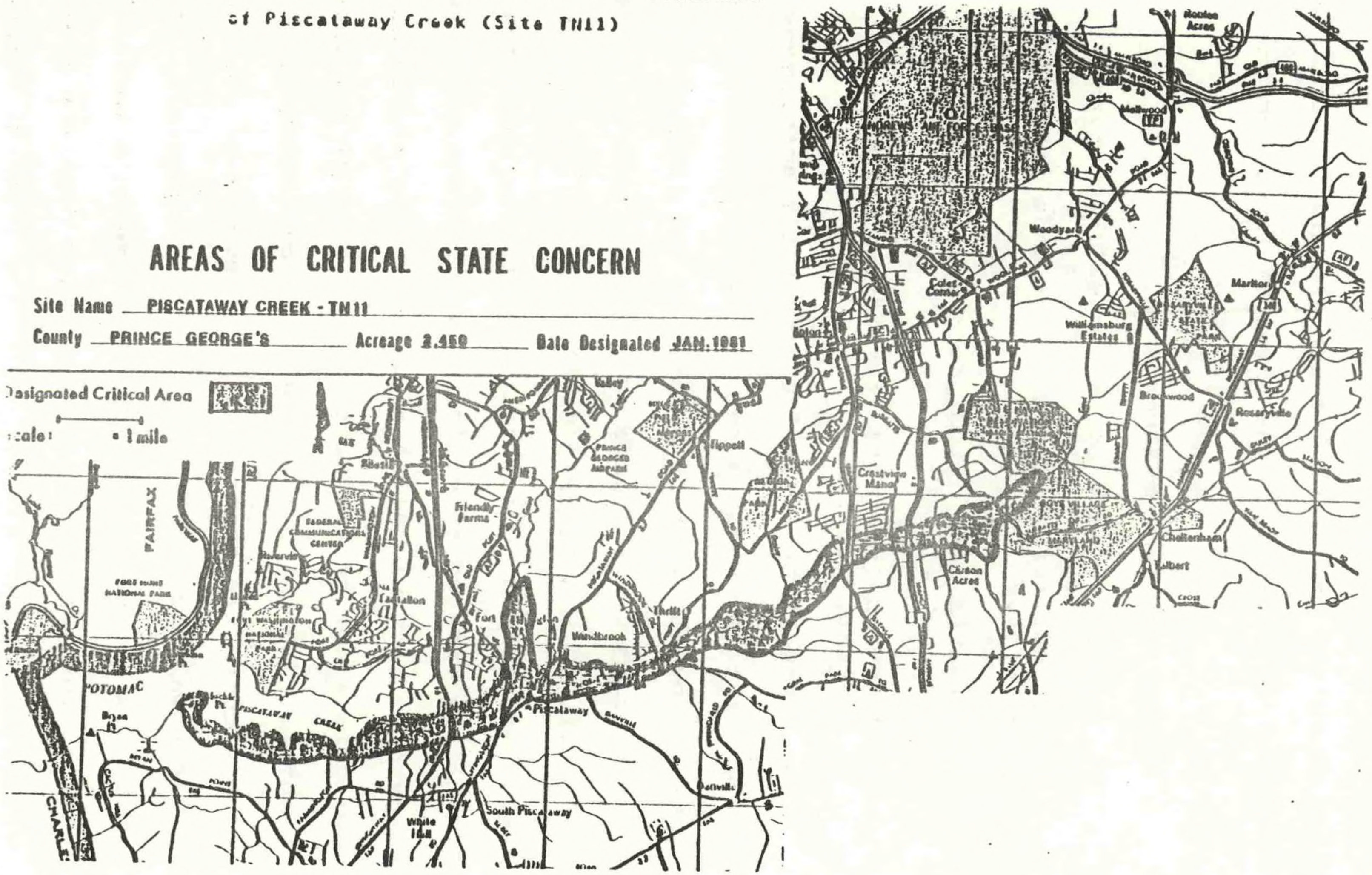


Figure 3.10

Reference Map for Unsupervised LANDSAT Classification of Piscataway Creek (Site TN11)



Much of the effort that remains to be completed involves finding suitable ground-truth data which are necessary to relate the LANDSAT spectral data to actual environmental conditions. The areas of focus for this task will be:

1. soil moisture measurements
2. vegetative maps of wetlands (plant types)
3. biomass measurements of wetlands (plant densities
4. climatic data (tidal records, rainfall records, etc.)
5. water quality data (turbidity, chlorophyll content, etc.)

As a result of initial efforts to examine many of the smaller Critical Areas sites, tentative evaluation statements can be made. It is clear that the long-term effect of relying on LANDSAT data sa a primary source for monitoring all of the State's Critical Areas will be to create a stable, uniform, quantitative data base which can be constantly updated at minimal cost. In the short term, however, a careful effort directed toward providing an appropriate set of ground-truth for each of the sites is essential. The principle limitation of LANDSAT satellite imagery currently appears to be frequency of coverage rather than detail of resolution. In principle, the LANDSAT satellite images the entire earth's surface every 18 days, but many attempts to acquire data are confounded by excessive cloud cover. Thus, the interval between successful acquisitions of image data from the same geographical point may be considerable. Table 3.2 shows the list of scenes, some of which have been acquired by the Department. of Natural Resources, and others by Salisbury State College, and are available for use in evaluating Critical Areas.

Taking into account both the advantages and limitations of applying LANDSAT digital analysis to the study of Critical Areas, it is clear that such an analysis provides a significant source of data relevant to management concerns.

Further, the data are in a form amenable to rapid, low-cost computer processing and are capable of being included in any existing or future data base. It remains to be shown that the application of the satellite data to appropriate management strategies is equally cost-effective and productive.

3.4 Comparison of Remotely-Sensed Data With Ground-Truth Information

Regardless of the appropriateness with which statistics and maps may be generated using satellite data, it is advisable at some point or another to provide both a visual and, if possible, a statistical comparison of these data with more traditional data such as maps and photography. Although it is likely that all ground-truth data will be distorted in some way (whether by sampling error, optical distortion, or human error in recording), there needs to be some mutually accepted standard data base to which all other data sources may be compared. Quadrangle sheets showing easily recognizable topographic features were chosen as the base maps in this study because of their general availability and widespread use. Other types of base maps could have been selected as well. For example, the state plane coordinate system provides the basis for entering encoded data into the Maryland Automated Geographic System (MAGI).

ASTEP data sets were prepared in three ways. First, data were extracted without any resampling. Maps prepared using this uncorrected data showed the greatest amount of distortion when compared to the corresponding base maps. Nevertheless, this approach allows very rapid processing, and, because no resampling is done, the original data fidelity is maintained. The disadvantage to this approach is that it is difficult to overlay maps produced in this fashion with other base maps. If the total size of the area being studied is relatively small it is possible to ignore this distortion. An example of map output prepared from uncorrected data is shown in Figure 3.11.

A second approach utilized ASTEP's internal deskewing and rescaling algorithm. Results of this approach using the same data set are shown for comparison in Figure 3.12.

The third approach involved an attempt to resample and rotate the data by quad sheet so that precise overlays could be generated.

In evaluating the relative success of various types of maps produced from remotely-sensed data compared to established sources of ground-truth information, several steps were followed:

1. a variety of Critical Areas were selected, ranging in size and type.

2. mylar overlays were produced for several 7.5 minute quad sheets corresponding to a subset of these Critical Areas.

3. existing aerial photography was examined and mosaics produced, where possible, to match the quad sheet base maps.

4. new aerial photography was acquired for areas of special interest

5. on-site inspection of small Critical Areas and some of the training sites was conducted to improve and update the accumulation of ground-truth information.

6. ground-control points were chosen mostly from the quad sheets, thereby reserving most of the ground-truth work for selection of training sites and for checking the accuracy of the classifications.

7. both unsupervised and supervised computer land-cover classifications were attempted.

Ground-truth data not only have many forms--direct observation from the ground, aerial photography, existing maps, and information solicited from field personnel--but they also have many uses. However, as in the interpretation of photo products, the assessment of ground-truth data is often highly subjective and difficult to quantify.

Figure 3.11

ASTEP Map of Uncorrected LANDSAT data
Howell Point

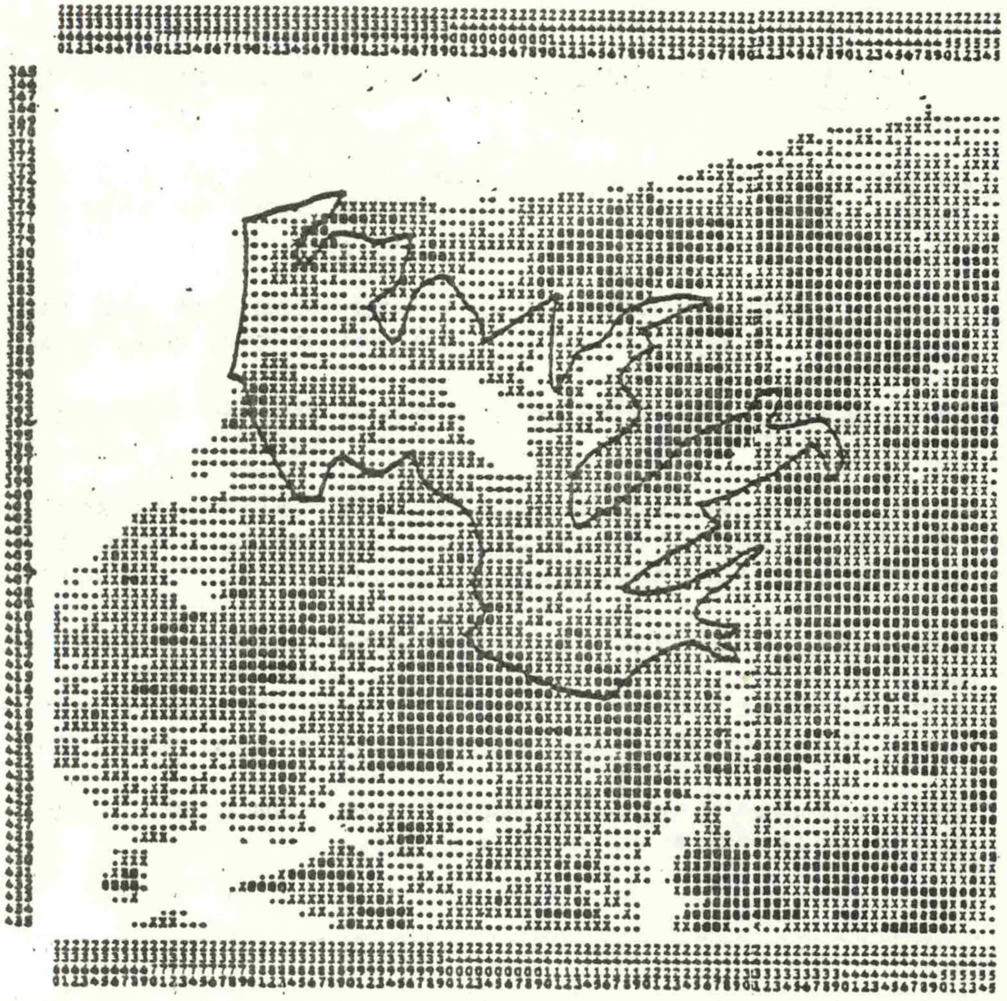
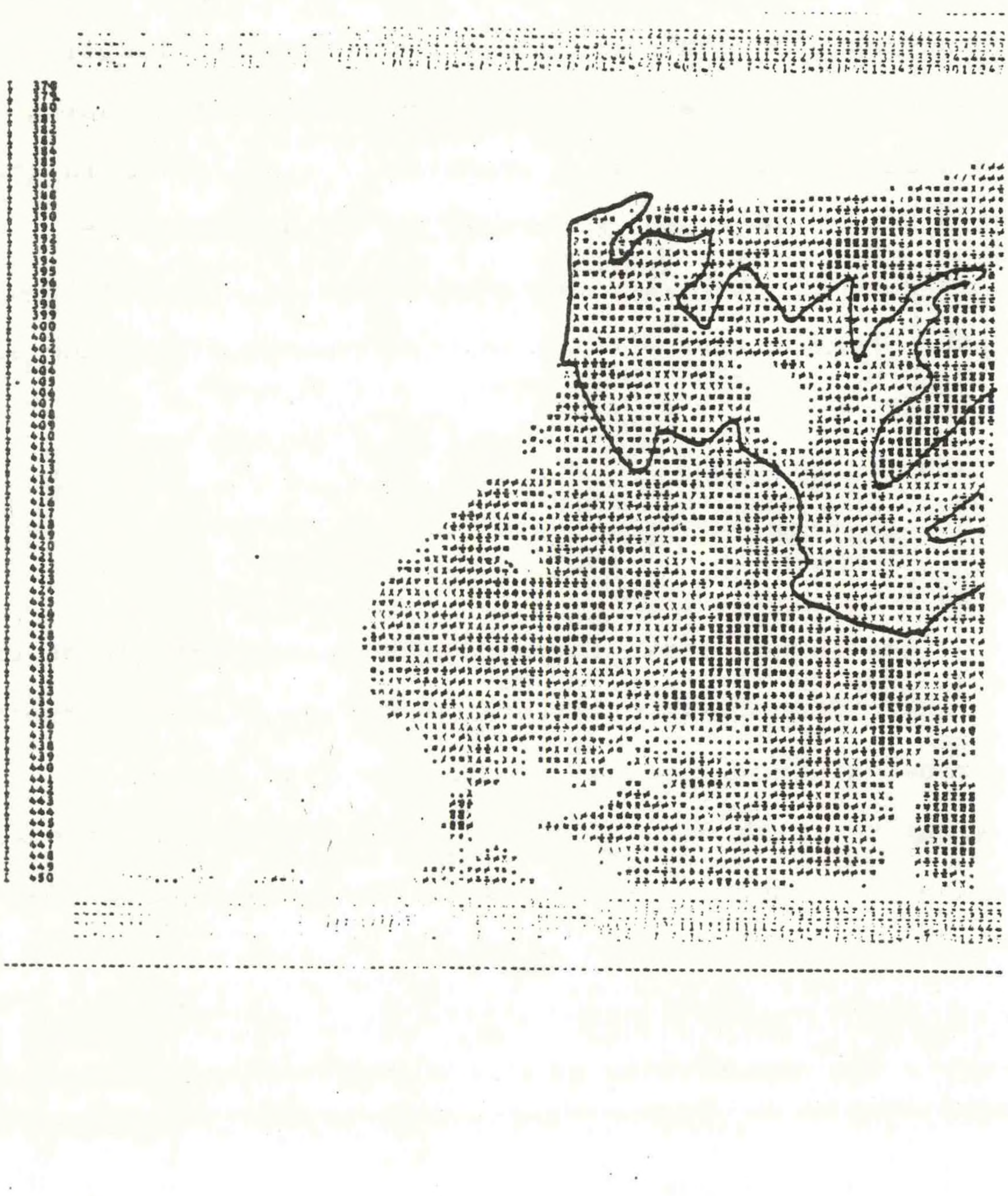


Figure 3.12

ASTEP Map of Geocorrected LANDSAT data

Howell Point (compare to Figure 3.11)



Additionally, the more detailed the ground-truth data, the more expensive it is likely to be to collect. Despite the continued popularity of such ground-truth information as infrared aerial photography and on-site collection of field data, such data cannot be easily incorporated into a computerized data base.

Ground-truth information retains its importance in verifying and substantiating the accuracy of digital data maps and the classification of these maps with respect to land-use and land-cover. Wherever Critical Areas in this study were large enough to make suitable targets for multispectral analysis using LANDSAT data, the resultant classifications were enhanced by comparison with correlative ground-truth data.

3.5 Accuracy Assessment

This study seeks in part to determine the extent to which LANDSAT classifications reveal significant variation among individual ground features and land cover types associated with each of the Critical Areas under investigation. Among the environmental features that LANDSAT can differentiate are: certain plant species, plant associations, plant vigor, seasonal or phenological vegetative variations, water bodies, beaches, mudflats, other surface anomalies and the range of man's efforts to alter the landscape.

LANDSAT data can be, and have been, used to accurately detect changes in the environment brought about by natural and man-made events. The success of the scanner in providing appropriate data for scientific investigation can be attributed to three factors. First, LANDSAT provides a broad perspective. Two LANDSAT scenes cover most of the State of Maryland and sizeable portions of adjacent states. This provides an integrated view of the varied topography and the relation that each special area bears to a much wider region. Second, the scanner records the same scene repetitively--season after season, year after year. This permits a multi-temporal view of a large surface area and documents accumulating changes in land-cover and land-use. Third, the scanner records information in four separate spectral bands. This allows not only comparison to ground-truth acquired in the visible portion of the electromagnetic spectrum, but also to infrared photography, especially high-level color infrared aerial photography.

In a variety of demonstration projects NASA has already documented the feasibility of utilizing LANDSAT data for:

- Monitoring strip mining and reclamation.
- Assessment of changes in extent and quality of urban areas.
- Monitoring effects of construction at major land developments.

- Classification of vegetation in different ecosystems.
- Detection of changes in the Coastal Zone.
- Delineation and assessment of wildlife habitats.
- Monitoring lake eutrophication and algal blooms.

As can be seen from this listing, LANDSAT classifications can address fairly specific questions concerning environmental quality. short-lived events, such as severe storms, forest fires, floral epidemics, and earthquakes can also be monitored by LANDSAT.

If the accuracy of LANDSAT classifications is to be measured in terms of usefulness to the planner, then such accuracy is largely a function of the degree to which the classified LANDSAT map can be registered to the map base used for management. Once successful registration has been achieved the potential error due to gross misregistration is significantly reduced.

It only remains then to determine the degree of correspondence between classes as they are delineated on the LANDSAT map and corresponding classes as they are represented in the ground-truth training areas. Both visual inspections and statistical tests can be used to assess and verify, either qualitatively or quantitatively, the accuracy of LANDSAT classifications for First-Round Designated Critical Areas.

CHAPTER 4
CASE STUDIES

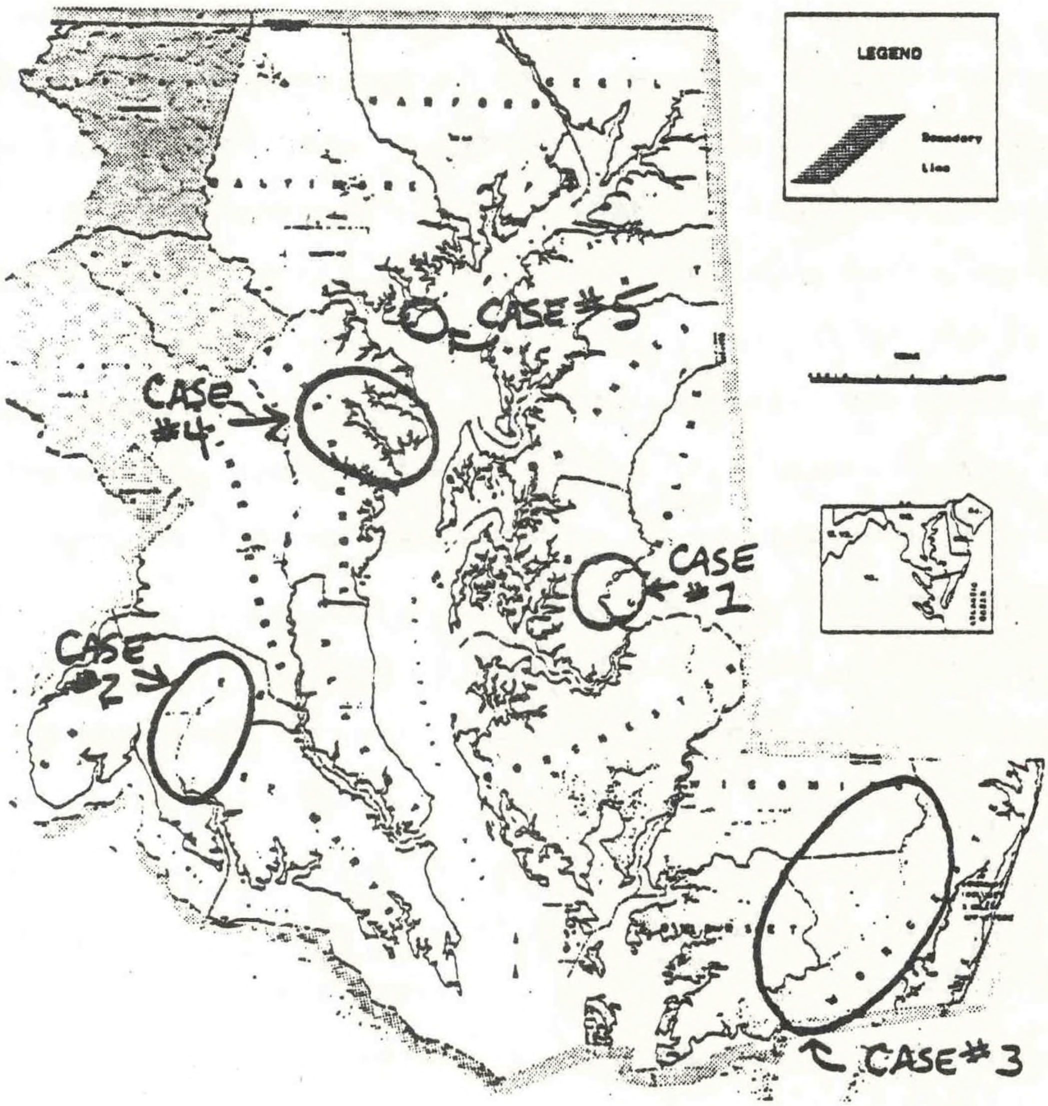
4.0 Introduction

The capabilities of remote-sensing techniques for monitoring environmental characteristics of Critical Areas (along with one site owned by the Nature Conservancy) are discussed in this chapter through the presentation of several case studies. In each case, the principal alternatives for monitoring these areas were: aerial photography, LANDSAT satellite digital data, and actual collection of environmental data on the ground (direct measurements of soil moisture, plant communities, turbidity, ground cover, etc.).

As summarized in Table 1.1 in Chapter 1, several of the monitoring requirements identified by the Department of State Planning (see page 16-17, Chapter 2) can be most effectively fulfilled with the collection of aerial photographs, or site visits. But several of the requirements for long-term data could be efficiently met with satellite imagery. The acquisition and initial processing of the satellite data by computer for the Critical Areas sites is discussed in Chapter 3 and Appendix A. Appendix A presents density sliced lineprinter maps of the satellite digital data produced by standard algorithms contained in

Figure 4.1

Sites of Case Studies in the Maryland Coastal Zone



the ASTEP package of programs used at Salisbury State College. (These are programs from the same package as those used by the Office of Planning Data at the Department of State Planning in Baltimore.)

ASTEP programs are capable of discriminating some general differences in land cover, water clarity, and vegetative type. Further, these results were obtained without requiring extensive training in the computer operation of the ASTEP programs. (Printouts of digital satellite imagery produced by simple computer routines from ASTEP can be found in Appendix A.) With a modest degree of training, new users, including several contributors to this report, were able to execute options within the ASTEP programs to analyze the statistical relationships among the data values in each of the four spectral bands, thereby arriving at classifications for various land covers by assigning each a separate spectral signature. This procedure enabled some considerations to be made regarding the possibility of using LANDSAT data and their analysis for monitoring changes in land cover and other environmental characteristics of concern to planners and managers. In all cases an attempt was made to relate information derived from the digital data to existing ground-truth information collected for the site, such as aerial photographs, or actual site measurements.

Much useful ground-truth information already exists as part of previous investigations by state and federal agencies, and by Bay-area universities. This type of data is discussed in the following case studies along with examples of the identification of training areas for adjusting the land-cover signatures for the characteristics of interest in the study sites.

The areas covered in the following case studies are shown on the map in Figure 4.1

Case I - The Nature Conservancy Choptank River Wetlands in Talbot and Caroline Counties

Prepared by Trisha Bednarz

4.1.1 Background

King's Creek Marsh and Hog Island Marsh (Frazier Neck) (Figures 4.2, 4.3, and 4. 4) are two wetlands on the Choptank River near the Route 383 Bridge (Dover Road running from Easton to Denton), which are owned by The Nature Conservancy. Important management concerns for these two marshes center on questions about their stability, i.e.: Are long-term trends able to be demonstrated for replacement of vegetated areas by mudflat, or vice versa? Similarly, another management concern is that those plant communities which are presently found at the sites be maintained in their present state. This would require minimizing off-site impacts, and more importantly, meeting the immediate threat to plant destruction which may come from the muskrat populations that are abundant within the perimeters of the two preserves. Another concern is that the threat of erosion of the marsh shorelines adjacent to the Choptank River be quantified and managed.

These management needs can be met with a program of site visits, coupled with the collection of on-site measurements of plant communities, wildlife distribution, shoreline changes, and changes in the aerial distribution

Figure 4.2

The Nature Conservancy Choptank River Wetlands in Talbot and Caroline Counties.

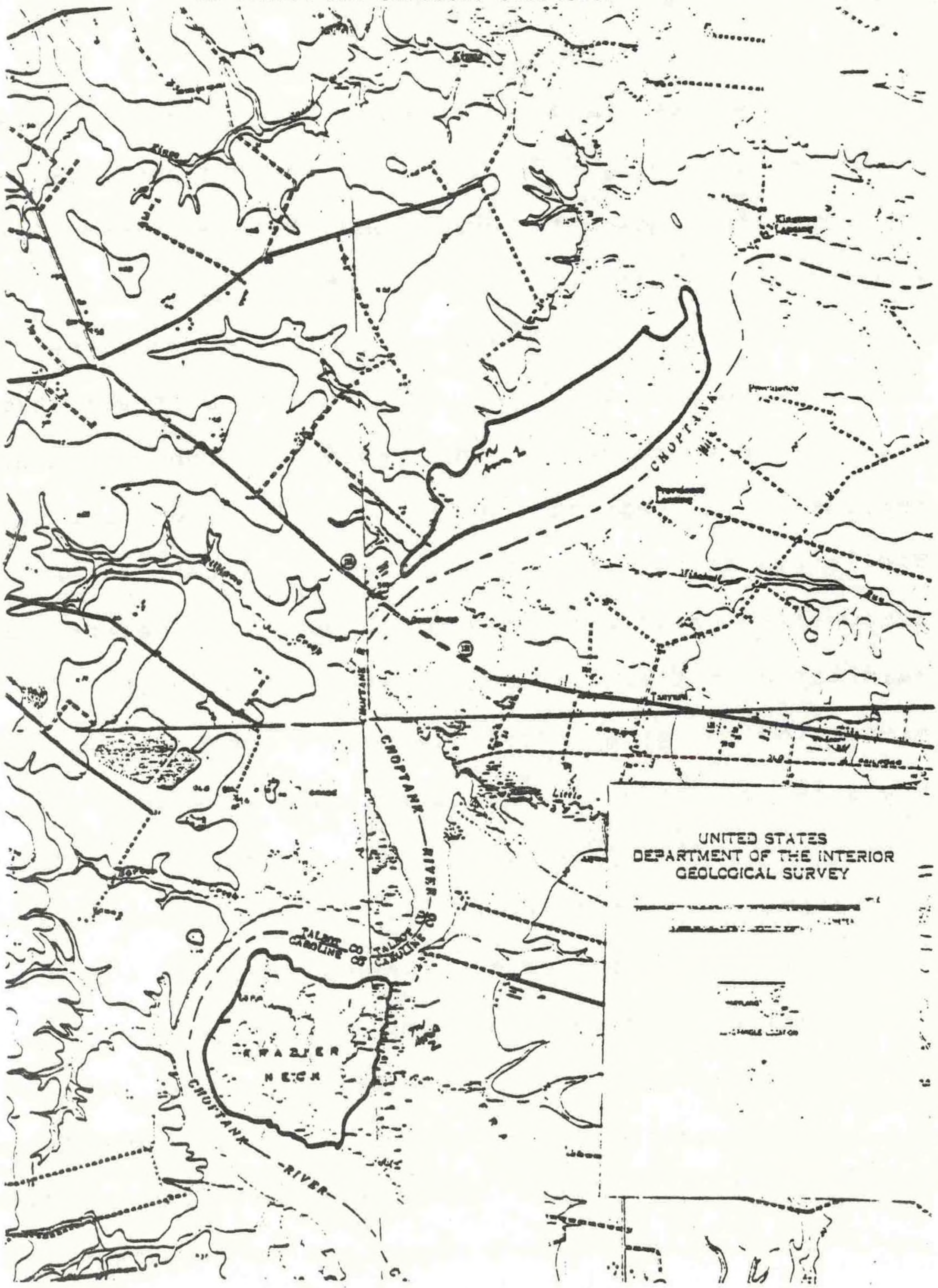


Figure 4.3

Aerial photo of King's Creek marsh looking north along the Choptank River.

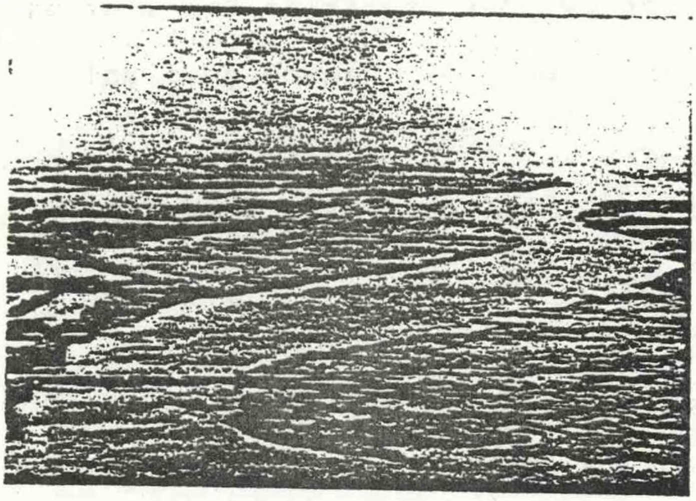
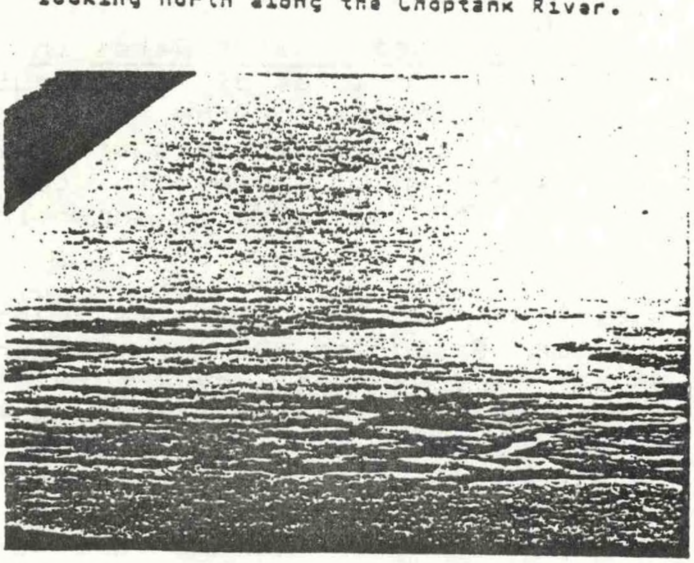


Figure 4.4

Aerial photo of Hog Island marsh looking north along the Choptank River.



of mudflats. Alternatively, a few of the areas of concern could be monitored with careful collection of aerial photography in the coming years, and subsequent photogrammetric analysis. However, with the LANDSAT satellite system, some potential also exists to address management concerns by characterizing the area since 1972, the date of the first LANDSAT imagery available.

4.1.2 Sources of Information for the Resource Management Data Base

Existing sources of information about environmental characteristics of the TNC Choptank River wetland sites include:

- Atlas of Historic Shore Erosion Rates in Maryland (MCZMP, 1975). A map atlas of 7.5 minute topographic quadrangle sheets for the Maryland shoreline showing locations of present shoreline, and historic shoreline from surveys in the 1800's. The data for the TNC Wetlands is shown in Figure 4.5.

- Photomaps of tidal wetlands on file at the Maryland DNR Water Resources Administration. After passage of the Maryland Wetlands Act in 1970, the tidal wetlands were delineated and classified on a series of approximately 2000 aerial photomaps at a scale of 1:2400 (1 inch = 200 feet). Sample wetlands photomaps are shown in figures 4.6 and 4.7. The classification scheme and state-wide summary statistics are contained in a DNR report The Coastal Wetlands of Maryland (McCormick and Somes, 1982).

- A site-specific vegetation survey completed by the Nature Conservancy. This is available as a TNC open-file report. The survey is shown in Figure

4.8.

- Soil surveys from the county soil reports, prepared by the Soil Conservation Service.

- Faunal species lists compiled by the DNR Wildlife Administration.

- A long-term river gauging station on the Choptank River at Tuckahoe Creek, approximately 7 miles upstream from the TNC Wetlands sites. The results are published by the USGS in their annual reports, Water Resources Data for Maryland and Delaware, and in Special Reports of the Maryland Geological Survey (Mack et al., 1971).

- Tidal records, available in the annual Tide Tables for the East Coast of North and South America (NOAA).

- Assorted aerial photography, both overhead and oblique, in infrared, color and black-and-white, collected by the U.S. Department of Agriculture, U.S. Department of State Planning, and other state and federal agencies. For instance, the National High Altitude Photography Program (NHAP) is funded by fourteen Federal agencies to provide a national data base for mapping and resource management. The black-and-white photography is of cartographic quality, and the color infrared is valuable for resource evaluation, monitoring, and management. The acquisition of this data base started in 1978. The Maryland Coastal Zone is one area where NHAP has completed the coverage, see Figure 4.9. A catalog of available airphoto coverage in Maryland has been compiled by the Maryland Remote Sensing Steering Committee (DSP, 1982). Another summary of aerial photographs is available from the National Cartographic Information Center (USGS, 1980).

- Occasional water quality data collected by the EPA Chesapeake Bay Program (EPA, 1982).

- Occasional environmental data collected as part of research studies at the University of Maryland Horn Point Environmental Laboratories.

4.1.3 Evaluation of Remote-Sensing Techniques

The initial processing of the LANDSAT digital data

<u>Figure 4.5</u>

Historic Shore Erosion Rate Map
for the TNC Choptank River wetlands.

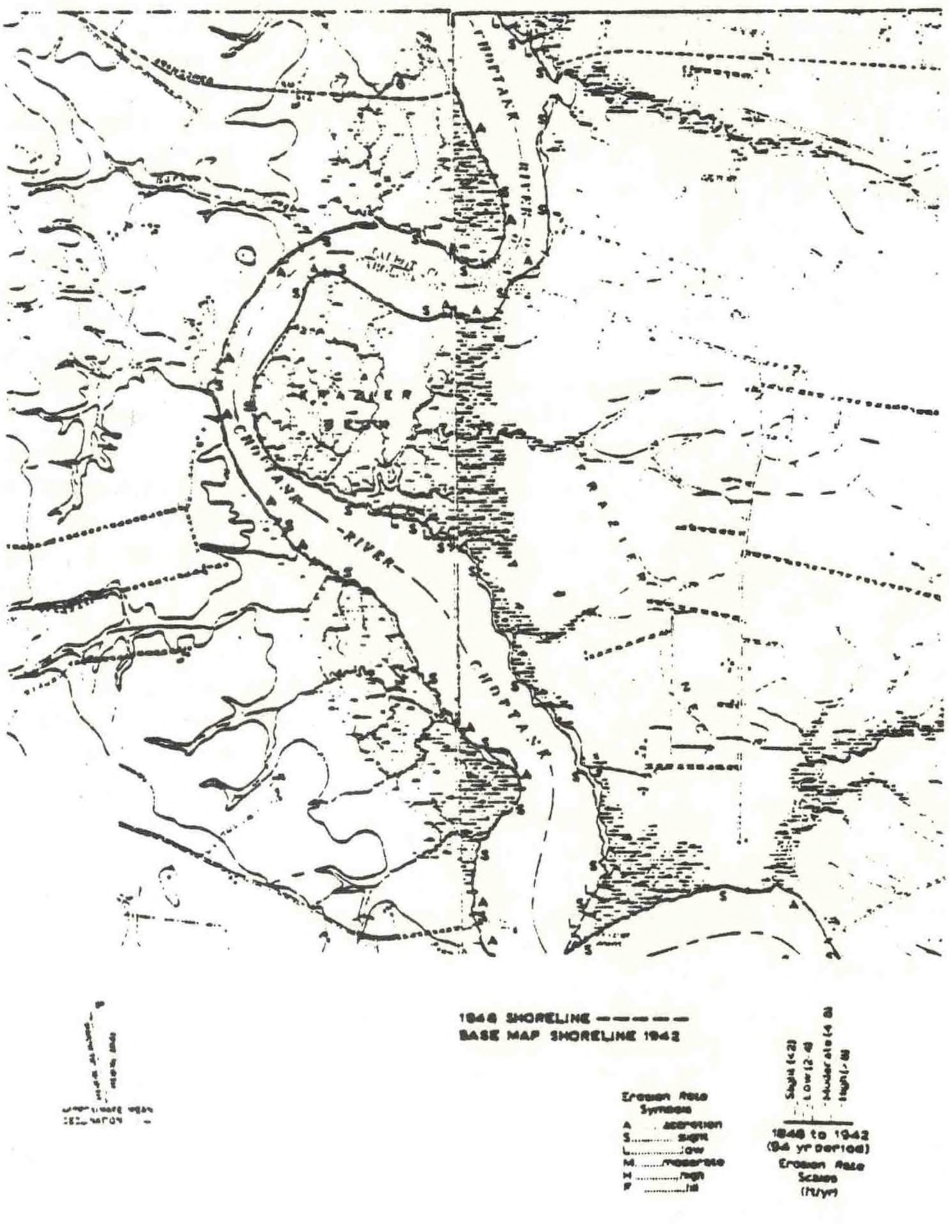


Figure 4.6

Sample Wetlands Photomap
on file at DNR Wetlands Permit Section, Annapolis

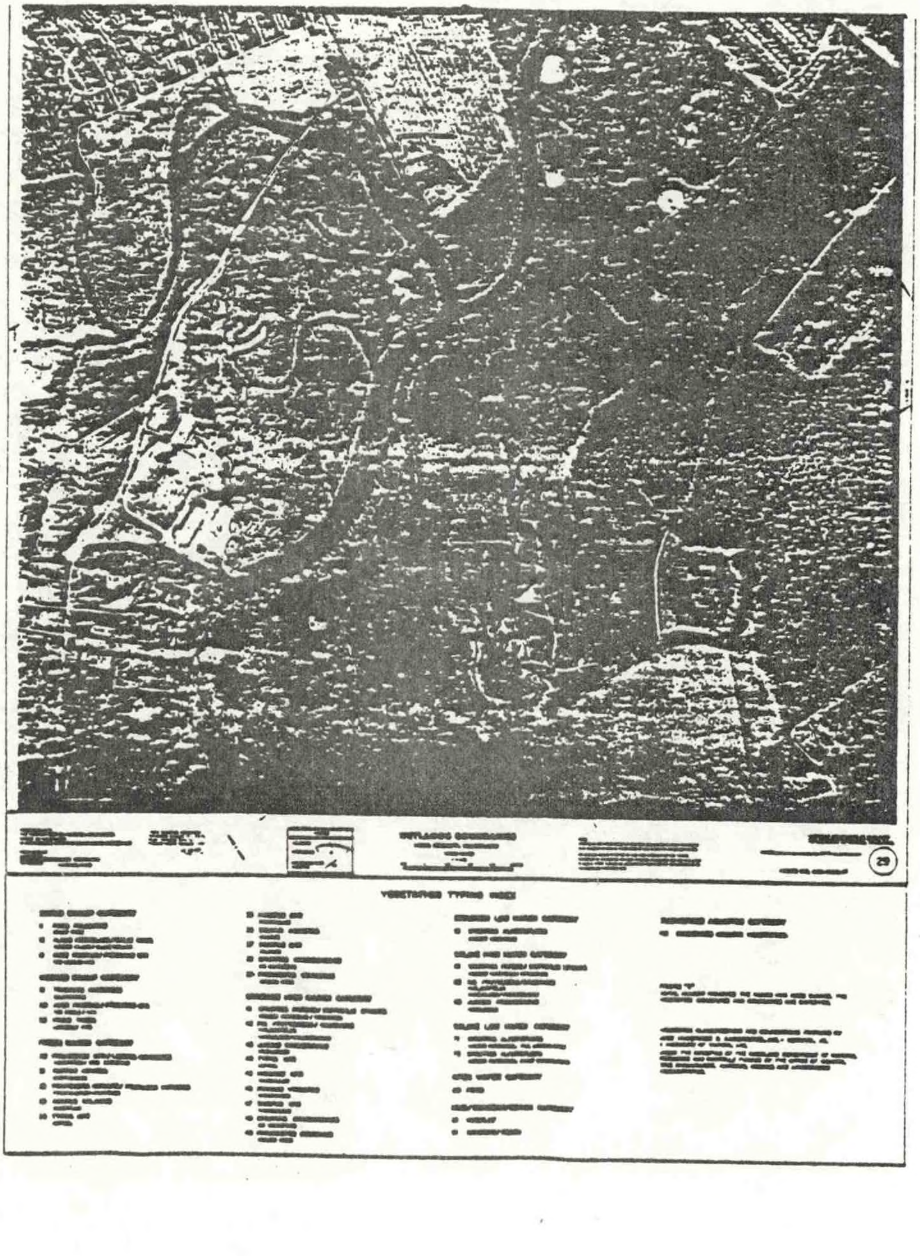
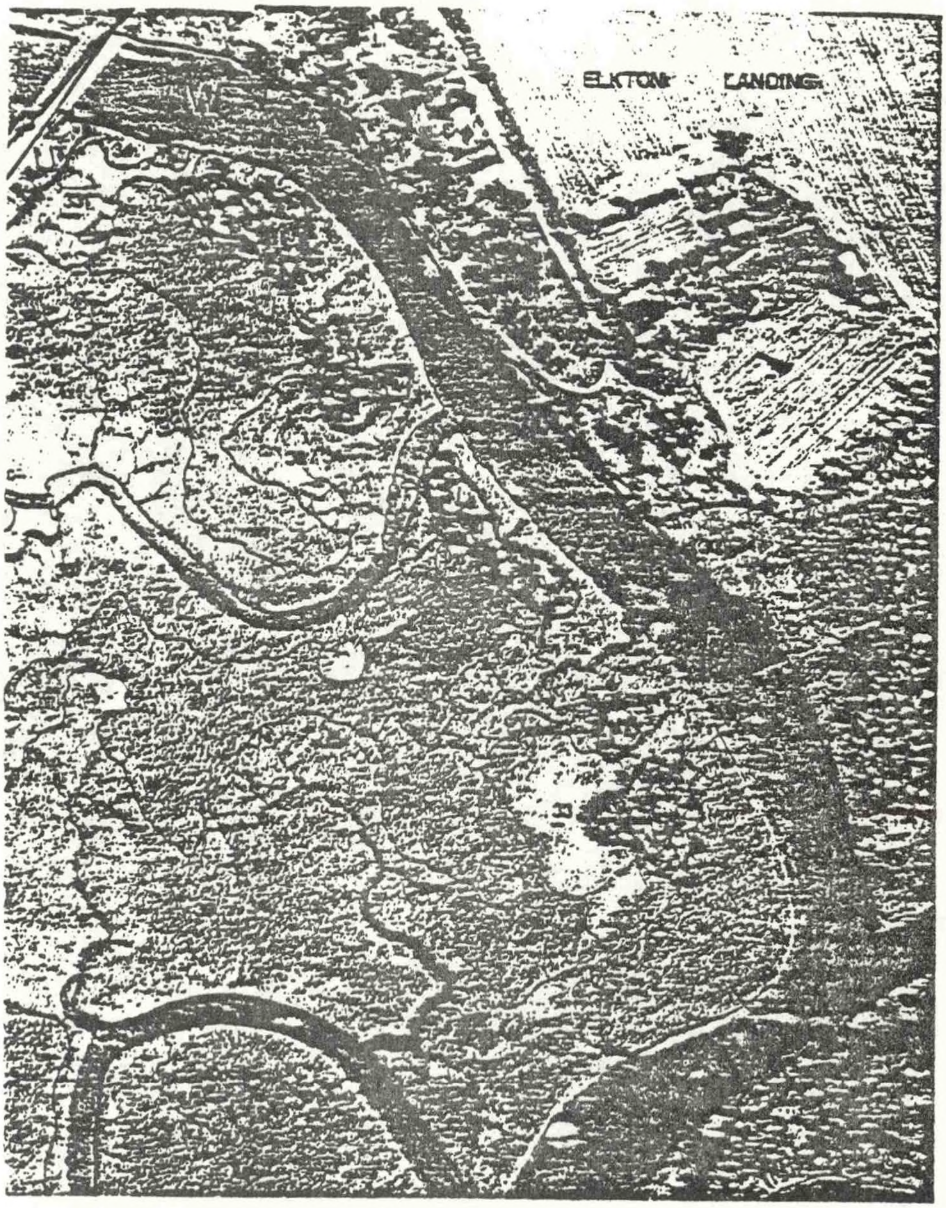


Figure 4.7

Enlargement of sample wetlands photo map.
The area shown is located in Cecil County.



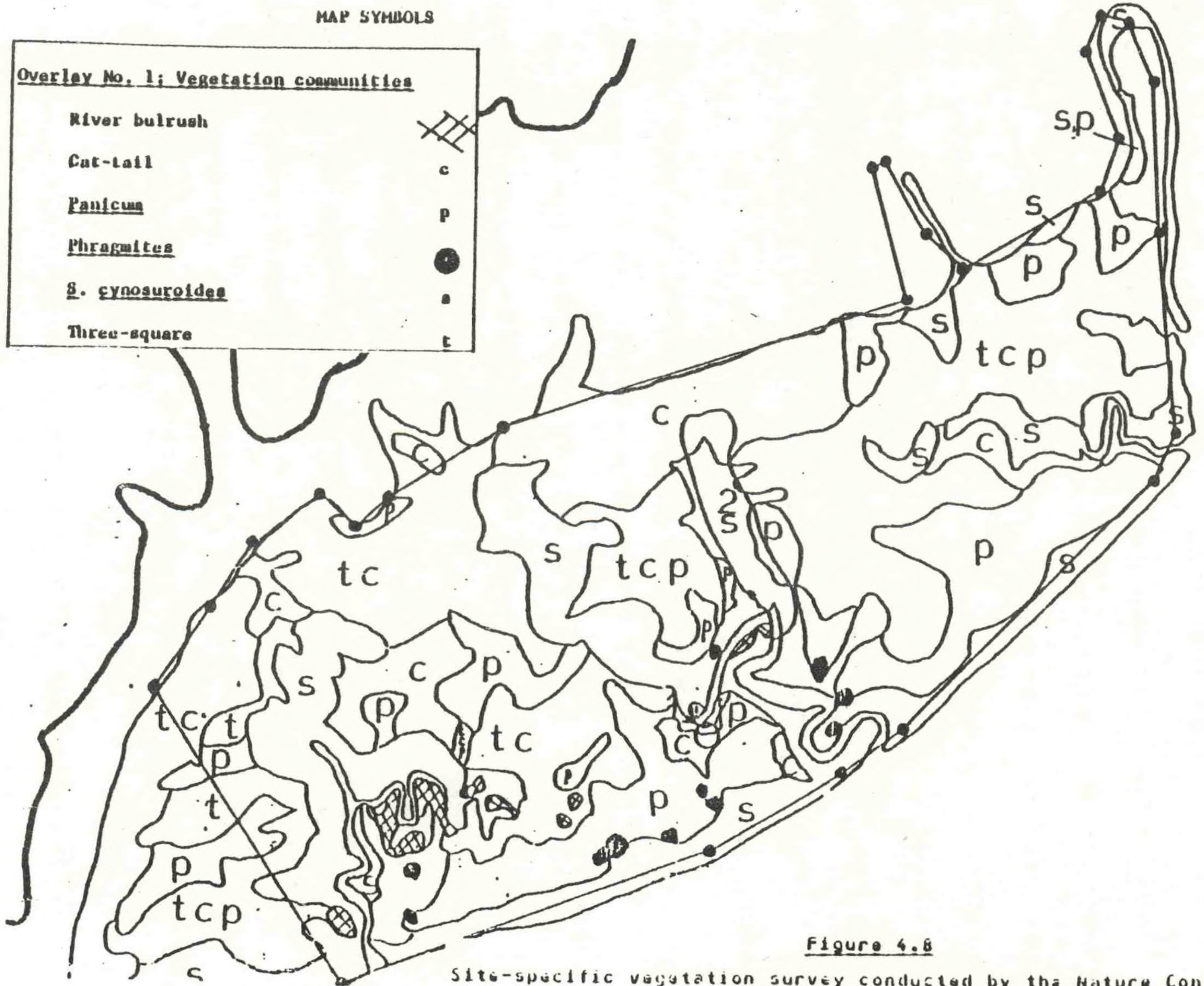


Figure 4.8

Site-specific vegetation survey conducted by the Nature Conservancy at King's Creek Marsh.

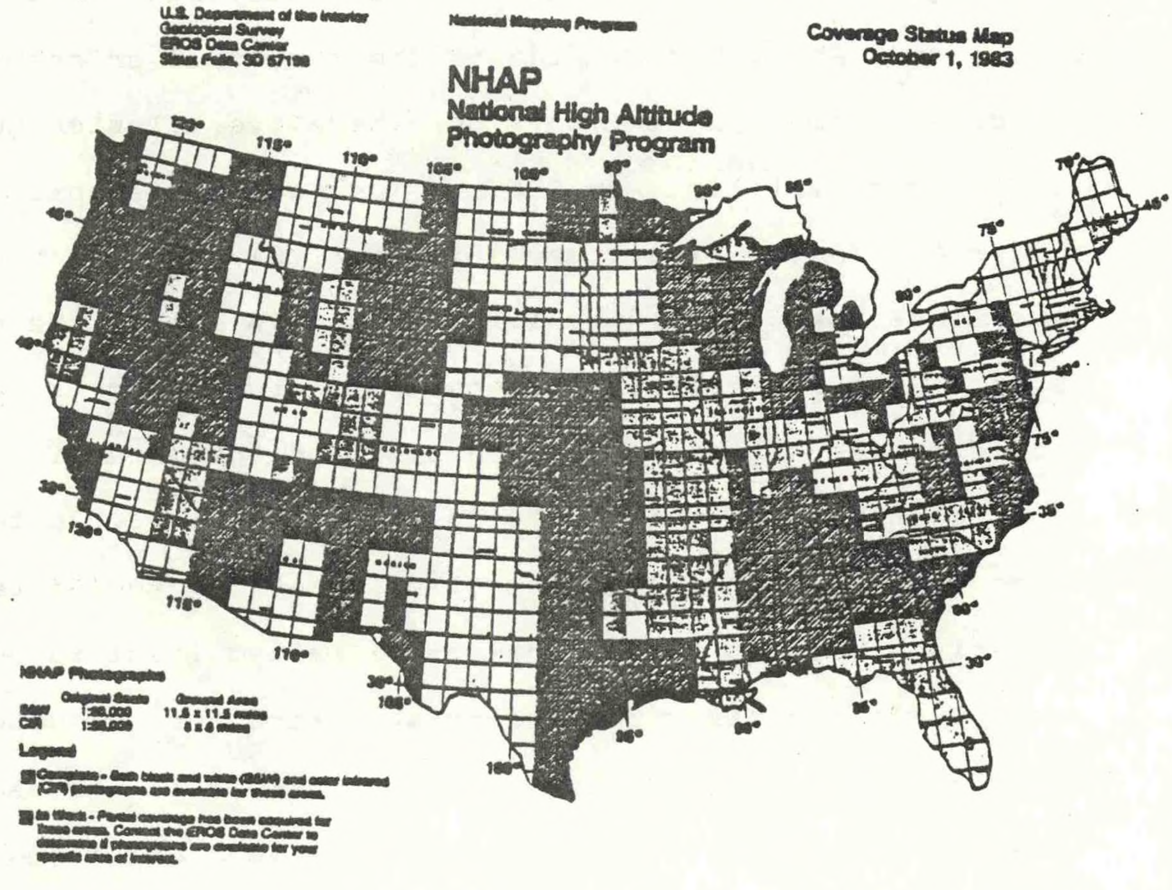
with the ASTEP algorithms showed that several of the sources of ground-truth listed above would be useful for comparison with the LANDSAT imagery to calibrate spectral signatures. This would amount to a supervised classification for this site, which was not included within the one-year scope of the project. An example of the steps which would be taken in such a supervised classification is shown in the following case study for a Designated Critical Area, where Non-Tidal Wetlands maps were used as a source of ground-truth, to develop a suitable classification for this land cover type.

Several unsupervised LANDSAT classifications for the TNC Choptank River Wetlands are shown in Figures 4.10 through 4.14. It is important to note that the actual size of the printouts shown in the figures is at the same scale as a 7.5 minute USGS topo quad sheet. In the analysis, the printouts are taken from the computer terminal as they are generated, and placed under clear plastic mylar reproductions of the USGS topo quad sheets (see Figure 4.2) for accuracy assessment. The results of the unsupervised LANDSAT classifications shown here are discussed below.

■ SHORE EROSION - The results presented in Figures 4.10 and 4.11 show that two of the ASTEP processing algorithms produce sharp delineations of the land/water boundary. When these printouts are placed beneath the clear plastic overlay of the topo quad sheet, both show good agreement,

Figure 4.9

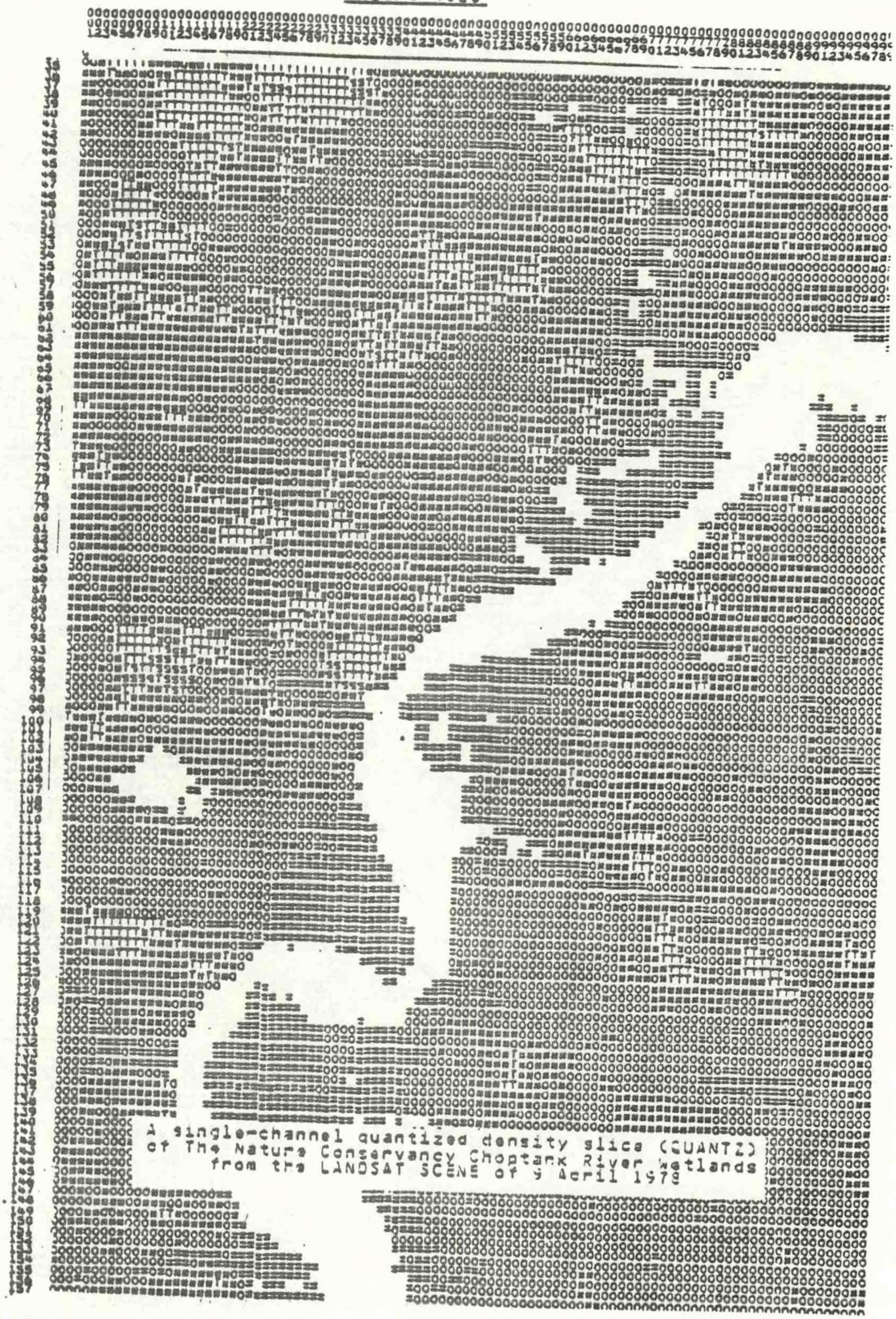
National Map of NHAP Coverage



although some differences do exist since the shoreline was last mapped in 1942-44. Careful inspection of the printouts will show there are some discrete differences, in the classification of pixels at the land/water boundary; and these are related to differences in the way LANDSAT digital data was classified to produce the two printouts.

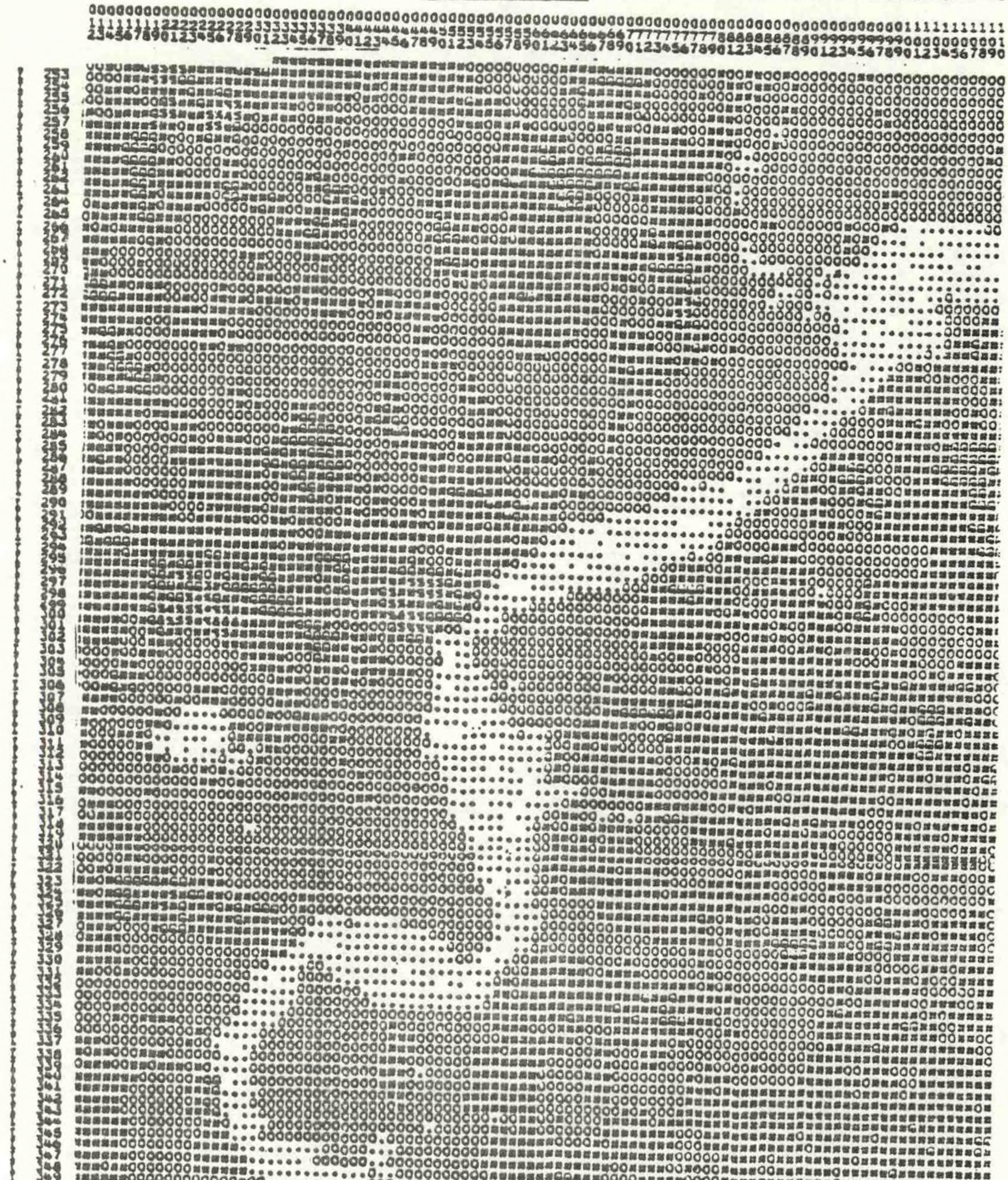
Figure 4.10 is a single-channel quantized density slice, or QUANTZ. Figure 4.11 is the result of processing the data through a two-pass non-iterative clustering algorithm classifier, or ADPCLU (pronounced "adaptive cluster"). In the first case (Figure 4.10), the printout represents the digital satellite data on a single channel (Band 4; see Table 3.1) which has been divided, or sliced, into discrete categories on the basis of the intensity of light that was reflected in each 1.1 acre pixel. In the second case (Figure 4.11) the classification represents a comparison between the amounts of reflected light in adjacent pixels (in all four channels) before the computer makes a decision to put two adjacent pixels in the same class, or in separate classes. The true land/water boundary is probably better derived from QUANTZ printouts, since the ADPCLU results can be thought of as grouping pixels according to the tone of the reflected light. The problem is analogous to using a photogrammetric procedure on a high altitude aerial photograph to draw a land/water boundary where the shoreline is difficult to recognize due to the presence of shallow nearshore shoals, algae blooms,

Figure 4.10



A single-channel quantized density slice (QUANTZ) of The Nature Conservancy Choptank River Wetlands from the LANDSAT SCENE of 9 April 1978

Figure 4.11



A two-pass non-iterative clustering algorithm classifier (AJPCLU)
with eighteen land-cover classes
applied to the 9 April 1978 LANDSAT scene of
The Nature Conservancy Choptank River wetlands

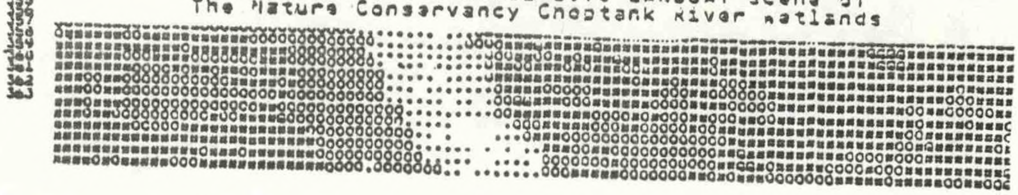
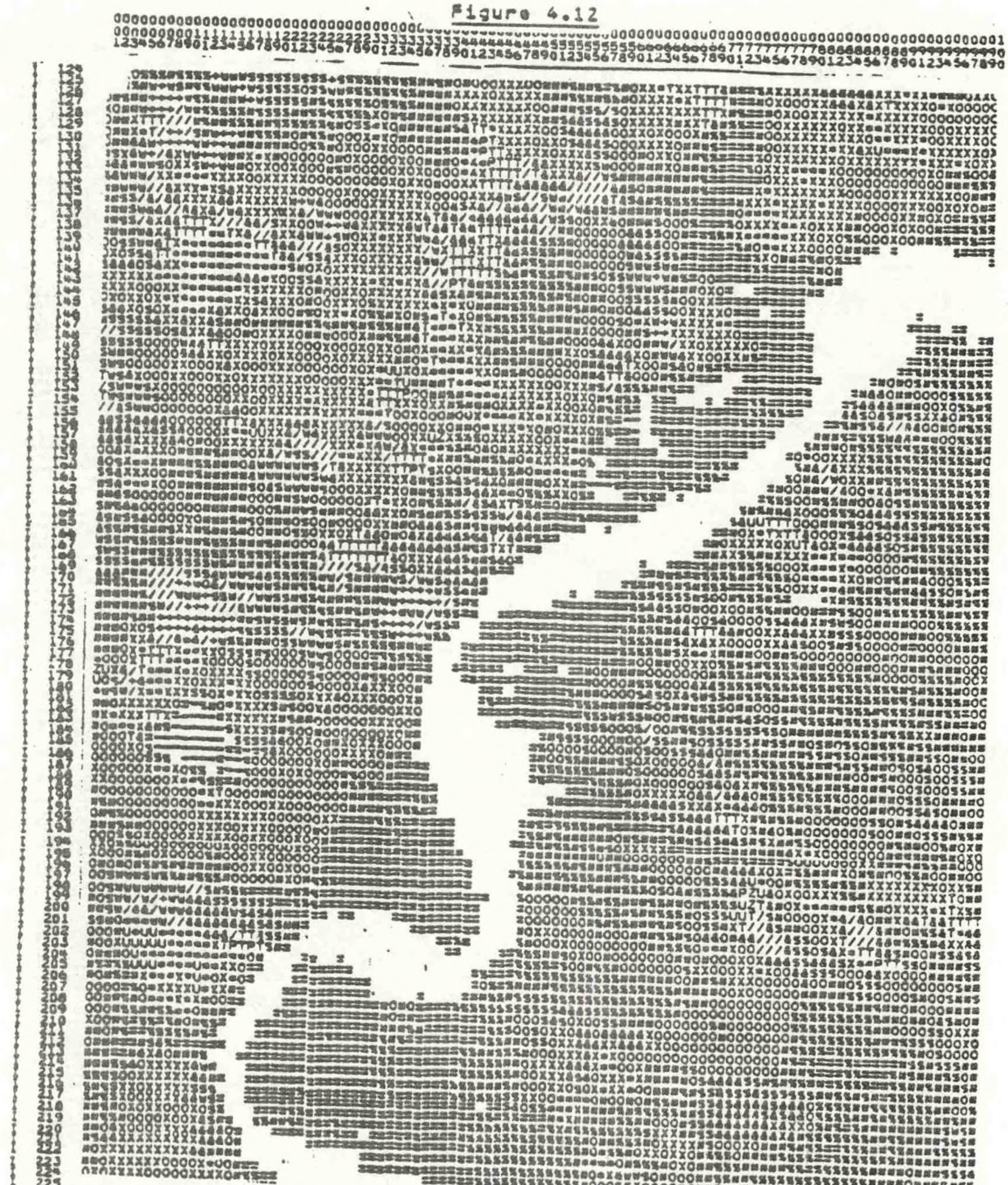
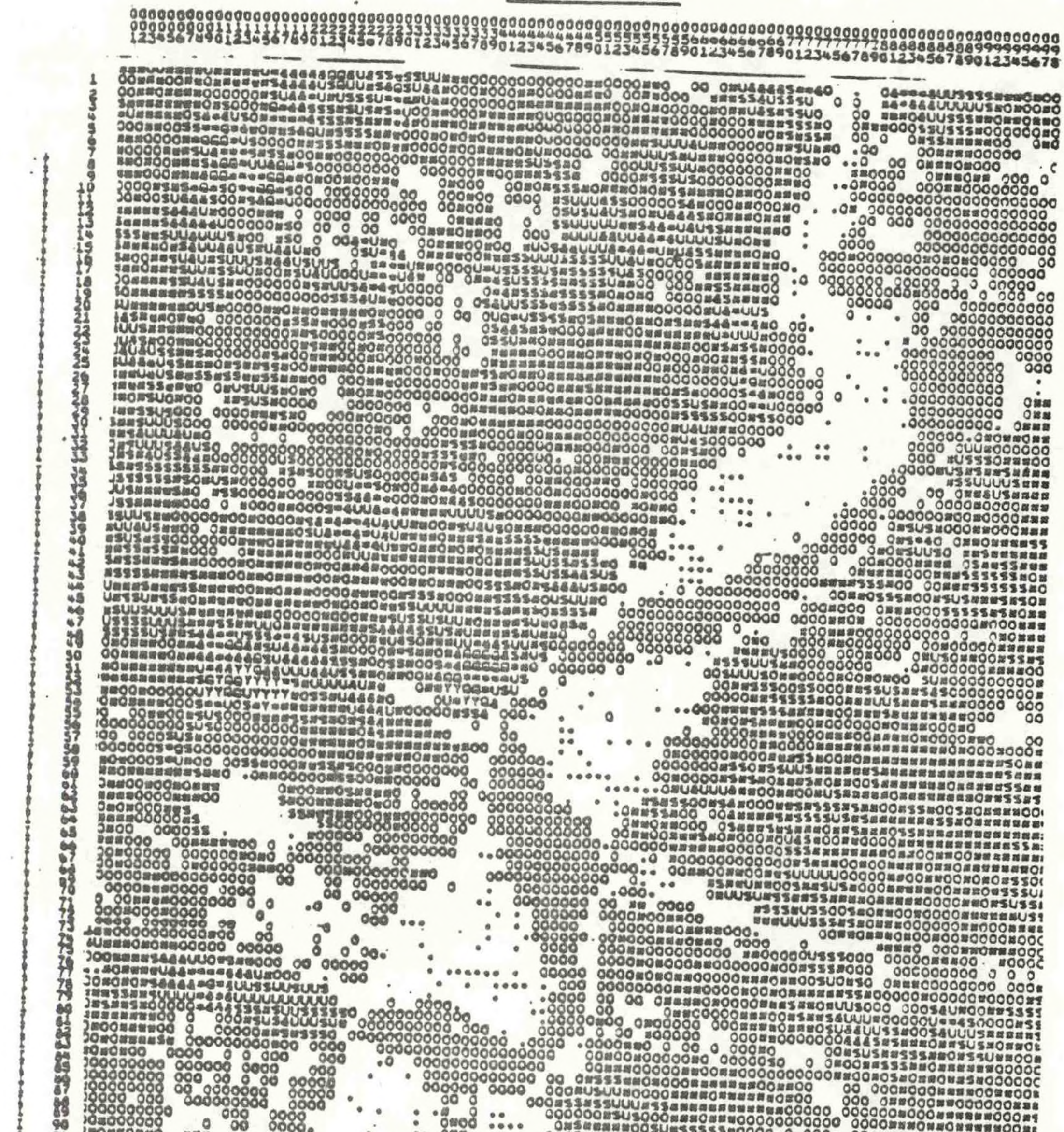


Figure 4.12



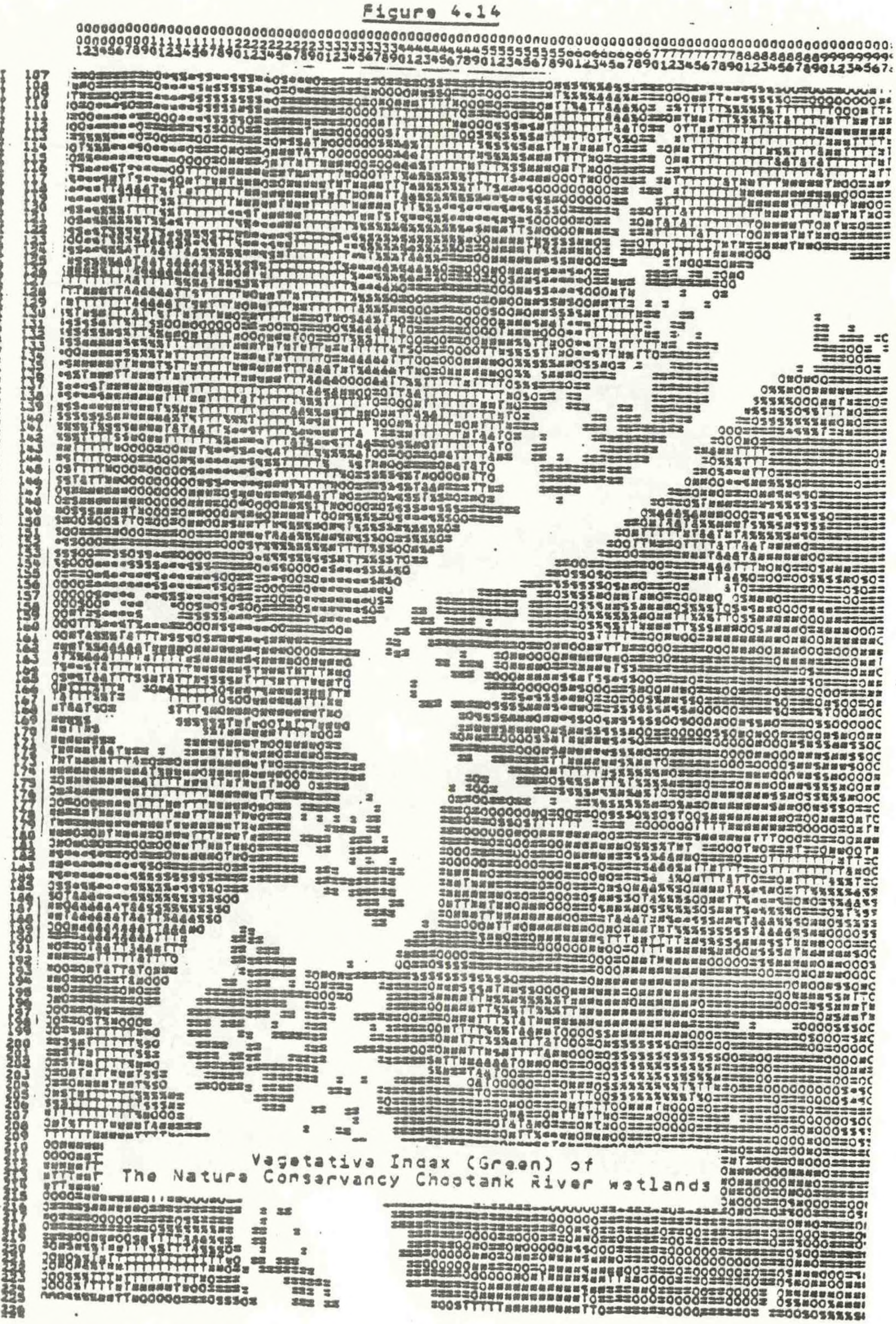
A two-pass non-iterative clustering algorithm classifier (AOPCLU)
with ten land-cover classes
applied to the 9 April 1978 LANDSAT scene of
The Nature Conservancy Choptank River wetlands

Figure 4.13



A ratioed image (bands 5/7) with contrast stretching applied and density sliced into ten levels of The Nature Conservancy Choptank River wetlands

Figure 4.14



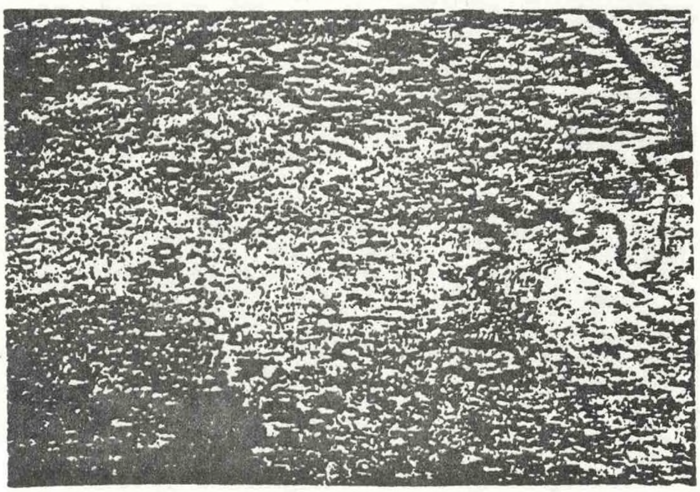
Vegetative Index (Green) of The Nature Conservancy Choptank River wetlands

Figure 4.15

Hog Island Marsh (Frazier Neck) viewed from the northeast.

Figure 4.16

Muskrat mounds in Hog Island Marsh



or turbid water.

The use of QUANTZ on successive satellite images collected through time gives a reliable measure of shoreline change apart from differences caused by tidal variations. For the 9 April 1978 scene shown in Figure 4.10, the Tide Tables show the river stage was conveniently near high water. Thus the printout can be regarded as a reasonable measure of the marsh/water boundary, determined by remote-sensing techniques.

■ <u>LAND COVER IN THE MARSH</u> - The most obvious result from the unsupervised LANDSAT classifications shown in Figures 4.11, 4.13, and 4.14, is that the unsupervised ASTEP programs were able to discriminate the forested high ground in the middle of the Hog Island (Frazier Neck) marsh. This is shown in an aerial photograph in Figure 4.15.

An approximation of the amount of wetland that is inundated during times of high water in this marsh is also shown in the LANDSAT classification in Figure 4.12. In order to produce a precise, remotely-sensed, quantification of the amount of marsh that is open water at high tide it would be necessary to combine the results of supervised and unsupervised classifications. To do this, a known area would have to be found in a LANDSAT scene, in either th e TNC Wetland site or in another wetland in the same scene. With this spectral signature, the computer could then map open water areas with equivalent spectral signatures.

The availability of State Wetlands Maps from 1971-1972 makes selection of such sites possible for appropriate training areas on early LANDSAT scenes. For future site evaluation, the recommended strategy would be to collect aerial photos of the site, or make field measurements on cloudless days when the LANDSAT satellite is also collecting data.

It may be necessary to repeat this procedure for a few future LANDSAT scenes, but gradually sufficient ground-truth could be collected to adequately classify the pixels in the marsh. This procedure would be affected by variations in the river level on the days of available imagery (Table 3.2), as well as by the limitation placed by the 1.1 acre resolution in the array of pixels. (The recently launched LANDSAT 4 has a Thematic Mapper collecting data in quarter acre pixels which will yield even greater resolution on the ground.)

By selecting training areas for plant communities or for mudflats, similar monitoring of these environmental characteristics could be accomplished. To use existing LANDSAT satellite imagery collected since 1972, the only requirement is to have aerial photography (either of the TNC Wetland sites or of another site in the same scene) to make a positive identification of an area with the land cover of interest. From this training area, a valid signature for the appropriate land cover class can be extracted, and the computer can then be instructed to map all similar areas in the scene. In this way changes in the distribution of any kind of land cover can be tracked with the LANDSAT satellite imagery commencing with 1972 and continuing to any time in the future for which LANDSAT satellite imagery would be available.

■ MUSKRAT MOUNDS - Low altitude aerial photographs collected in 1982 (Figure 4.1 6) documented areas where muskrat habitation in the Hog Island Marsh was extensive. While further detailed analysis of airphotos of this site might be able to associate the muskrat mounds with a unique class of marsh vegetation whose distribution could be mapped with LANDSAT , the direct mapping of muskrat mounds on the historical LANDSAT imagery would not be possible because they fall well below the 1.1 acre limit of resolution in the pixels.

■ OFF-SITE IMPACTS - One type of off-site impact which could affect the TNC Chop tank River Wetlands is land clearing and urban development on adjacent areas, with associated decline in the quality of wildlife habitat inside the marsh perimeter. As in the case of wetlands discussed above, changes in any kind of land cover can be identified and mapped with the LANDSAT system. To monitor clearing of land, or expansion of suburban development, suitable training areas for these land cover classes would have to be found in t he surrounding area and classified on previous LANDSAT scenes. This is certainly feasible since low altitude high resolution aerial photography of all of the Maryland coastal zone is available for the previous ten to fifteen year period. Photogrammetric methods could be applied to the existing data for analysis of land cover changes. An analogous approach relying on the LANDSAT system offers the advantages of automating the procedure and extending it over a wider area, in a more efficient manner.

Another kind of off-site impact to the TNC Choptank River Wetlands is from turbidity which could be generated by land clearing in the upper reaches of the watersheds of creeks flowing into the marsh. During the collection of aerial photographs conducted by DNR, turbidity plumes were observed on one occasion flowing through the King's Creek Marsh. King's Creek is a sufficiently large enough surface feature to be recognizable in the arrangements of pixels in computer printouts of LANDSAT data. For this reason long-term tracking by LANDSAT of sedimentation and in-filling of the creek is a possibility. Yet turbidity in the creek should properly be regarded as an episodic event related to the pattern of precipitation in the region. The LANDSAT system, which contains only passive sensors, is unable to remotely sense the earth's surface on rainy days, due to the presence of clouds. Thus, unless previous LANDSAT scenes of the Maryland Coastal Zone (path 16/33) happened to have been collected by the satellite on clear days immediately following rainy weather, the potential for calibrating turbidity in King's Creek with LANDSAT imagery is unlikely. Nonetheless there is a capability for calibrating LANDSAT imagery to the turbidity of the Choptank River. This potential has been demonstrated in many other coastal areas where turbidity has been considered a problem (Colwell, 1983).

Case II - THE ZEKIAH SWAMP IN CHARLES COUNTY (Site TN7)

Prepared by Frank Dawson

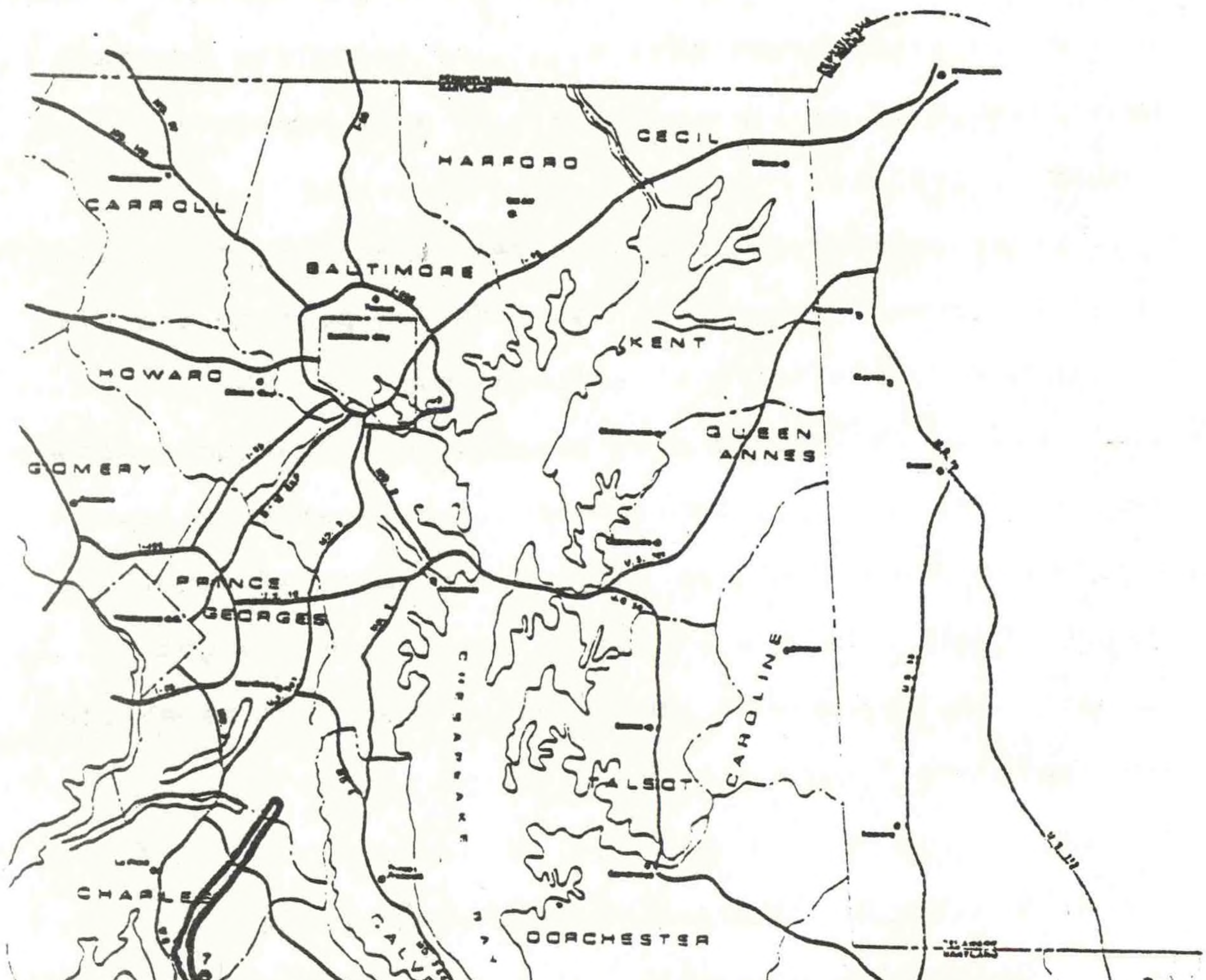
4.2.1 Background

The Zekïah Swamp is located within the watershed of the Wicomico River in Charles County (Figure 4.17). The 17,800-acre Critical Area contains important forested habitat which includes both tidal and non-tidal wetlands. Important management concerns for this Critical Area center on impacts from off-site development and urbanization within the watershed in Charles County. The land-use changes which are of concern include sand and gravel mining and clear-cutting of trees in areas adjacent to Zekiah Swamp, for instance in upstream areas in Cedarville Wildlife Management Area, managed by DNR. Also of concern are off-site impacts due to urbanizing areas along Route 301, and in the new Town of St. Charles. Off-site impacts can take the form of either changes in run-off and eroded sediments flowing downstream into Zekiah Swamp, or changes in the hydrologic budget of this Critical Area due to excessive withdrawal of ground water by the new municipal and commercial users in the area.

These management needs can be met with a program of extensive on-site data collection (both surface water and ground-water measurements) to ascertain the hydrologic budget and impacts due to new development. Studies of

Figure 4.17

Zekiah Swamp Critical Area in Charles County



this nature are presently being formulated by USGS which is participating in an ad-hoc committee comprised of state, local, and federal agencies who are concerned with managing this Critical Area. LANDSAT could be of some use in characterizing changes in the hydrologic budget, since studies in other areas have shown the satellite digital data capable of monitoring levels of soil moisture (Colwell, 1983).

Other ongoing studies include the mapping of vegetation, principally non-tidal wetlands, as part of the U.S. Fish and Wildlife National Wetland Inventory (NWI). The maps need to be checked with on-site verification. Alternatively the distribution of non-tidal vegetative cover within the Swamp could be checked with LANDSAT satellite imagery, which could also assess vegetative changes through time since 1972 (the date of the first satellite coverage; see Figure 3.3).

4.2.2 Sources of Information for the Resource Management Data Base

Existing sources of information about environmental characteristics in the Zekiah Swamp Critical Area include:

- Photomaps of tidal wetlands on file at the Maryland DNR Water Resources Administration. After passage of the Maryland Wetlands Act in 1970, the tidal wetlands were delineated and classified on a series of approximately 2000 aerial photomaps at a scale of 1:2400 (1 inch = 200 feet). Sample wetlands photomaps are shown in Figures 4.6 and 4.7. The classification scheme and state-wide summary statistics are contained in a DNR report The Coastal Wetlands of Maryland (McCormick and Somes, 1982).

- Non-tidal wetlands maps. A set of 7.5 minute topo quad sheets with areas delineating non-tidal wetland vegetation types has been prepared as part of the NWI program, utilizing a classification scheme developed by the U.S. Fish and Wildlife Service. The categories used are described in the U.S.F.& W. report Classification of Wet lands and Deep Water Habitats of the United States (Cowardin et al., 1979).

- Soil surveys from the county soil report, prepared by the Soil Conservation Service.

- Tidal records, available in the annual Tide Tables for the East Coast of North and South America (NOAA).

- Assorted aerial photography, both overhead and oblique, in infrared, color and black-and-white, collected by the U.S. Department of Agriculture, U.S. Department of State Planning, and other state and federal agencies. For instance, the National High Altitude Photography Program (NHAP) is funded by fourteen Federal agencies to provide a national data base for mapping and resource management. The black-and-white photography is of cartographic quality, and the color infrared is valuable for resource evaluation, monitoring, and management. The acquisition of this data base started in 1978. The Maryland Coastal Zone is one area where NHAP has completed the coverage, see Figure 4.9. A catalog of available airphoto coverage in Maryland has been compiled by the Maryland Remote Sensing Steering Committee (DSP, 1982). Another summary of aerial photographs is available from the National Cartographic Information Center (USGS, 1980).

- Occasional water quality data collected by the EPA Chesapeake Bay Program (EPA, 1982), and by the USGS Potomac River Study (Lippson, 1979).

- Bathymetric charts compiled and updated by the National Ocean Survey.

- Land-cover maps, at a scale of 1:24000, prepared by the Maryland Department of State Planning from analysis of aerial photographs.

4.2.3 Evaluation of Remote-Sensing Techniques

Initial processing of the LANDSAT digital data produced locational maps delineating the land cover in this Critical Area (see Appendix A). The detail map shown in Figure 4.18 is of the ADPCLU algorithm for the delta area of Zekiah Swamp. For comparison of the land cover classes shown on this computer printout, refer to the aerial photos shown in Figures 4.19 and 4.20. The LANDSAT classification in the delta yielded a reasonable discrimination between emergent wetland vegetation, the adjacent submerged aquatic areas, and the upstream forested fastland. The particular scene which was analyzed most extensively for Zekiah Swamp was collected by the LANDSAT satellite on 2 June 1973. Computation from the Tide Tables revealed that the time of collection of the satellite data (which is always 9:30 a.m. local time) coincided with the low Spring tide in the Wicomico River. Thus the principal factor which should be influencing a determination of submerged areas from mudflat and vegetated wetland in this case is solely stream flow into the delta.

The delineation of non-tidal wetlands and other land-cover types farther upstream in the Zekiah Swamp watershed is less satisfactory with the unsupervised classifications performed by the ASTEP programs on this scene. Figures 4.21 and 4.23 show portions of the upland

Figure 4.18

A two-pass non-iterative clustering algorithm classifier (ADPCLU)
with eighteen land-cover classes
applied to the 7 April 1978 LANDSAT scene of
The Zekiah Swamp Critical Area

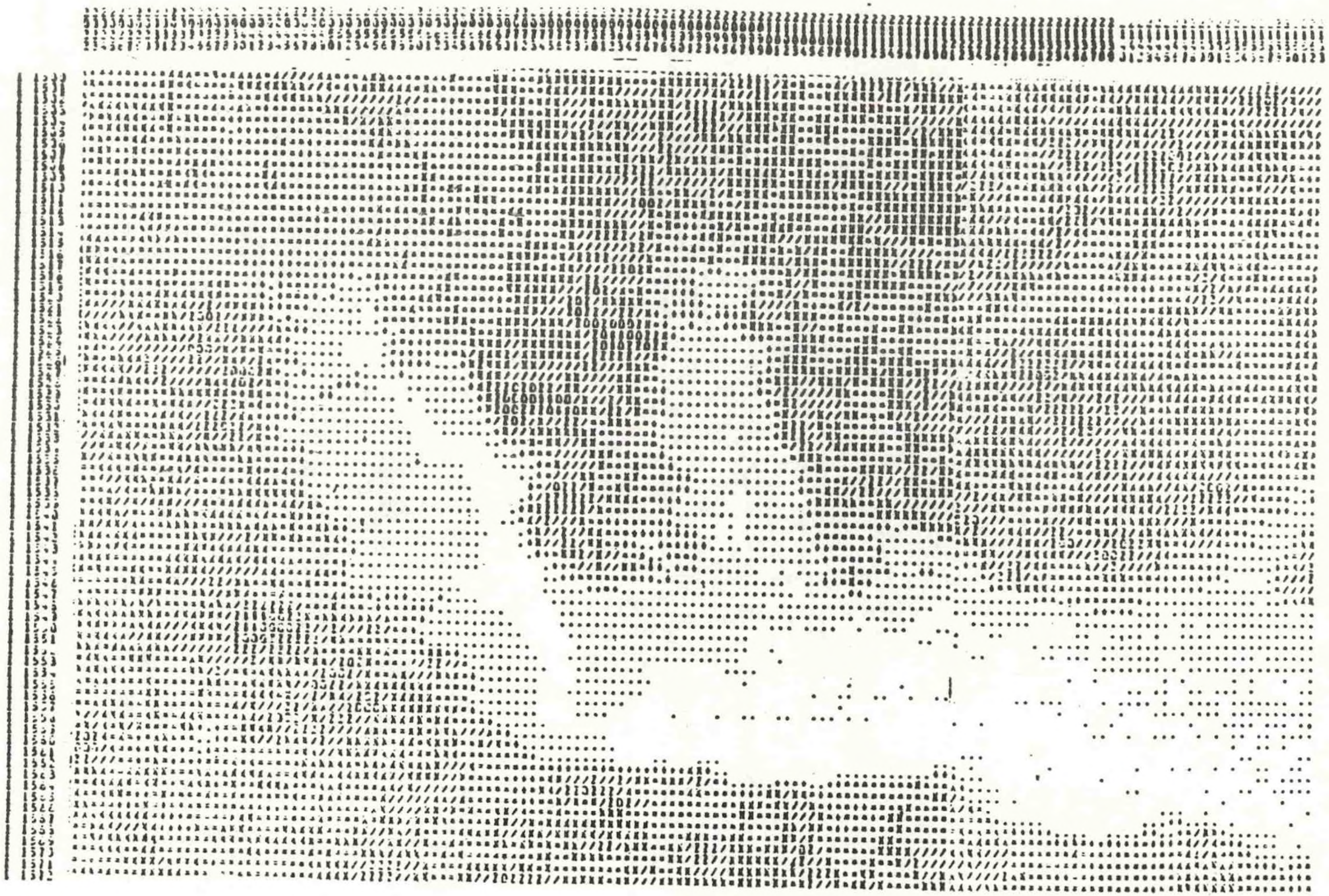


Figure 4.19

Zekiah Swamp delta viewed from the North

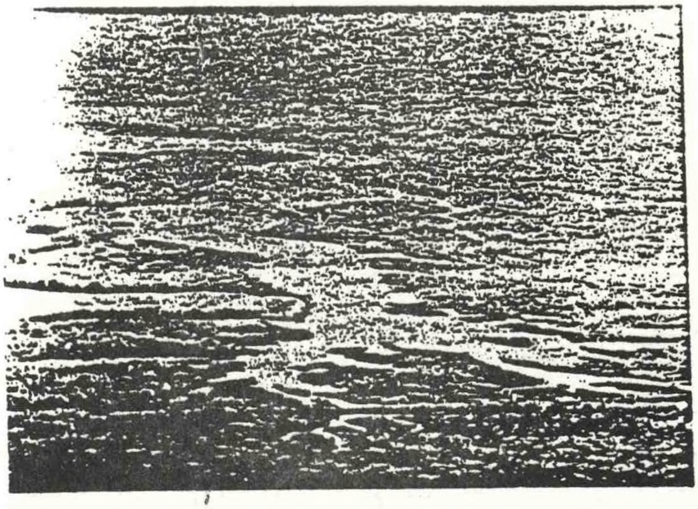
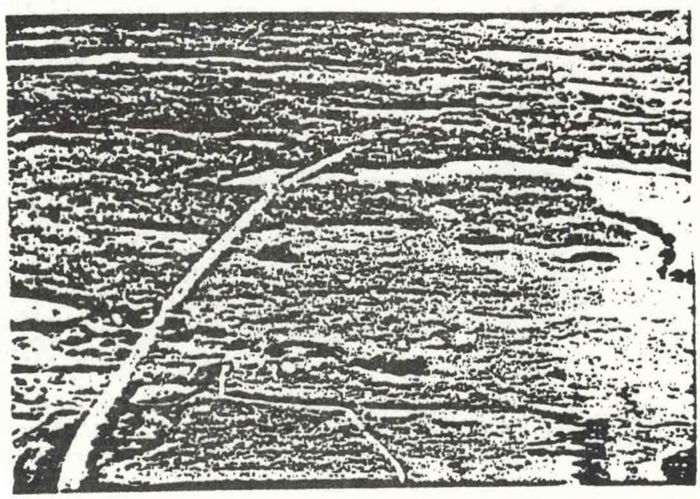


Figure 4.20

Zekiah Swamp delta viewed from the West

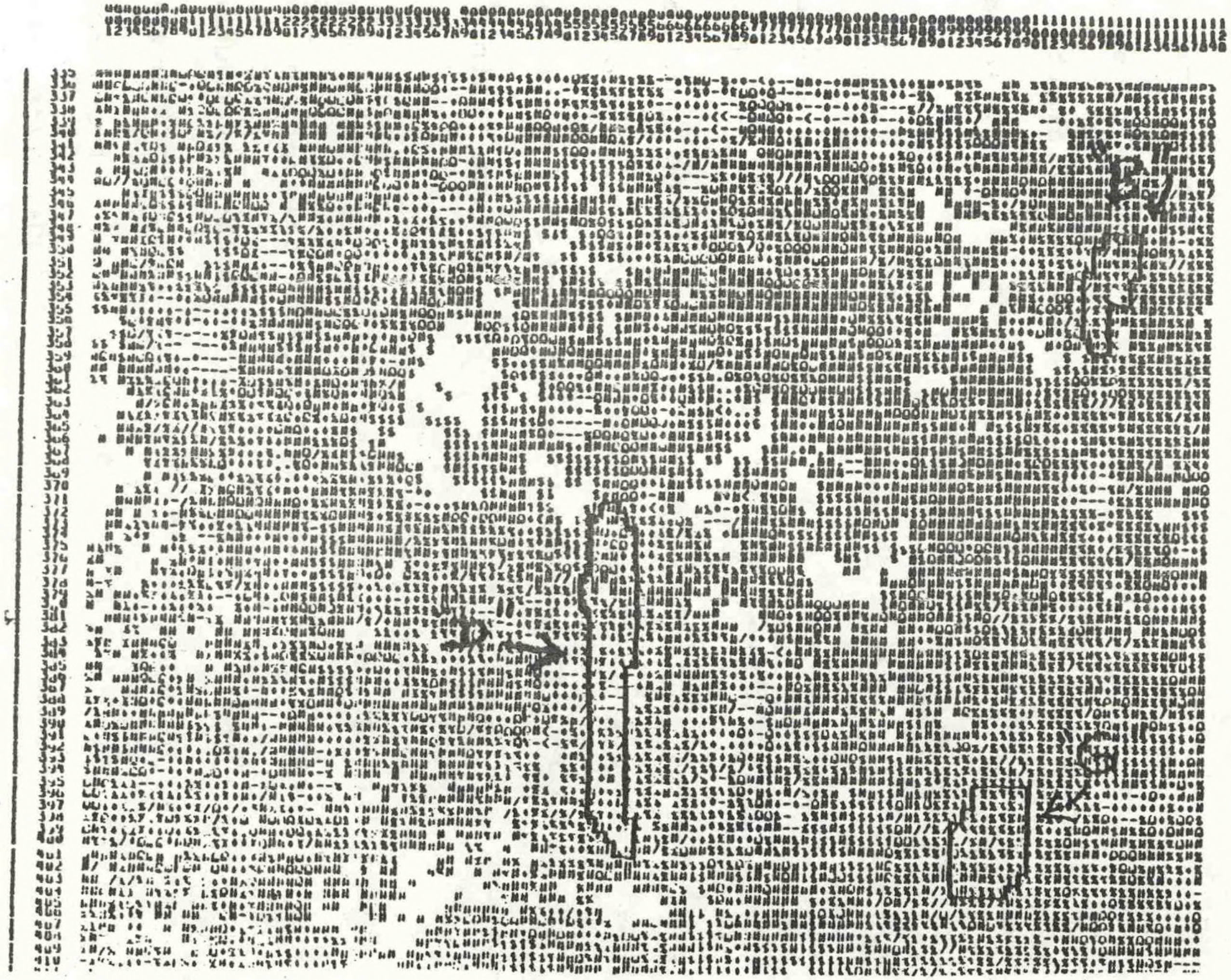


area on the unclassified scene which are known to contain patches of the desired non-tidal forested wetlands land-cover class mapped by the U.S. Fish and Wildlife Service. The spectral signatures represented in the populations of pixels within the polygons on these printouts are discussed here in some detail because they constitute a good example of the analysis of the LANDSAT digital data to produce the precise classification of a desired land-cover type.

Figures 4.21 and 4.23 show portions of the scene from 2 June 1973, where the LANDSAT digital data was processed through a DCLASS algorithm in the ASTEP programs. DCLASS utilizes spectral signatures derived through polygon analysis and applies these signatures to the entire scene. The result is a classification of the entire scene based on a supervised analysis of a limited set of training areas.

The training areas were selected from maps of non-tidal wetlands cover classification prepared by the U.S. Fish and Wildlife Service, and recently introduced to State agencies as part of the NWI program. Portions of the non-tidal wetlands maps corresponding to the areas shown in the LANDSAT printouts are included here for comparison in Figures 4.22 and 4.24. The training areas which were selected represent specific types of land cover classes listed in Table 4.1. Once large enough training areas were found on the NWI maps, the locations of

Figure 4.21

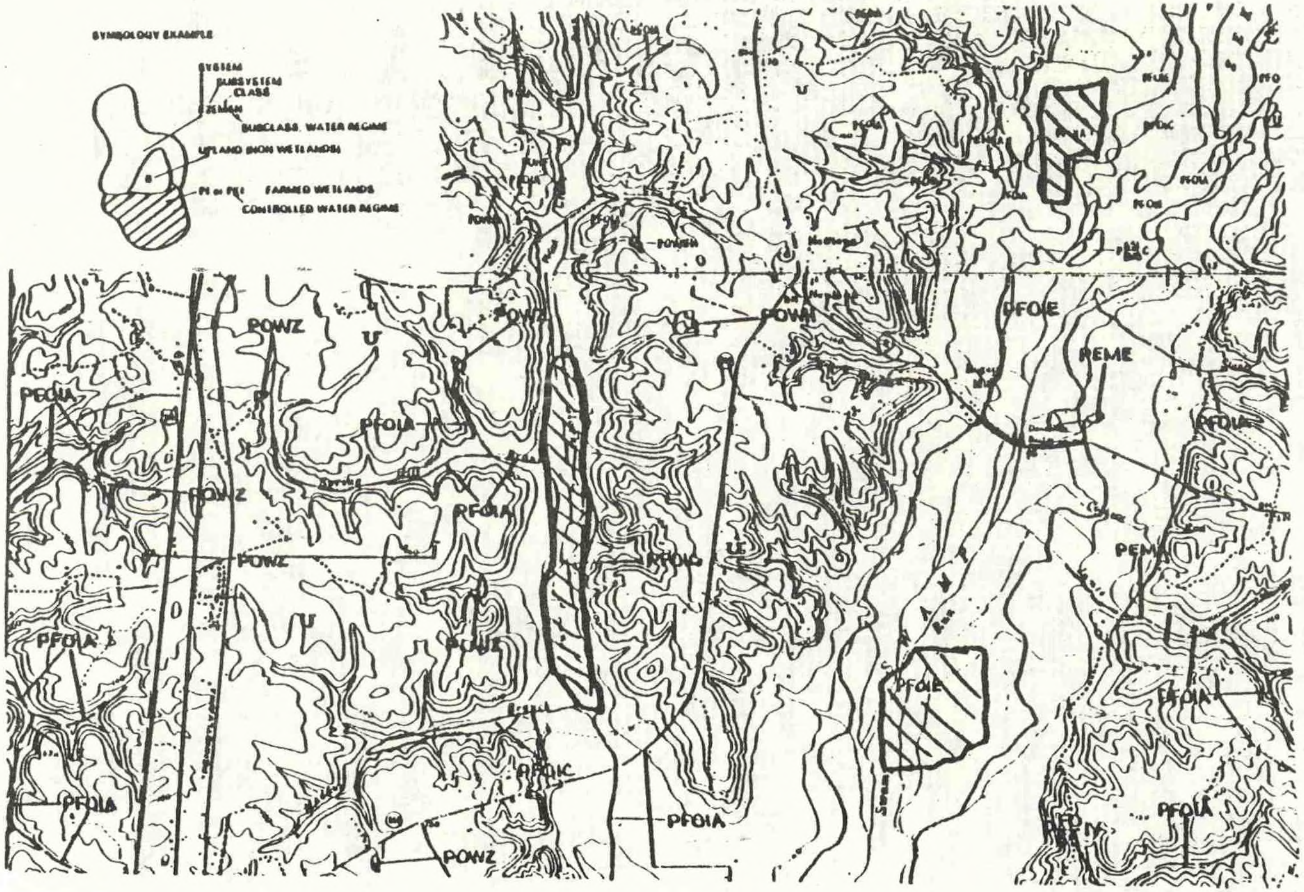


Zakiah Swamp 2 June 1973
Supervised Classification using Extracted
Means and Covariances for Unique Signatures
(DCLASS Algorithm)

Figure 4.22

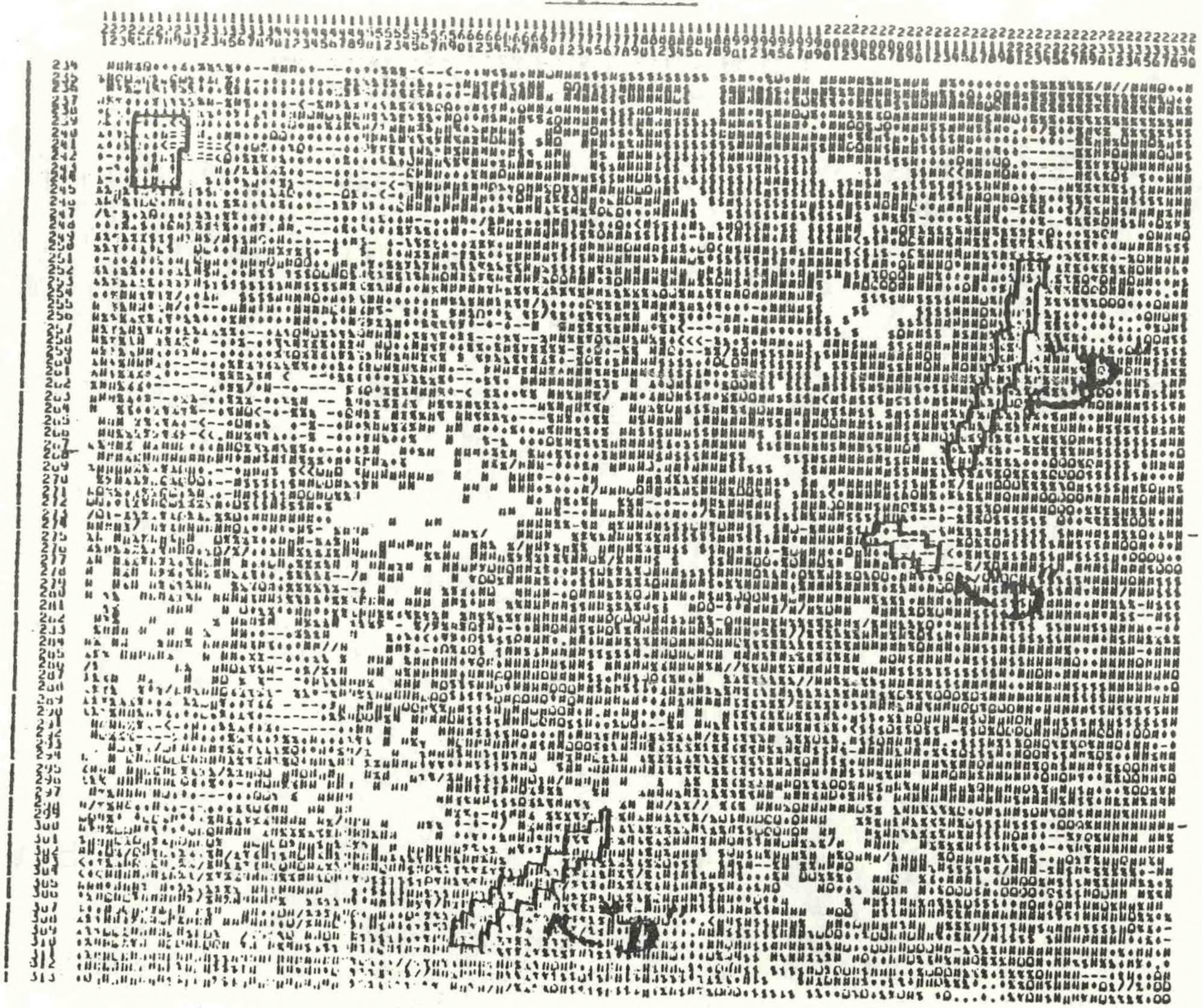
NATIONAL WETLANDS INVENTORY

UNITED STATES DEPARTMENT OF THE INTERIOR



Zakiah Swamp Critical Area
Portion of Non-Tidal Wetlands Map
Prepared by the U.S. Fish & Wildlife Service

Figure 4.23

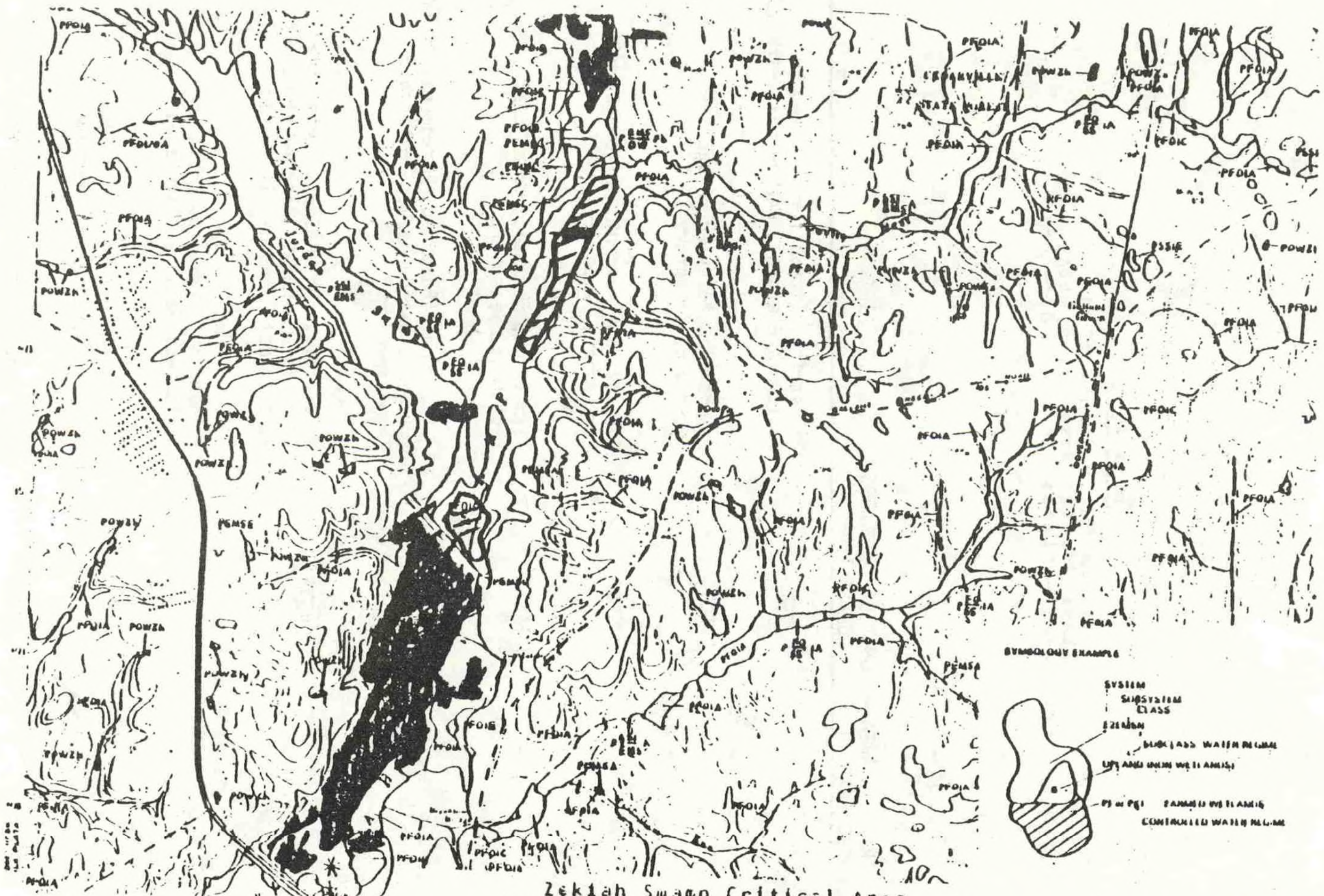


Zekian Swamp 2 June 1973
Supervised Classification using Extracted
Means and Covariances for Unique Signatures
(DCLASS Algorithm)

Figure 4.24

NATIONAL WETLANDS INVENTORY

UNITED STATES DEPARTMENT OF THE INTERIOR



Zekiah Swamp Critical Area
Portion of Non-Tidal Wetlands Map
Prepared by the U.S. Fish & Wildlife Service

Table 4.1

Zekiah Swamp 2 June 1973
Class Symbols associated with
Non-Tidal Wetlands Landcover Categories

TRAINING AREA DESIGNATION	NON-TIDAL WETLANDS CLASS TYPE	DESCRIPTION
A	P SS1/EM5 A	Palustrine, (scrub shrub, broad leaf Deciduous/Emergent, Narrow Leaf Persistent)
B	PFO1A	Palustrine, Forested, Broad Leaf, Deciduous, Temporary
C	PEM5A	Palustrine, Emergent, Narrow-Leaved Persistent, Temporary
D	PFO1C	Palustrine, Forested, Broad Leaf Deciduous, Seasonal
E	P FO1/EM5 A	Palustrine, (Forested, Broad Leaf Deciduous/ Emergent, Narrow-Leaved Persistent), Temporary
F	P SS1/EM5 E	Palustrine, (Scrub/Shrub, Broad Leaf Deciduous/Emergent, Narrow-Leaved Persistent), Seasonal Saturated
G	PFO1E	Palustrine, Forested, Broad Leaf Deciduous, Seasonal Saturated
H	L1OWK2H	Lacustrine, Limnetic, Open Water, Artificial, Eubaline, Permanent
J	E1OWL	Estuarine, Subtidal, Open Water, Subtidal
K	E2EMP	Estuarine, Intertidal, Emergent Irregular

Table 4.2

Zekiah Swamp 2 June 1973
Summary of Signature Classes and
Pixel Count for Each Class

CLASS	WETLANDS SYMBOL	#	@	$	%	&	*	/	.	-	=	<		>
A	P$\frac{SS1}{EM5}$A	15	5	5	1		4							
B	PFO1A	41	1	15	81		5	3		4			8	
C	PEM5A			3									5	
D	PFO1C	52	12	1	105		34	3		7			14	
E	P$\frac{FO1}{EM5}$A	2	1		12		1	1		1				
F	P$\frac{SS1}{EM5}$E	6	7				4			12				
G	PFO1E	36	4		89		6	6		2			5	
H	L1OWK2H	4	1	4	2		11		1	1	4		1	4
J	E1OWL										58			
K	E2EMP		1	1	3		5			5		73		

corresponding groups of pixels (line and row numbers of all the pixels in each polygon) were located on the LANDSAT printouts in Figures 4.21 and 4.23. The perimeters of the training areas are drawn on these printouts as polygons. The steps taken to develop a supervised classification from the training areas are described below.

SUPERVISED CLASSIFICATION PROCEDURE

1. The data for the pixels within each polygon are extracted by the computer for de tailed analysis of the spectral signatures.

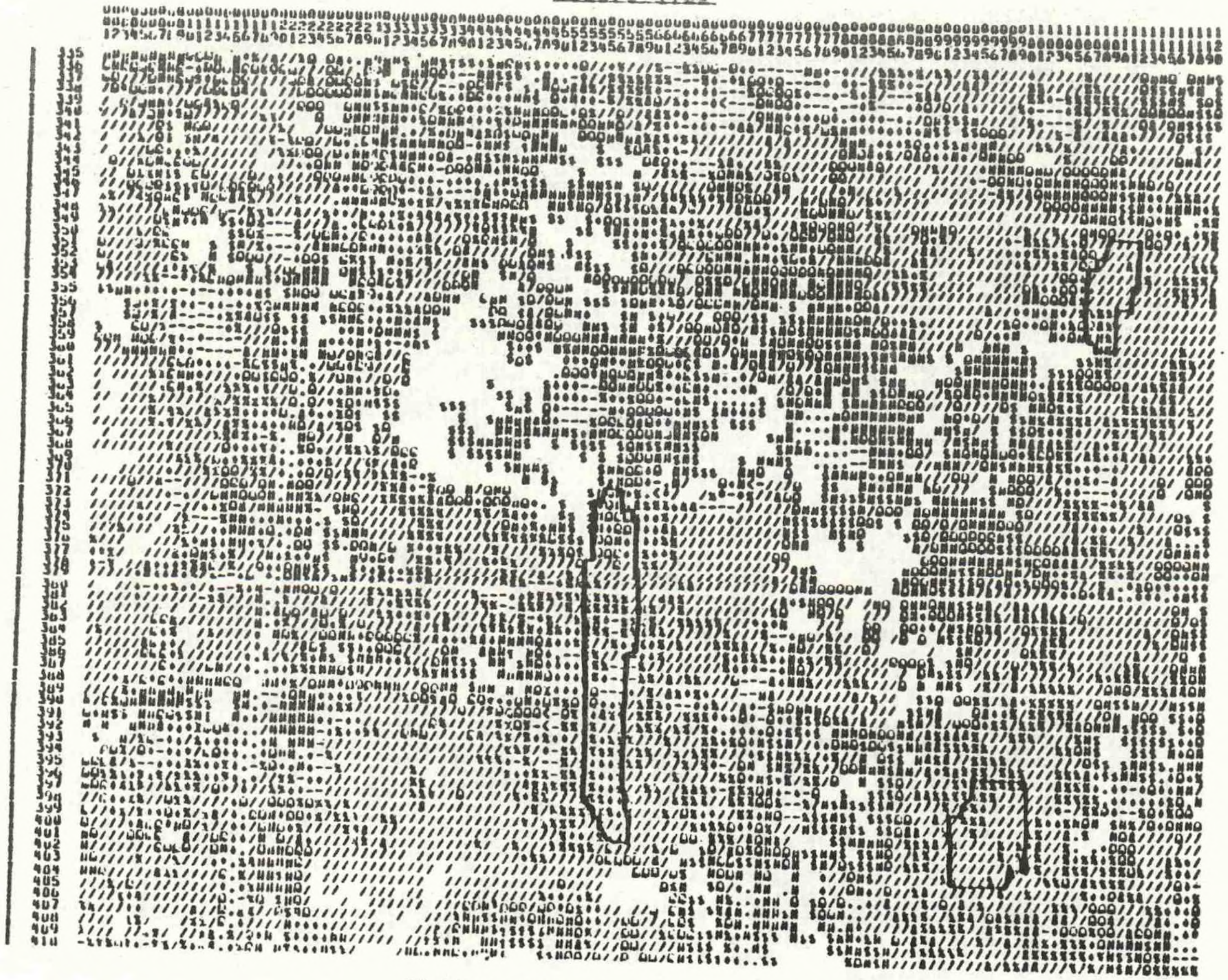
2. The data are grouped by the computer according to the number of actual land cover classes which are being investigated. In this case over 25 training areas were selected to represent different locations within the Zekiah Swamp watershed and included all five of the land-cover classes as they are presented on the NWI maps.

3. The computer takes all the polygons of the same land-cover class and extracts a spectral signature specific to that group of polygons. This is done through ALLSIG, an algorithm in the ASTEP program. The results are presented in Table 4.2. This table shows for each class the number of pixels which were included within the perimeter of the set of polygons circumscribed for that class; This table shows for each class: the number of pixels which were included within the perimeters of the polygons circumscribed for that class; the mean of each channel of data included in the analysis; and the associated co variance matrix (a statistical summary of the degree of variation existing for the data within the polygon(s)).

4. The user instructs the computer to execute the DCLASS algorithm in the ASTEP pro grams. This uses the means derived through polygon analysis (ALLSIG) of each land-cover type and applies them for the purpose of classifying the full scene.

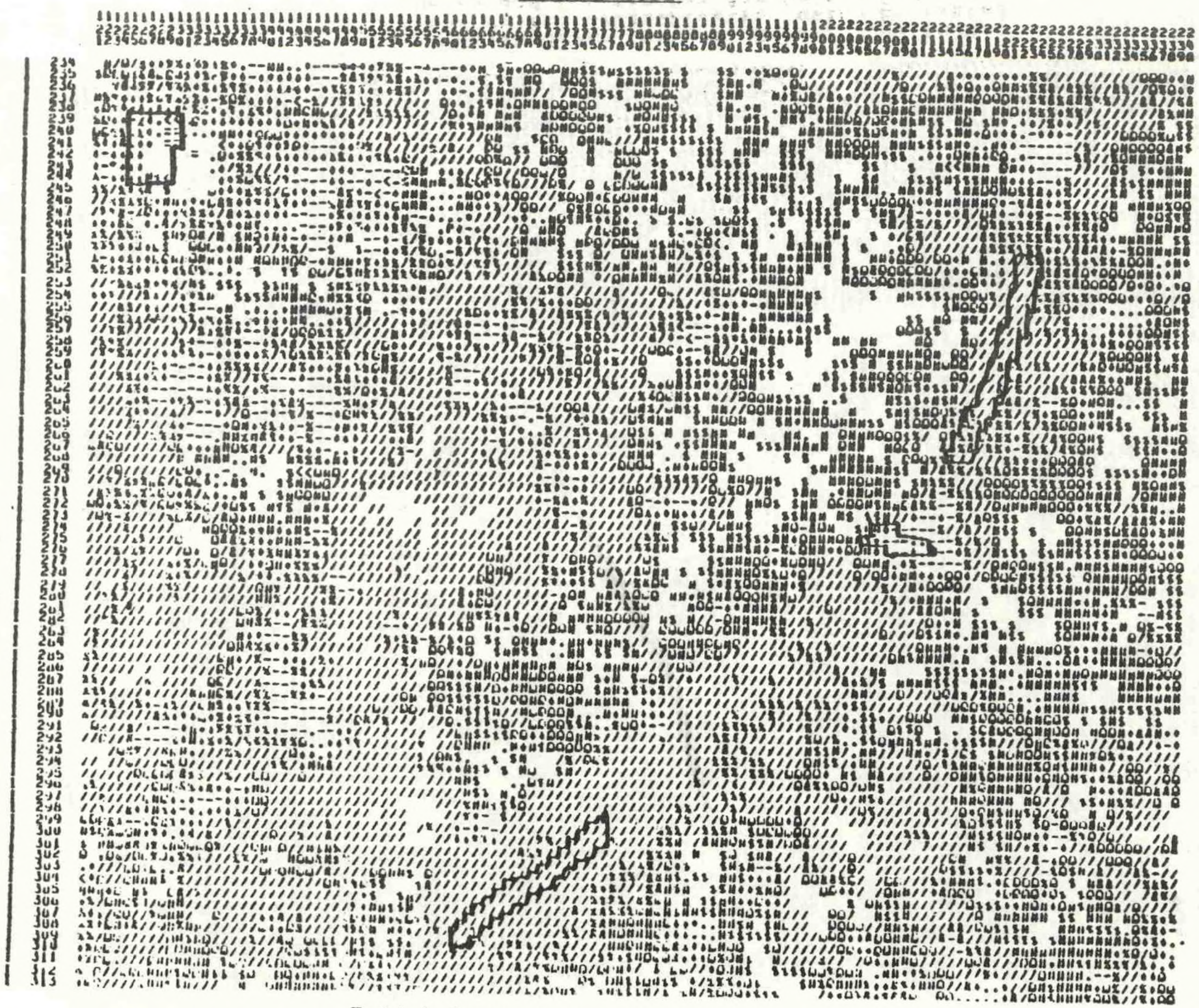
5. The resultant new supervised classification of land

Figure 4.25



Zekiah Swamp Critical Area 2 June 1973
Supervised Classification using Extracted
Means and Covariances for Unique Signatures
(DCLASS Algorithm)

Figure 4.28



Zekiah Swamp Critical Area 2 June 1973
Supervised Classification using Extracted
Means and Covariances for Unique Signatures
(DCLASS Algorithm)

cover is printed out through the IMAGES option. An example derived from the case shown here appears in Figures 4.25 and 4.26. By comparing Figure 4.25 with Figures 4.21 and 4.22 (and by comparing Figure 4.2 6 with Figures 4.23 and 4.24) it is apparent that the initial unsupervised classification shown in Figures 4.21 and 4.23 have been improved somewhat. However, the classification is still not sufficiently rigorous to include only the land cover types shown on the NWI map (compare Figures 4.22 and 4.24 with Figures 4.25 and 4.26). The reasons for this are covered in the points below.

POINT 1 - This is an iterative process and needs to be repeated with additional training area selection and refinement of critical limits to prevent both overclassification and underclassification. (The term "critical limits" is used here to specify the range of statistical inclusion for applying the means within the DCLASS algorithm and not in the sense of "Critical Areas Designation" by DSP.) An example of this iterative process is presented in the next case study of the Pocomoke River Designated Critical Area.

POINT 2 - The successful completion of the supervised classification of LANDSAT digital data to show land-cover classes of interest is based on the assumption that the sources of ground truth do represent distinctly different surficial features. If a set of baseline data maps that are selected as ground-truth contain classifications of land cover which are drawn for other generic reasons, then development of statistically unique spectral signatures is very difficult. For instance, on land-cover maps drawn for the counties, the delineation of "suburban areas" from photogrammetric analysis of aerial photos is likely to include several distinctly different forms of land cover: asphalt parking lots, grassy parks, wooded bird sanctuaries, dumps, and suburban residential areas, often accompanied by buffer zones composed of marsh where housing developments abut the shoreline. It is possible in such a case to develop a spectral signature in the LANDSAT data. However this involves treating the digital data for each type of land cover separately, then combining all classified land-cover classes together at the end and mapping the distribution of particular types of land-cover, for instance, suburban area within a watershed or county.

Similarly, for baseline maps which are potential sources of ground-truth such as the NWI maps, the classification scheme (Cowardin, et al. 1979) needs to be carefully assessed in an appropriate field area to make sure that the boundaries represent mutually exclusive land-cover classes. On the basis of the initial pass through the LANDSAT data which was performed as part of this project it can be concluded that Zekiah Swamp constitutes one such suitable area for checking the NWI classification. This is due to the large size of the swamp, the presence of several different NWI vegetative types within relatively close proximity of each other, and within the same watershed and presumably the same hydrologic regime.

POINT 3 - Assuming for the moment that the NWI vegetative classification discussed in the above paragraph does translate reasonably well into mutually exclusive land-cover types on the earth's surface within the Zekiah Swamp watershed, then the reason why the supervised classification obtained through the DCLASS algorithm (Figures 4.26 and 4.27) is not very rigorous, may be due to some inherent variation other than NWI vegetative type in the training areas which were selected. It is important to note that training areas were chosen precisely to permit study with LANDSAT the locations of a few NWI classes throughout the entire Swamp. Thus, at least three of four training areas were chosen for each NWI land-cover type in areas close to the Zekiah Swamp delta, in areas nearer the headwaters about 20 miles upstream, in areas close to the main longitudinal axis of the Swamp , and in fringe areas of the Swamp. For the reasons discussed in the section on management concerns above (see Section 4.2.1), the hydrologic regime in each of these areas may be different. Thus, while for all apparent purposes the NWI classification would be correct, a nd photogrammetric analysis would show the training areas represent mutually exclusive land-cover types, the LANDSAT data could be responding to subtle variations in soil moisture or other factors which would be difficult to identify from aerial photos or cursory site visits. The USGS ongoing geohydrologic studies in this area may shed some light on this subject, but collection of data needs to be coordinated with the collection of new satellite imagery. The general needs for this kind of consideration in future DNR field studies is discussed in Chapter 5. An attempt was made as part of the present project to find suitable ground-truth measurements of soil moisture in areas covered by LANDSAT scenes for Maryland, but neither U.S.D.A. nor S.C.S. had data which was useful.

POINT 4 - Once a suitable source of ground-truth base maps is in hand for any particular LANDSAT project (and it needs to be emphasized here that the NWI wetlands vegetation maps are probably suitable for further analysis in the Maryland Coastal Zone), and once all additional factors, such as soil moisture, are recognized and dealt with in the selection of training areas, it must be kept in mind that there needs to be consideration of the seasonal variation which affects the results of remote-sensing projects. This is true both for photogrammetric methods and satellite techniques; that is, the base maps containing the ground-truth classification scheme of interest for any particular case study needs to be evaluated against air photos or satellite scenes for different seasons. The LANDSAT technology is such that the satellite passively produces a remotely-sensed image for each scene about every 18 days, unless the area is obscured by clouds. The data that are collected on cloudless days is beamed back to earth and stored at the EROS Data Center. Thus, there is a wide array of digital data for a variety of scenes that is potentially retrievable by State agencies for comparison with suitable ground-truth data bases. This is not always the case with existing aerial photographic coverage of the Maryland Coastal Zone (DSP, 1982). Better coordination between the collection of remotely-sensed data and on-site field sampling should be expected in the future as the cost increases for new comprehensive field studies of natural resource management problems in the Maryland Coastal Zone.

Case III - The Pocomoke River (Site SA2)

Prepared by Edward P. Phillips

4.3.1 Background

The Pocomoke River watershed is located on the lower Eastern Shore in Somerset, Worcester, and Wicomico Counties. The Pocomoke River is a major tributary of the Chesapeake Bay which begins in th e great Cypress Swamp several miles north of the Maryland/Delaware state line and meanders southward for 54 miles in Maryland before emptying into the Pocomoke Sound. Fish and wildlife abound in the treasured habitat of the Pocomoke. The endangered Bryant fox squirrel (commonly known as the Delmarva fox squirrel) is found here along with varied other wildlife. Bald Cypress swamps, the northernmost along the U.S. Atlantic Coast border a portion of the length of the Pocomoke River. The River and these swamps provide a meeting ground for major southern and northern species. Most of the Pocomoke is inaccessible because of the jungle-like community of plants in the forest swamps. The Pocomoke Critical Area is a classic case where the solution to one problem in the watershed presents a threat to other natural characteristics of the ecosystem. The Pocomoke River presently enjoys high water quality, except for areas around Pocomoke City and Snow Hill where pollution exists. Development pressures are increasing throughout the Basin and there is no comprehensive coordinated policy within the 26 different zoning districts in the three counties of the Maryland Coastal Zone. Besides the land-clearing activities associated with new urban development, pressures are increasing for public use of the remaining preserve areas. In addition other water management techniques have been implemented in portions of the river system to increase arable land, and to improve navigation for a wide spectrum of new boat traffic.

For all of these reasons considerable care must be exercised immediately in developing a resource management data base to prevent deterioration of all the intrinsic natural features that make the Pocomoke River an Area of Critical State Concern.

4.3.2 Sources of Information for the Resource Management Data Base

Existing sources of information about environmental characteristics of the Pocomoke River Designated Critical Area include:

- Atlas of Historic Shore Erosion Rates in Maryland (MCZMP, 1975). A map atlas of 7.5 minute topographic quadrangle sheets for the Maryland shore-

shoreline showing locations of present shoreline, and historic shoreline from surveys in the 1800's.

- Photomaps of tidal wetlands on file at the Maryland DNR Water Resources Administration. After passage of the Maryland Wetlands Act in 1970, the tidal wetlands were delineated and classified on a series of approximately 2000 aerial photomaps at a scale of 1:2400 (1 inch = 200 feet). Sample wetlands photomaps are shown in figures 4.6 and 4.7. The classification scheme and state-wide summary statistics are contained in a DNR report The Coastal Wetlands of Maryland (McCormick and Somes, 1982).

- Faunal species lists compiled by the DNR Wildlife Administration.

- A long-term river gauging station. The results are published by the USGS in their annual reports, Water Resources Data for Maryland and Delaware, and in Special Reports of the Maryland Geological Survey.

- Non-tidal wetlands maps. A set of 7.5 minute topo quad sheets with areas delineating non-tidal wetland vegetation types has been prepared as part of the NWI program, utilizing a classification scheme developed by the U.S. Fish and Wildlife Service. The categories used are described in the U.S.F.& W. report Classification of Wetlands and Deep Water Habitats of the United States (Cowardin et al., 1979).

- Occasional water quality data collected by the EPA Chesapeake Bay Program (EPA, 1982).

- Occasional environmental data collected as part of research studies at Bay-area research institutions, such as the University of Maryland Horn Point Environmental Laboratories.

- Soil surveys from the county soil report, prepared by the Soil Conservation Service.

- Tidal records, available in the annual Tide Tables for the East Coast of North and South America (NOAA).

- Assorted aerial photography, both overhead and oblique, in infrared, color and black-and-white, collected by the U.S. Department of Agriculture, Maryland Department of State Planning, and other state and federal agencies. For instance, the National High Altitude Photography Program (NHAP) is funded by fourteen Federal agencies to provide a national data base for mapping and resource management. The black-and-white photography is of cartographic quality, and the color infrared is valuable for resource evaluation, monitoring, and management. The acquisition of this data base started in 1978. The Maryland Coastal Zone is one area where NHAP has completed the coverage, see Figure 4.9 A catalog of available airphoto coverage in Maryland has been compiled by the Maryland Remote Sensing Steering Committee (DSP, 1982). Another summary of aerial photographs is available from the National Cartographic Information Center (USGS, 1980).

- Bathymetric charts compiled and updated by the National Ocean Survey.
- Land-cover maps, at a scale of 1:24000, prepared by the Maryland Department of State Planning from analysis of aerial photographs.
- County Comprehensive Plans.

4.3.3 Evaluation of Remote-Sensing Techniques

The results of the LANDSAT evaluation for the Pocomoke River are presented here for two small portions of the watershed where a resource management data base is particularly appropriate to monitor development impacts. These two areas are Snow Hill and Pocomoke City. Figures 4.27 and 4.28 show portions of the USGS topo quad sheets for these two areas which can be compared with the print-outs of LANDSAT digital data on the following pages. Two dates for which LANDSAT scenes were available were then selected for both of these areas: 10 October 1972 and 9 April 1978. Brightness intensity maps (NMAPS) for the earlier date are to be found in Appendix A, while similar

Figure 4.27

Pocomoke River - Portion of USGS 7.5 Minute
Topo Quad Sheet of Snow Hill subarea

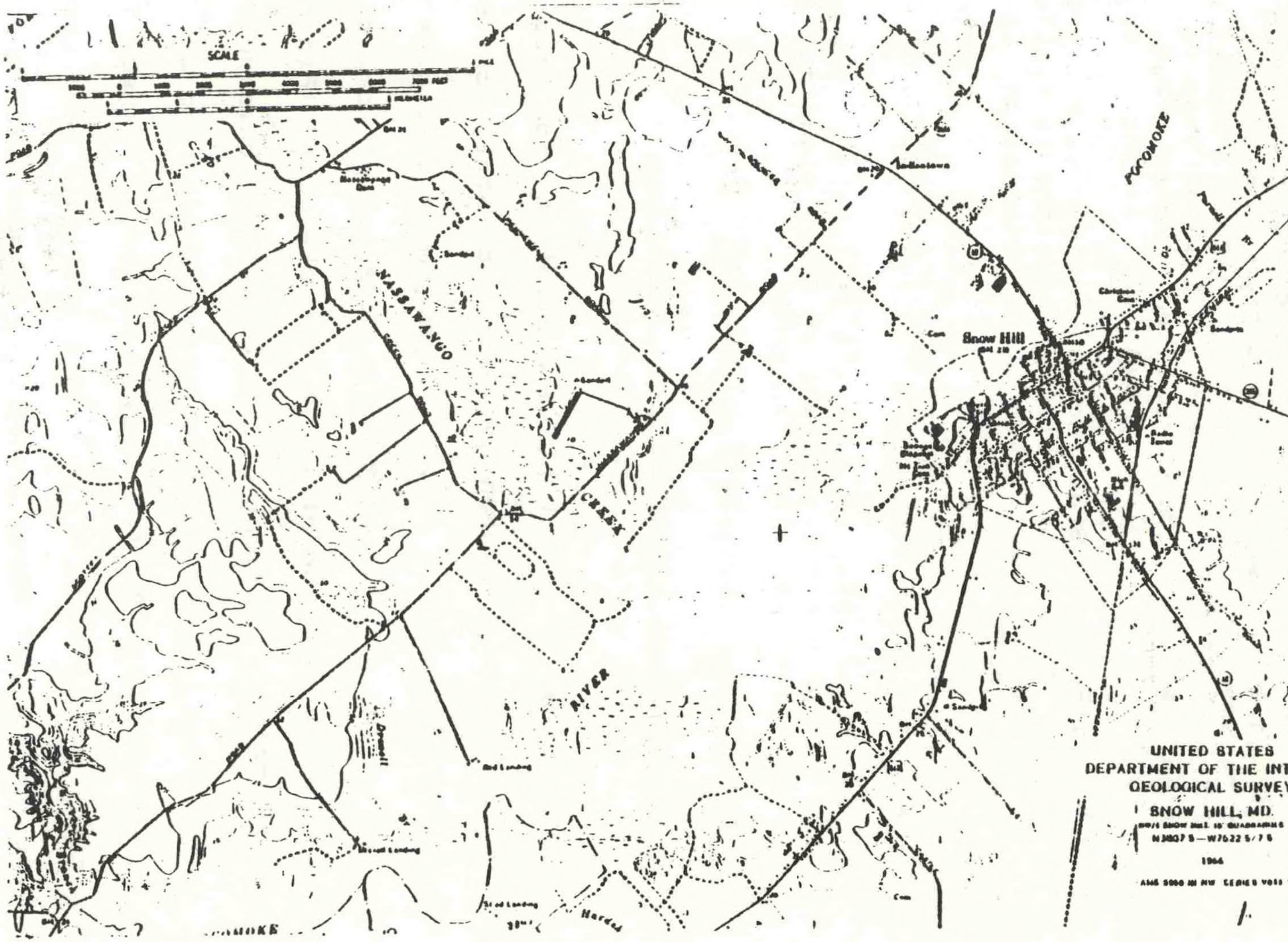


Figure 4.28

Pocomoke River - Portion of USGS 7.5 Minute Topo Quad Sheet of Pocomoke City subarea

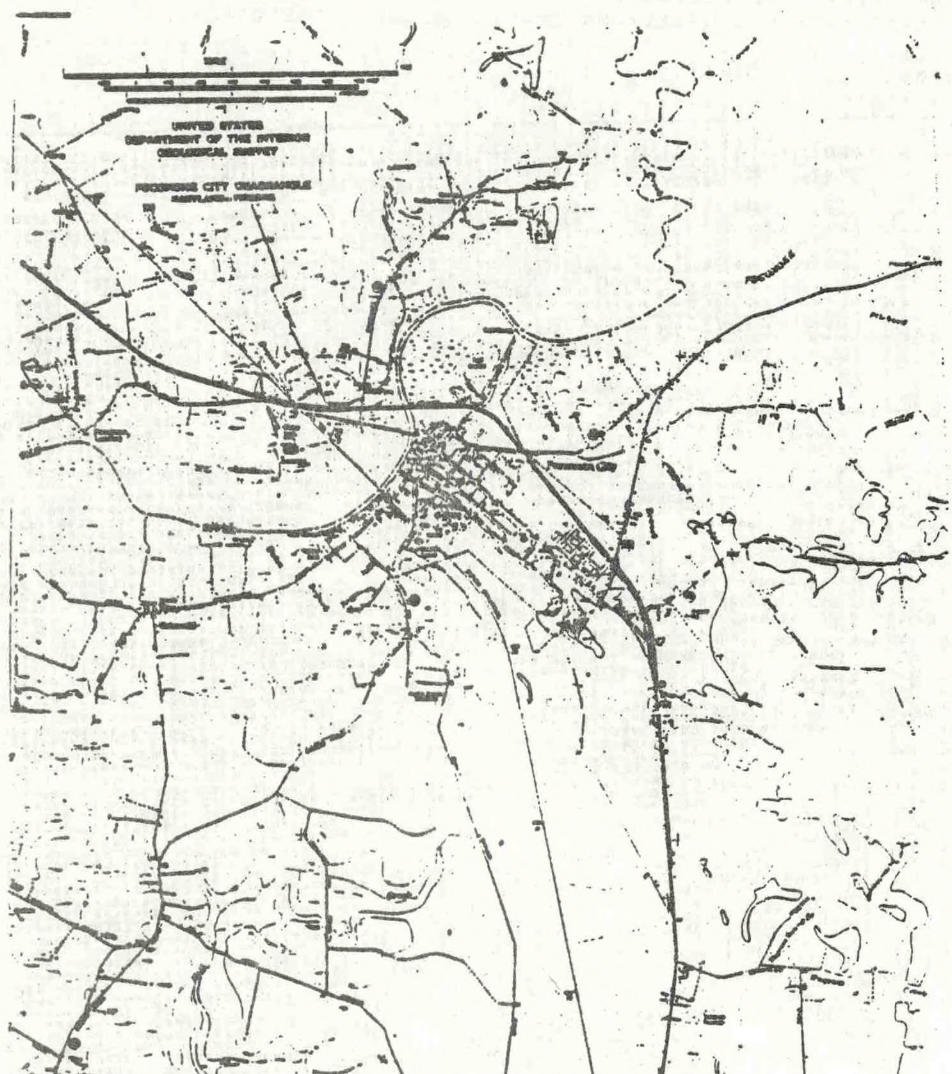


Figure 4.29

Pocomoke River (Snow Hill subarea)
Brightness Intensity Map (NMAP) for 9 April 1978

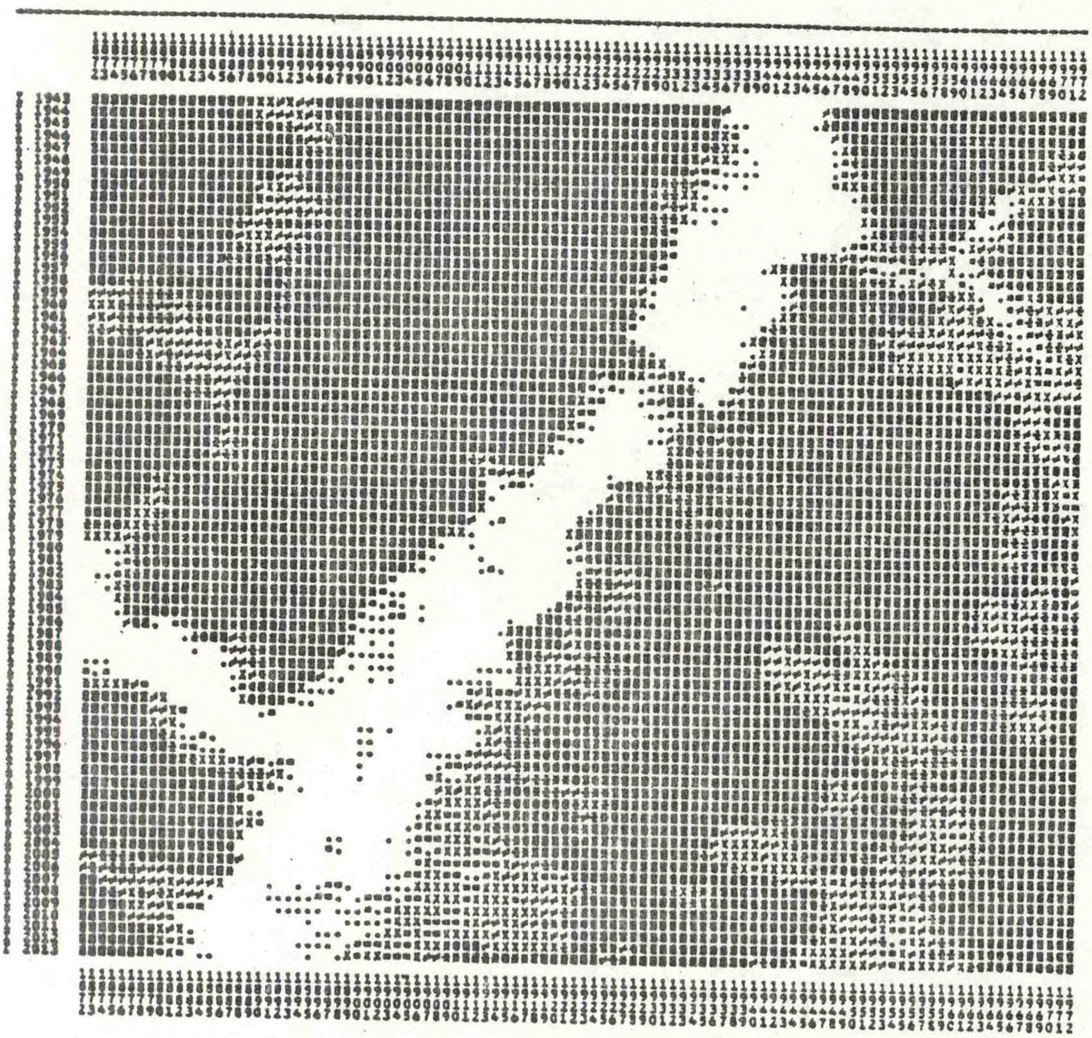
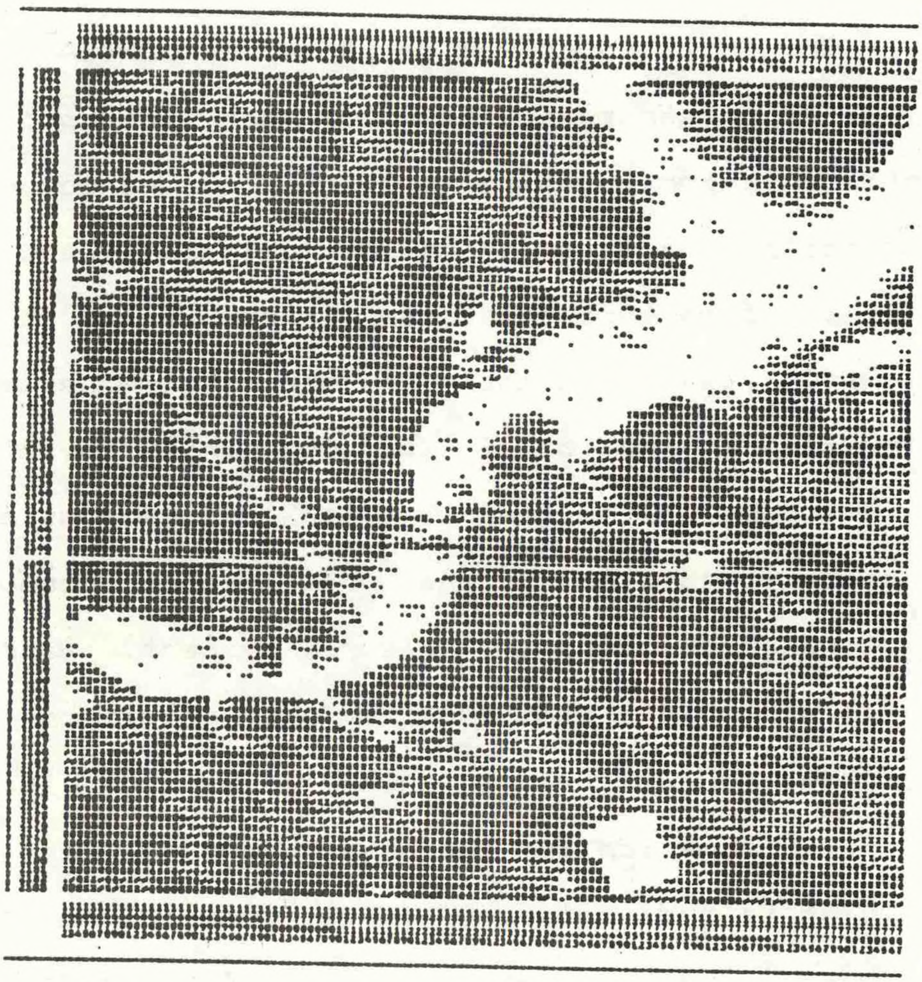


Figure 4.30

Pocomoke River (Pocomoke City subarea)
Brightness Intensity Map (NMAP) for 9 April 1978



maps for the more recent date are presented in Figures 4.29 and 4.30. The Snow Hill subarea was selected for extensive analysis by a series of statistical procedures for land cover classification. Results similar to those below can also be obtained for the Pocomoke City subarea.

Figures 4.31 to 4.34 show density sliced images for each of the four spectral bands for the portion of the scene near Snow Hill which was collected by LANDSAT on 9 April 1978. As presented in Table 3.1 each band provides information on important aspects of both ground cover and other surficial characteristics. For example, Band 4 (Figure 4.31) clearly identifies the course of the Pocomoke River itself and the much more shallow Nassawango tributary. Some indication of field boundaries may also be seen on this band, although only large homogeneous areas such as that immediately to the west of the Pocomoke River/Nassawango juncture are clearly evident. Band 5 (Figure 4.32) provides considerably more detail on the nature of the ground cover in this area without losing much of the information on the river boundary. Particularly evident is the deciduous forest cover along both sides of the Pocomoke. Band 6 (Figure 4.33) measures reflected light in the near-infrared portion of the spectrum and provides information that is not usually available to the interpreter or resource manager unless this type of data has been collected with an appropriate sensor (or film). Changes in the boundary between land and water

Figure 4.31

Pocomoke River (Snow Hill subarea)
Density Slice for LANDSAT MSS Band 4
9 April 1978

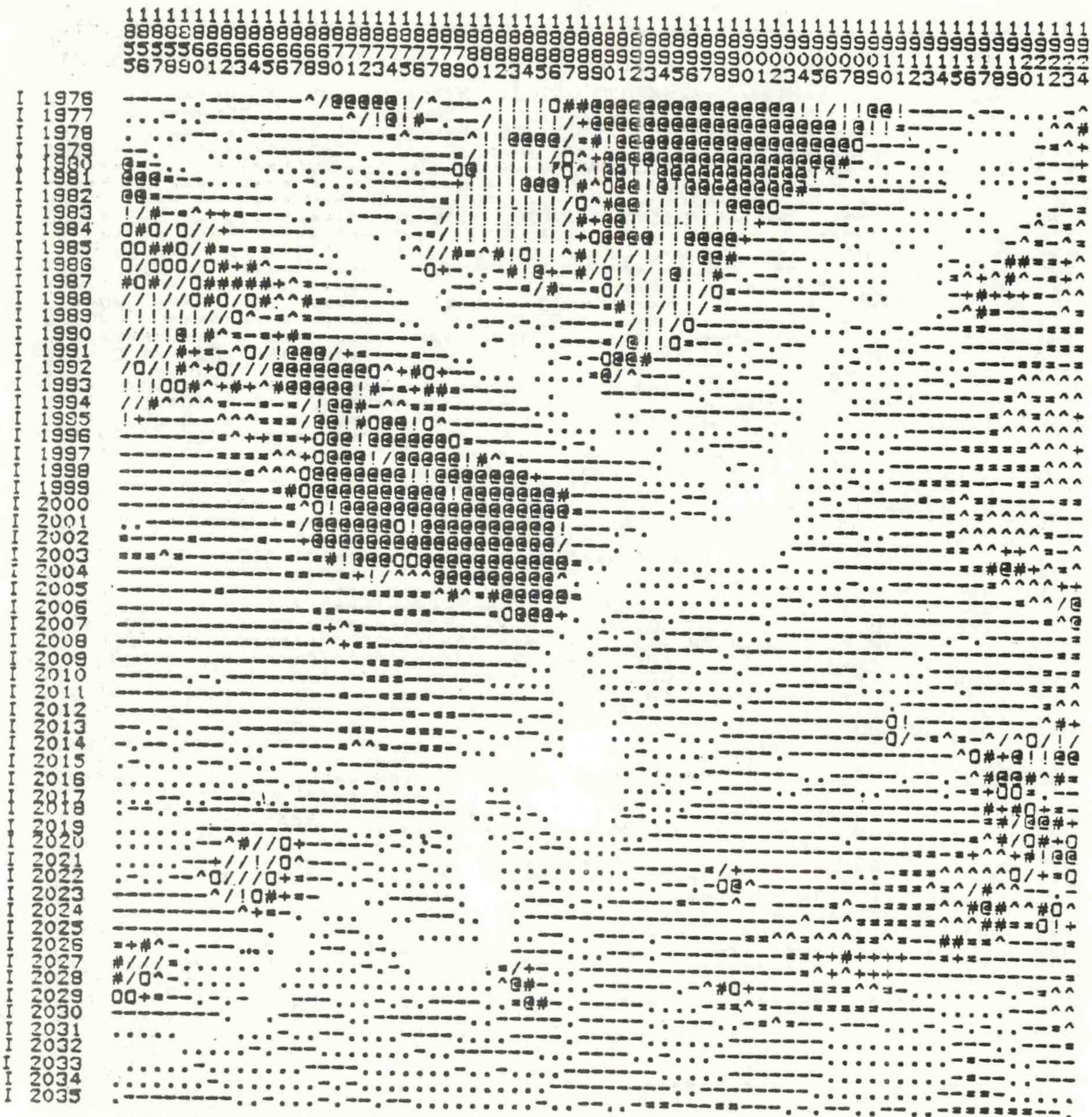


Figure 4.32

Pocomoke River (Snow Hill subarea)
Density Slice for LANDSAT MSS Band 5
9 April 1978

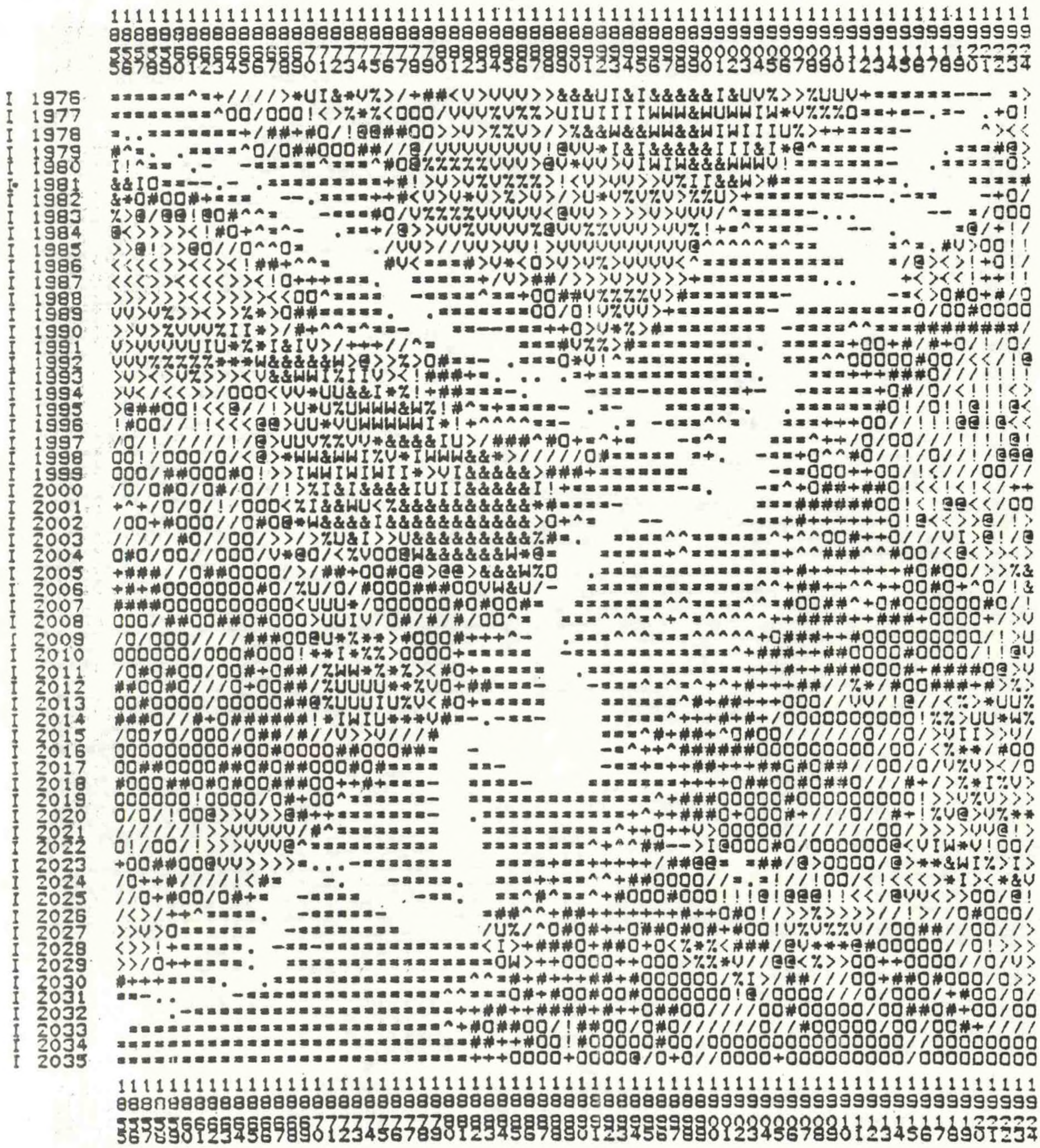


Figure 4.33

Pocomoke River (Snow Hill subarea)
Density Slice for LANDSAT MSS Band 6
9 April 1978

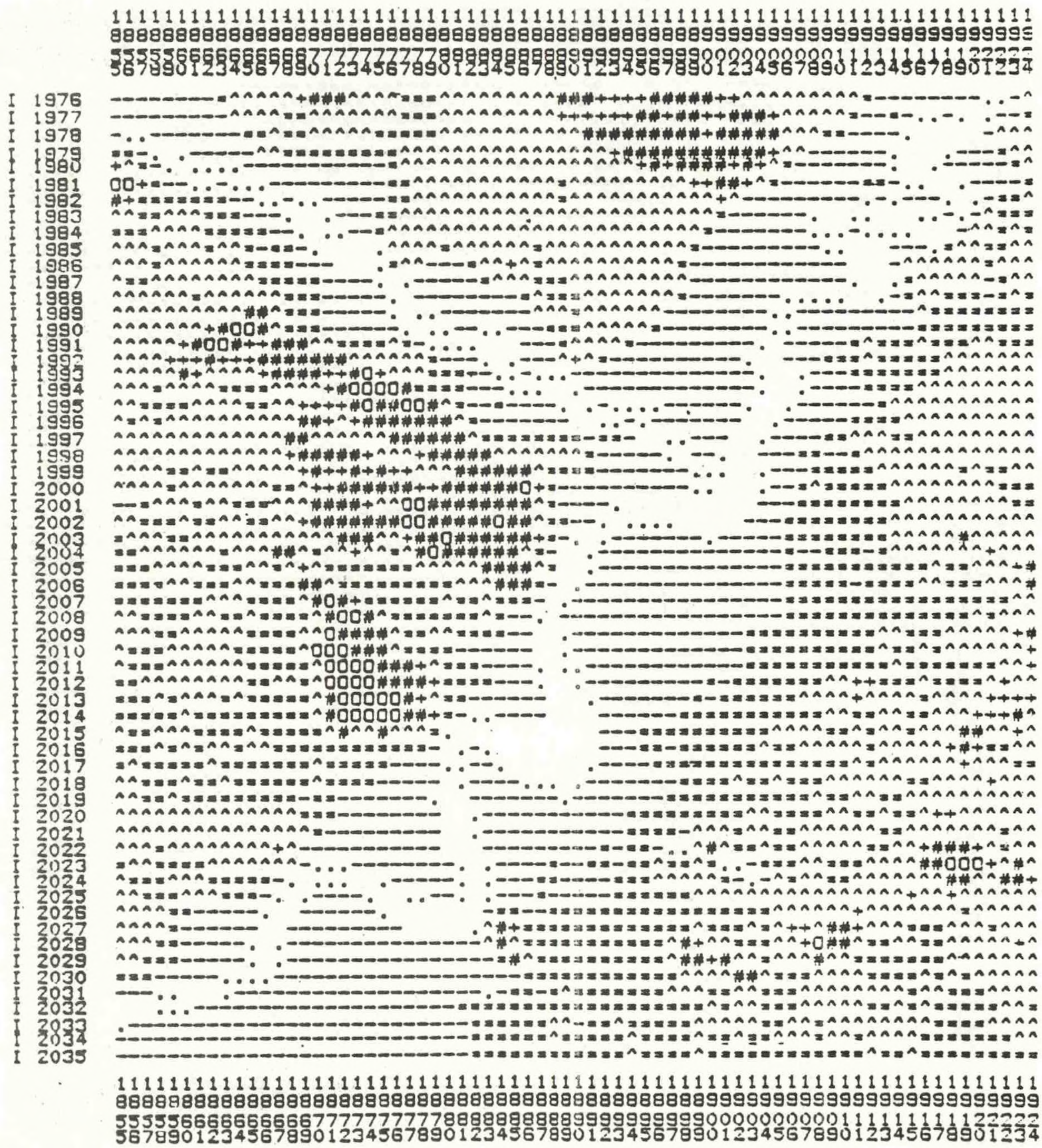
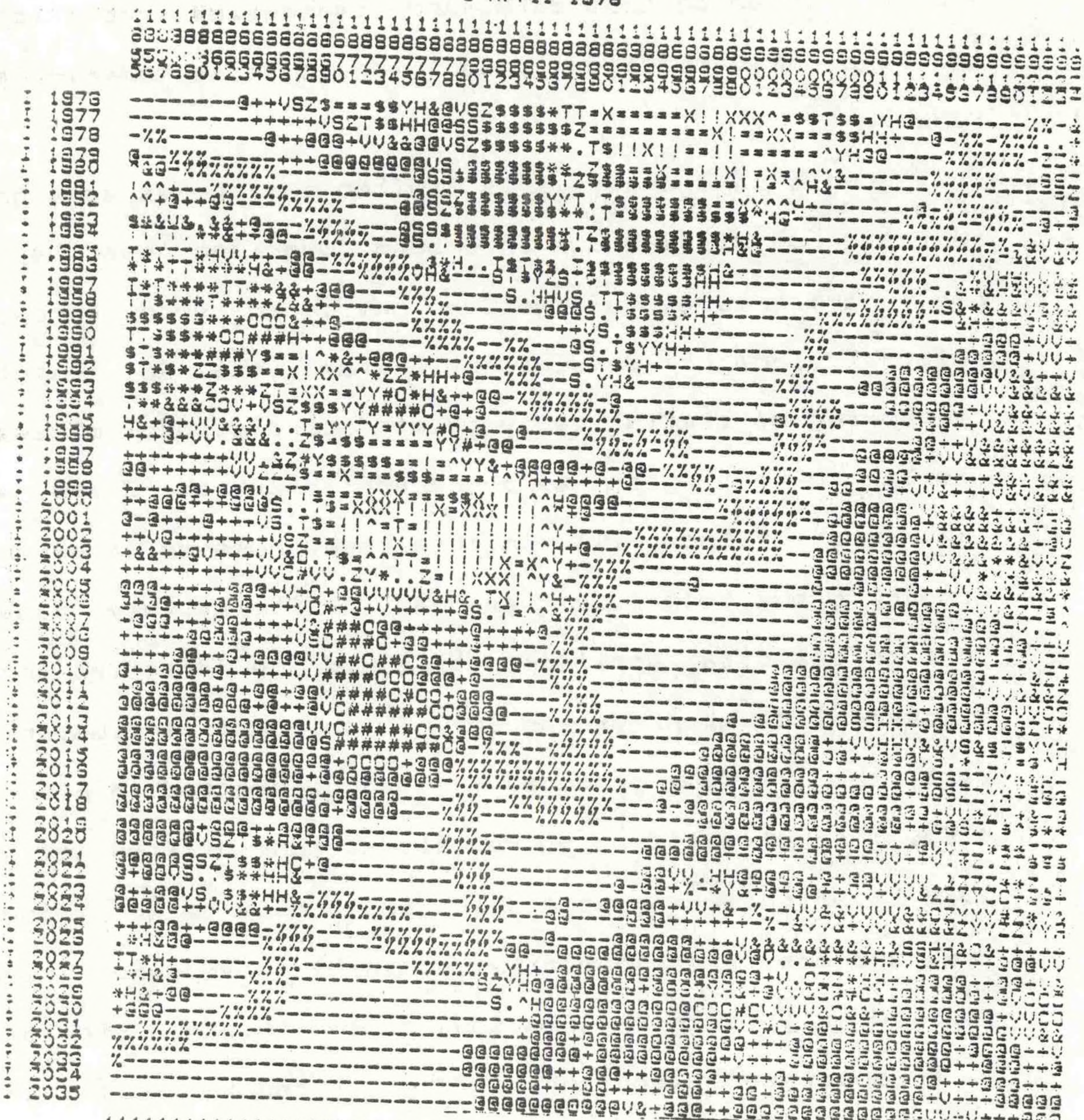


Figure 4.34

Pocomoke River (Snow Hill subarea)
Density Slice for LANDSAT MSS Band 7
9 April 1978

Figure 4.35

Pocomoke River (Snow Hill subarea)
Iterative Clustering Algorithm (ITRCLU)
9 April 1978



as well as seasonal and yearly variations in the vegetation and landforms in this portion of the Pocomoke River can be effectively monitored in this band. Band 7 (Figure 4.34) provides the best penetration of atmospheric haze (not a problem on this date) and emphasizes vegetational and landform variations in addition to those observable in Band 6.

Single band analysis is limited and serves as a gross indicator of differences in ground cover and possible land use. More precise information may be achieved through spectral signature development and analysis. An adaptive clustering of statistically related pixels into classes, similar to that which was prepared for Zekiah Swamp, was generated for Snow Hill. In this case, however, a slightly more rigorous technique was used to iteratively pass through the data until p-tests could be satisfied for successful cluster development. This iterative clustering algorithm (ITRCLU) produced the map presented in Figure 4.35. This classification reveals strong differences in land cover including some sharp boundaries between wooded area and open exposed habitat south of Nassawango Creek. Additionally, such information as the distribution of major species of woodland and crop types in cultivated fields may also be derived from this classification and then verified through appropriate ground-truthing.

The first step in developing supervised classification was to generate a uniformity map (see Figure 4.36).

Figure 4.36

Pocomoke River (Snow Hill subarea)
Uniformity Map with Polygons Indicated
for Selection of Training Areas

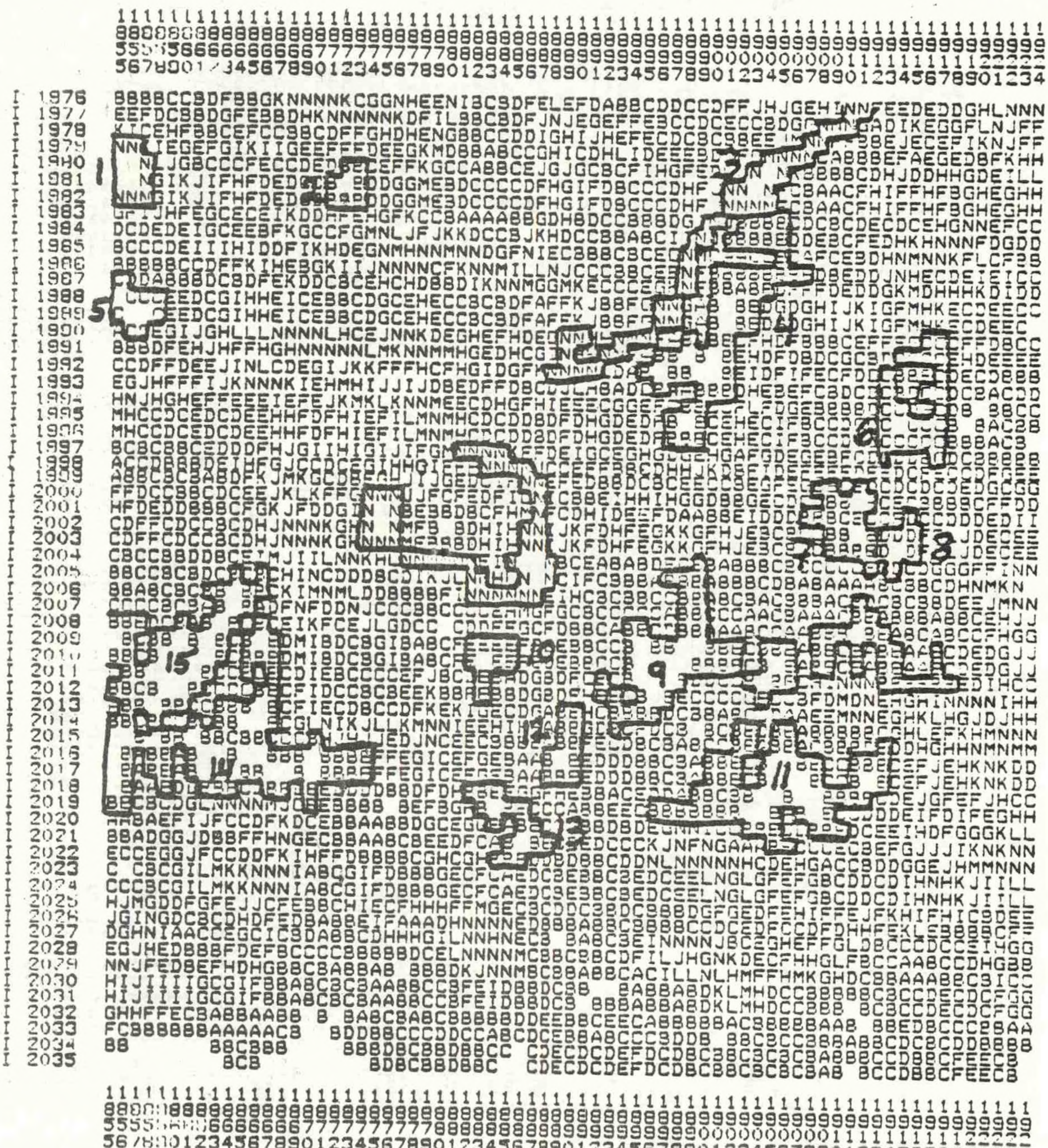


Figure 4.37

Pocomoke River (Snow Hill subarea)
Supervised Land-Cover Classification
Using Maximum Likelihood Classifier (MAXLIK)

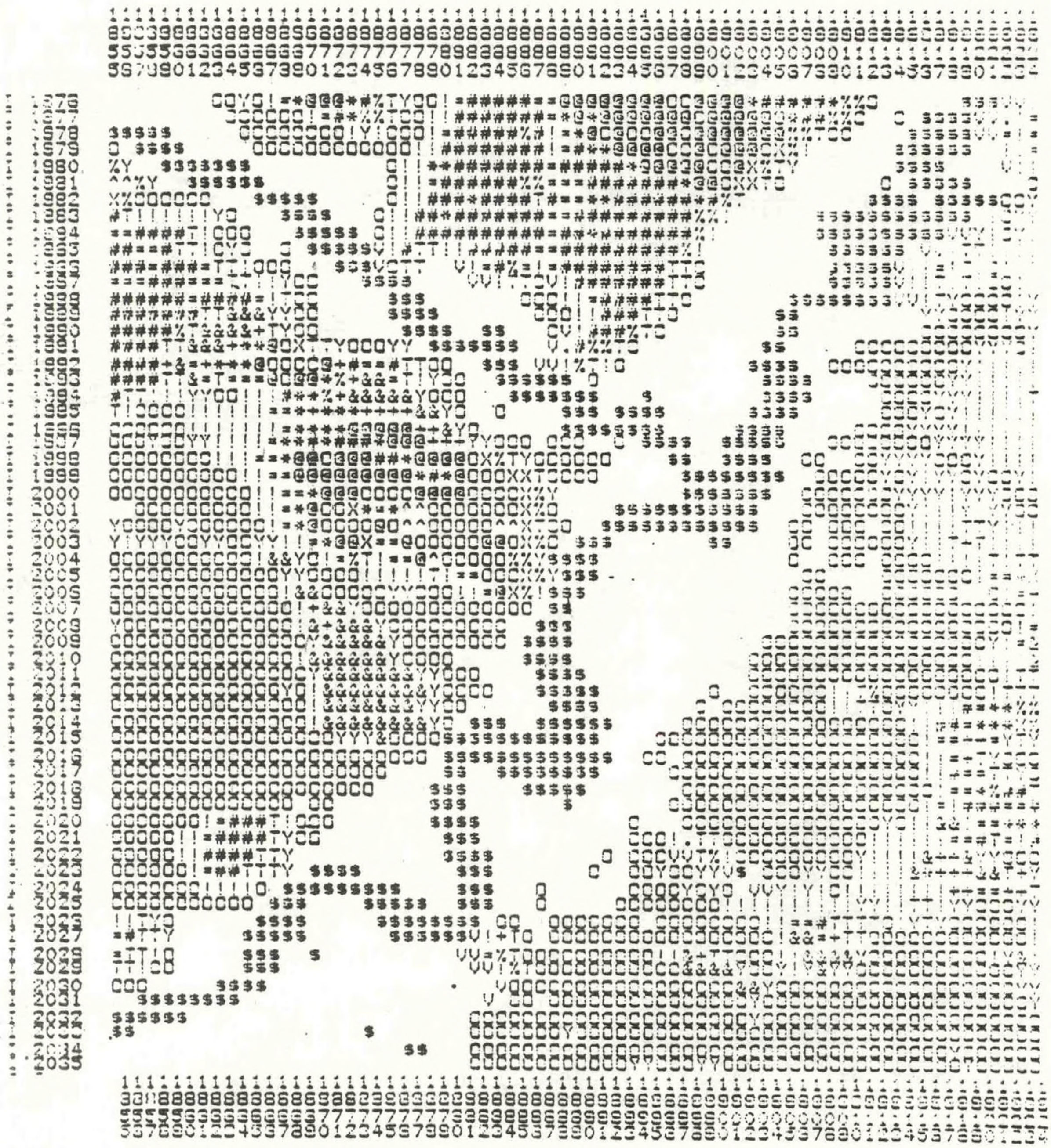


Figure 4.38

Pocomoke River (Snow Hill subarea)
Unsupervised Classification of LANDSAT MSS 9 April 1978
Linear Vegetative Index (LINEAR VI)

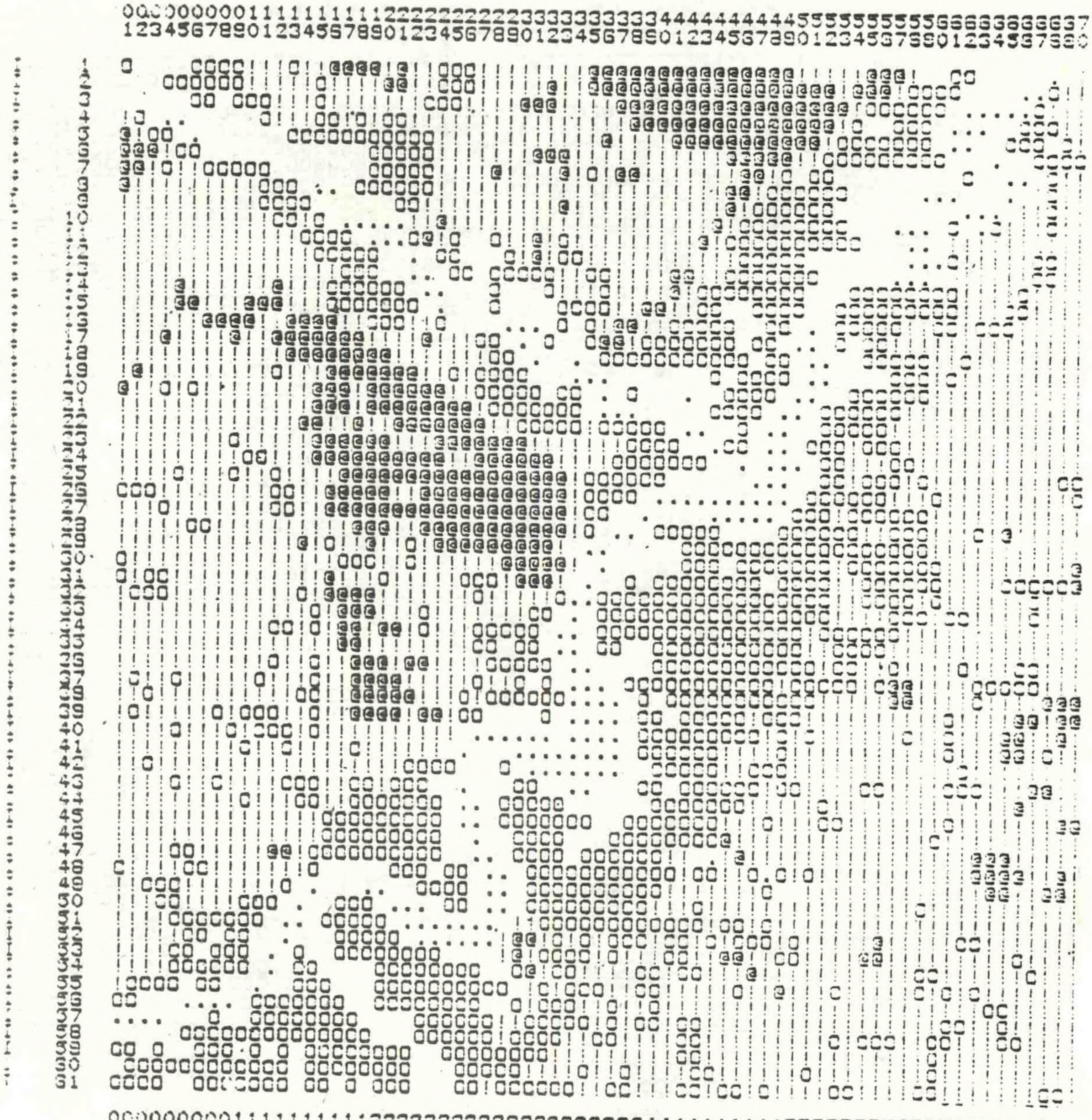


Figure 4.39

Pocomoke River (Snow Hill subarea)
Unsupervised Classification of LANDSAT MSS 9 April 1978
Perpendicular Vegetative Index (PERP VI)

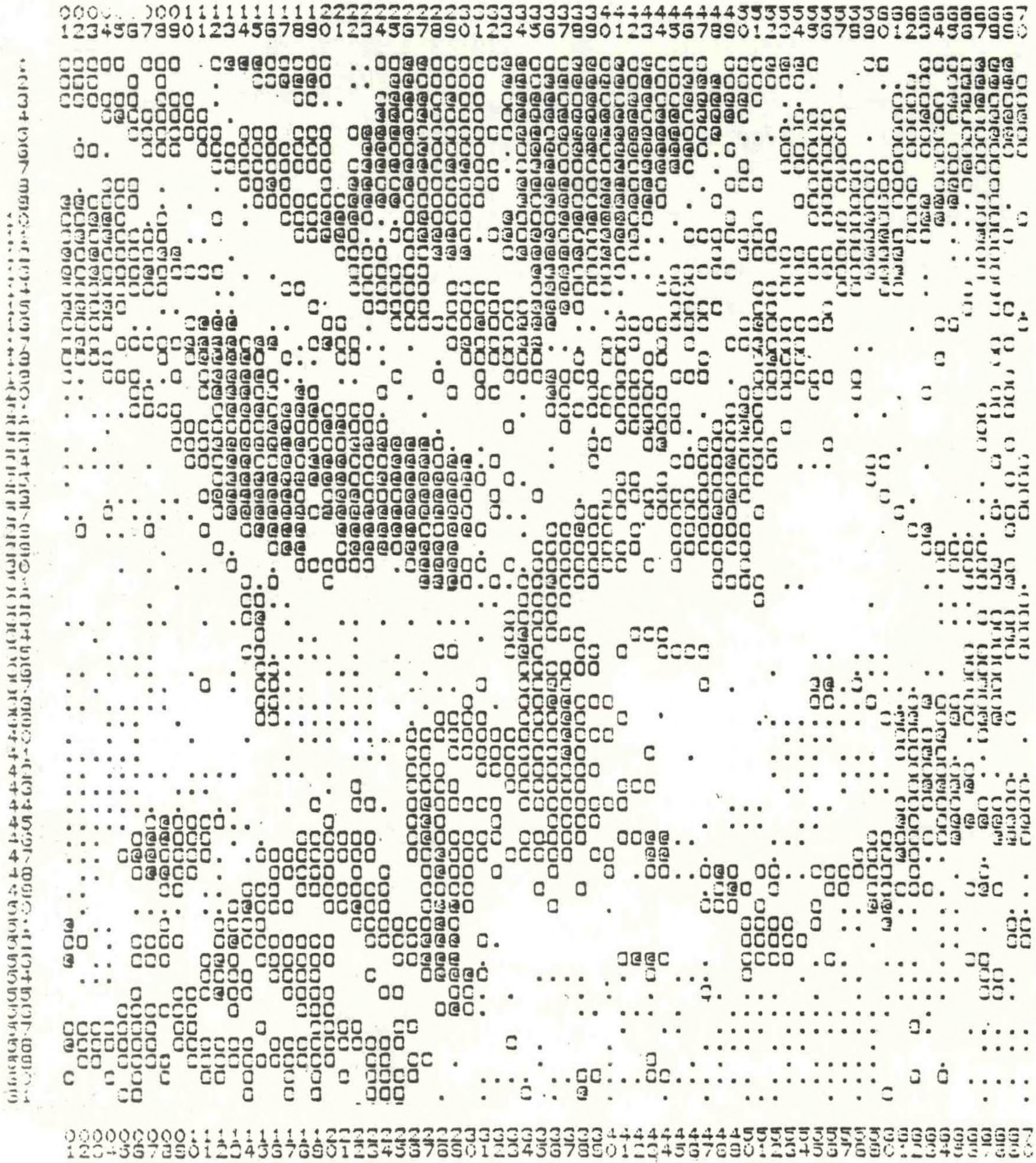


Figure 4.40

Pocomoke River (Snow Hill subarea)
Unsupervised Classification of LANDSAT MSS 9 April 1978
Green Vegetative Index (GREEN VI)

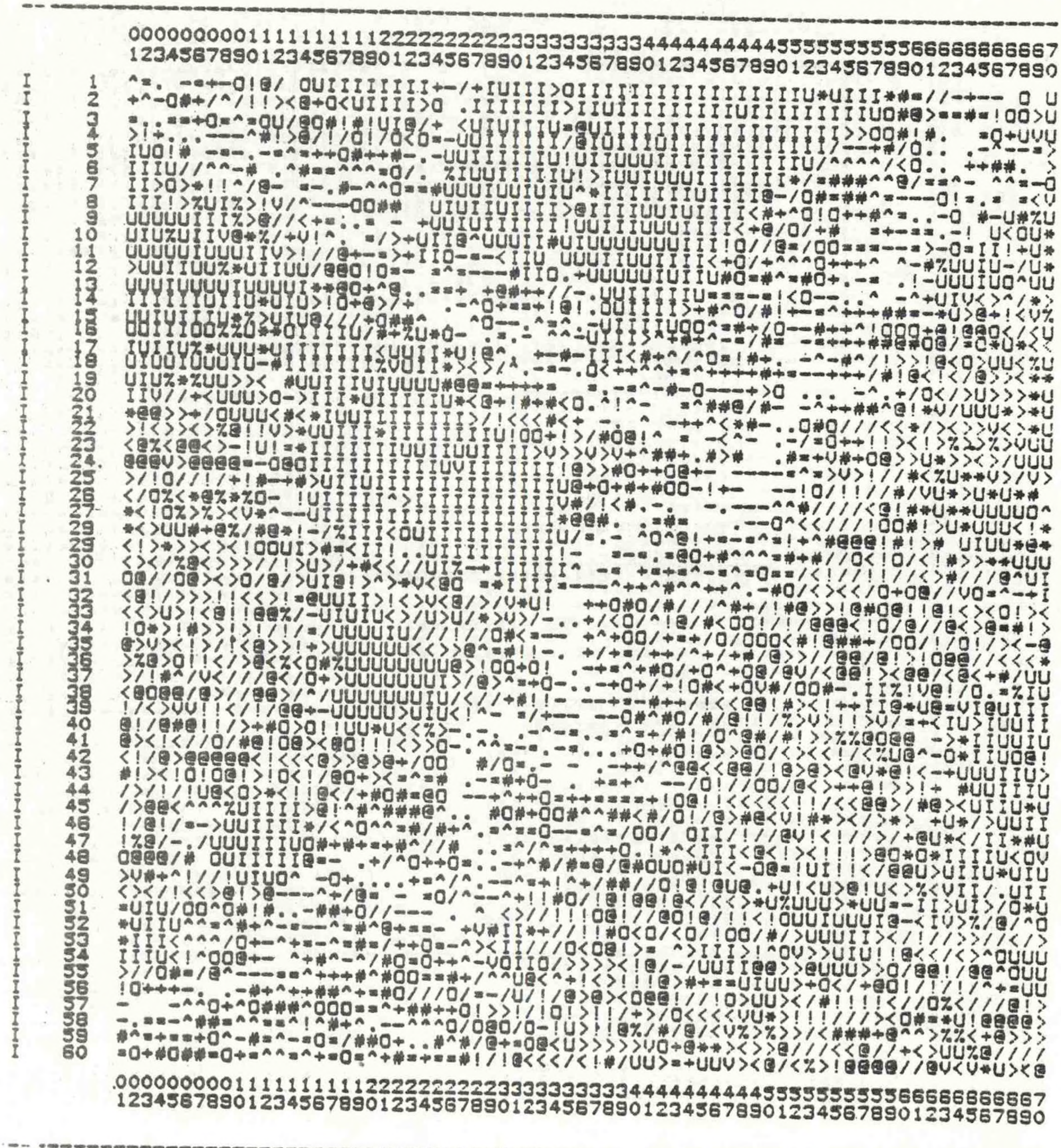


Figure 4.41

Pocomoke River (Snow Hill subarea)
Unsupervised Classification of LANDSAT MSS 9 April 1978
Transformed Vegetative Index (TRANS VI)

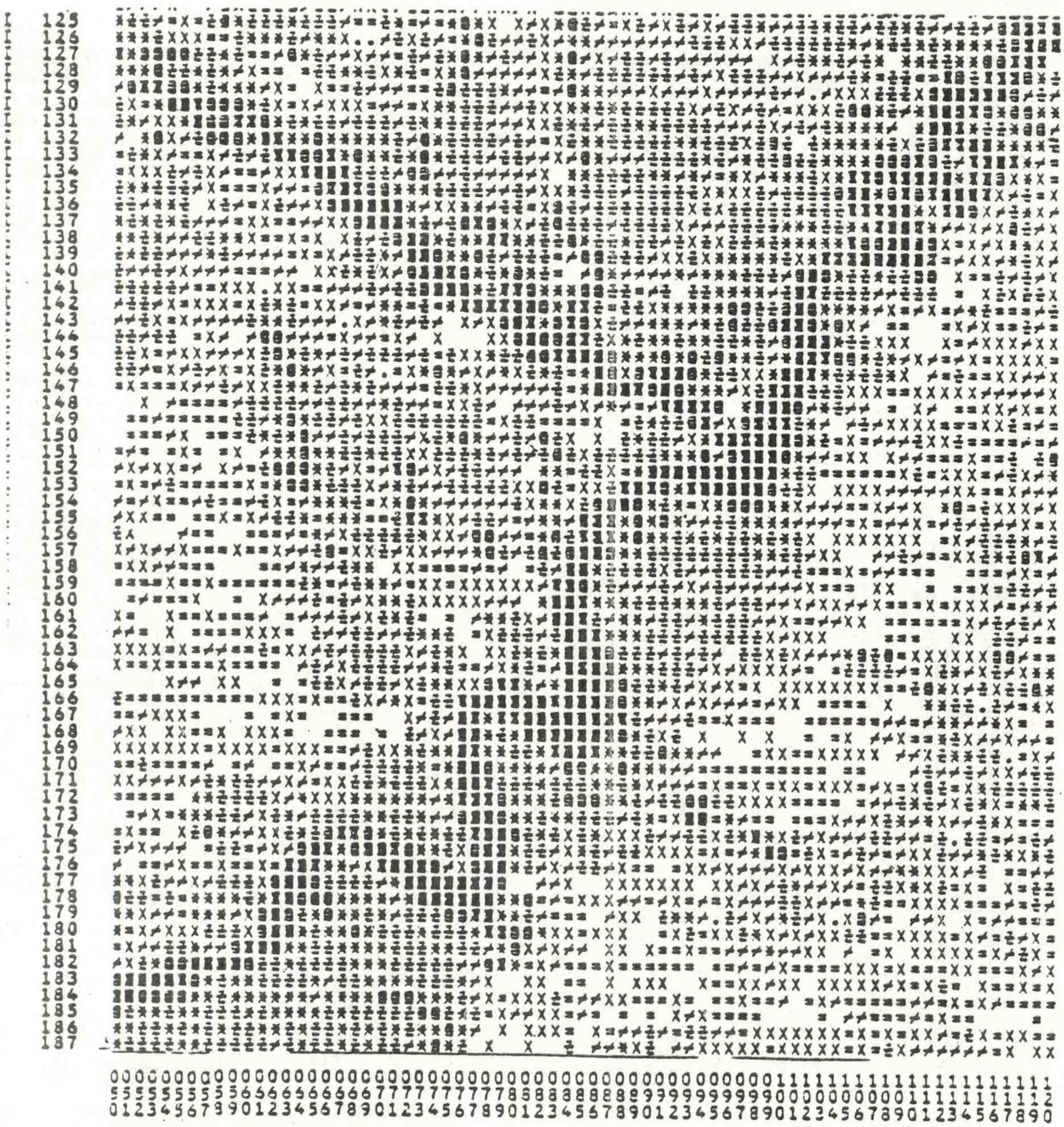


Figure 4.42

Pocomoke River (Snow Hill subarea)
Unsupervised Classification of LANDSAT MSS 9 April 1978
Differenced Vegetative Index - Bands 5 & 7 (DIFF VI)

Figure 4.43

Pocomoke River (Snow Hill subarea)
Unsupervised Classification of LANDSAT MSS 9 April 1978
Ratioed Vegetative Index - Bands 5/7 (RATIO VI)

Table 4.3

Six Vegetative Indices, each Representing a Different Combination of MSS Data -- Bands 4 through 7

Ratio VI $= \text{MSS } 7/\text{MSS } 5$

Difference VI $= 2.40 \times (\text{MSS } 7 - \text{MSS } 5)$.

Transformed VI $= \sqrt{\dfrac{\text{MSS } 7 - \text{MSS } 5}{\text{MSS } 7 + \text{MSS } 5} + 0.5}$.

Green VI $= -0.29\,(\text{MSS } 4) - 0.56\,(\text{MSS } 5) + 0.60\,(\text{MSS } 6) + 0.49\,(\text{MSS } 7)$.

Perpendicular VI $= \sqrt{(\text{Soil } 5 - \text{MSS } 5)^2 + (\text{Soil } 7 - \text{MSS } 7)^2}$

where $\text{Soil } 5 = 0.85\,(\text{MSS } 5) + 0.35\,(\text{MSS } 7)$,
$\text{Soil } 7 = 0.35\,(\text{MSS } 5) + 0.15\,(\text{MSS } 7)$.

Linear VI $= -2.58\,(\text{MSS } 4) - 7.28\,(\text{MSS } 5) + 0.88\,(\text{MSS } 6) + 3.59\,(\text{MSS } 7)$.

after Short, 1982 and Williams, et. al., 1979

Utilizing this map a number of polygons were identified that were characterized by high local spectral uniformity. Signatures were then extracted for each of these polygons and resulted in 18 classes of distinct ground spectral variation. Classification was achieved through the use of a maximum likelihood classifier (MAXLIK) and the results of the classification are shown in Figure 4.37). All major features of the Snow Hill area are appropriately identified in this classification, including land/water interfaces, cultivated fields, and the extent of predominant forest cover. However, the classifier did not successfully portray the more subtle features that may be important for managing this area. Included in this category are small tilled fields, plumes from the sewer outfall , and mosquito ditching of marshes. The success of the classification is due to the repeated selection of additional training areas after preliminary classification. This iterative process of training area selection followed by classification has traditionally been used to provide good ground-cover maps. Unless appropriate and extensive ground-truth is available, however, this process is time-consuming.

As an alternative to this process, which becomes even more difficult in areas that are both large and heterogeneous in ground cover, several authors have suggested the application of vegetative indexes to data analysis (Short, 1982). Figures 4.38 through 4.43 respectively show the following: Linear VI, Perpendicular VI, Green VI, Transformed VI, Differenced VI, and finally a ratioed image of Bands 5 and 7. Table 4.3 lists the formulae used to generate each of these indexes. A proper analysis of the information provided by these statistical procedures lies beyond the scope of this case study. However, it is evident that they do provide considerable data that, when combined with the appropriate ground-truth, should provide the basis for a comprehensive management strategy and monitoring system.

Case IV - Severn River Designated

Critical Areas

Prepared by K.-Peter Lade

4.4.1 Background

Several First-Round Designated Critical Area Sites located along the Severn River are considered here together in a single case study. These include:

1. Severn Run Tributaries (TN1)
2. Eagle Hill Bog (TN3)
3. Round Bay Bog (TN5)
4. Sullivan's Cove Marsh (T15)
5. Fresh Pond/Angel's Bog (N15)

SEVERN RUN TRIBUTARIES - This Designated Critical Area encompasses 3000 acres of wetlands and woodlands in the headwaters of the Severn River watershed. The Critical Area includes the Severn Run Natural Environment Area which is under State ownership. The major threat to Severn Run centers on development pressures occurring at the periphery of the impact area. The resulting increase in storm water runoff and consequent siltation are the major threats to the natural features and aquatic life at the site.

ROUND BAY BOG - This Designated Area covers approximately

90 acres and consists mainly of a shrub swamp, with plants unusual to Anne Arundel County. The principal concern in the DSP Critical Areas Designation Report is with the BG&E power line corridor which runs across the site. Any herbicide spraying or grading within the transmission line right-of-way could damage the bog.

EAGLE HILL BOG - This Designated Area is approximately 320 acres in size and includes several rare plant species. The adjoining areas within the watershed are presently undergoing conversion from undisturbed woodland to suburban residential areas. Several impacts could result from the construction of new roads, new storm water runoff patterns, and sediment erosion.

SULLIVAN'S COVE MARSH - This Designated Area of approximately 30 acres is the only significant tidal brackish water marsh on the Severn River. The area is used heavily by wildlife and contains a great variety of species of plants. In particular, the presence of healthy stands of Atlantic white cedar, a tree rarely found in natural stands on the Chesapeake Bay's western shore, makes this site botanically noteworthy. The DSP Critical Areas Designation Report does not list any immediate threats to this site; however, the area is zoned for residential development, water service exists at the site property line, and sewer service facilities are in the 6-10 year service category.

FRESH POND/ANGEL'S HILL BOG - This Designated Area includes a 12 acre pond, a 23 acre shrub swamp and bog, and adjacent forest and farmland. Rare plants are located within the site boundary; and an extensive list of vegetation has been compiled for the site. One side of the bog is managed as a pig farm, and off-site impacts include threats from erosion inside the pig pens and transport of fecal material to the pond. In addition, runoff from farming operations adjacent to this area constitutes a potential threat if not properly managed.

4.4.2 Sources of Information for the Resource Management Data Base

Existing sources of information about environmental characteristics of the Severn River Designated Critical Areas include:

- Atlas of Historic Shore Erosion Rates in Maryland (MCZMP, 1975). A map atlas of 7.5 minute topographic quadrangle sheets for the Maryland shoreline showing locations of present shoreline, and historic shoreline from surveys in the 1800's.

- Photomaps of tidal wetlands on file at the Maryland DNR Water Resources Administration. After passage of the Maryland Wetlands Act in 1970, the tidal wetlands were delineated and classified on a series of approximately 2000 aerial photomaps at a scale of 1:2400 (1 inch = 200 feet). Sample wetlands photomaps are shown in figures 4.6 and 4.7. The classification scheme and state-wide summary statistics are contained in a DNR report The Coastal Wetlands of Maryland (McCormick and Somes, 1982).

- Faunal species lists compiled by the DNR Wildlife Administration.

- Non-tidal wetlands maps. A set of 7.5 minute topo quad sheets with areas delineating non-tidal wetland vegetation types has been prepared as part of the NWI program, utilizing a classification scheme developed by the U.S. Fish and Wildlife Service. The categories used are described in the U.S.F.& W. report Classification of Wetlands and Deep Water Habitats of the United States (Cowardin et al., 1979).

- Occasional water quality data collected by the EPA Chesapeake Bay Program (EPA, 1982).

- Occasional environmental data collected as part of research studies at Bay-area research institutions, such as the Environmental Center, Anne Arundel Community College.

- Soil surveys from the county soil report, prepared by the Soil Conservation Service.

Tidal records, available in the annual Tide Tables for the East Coast of North and South America (NOAA).

- Assorted aerial photography, both overhead and oblique, in infrared, color and black-and-white, collected by the U.S. Department of Agriculture, U.S. Department of State Planning, and other state and federal agencies. For instance, the National High Altitude Photography Program (NHAP) is funded by fourteen Federal agencies to provide a national data base for mapping and resource management. The black-and-white photography is of cartographic quality, and the color infrared is valuable for resource evaluation, monitoring, and management. The acquisition of this data base started in 1978. The Maryland Coastal Zone is one area where NHAP has completed the coverage, see Figure 4.9 A catalog of available air photo coverage in Maryland has been compiled by the Maryland Remote Sensing Steering Committee (DSP, 1982). Another summary of aerial photographs is available from the National Cartographic Information Center (USGS, 1980).

- Bathymetric charts compiled and updated by the National Ocean Survey.

- Land-cover maps, at a scale of 1:24000, prepared by the Maryland Department of State Planning from analysis of aerial photographs.

- County Comprehensive Plans.

4.4.3 Evaluation of Remote-Sensing Techniques

Figures 4.44 through 4.48 show portions of the USGS topo quad sheets which can be compared with the printouts of LANDSAT digital data on the following pages. Two dates for which LANDSAT scenes were available were then selected: 11 October 1972 and 30 June 1978. Brightness intensity maps (NMAPS) for the earlier date are to be found in Appendix A, while similar maps for the more recent date are presented in Figures 4.49 through 4.53.

Figure 4.44

Portion of USGS 7.5 Minute Topo Quad Sheet
Severn Run Tributaries (TN1)

AREAS OF CRITICAL STATE CONCERN

Site Name SEVERN RUN TRIBUTARIES - TN1

County ANNE ARUNDEL Acreage 2000 Date Designated JAN. 1981

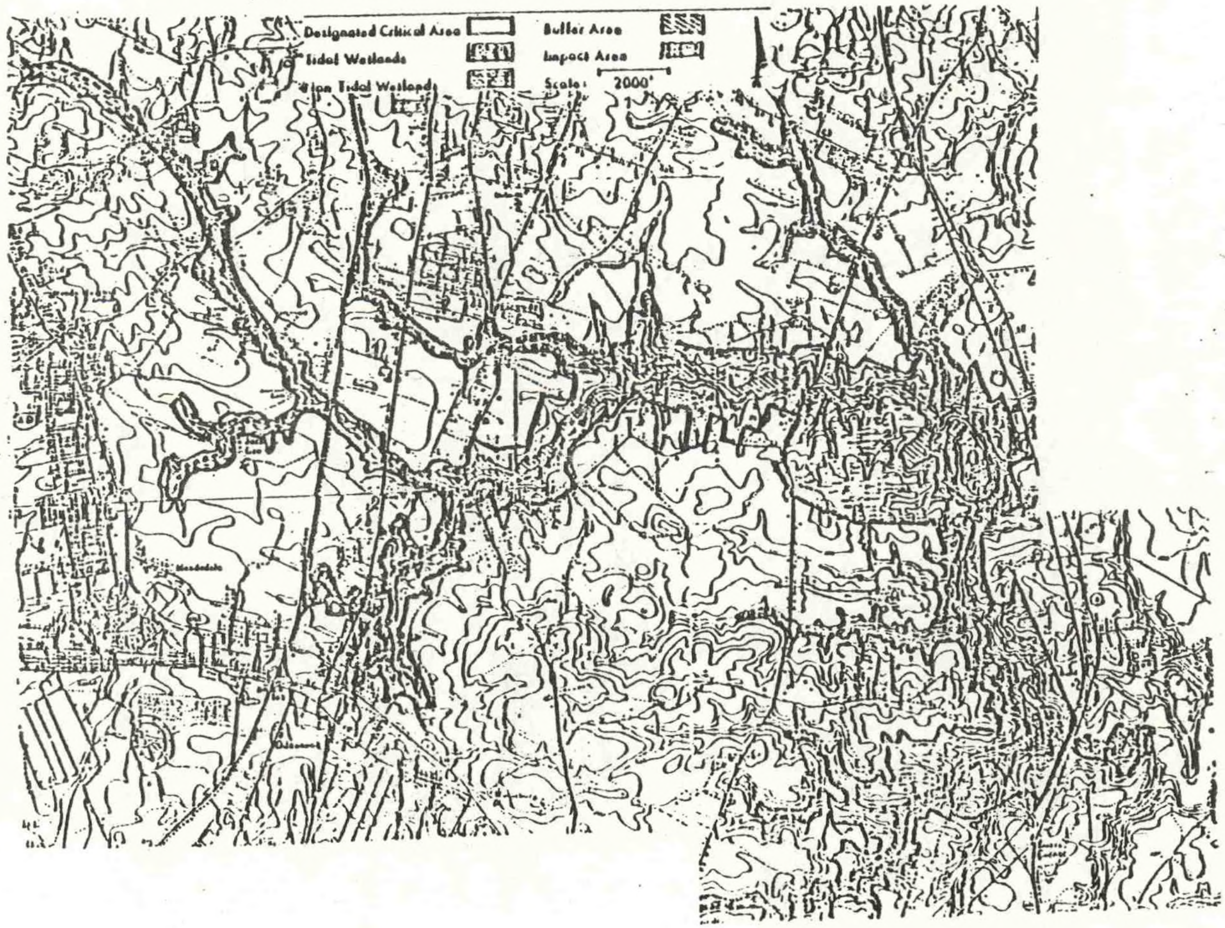


Figure 4.45

Portion of USGS 7.5 Minute Topo Quad Sheet
Eagle Hill Bog (TN3)

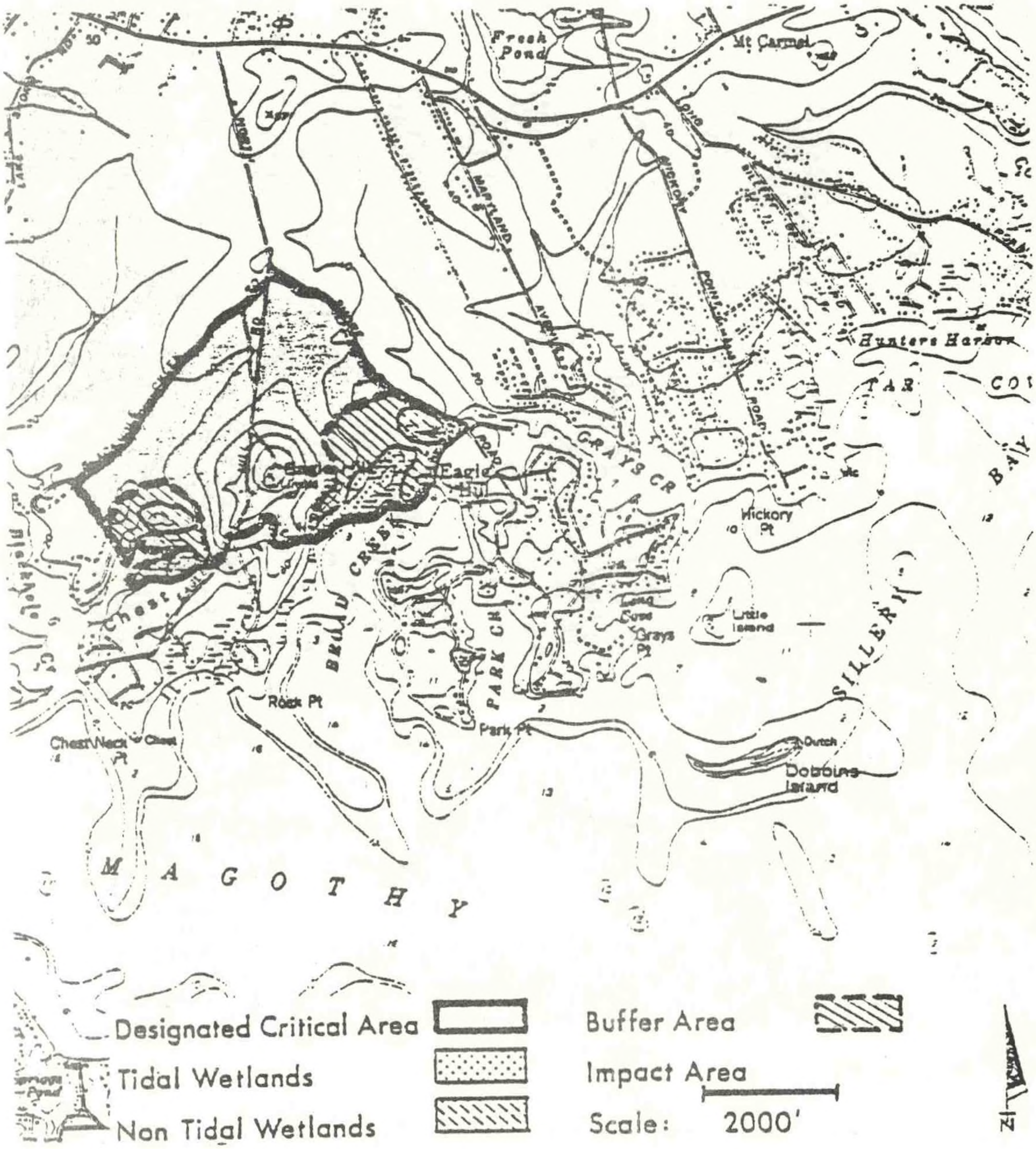


Figure 4.46

Portion of USGS 7.5 Minute Topo Quad Sheet
Round Bay Bog (TN5)

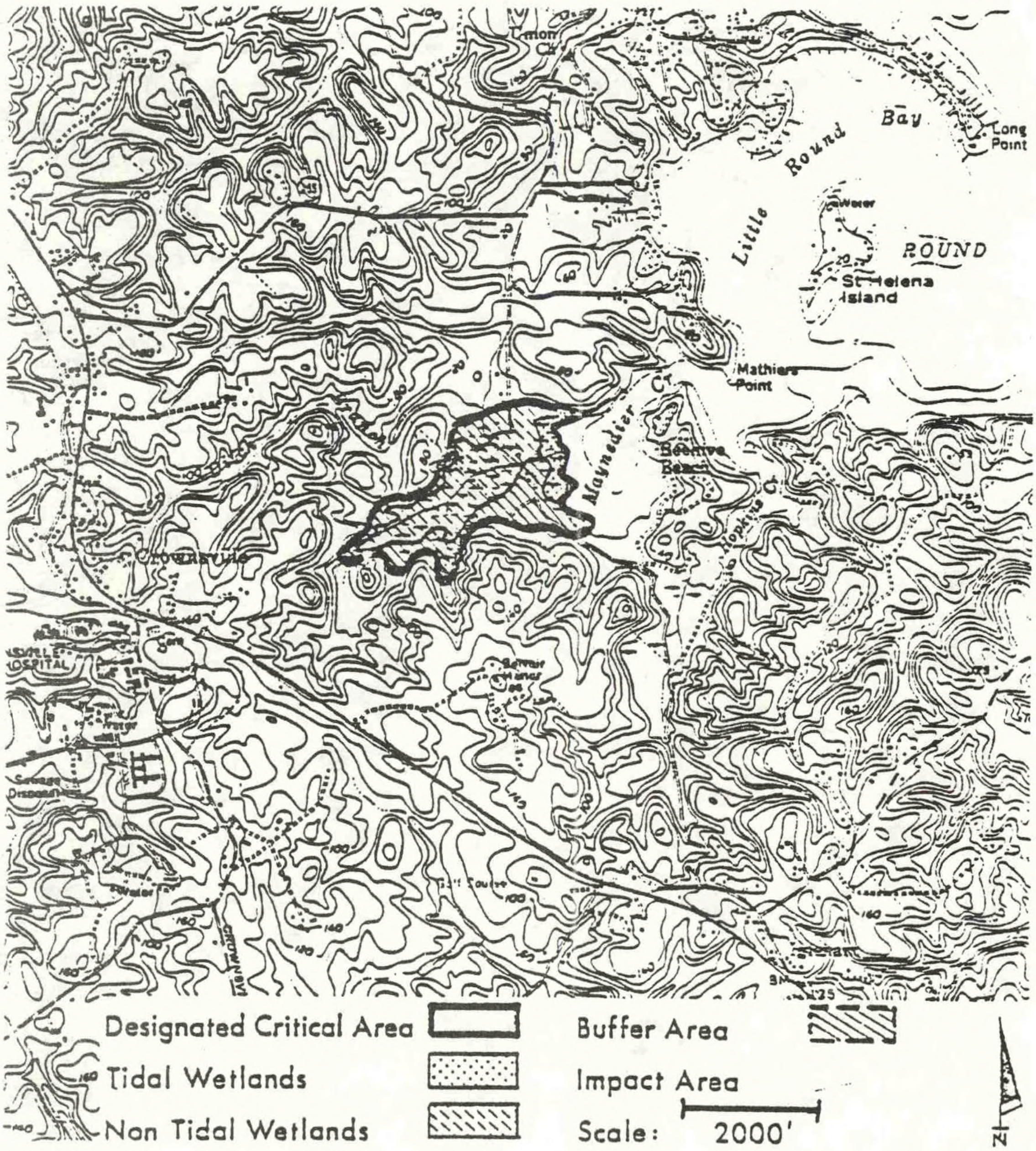


Figure 4.47

Portion of USGS 7.5 Minute Topo Quad Sheet
Sullivan's Cove Marsh (T15)

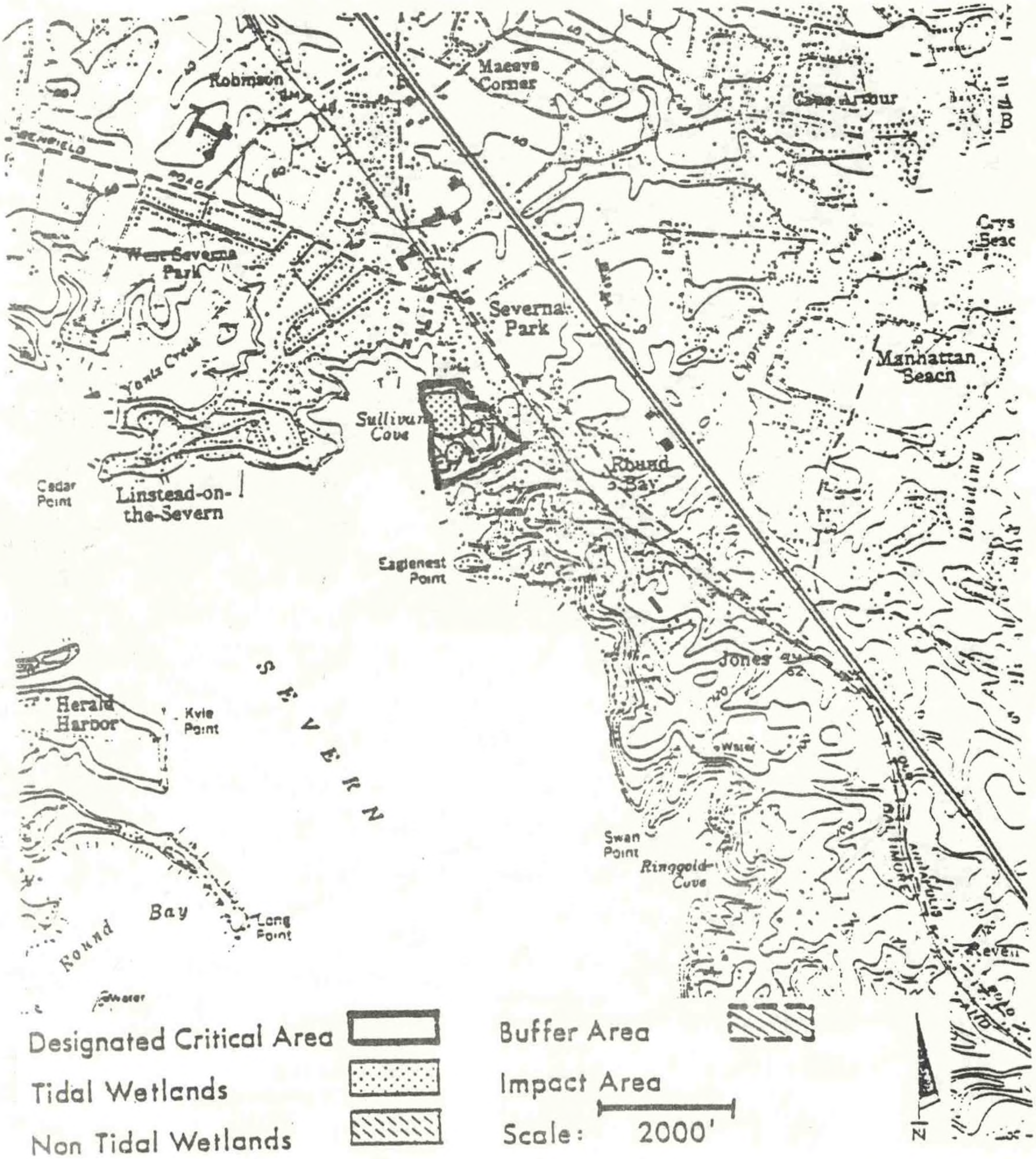
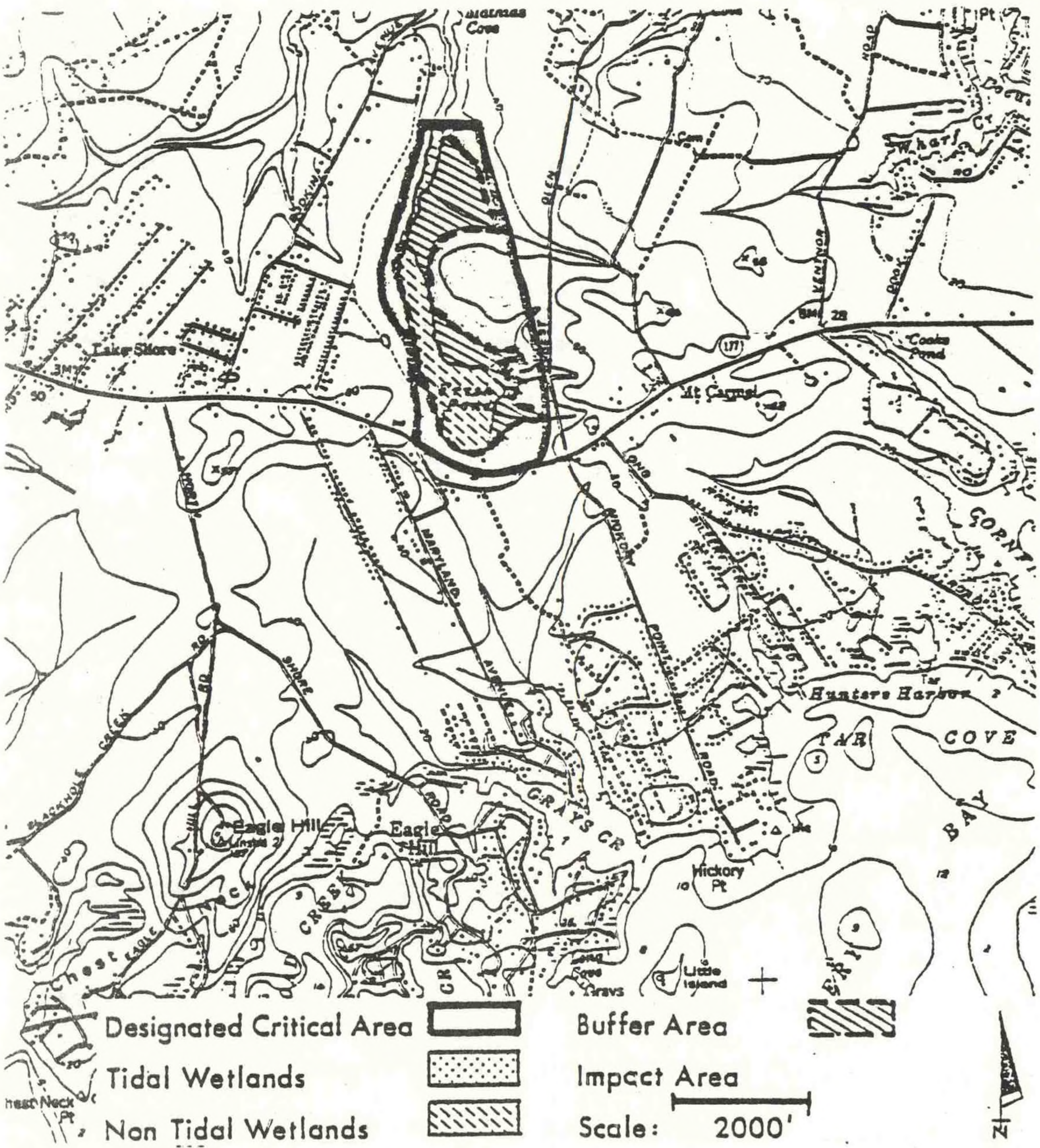


Figure 4.48

Portion of USGS 7.5 Minute Topo Quad Sheet
Fresh Pond/Ansel's Bog (N15).page



The analysis of the Severn Run headwaters (Figures 4.44 and 4.49) was performed using the adaptive clustering algorithm. The classified image revealed several striking features characteristic of this area. The uppermost reaches of the Severn River, at the mouth of Severn Run, show a sharp delineation between the land and water interface. To see this compare Figures 4.54 with 4.55. This area is prone to siltation impacts from any development or land clearing farther upstream in the Severn Run watershed. Sequential analysis of LANDSAT imagery collected through time for this area could aid in the description of the siltation and infilling since 1972. Ongoing LANDSAT analysis in the future could also serve as a useful monitoring tool to assess continuing impacts. This is particularly useful if the present revisions to development regulations proposed by the county government are enforced, thereby reducing soil loss at new development sites. The seven-band quarter-acre resolution data being collected by the Thematic Mapper on LANDSAT 4 may be appropriately used within this context to monitor small areas of high impact. Another feature that may be easily identified on both the brightness intensity maps and the classified image is the railroad right-of-way for the B&O and Conrail routes running between Bridgeway and Odenton. Potential impacts along this right-of-way include the possible removal of trees and other trackside vegetation as well as the storage and dumping of construction

Figure 4.48

Severn Run Tributaries (TN1)
Brightness Intensity Map (NMAP)

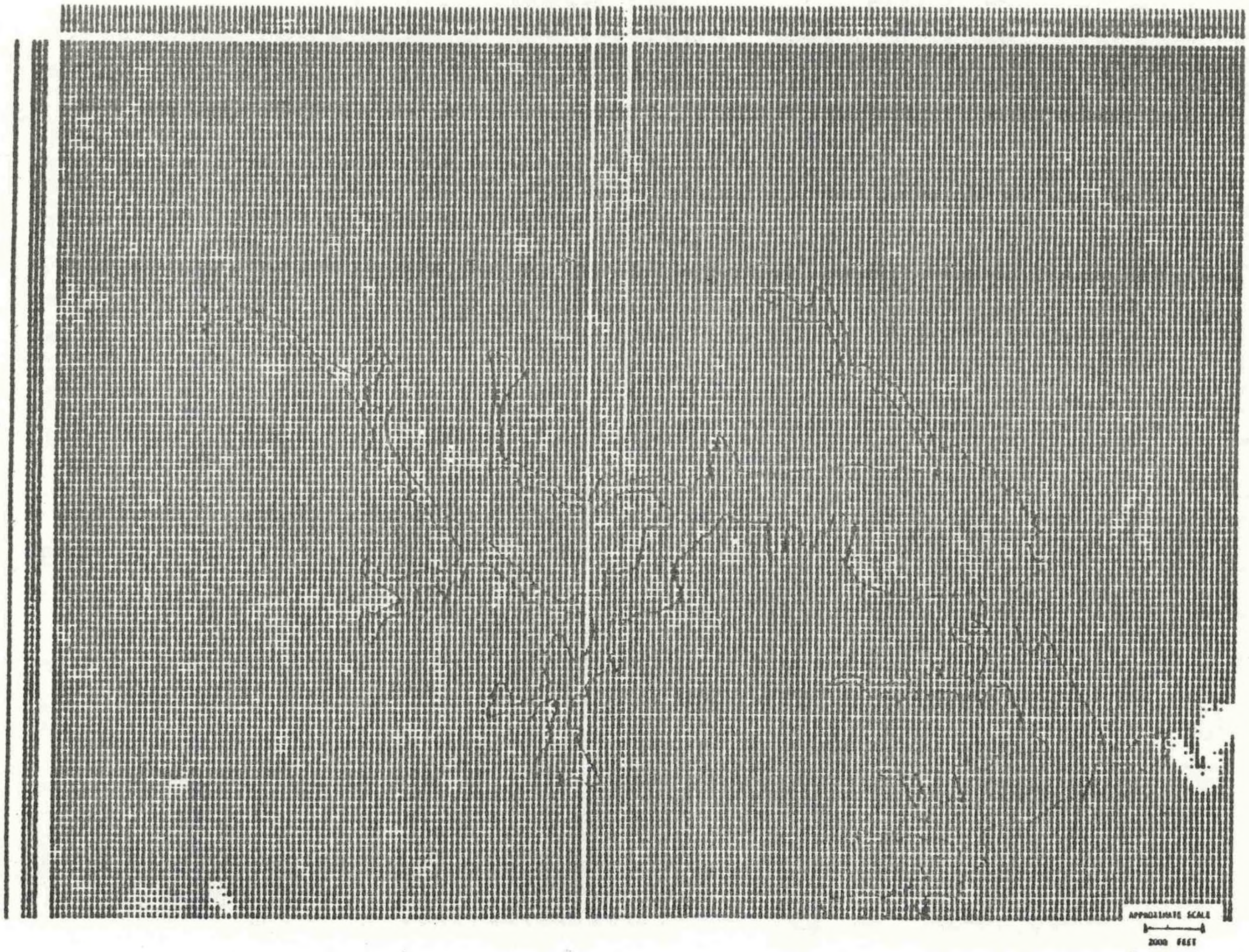


Figure 4.50

Eagle Hill Bog (TN3)
Brightness Intensity Map (NMAP)

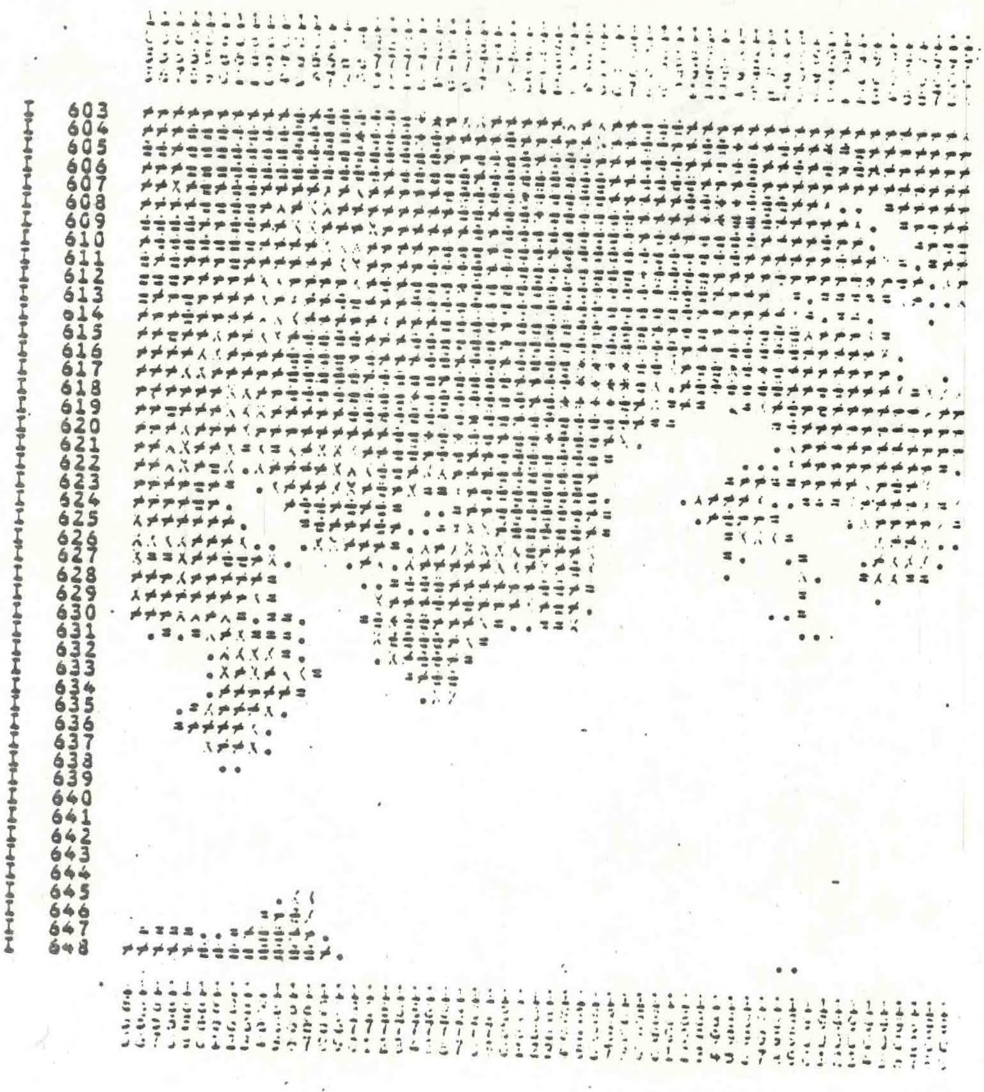


Figure 4.51

Round Bay Bog (TNS)
Brightness Intensity Map (NMAP)

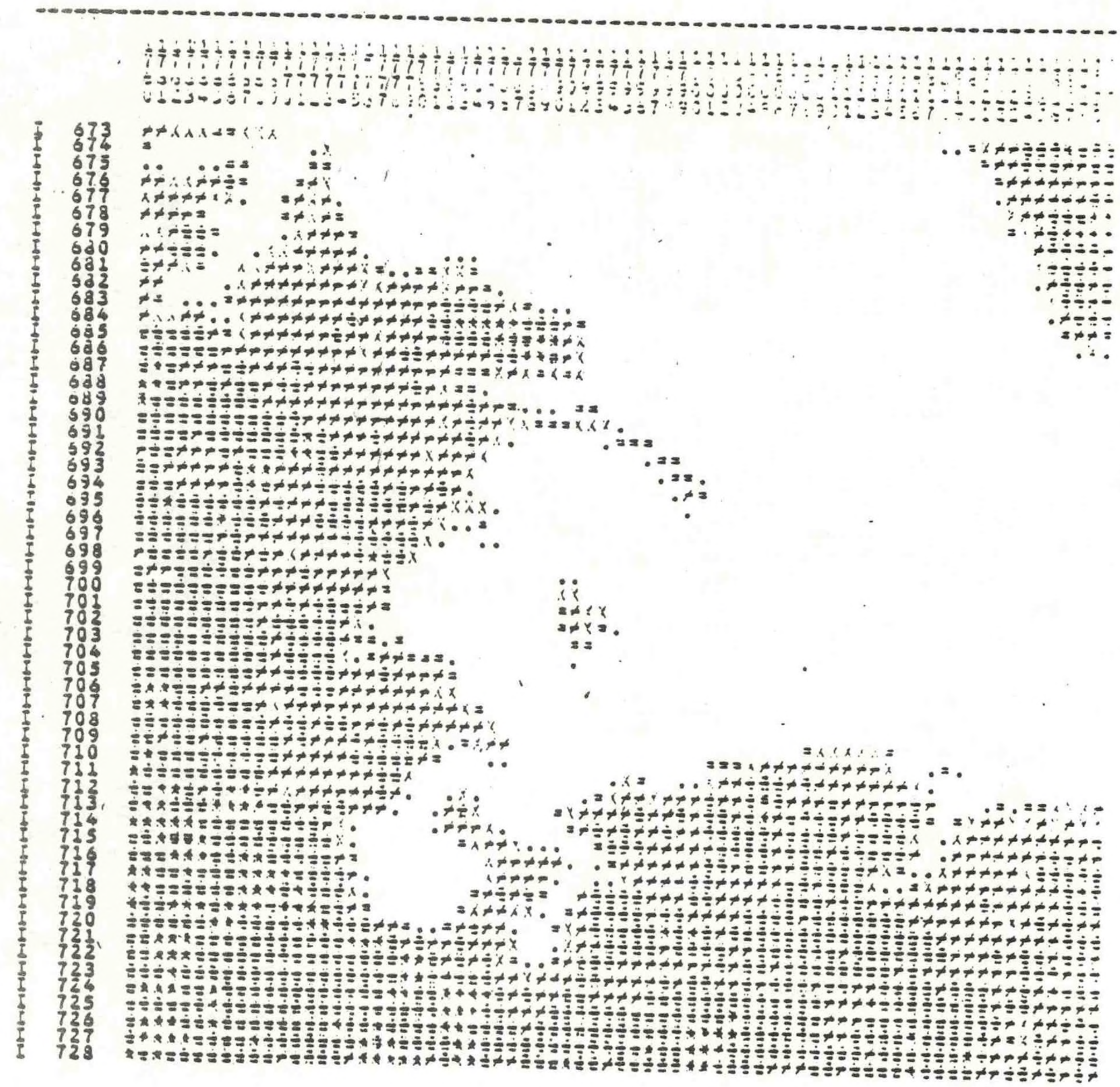


Figure 4.52

Sullivan's Cove Marsh (T15)
Brightness Intensity Map (NMAP)

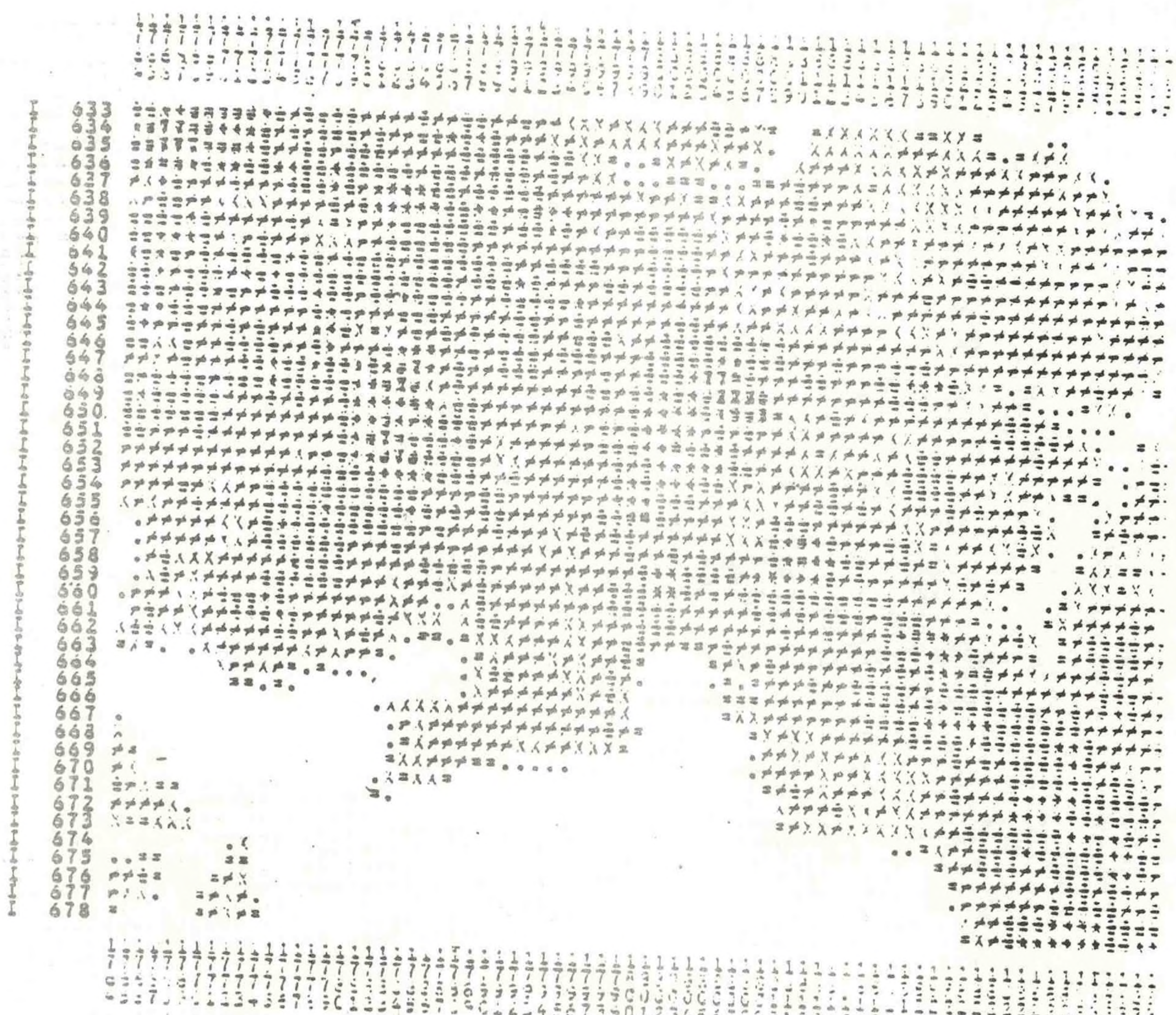


Figure 4.53

Fresh Pond/Ansel's Bog (N15)
Brightness Intensity Map (NMAP)

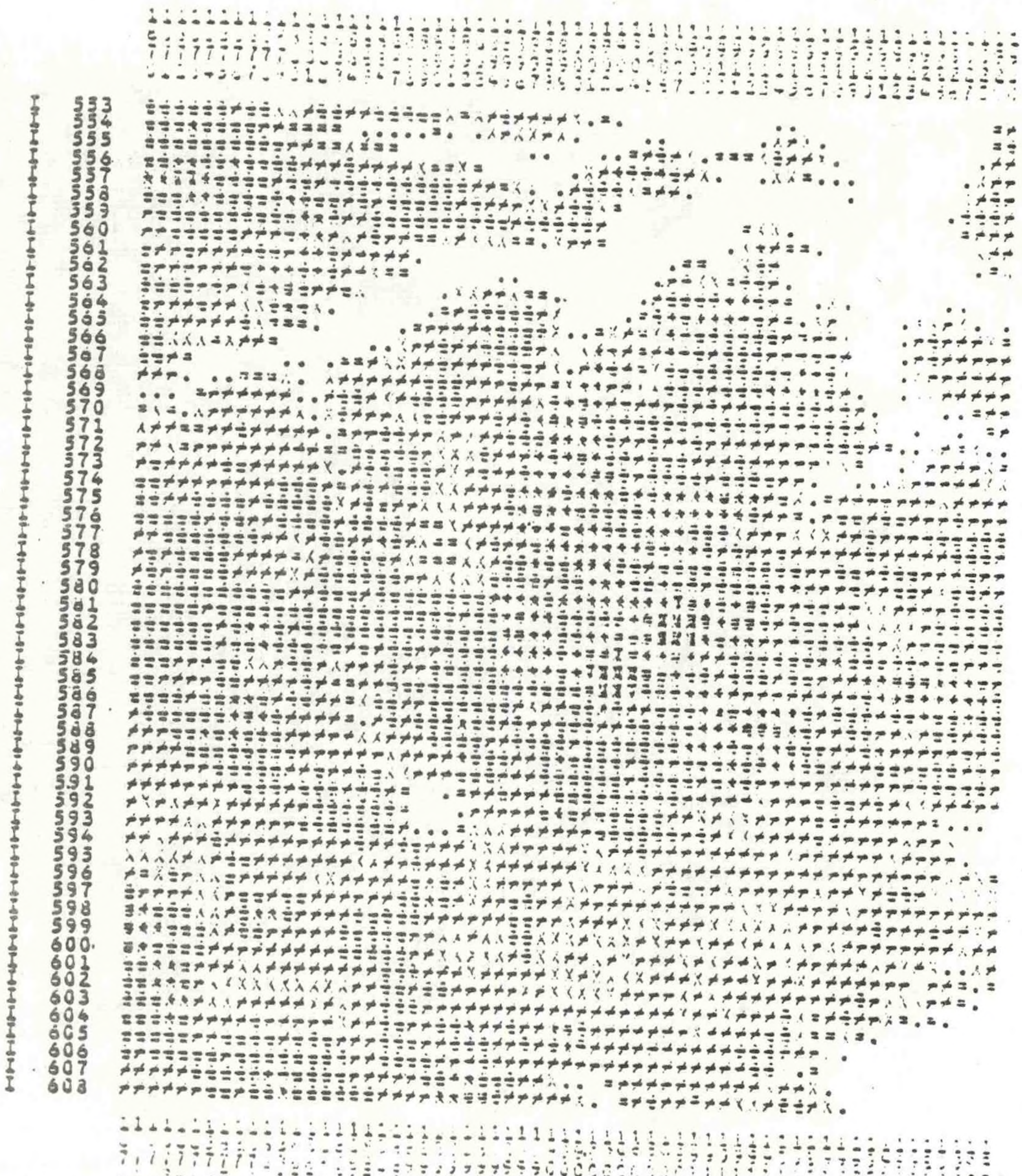
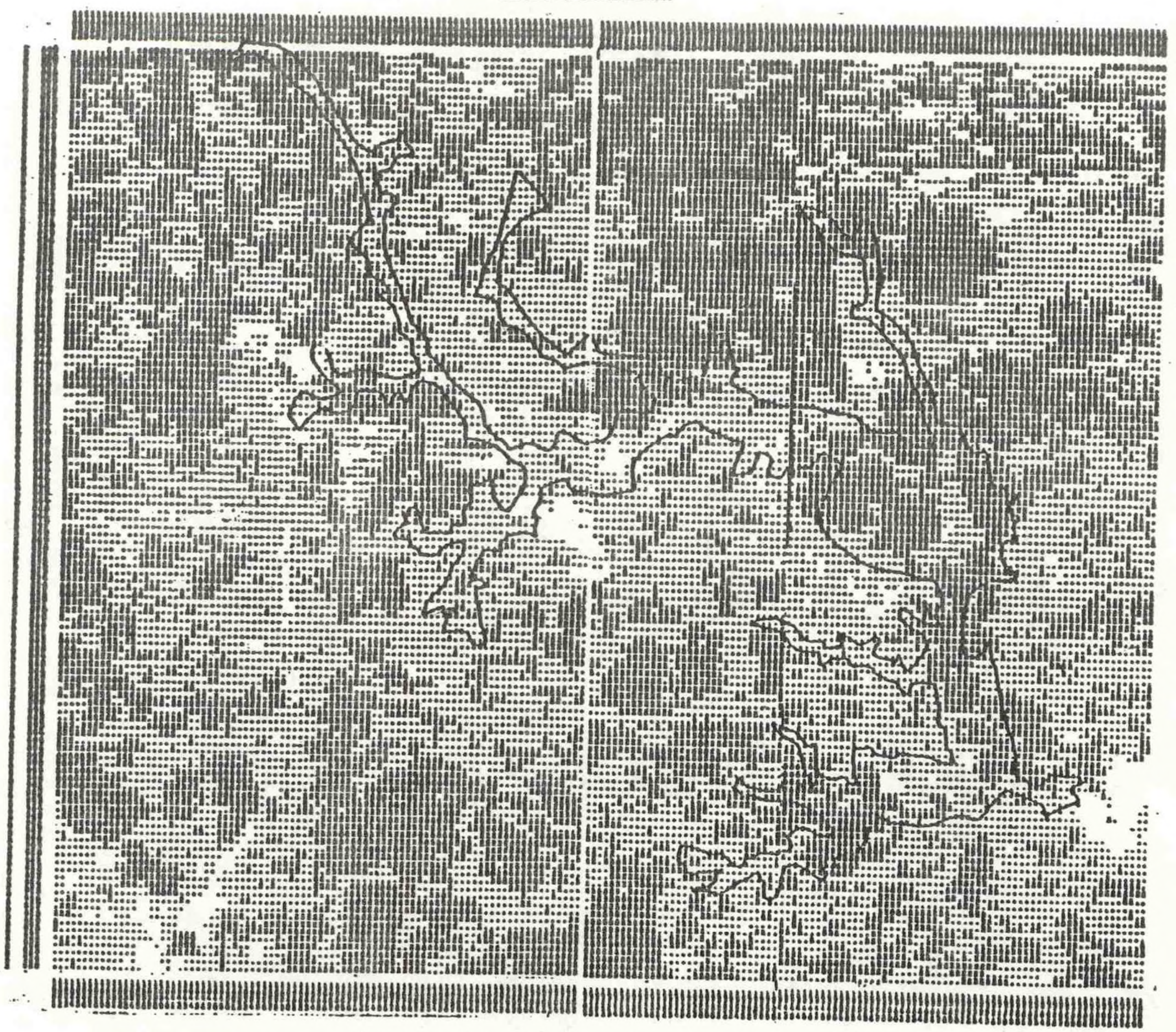


Figure 4.54



Severn Run Tributaries (TNI)
Adaptive Clustering Algorithm of LANDSAT MSS Data
30 June 1978

Figure 4.55

Severn River Headwaters
Viewed from the West

Figure 4.56

Round Bay Bog
Adaptive Clustering Algorithm of LANDSAT MSS Data
30 June 1978

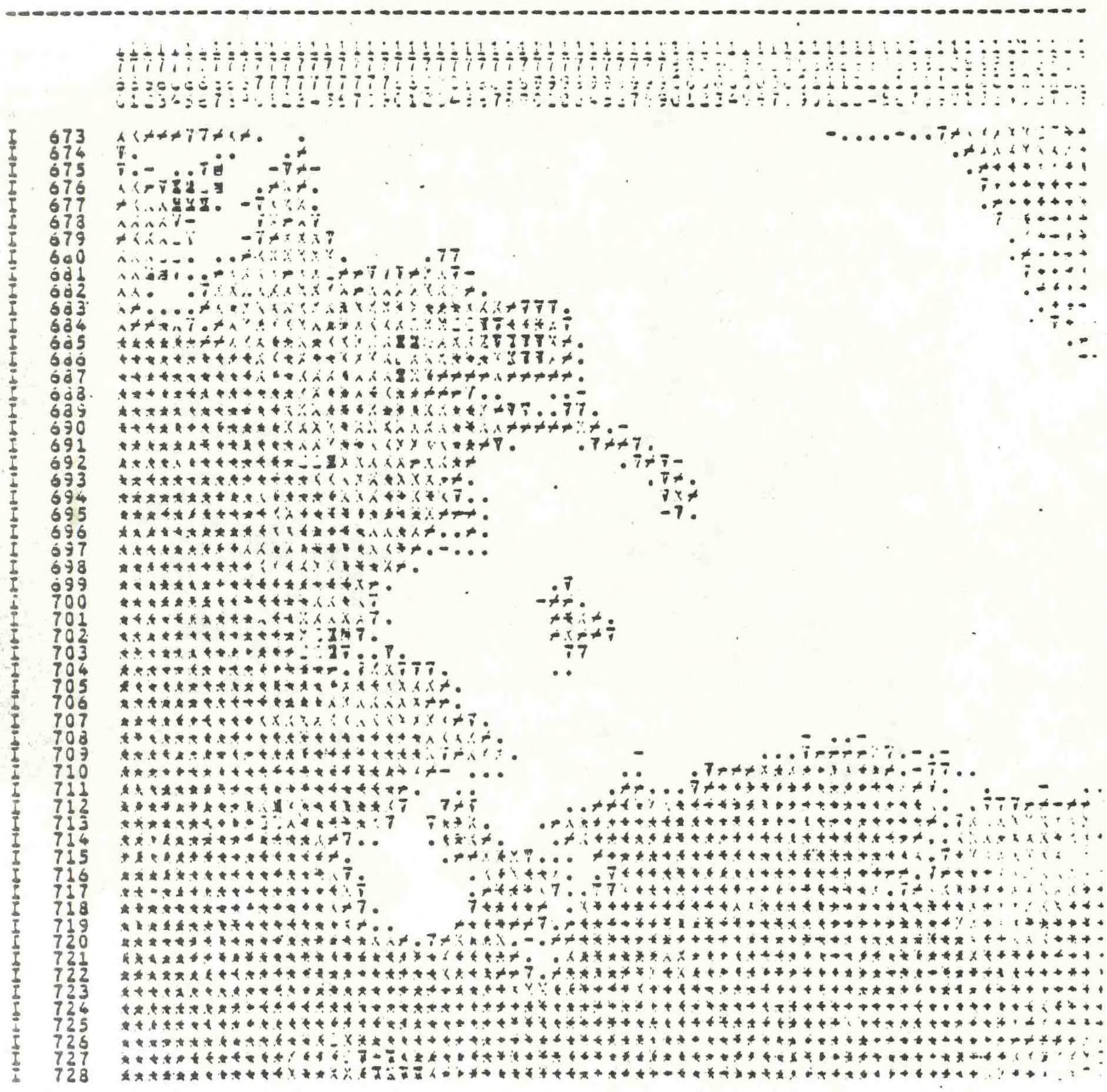
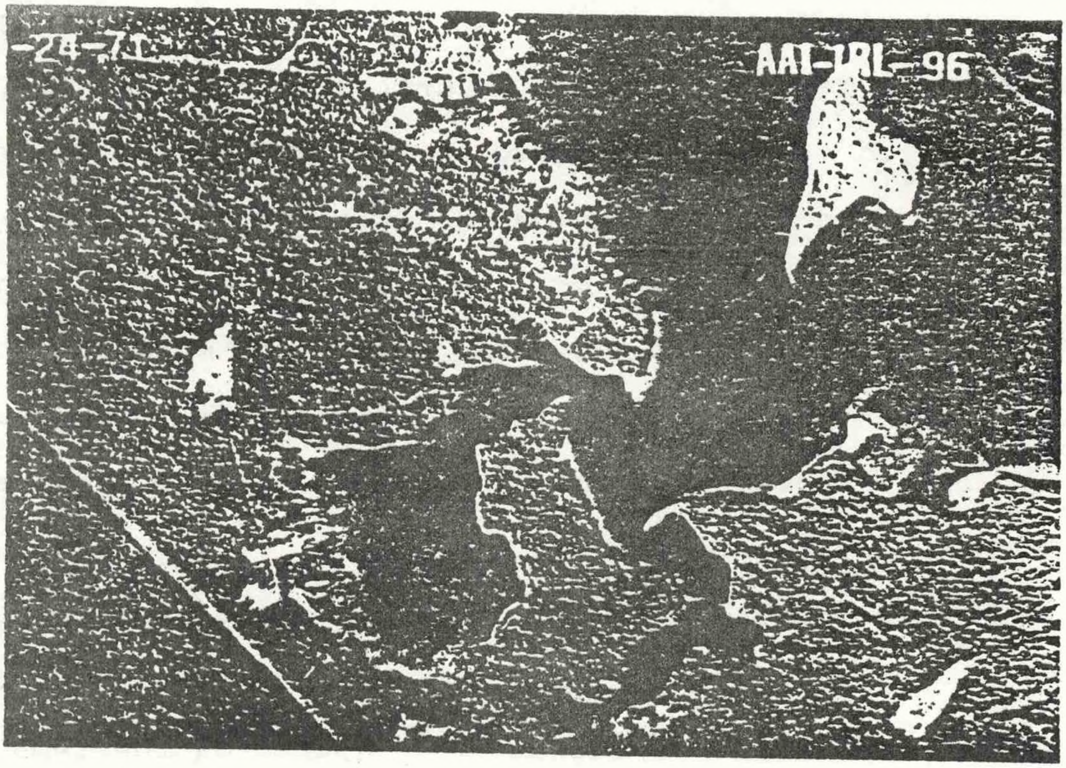


Figure 4.57
Aerial Views of Round Bay Bog



materials. Although the 1.1 acre resolution of the previous LANDSAT satellites could only detect these potential alterations to the landscape if they were of significant scope and size, data being collected by the LANDSAT 4 Thematic Mapper (TM) sensor might be appropriately employed to monitor even such small impacts. Finally, several small towns within this Critical Area, including Bridgeway, Mayfield, Dorrs Corner, Benfield, Gambrills, and Odenton may be identified on the LANDSAT digital maps. Future growth of these towns is likely and such growth will be at the expense of the natural vegetation and ground cover of this area. Some measure of rate of expansion may be made by combining a number of different sources of information to which LANDSAT data can be added as a temporal measure of change.

The Round Bay Bog Critical Area cannot be effectively monitored by LANDSAT owing to its small size (90 acres). The Bog itself can be adequately located on the LANDSAT imagery and printouts, however, the length of the transmission line through the bog is so short that its impact is not clearly defined.

Eagle Hill Bog Critical Area, draining into Blackhole Creek, is recognizable on the LANDSAT imagery and can be clearly differentiated from both the surrounding watershed and Eagle Hill. LANDSAT analysis may be used in this case, as in others of relatively small size, to maintain a general picture of changes over time to the bog as an

Figure 4.58

Eagle Hill Bog
Adaptive Clustering Algorithm of LANDSAT MSS Data
30 June 1978

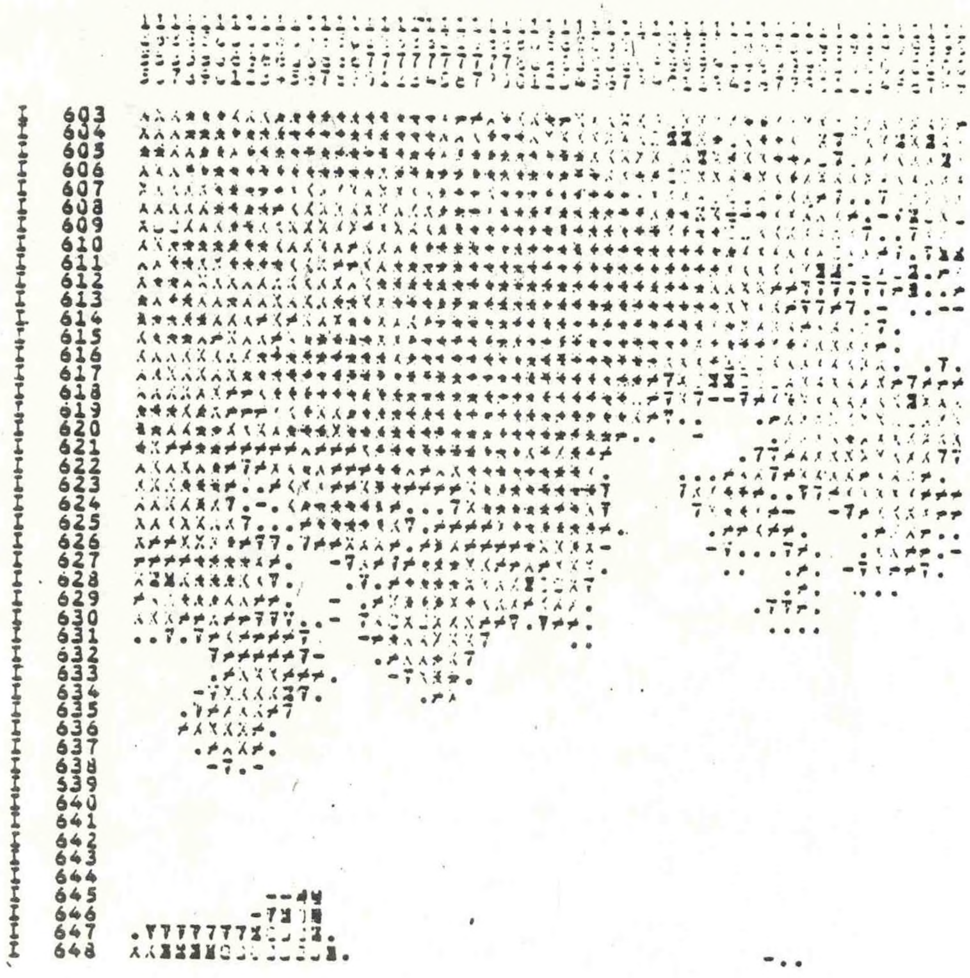


Figure 4.59

Aerial Views of Eagle Hill Bog

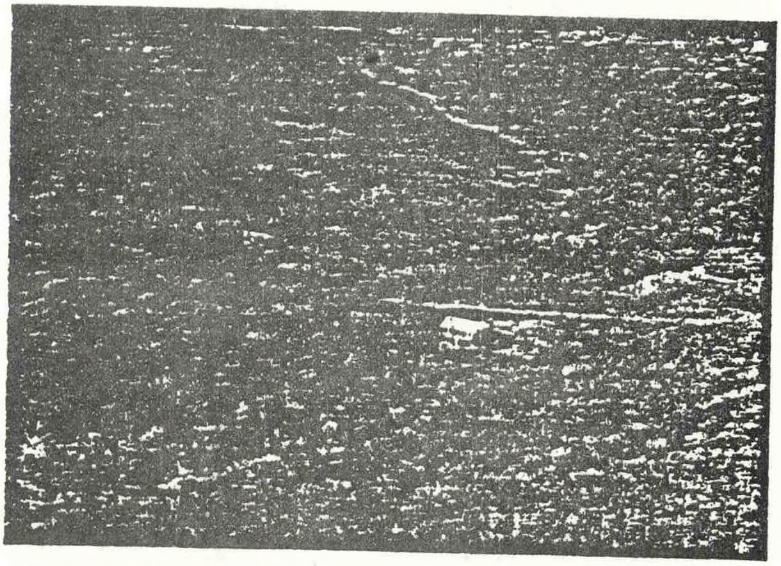


Figure 4.60

Fresh Pond/Ansel's Bog
Adaptive Clustering Algorithm of LANDSAT MSS Data
30 June 1978

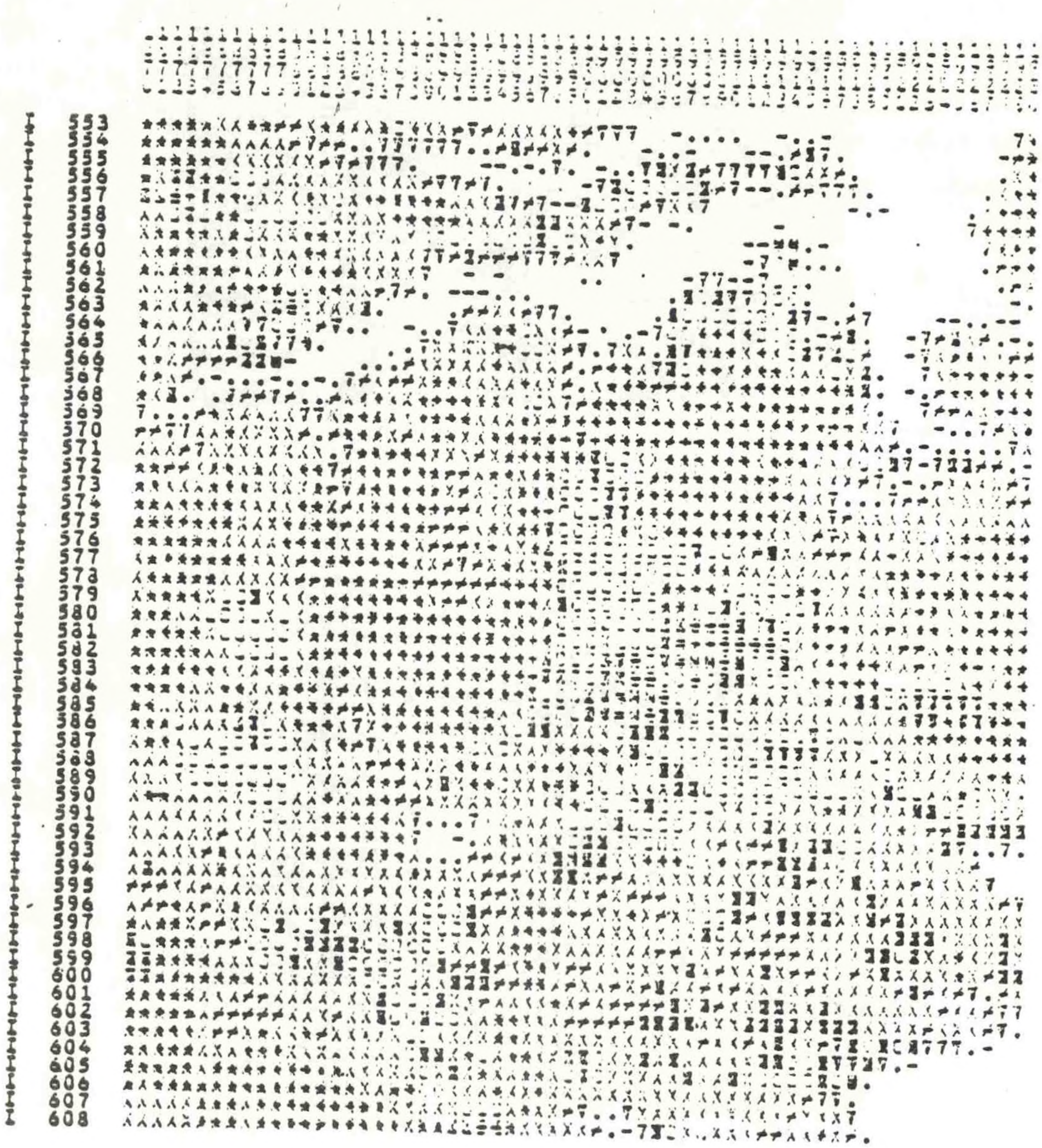
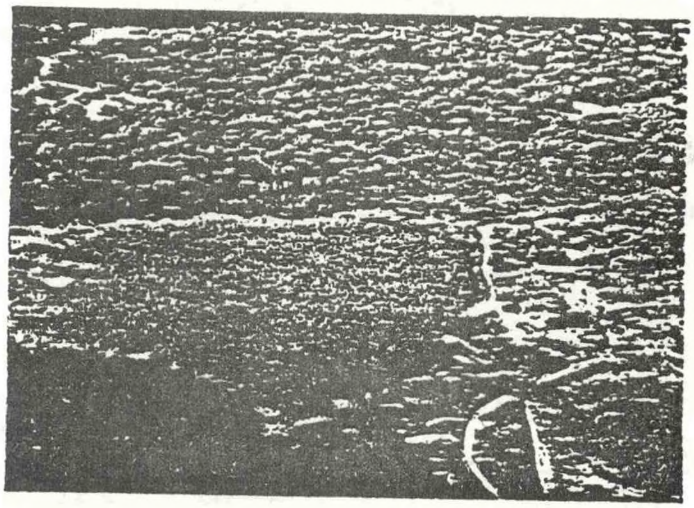


Figure 4.61

Aerial View of Fresh Pond/Angel's Bog
From the East



From the Northwest

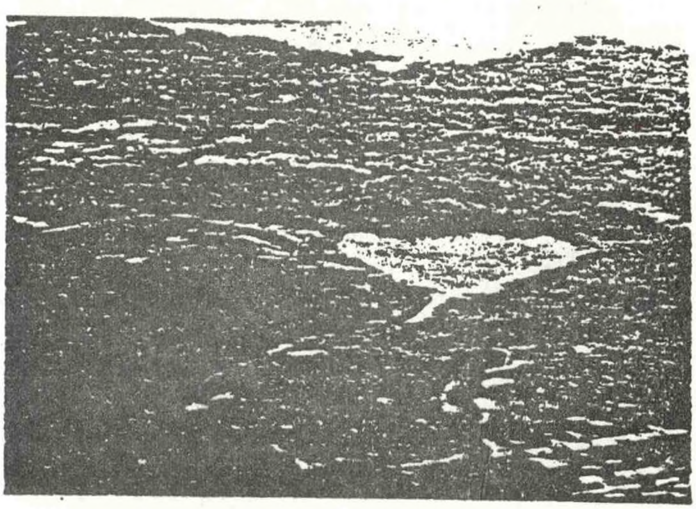


Figure 4.62

Sullivan's Cove Marsh
Adaptive Clustering Algorithm of LANDSAT MSS Data
30 June 1978

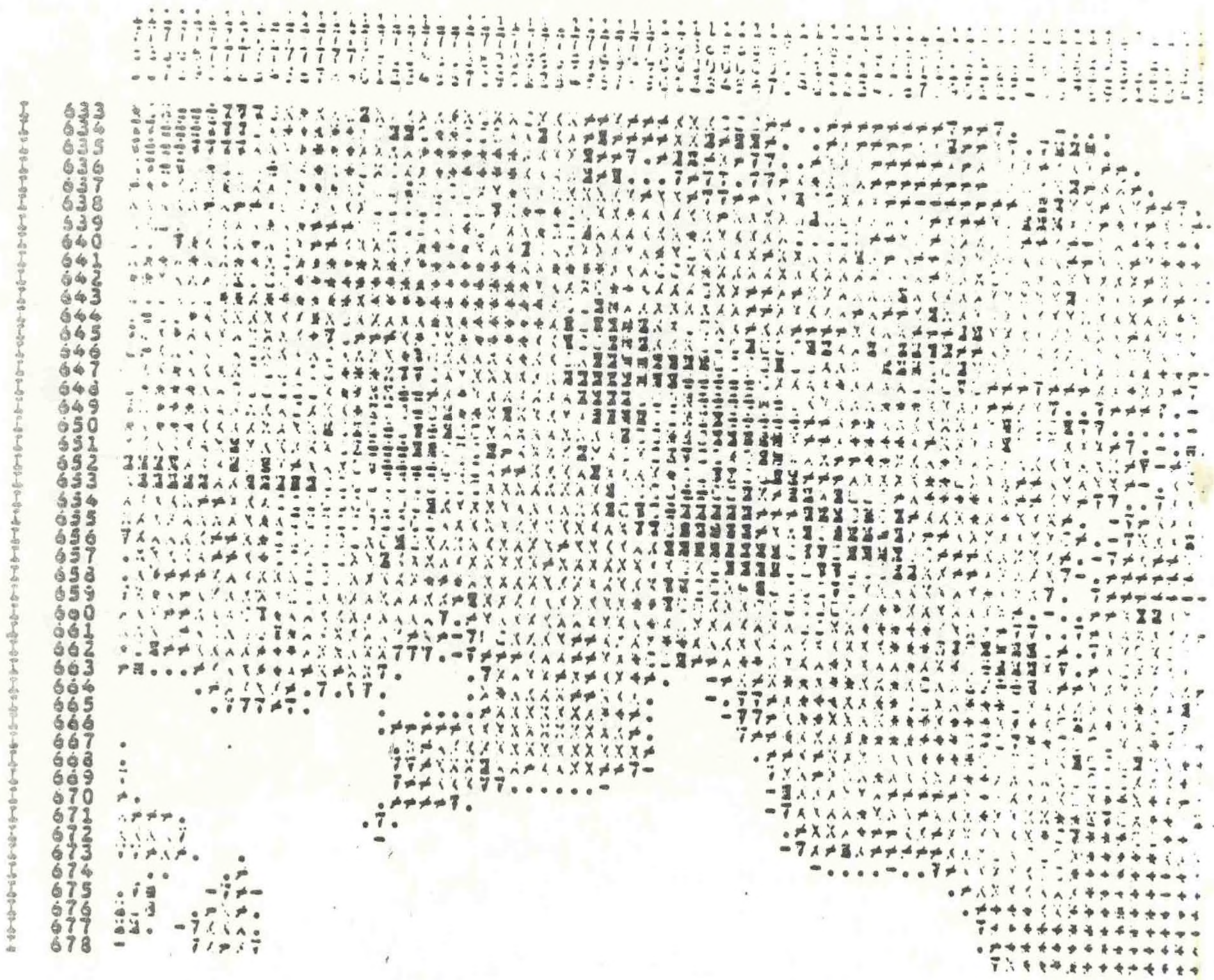
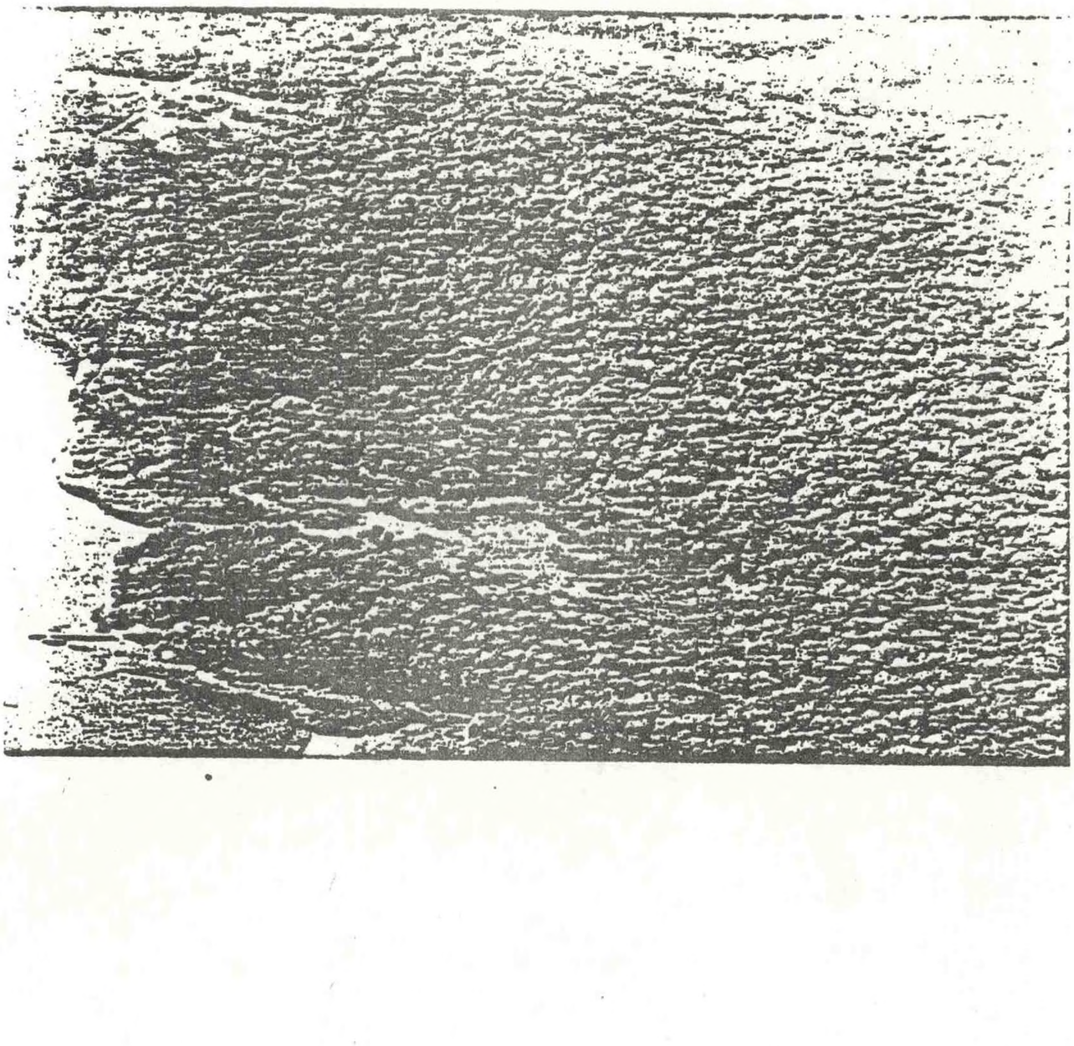


Figure 4.83

Aerial View of Sullivan's Cove
From the Southeast



entity. Conditions affecting the bog, such as significant changes in the sediment inflow , ground-water level, and the effects of pollutants, may be monitored through LANDSAT if these conditions produce changes in the spectral signatures measured for the bog. The same potential for monitoring with remote sensing techniques applies to Fresh Pond/Angel's Bog (Figures 4.60 and 4.61).

Sullivan's Cove Marsh, located along the northern shore of the Severn River, is recognizable on the LANDSAT classified printout (Figure 4.56). The buffer zone between Severna Park and Sullivan's Cove Marsh is clearly identifiable using LANDSAT data. Future changes within this buffer zone can be monitored using LANDSAT data and, as in the case of the Severn Run (TN1), potential application of TM data would be appropriate to monitoring this Critical Area. The effect of nearby residential development is potentially the greatest threat to Sullivan's Cove Marsh and should be closely monitored. Although close on-ground inspection is most appropriate to such monitoring needs, LANDSAT data might prove useful in determining the effects of increased human activity by such measures as water quality studies and the overall changes that might take place in the buffer and adjacent landscape.

Case V - BLACK MARSH IN BALTIMORE COUNTY (SITE T17)

Prepared by H.J. Reed

4.5.1 Background

This Designated Critical Area Site is located on the Chesapeake Bay in Baltimore County between the Patapsco River mouth and Hart-Miller Islands. The site consists of a large tidal marsh, approximately 150 acres in size, bordered by an upland forest. Animal life in the area embraces many bird species, including the red-shouldered hawk. The entire area is owned by the Bethlehem Steel Corporation, whose program to utilize the area for a materials storage site poses a significant problem to the protection of the wetland. Utilization of the area for this purpose will reduce the protective buffer around the wetland, particularly crucial to the preservation of a small wetland. Further it will create the potential for storm water runoff impacts and the destruction of native wildlife habitat.

4.5.2 Sources of Information for the Resource Management Data Base

Existing sources of information about environmental characteristics of the Black Marsh Designated Critical

Area include:

- Atlas of Historic Shore Erosion Rates in Maryland (MCZMP, 1975). A map atlas of 7.5 minute topographic quadrangle sheets for the Maryland shoreline showing locations of present shoreline, and historic shoreline from surveys in the 1800's.

- Photomaps of tidal wetlands on file at the Maryland DNR Water Resources Administration. After passage of the Maryland Wetlands Act in 1970, the tidal wetlands were delineated and classified on a series of approximately 2000 aerial photomaps at a scale of 1:2400 (1 inch = 200 feet). Sample wetlands photomaps are shown in Figures 4.6 and 4.7. The classification scheme and state-wide summary statistics are contained in a DNR report The Coastal Wetlands of Maryland (McCormick and Somes, 1982).

- Faunal species lists compiled by the DNR Wildlife Administration.

- Non-tidal wetlands maps. A set of 7.5 minute topo quad sheets with areas delineating non-tidal wetland vegetation types has been prepared as part of the NWI program, utilizing a classification scheme developed by the U.S. Fish and Wildlife Service. The categories used are described in the U.S.F.& W. report Classification of Wet lands and Deep Water Habitats of the United States (Cowardin et al., 1979).

- Occasional water quality data collected by the EPA Chesapeake Bay Program (EPA, 1982).

- Occasional environmental data collected as part of research studies at Bay-area research institutions, such as the Johns Hopkins University Chesapeake Bay Institute.

- Soil surveys from the county soil report, prepared by the Soil Conservation Service.

- Tidal records, available in the annual Tide Tables for the East Coast of North and South America (NOAA).

- Assorted aerial photography, both overhead and oblique, in infrared, color and black-and-white, collected by the U.S. Department of Agriculture, U.S. Department of State Planning, and other state and federal agencies. For instance, the National

High Altitude Photography Program (NHAP) is funded by fourteen Federal agencies to provide a national data base for mapping and resource management. The black-and-white photography is of cartographic quality, and the color infrared is valuable for resource evaluation, monitoring, and management. The acquisition of this data base started in 1978. The Maryland Coastal Zone is one area where NHAP has completed the coverage. (See Figure 4.9.) A catalog of available airphoto coverage in Maryland has been compiled by the Maryland Remote Sensing Steering Committee (DSP, 1982). Another summary of aerial photographs is available from the National Cartographic Information Center (USGS, 1980).

- Bathymetric charts compiled and updated by the National Ocean Survey.
- Land-cover maps, at a scale of 1:24000, prepared by the Maryland Department of State Planning from analysis of aerial photographs.
- County Comprehensive Plans.

4.5.3 Evaluation of Remote-Sensing Techniques

Black Marsh was investigated for the dates: 11 October 1972 and 30 June 1978. An NMAP of the October, 1972 date is located in the Appendix; for June 1978 a similar map is shown in Figure 4.65b. A deskewed NMAP of the site (Figure 4.66) clearly shows the limits of both the marsh and the nearby forest cover. These may be compared to the topo quad sheet (Figure 4.64) and an air photo (Figure 4.65a) of the Critical Area. Without classification, however, the reflective albedo of the forest and marsh are not always clearly delineated.

Next applied were both clustering algorithms available in ASTEP: an adaptive cluster (ADPCLU in Figure 4.67)

Figure 4.64

Portion of USGS 7.5 Minute Topo Quad Sheet
Black Marsh Critical Area (T17)

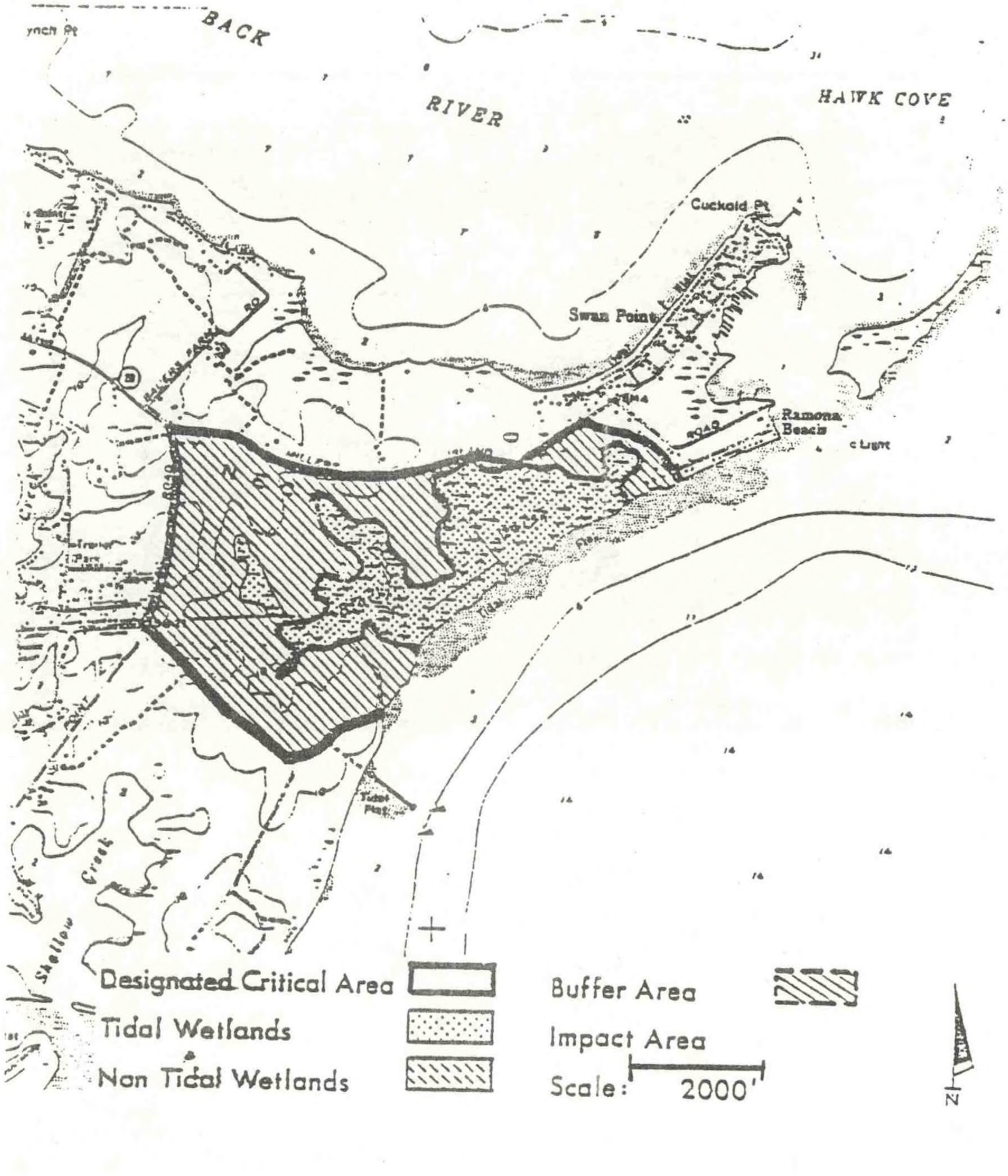


Figure 4.65a

aerial view of Black Marsh

from the South

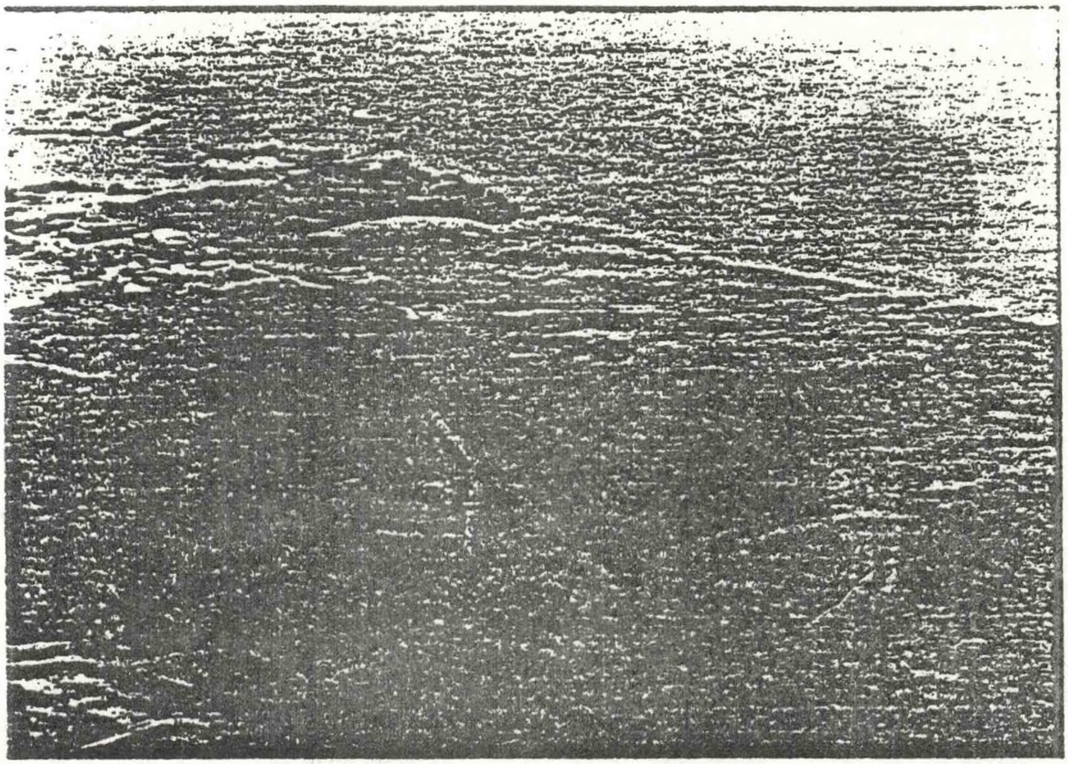


Figure 4.65b

Black Marsh
Brightness Intensity Map (NMAP) of LANDSAT MSS Data
30 June 1978

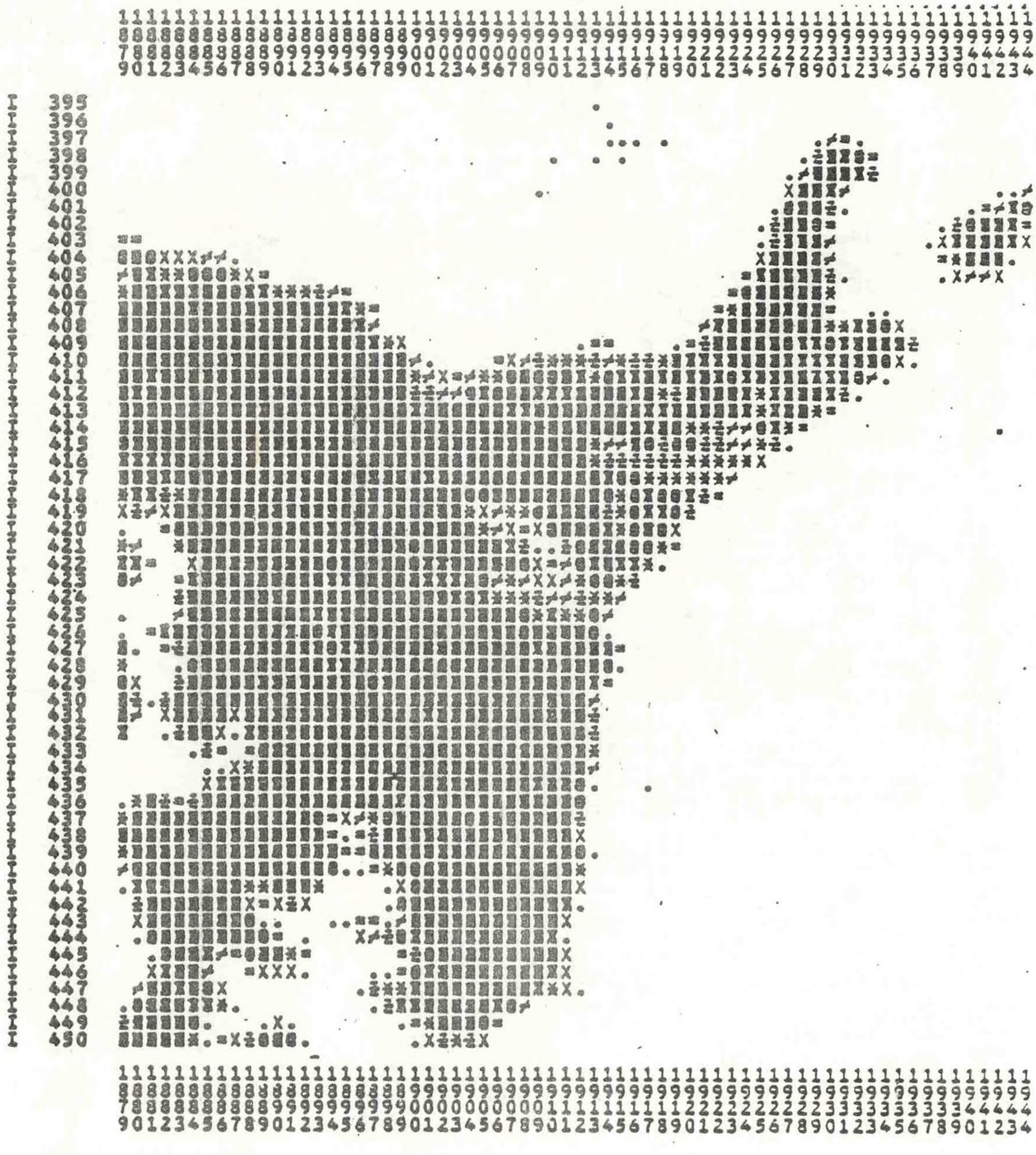
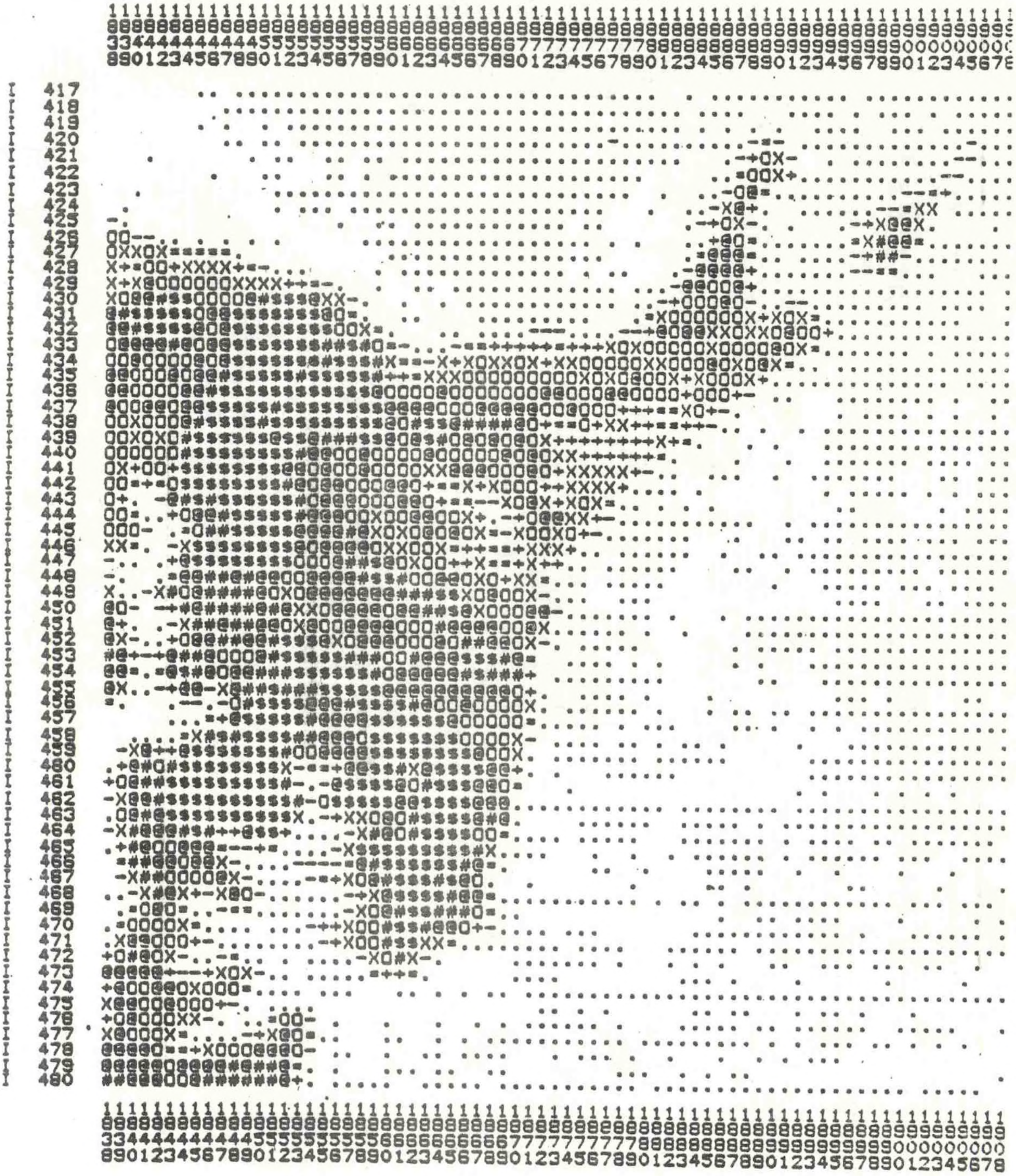


Figure 4.66

Black Marsh

Deskewed NMAP - 30 June 1978



and an iterative cluster (ITRCLU in Figure 4.68). The adaptive clustering algorithm identifies the characteristic marsh land (represented by the '^' symbol) and correctly segregates deeper water within the marsh (represented by the '-' symbol). Any future changes in the extent in size and ground saturation of the marsh can be expected to be evident from LANDSAT analysis.

The adaptive clustering algorithm does not, however, distinguish variations in vegetative cover within the marsh. This is more successfully done by use of a multiple pass algorithm such as ITRCLU (Figure 4.68). In the latter case three distinct signatures pertain to the marsh (represented by the symbols '%', '>' and '<').The '%' symbol predominates over the main portion of the marsh with the vegetated periphery assigned to complementary classes. Additionally tidal flats and beach sands are also assigned separate signatures (represented respectively by the symbols '#' and 'W').

The final four figures (Figures 4.69 to 4.72) apply vegetative indexes to the data. All of the vegetative index combinations share one thing in common--the importance of bands 6 or 7 (the infrared bands) and band 5 (reflected visible red) in numerical calculations leading to statistical classifications. Band 7 (or 6) is especially sensitive to the presence and variations of vegetations, while band 5 is particularly sensitive to rocks and soils.

Almost any calculation that produces an inverse relation between these bands, as in the case of the vegetative indexes (VI's), increases the ability to measure small but significant variations in vegetation characteristics such as species, proportion of different types, density, biomass and vigor. Loss of chlorophyll in both the marsh and upland forest would be immediately detectable by any of the vegetative indexes.

It is thus important that periodic ground-truthing be employed to verify the appropriateness of these measures and to determine the ground cover equivalence to the mathematically derived clusters. However, even without ground-truth, periodic inspection of clustered maps, conveniently and easily generated from LANDSAT data by computer for any of the State's marshes, will immediately signal the presence of threats to the vegetative stability of such areas. Stream eutrophication and excessive siltation can likewise be easily monitored using vegetative index analysis.

Black Marsh should be viewed as an example of an ideal area for continued future study. In addition to the LANDSAT coverage available for study of the area, Black Marsh 's strategic proximity to Baltimore and its commercial ownership will permit other kinds of data to be correlated with the LANDSAT data. On-site inspection, acquisition of aerial photographic coverage suitable for photogrammetric analysis, high-level infrared coverage, and vegetation studies might be combined with the LANDSAT monitoring data to construct a temporal picture of the marsh and its relation to the surrounding area.

Figure 4.67

Black Marsh
ADPCLU - 30 June 1978

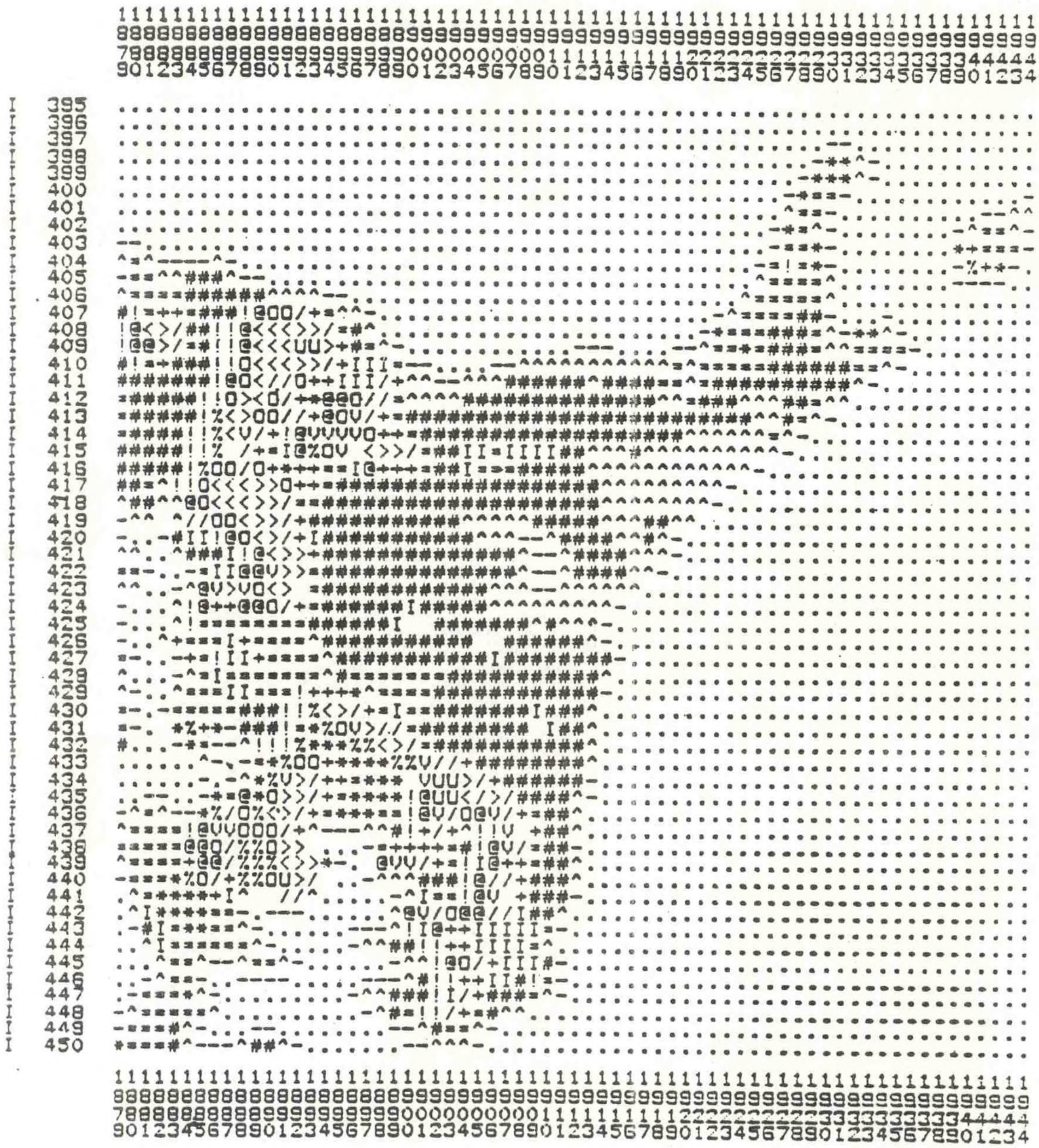


Figure 4.68

Black Marsh
ITRCLU - 30 June 1978

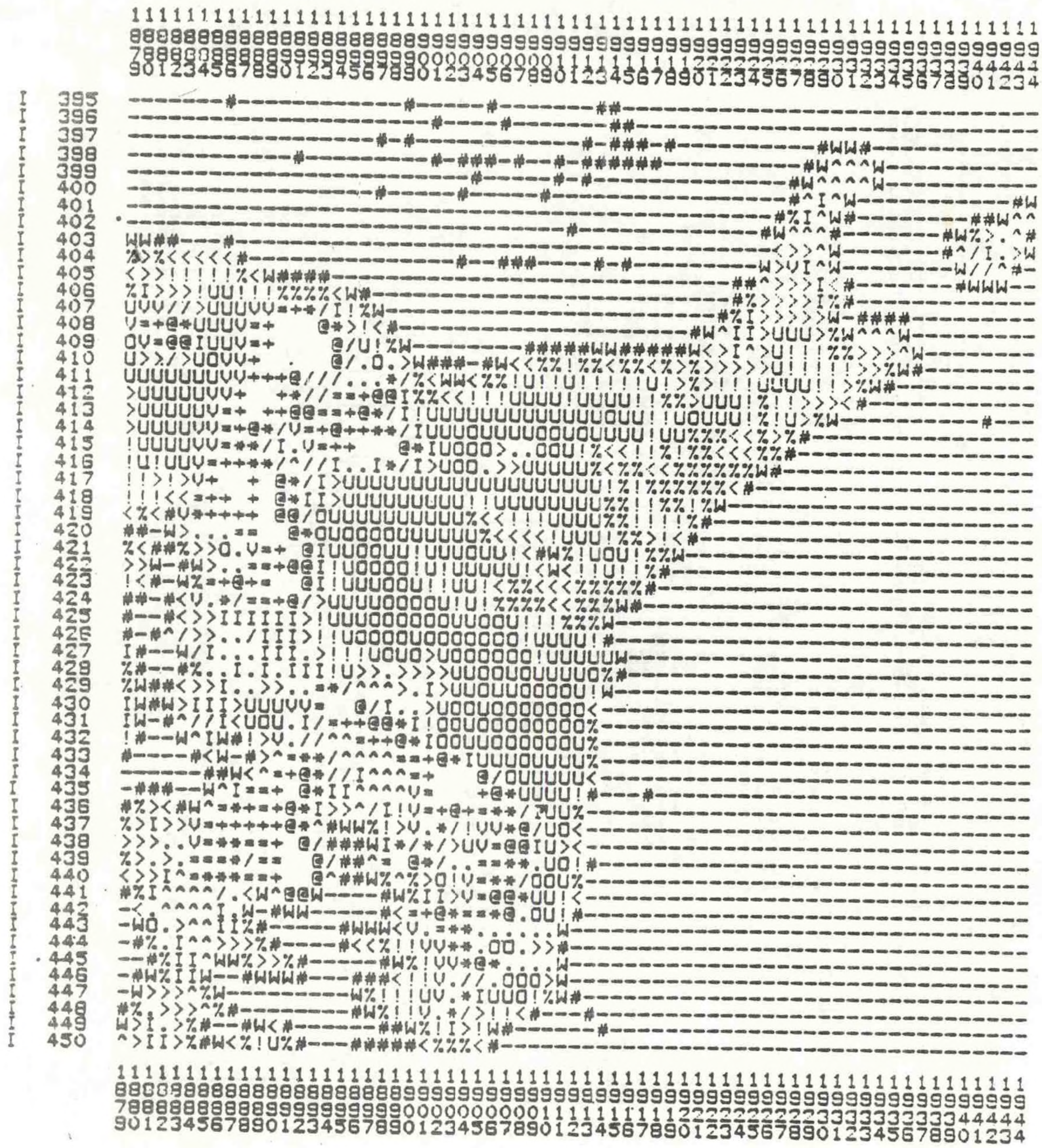


Figure 4.69

Black Marsh
Green Vegetative Index (GREEN VI)

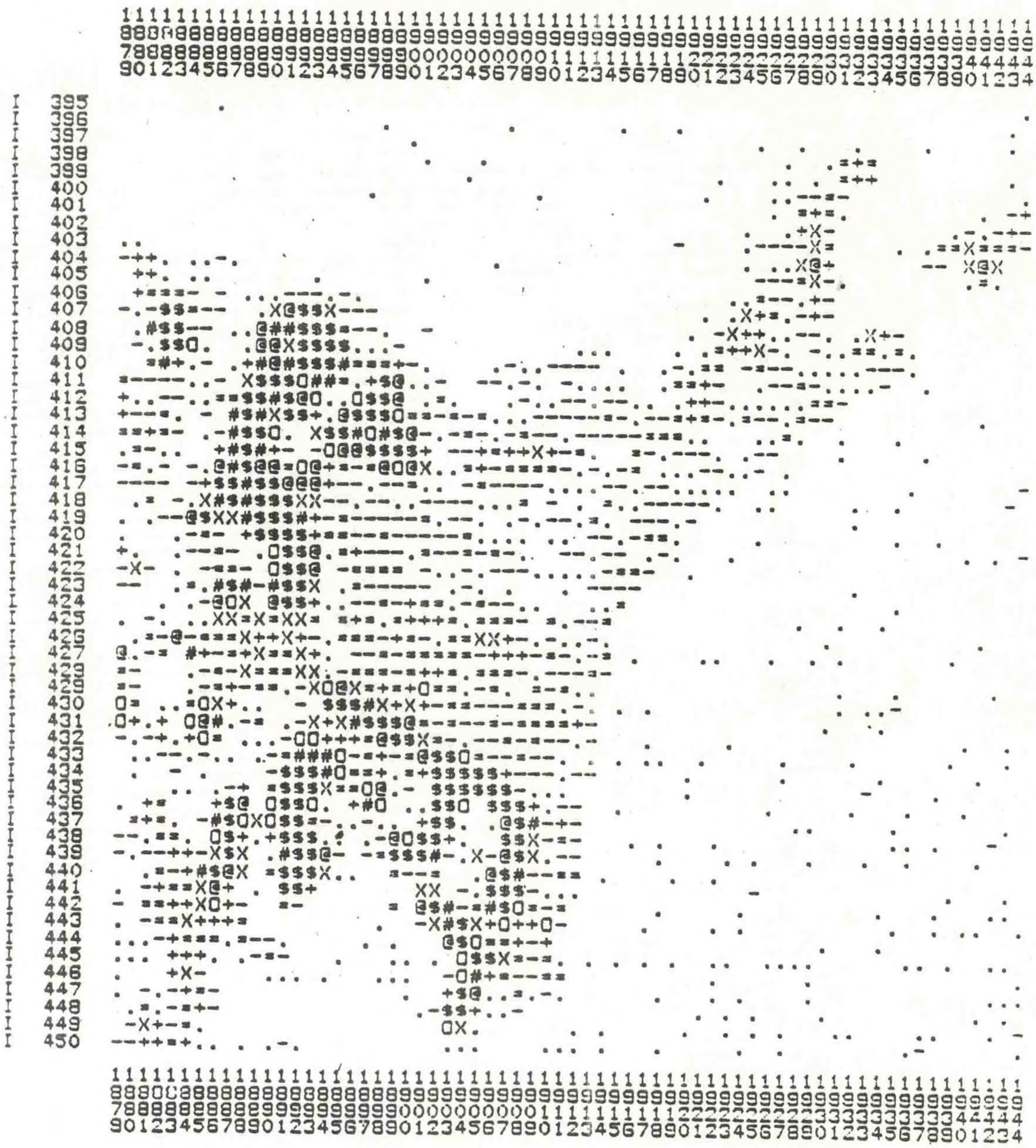


Figure 4.70

Black Marsh
Perpendicular Vegetative Index (PERP VI)

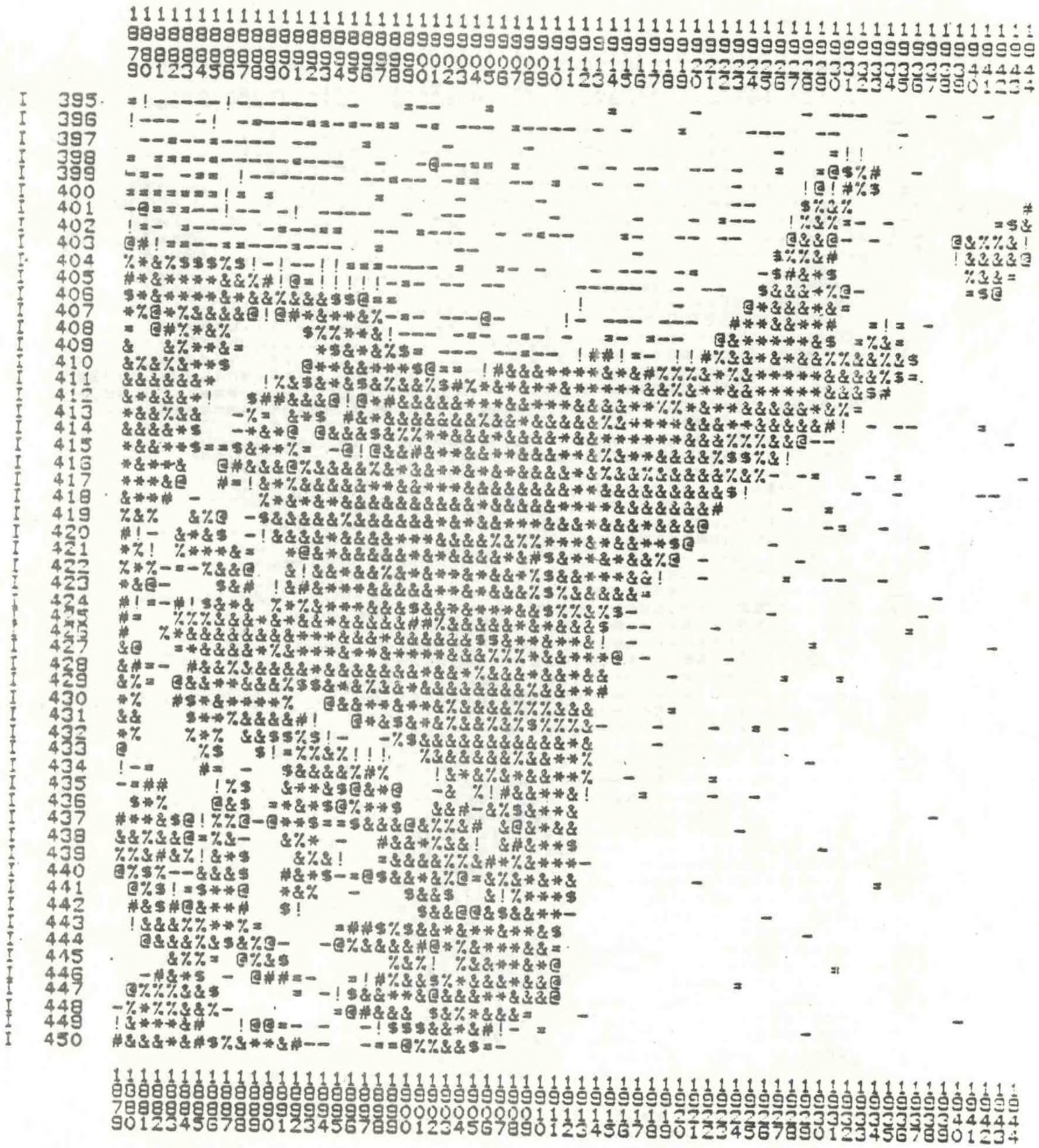


Figure 4.71

Black Marsh
Linear Vegetative Index (LINEAR VI)

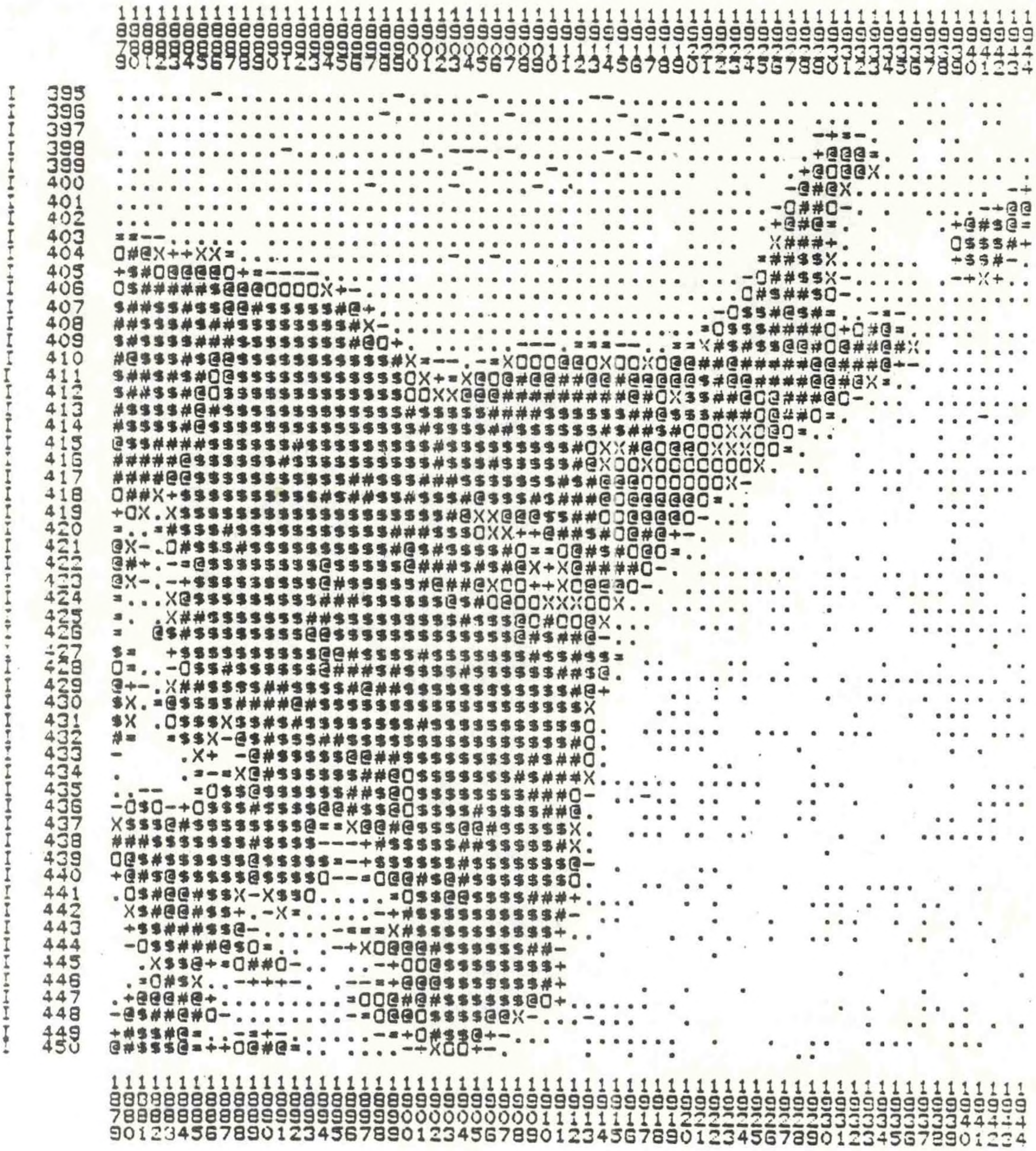
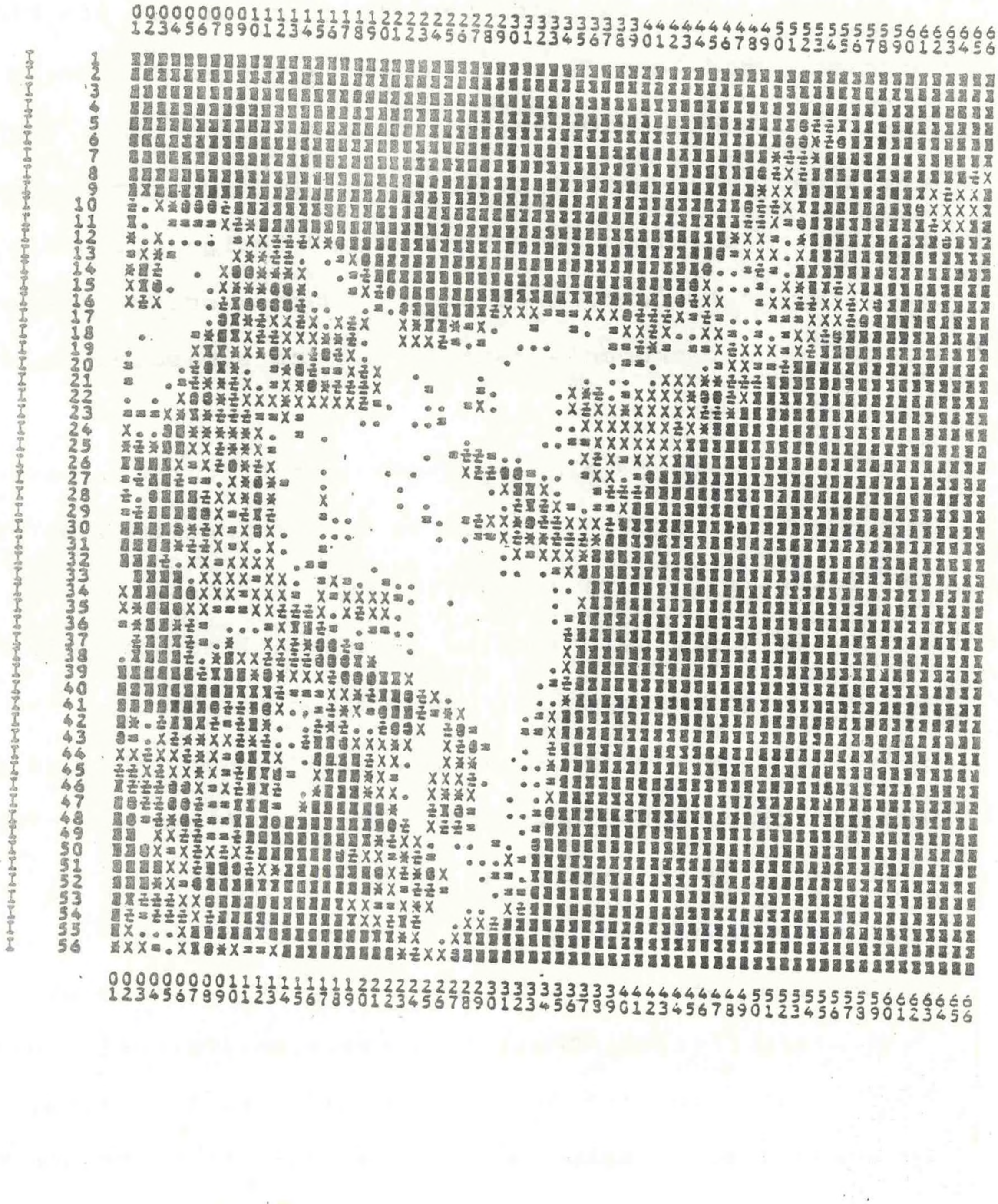


Figure 4.72

Black Marsh

Ratioed Vegetative Index - Bands 5/7 (RATIO VI)



CHAPTER 5

CONCLUSIONS

K.-Peter Lade

State and local agencies are increasingly confronted with the need to make informed decisions about how to use the natural resources within their jurisdictions. Such decisions, when anticipated, take the form of management strategies or plans. The First-Round Designated Areas of Critical State Concern constitute such a set of resources which, if not properly managed, may be subjected to unacceptable stress.

The key to developing a management strategy is to provide for a continuing source of information about each Critical Area. Such a "monitoring" task can, in most instances, only be effective if data collection and analysis are highly automated. One reason for this is the substantial number of sites which have been included in the First-Round Designation of Critical Areas (see Tables 1.2a and 1.2b in Chapter 1), and the certainty that many more sites await designation in subsequent generic classes of Critical Areas. The total acreage encompassed by the Designated Critical Areas is already sufficiently large that on-site inspection, even on an irregular basis, is not feasible. A solution to this problem is the use of

LANDSAT multispectral data.

The benefits to be achieved through the application of LANDSAT data are considerable. On-site sampling and periodic aircraft surveys combined with special on-site environmental sampling of selected Critical Areas would provide some of the same synoptic and detailed data as provided by LANDSAT. However, these more traditional means of environmental monitoring would have to be conducted with an intensity that current funding levels and staff considerations are not likely to easily permit.

Aside from funding considerations alone, success with those managerial goals for the Critical Areas which are contained in the DSP Designation Report will be impeded unless data can be stored, retrieved, and displayed in an efficient and organized manner.

We have shown that LANDSAT data can be classified sufficiently well to provide vital information on natural and human effects on the continuing stability of ecologically fragile areas. The detailed information provided by on-site investigations and special low-level aerial reconnaissance flights will continue to be useful to resolve special problems. However, the larger monitoring concerns can be accomplished through the use of LANDSAT data, combined with the types of ground-truth information which were summarized under each of the case studies in Chapter 4. Through such a procedure, LANDSAT analysis provides a means by which gaps in the more traditional data-collection process can be filled. In addition, and perhaps more importantly, the regular use of LANDSAT data, in combination with new on-site data, will allow the limited resources of human labor and funding to be applied to Critical Areas in the comprehensive manner that is needed.

The greatest difficulty in the past use of LANDSAT data by state and local agencies has been the complexity of the task of analyzing the data. The need for special computer hardware and computer training was often beyond the scope of tasks customarily undertaken by managers and their staffs. One goal of this study was to determine whether practical LANDSAT data analysis could be performed outside the academic setting by individuals with varying backgrounds and computer skills. Although the case studies attest to the fact that this goal was achieved, a few additional comments are added here prior to evaluating the degree of success achieved in meeting that goal.

LANDSAT data, like most data acquired by remote sensors, can be processed as a film product or a digital tape. Using standard photogrammetric techniques, LANDSAT photo products (the large-scale infrared false-color composites) have been successfully analyzed for land-use, geologic, and other studies. By using the photo products alone, there is no need for specialized equipment and costly computer hardware and software. However, only gross estimations of the ground features being investigated are possible using the photo product by itself.

In each case study prepared for this report, the investigators used the LANDSAT photo products to choose those dates which were best suited for their needs. They proceeded immediately to process the digital data with the ASTEP programs using a remote terminal accessing a mainframe computer, and adapt the resultant classifications of the MSS data to their own special project. Except for the occasional system crash, these sessions went with unusual smoothness, demonstrating the ease with which non-specialists can manage the computer processing of digital data for natural resource projects.

Each investigator used slightly different techniques and attempted different approaches using various statistical procedures. Even with the limited types of ground-truth that were available to meet management concerns, it was possible to determine accurately a number of land-uses, land/water boundaries, wetlands, and similar features. Each study revealed a new understanding of the particular Critical Areas being investigated, while also pointing out the importance of providing correlated ground-truth data.

Water resources were possibly the most easily investigated. As in the case of the Severn River, sediment and turbidity patterns play an important role in the long-term stability of the Critical Area. A determination of these patterns can be reviewed for the past decade with the aid of LANDSAT archival data; the ongoing collection and processing of LANDSAT data could also be relied upon to show future improvements or deteriorations in this kind of problem. Other possible applications include: the determination of water boundaries and surface water and volume for such sites as the Pocomoke River, mapping of floods and floodplains, the delineation of irrigated fields, and determination of water depth.

Coastal resources within the Chesapeake Bay watershed to which LANDSAT analysis could also be applied include shoreline changes and shoal and shallow area morphology. As new areas of concern are identified in the future, particularly along the shores of the Bay, the techniques developed as part of this study may be readily applied.

The effects of pollution may also be subjected to earlier mitigation if regular LANDSAT analyses are carried out. Stream and river eutrophication, forest defoliation, and loss of vigor in both terrestrial and aquatic vegetation may be detected at an early stage. Zekiah Swamp and Jug Bay, for example, are both areas of sufficient size that other monitoring techniques could be optimized by the appropriate use of LANDSAT data.

The selection of Designated Critical Areas as sites for evaluation of the LANDSAT technology was particularly fortuitous because they range considerably in size from just a few acres to several hundred acres. Many kinds of information may ultimately be collected for these areas depending, in some measure, on the specific type of area it is, in each case. As we have seen from the case studies in Chapter 4, many important features of most of the Critical Areas can be studied at the 1:24000 scale common to the USGS 7.5 minute quadrangle sheets. If further resolution is needed the new Thematic Mapper sensor aboard LANDSAT-4 provides data at 1/4 acre resolution. Such resolution would be particularly helpful in assessing impacts on the smaller Critical Areas. However it should be noted that the higher resolution brings with it a concomitant increase in data volume and the cost of processing the greater volume; may not be justified in cases where the study areas are of larger size.

Having completed this project, we may conclude that LANDSAT data are a valuable addition to other data sources. The 1/4 acre resolution digital data from LANDSAT 4 is extraordinarily useful, though it does not by itself alone answer every need that resource managers might have concerning information on the areas under their jurisdiction. For example, species identification of vegetation is still difficult if one is to rely on remotely sensed data entirely. Nonetheless, it is possible for the first time, and specifically through the application of LANDSAT data, to investigate in considerable detail throughout the Coastal Zone (at a scale of 1:24000), a diverse range of areas to be managed. This can be further done with the advantage that the data are uniform, acquired by the same instrument, and virtually at the same time. The significance of this data base must be emphasized since it resolves so much of our difficulty in reaching meaningful decisions about the disposition of various resources. Furthermore, it is now possible to make use of much previously collected data, including uneven, temporally unrelated, and sometimes poorly sampled data, all of which are ideally suited to calibrating the LANDSAT MSS data by serving as an essential set of ground-truth information.

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A P P E N D I X   A

In the following pages density sliced brightness intensity maps (NMAP's) have been generated for each of the Critical Areas considered in this report. All four channels of data collected on October 10, 1972 (path/row 15/33) and October 11, 1972 (path/row 16/33) were processed through the ASTEP programs to produce the classified images. Density levels were set so that water bodies would be heavily pronounced.

Quantization of image data provides a means of displaying pixel values when clusters have not been computed. Density slicing is a specific application of the quantization algorithm. For single-band images, a frequency distribution of pixel values can be effectively used as the basis for determining the breakpoints separating the levels to be displayed. This is the case for QUANTZ displays of raw data bands and also for displays of special applications, such as vegetative indexes, where a new single band is generated by computation.

Quantization may also be done in even levels ranging between the minimum and maximum values of the data set. This procedure is especially useful for a first look at data and for displaying a composite image of all four bands (NMAP). NMAP's can contain significant information and are often sufficient to determine both major land covers as well as land/water boundaries. An example of a comparison of an NMAP with a classified scene (ITRCLU) is shown in Figures A.1 and A.2. Symbols and the number of classes were matched as closely as possible to facilitate comparison.

Figure A.1

NMAP of Snow Hill (9 April 1978)
10 Classes

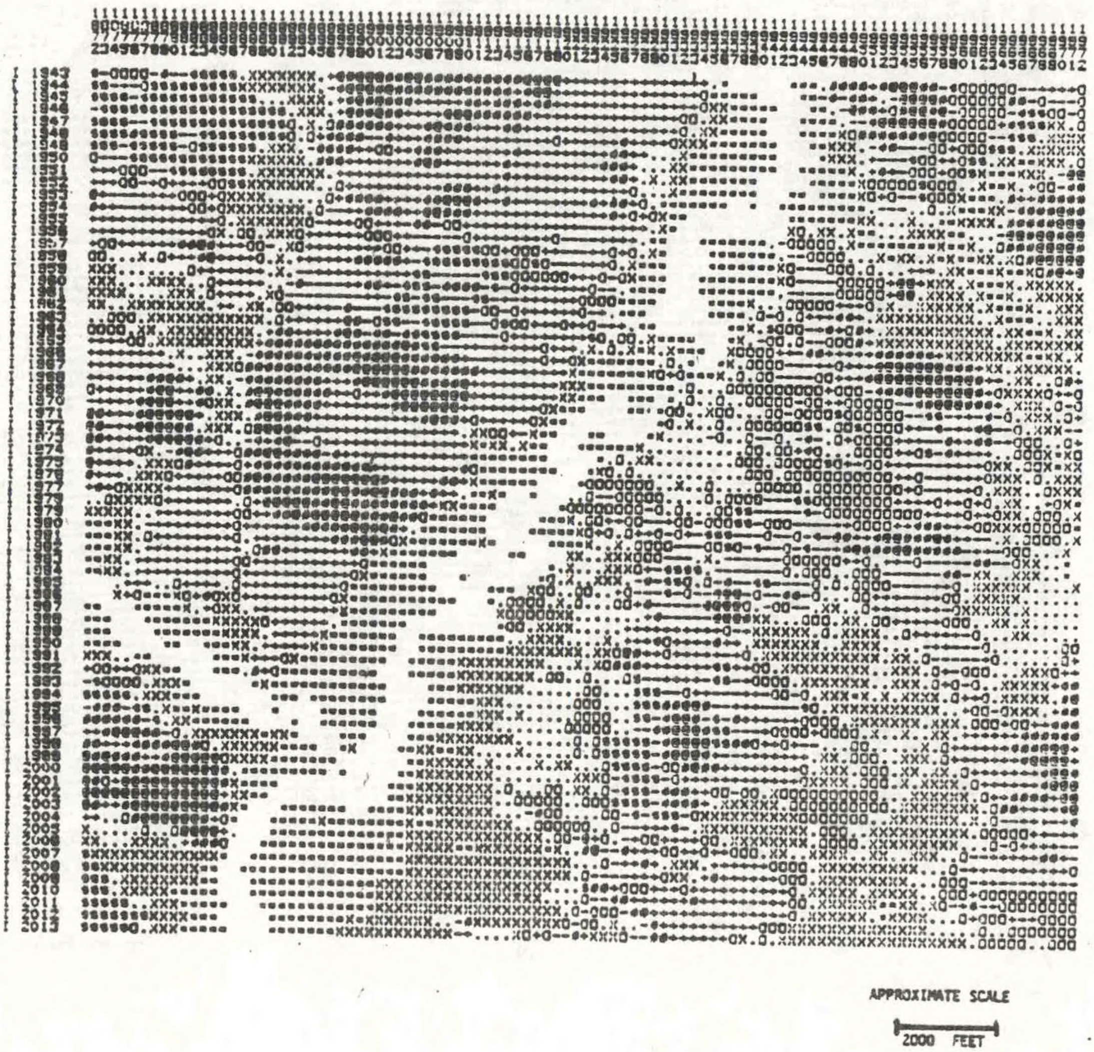


Figure A.2

ITRCLU Classified Map of Snow Hill (9 April 1978)
10 Classes

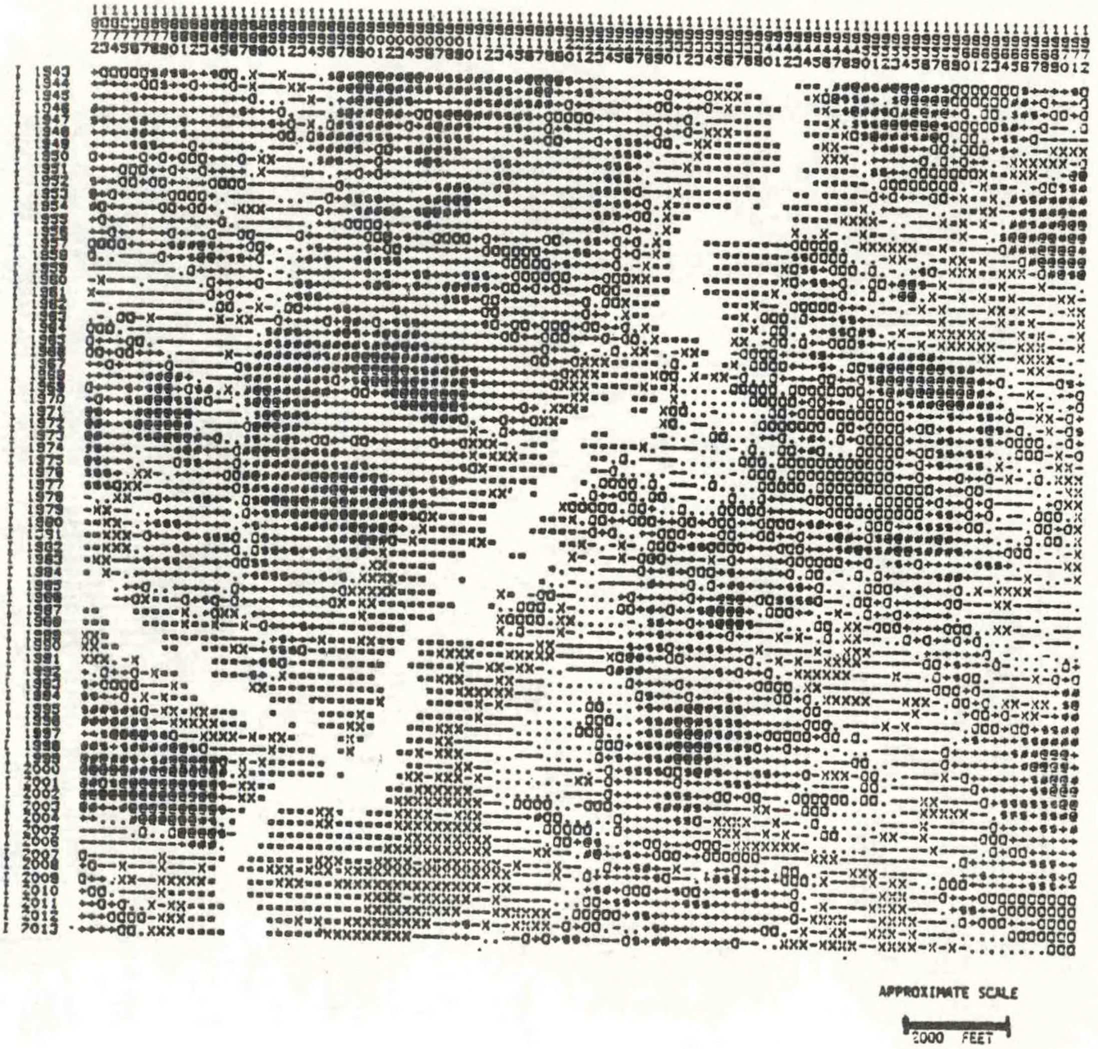


Figure A.3

Severn Run Tributaries (TN1)

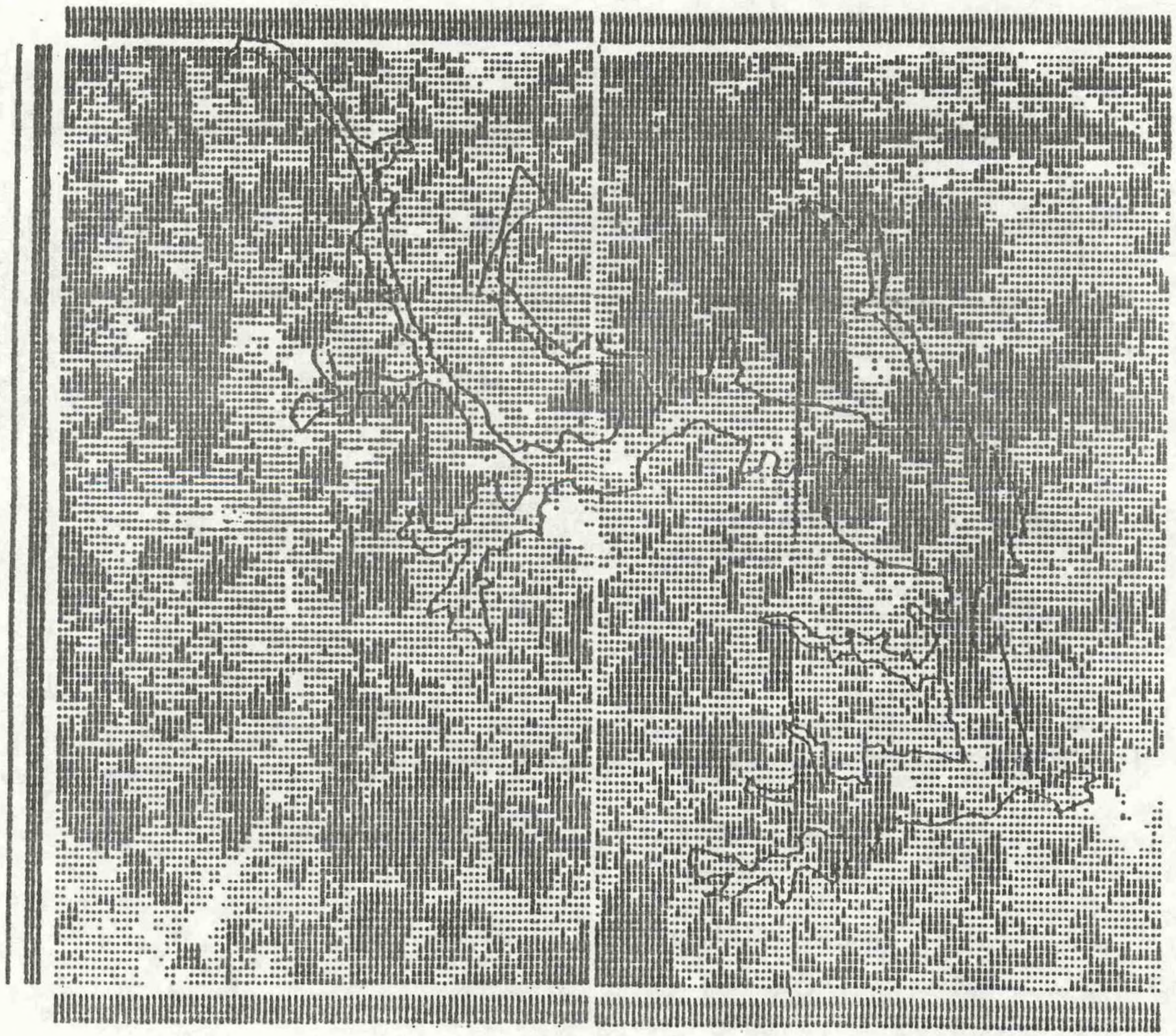


Figure A.4

Jug Bay (TN2)

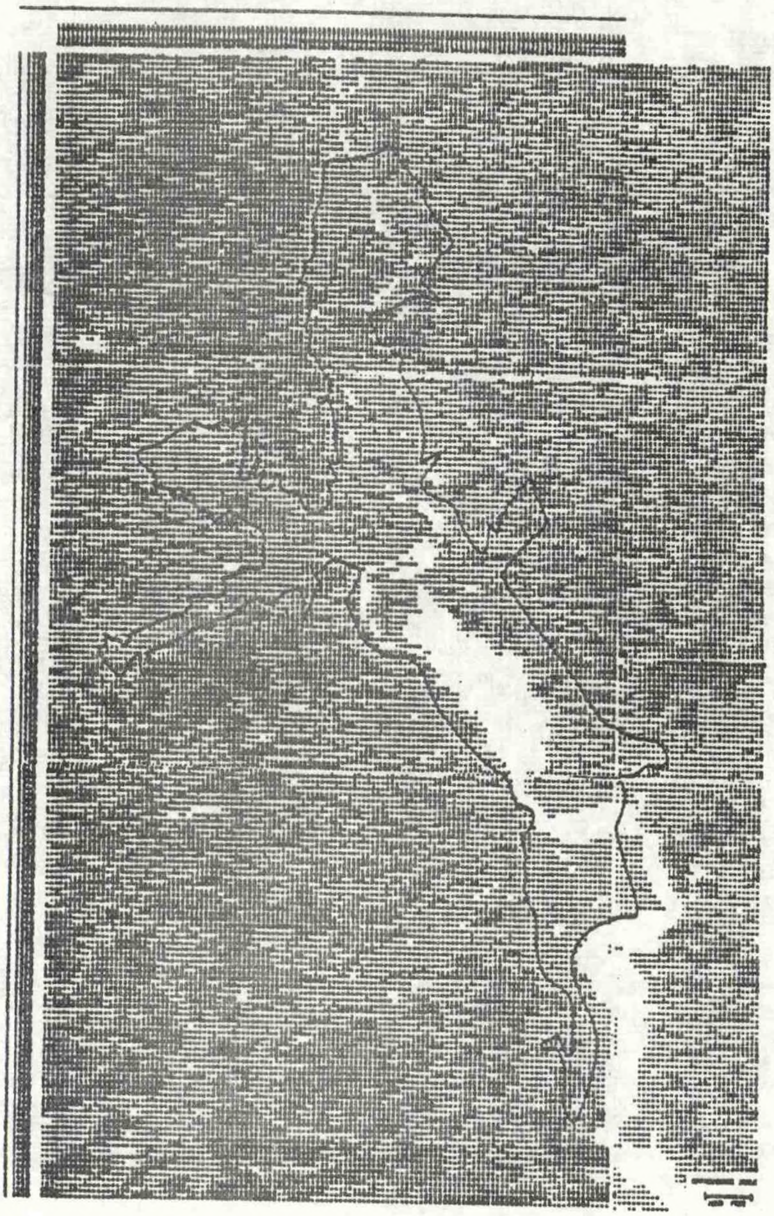


Figure A.5

Eagle Hill Bog (TN3)

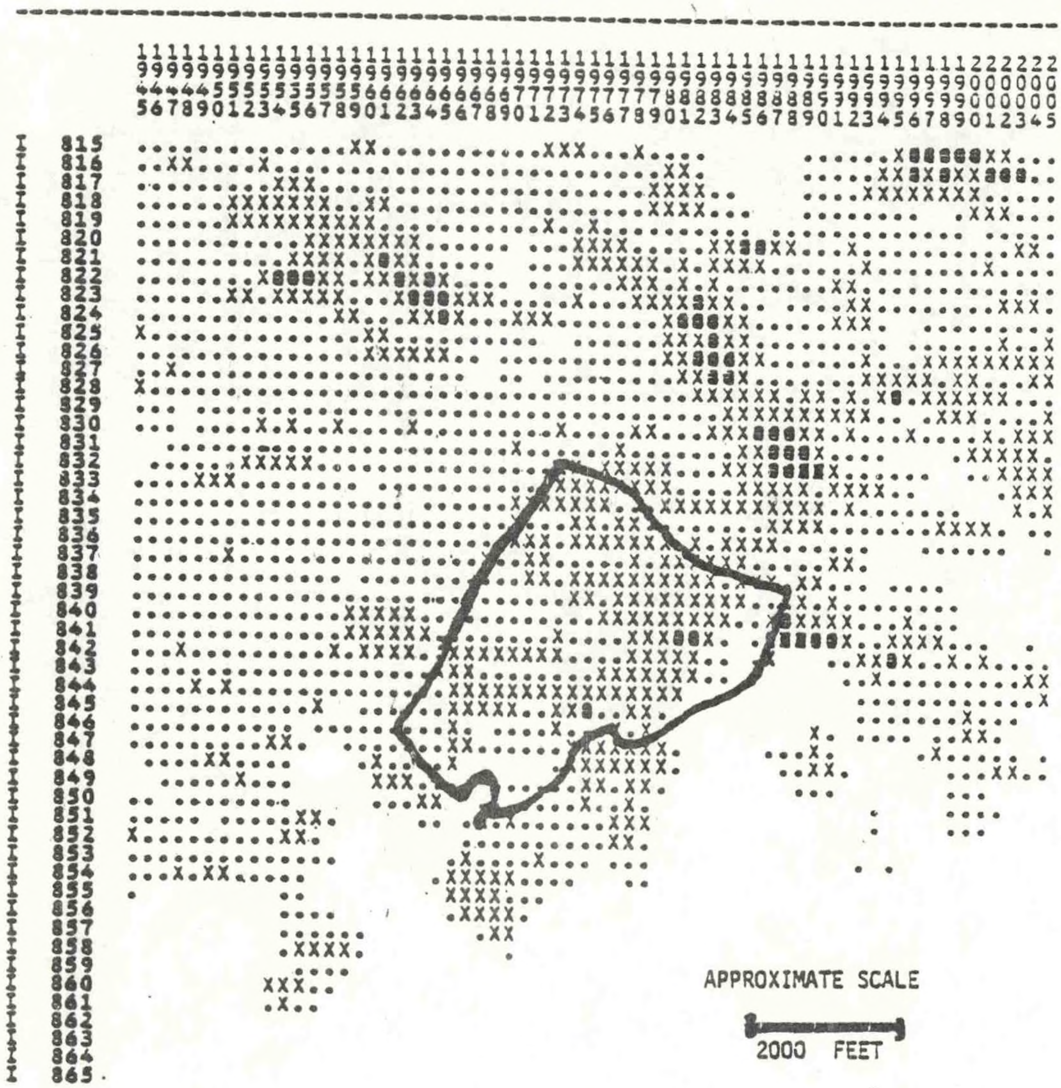


Figure A.8

South River Headwaters (TN4)

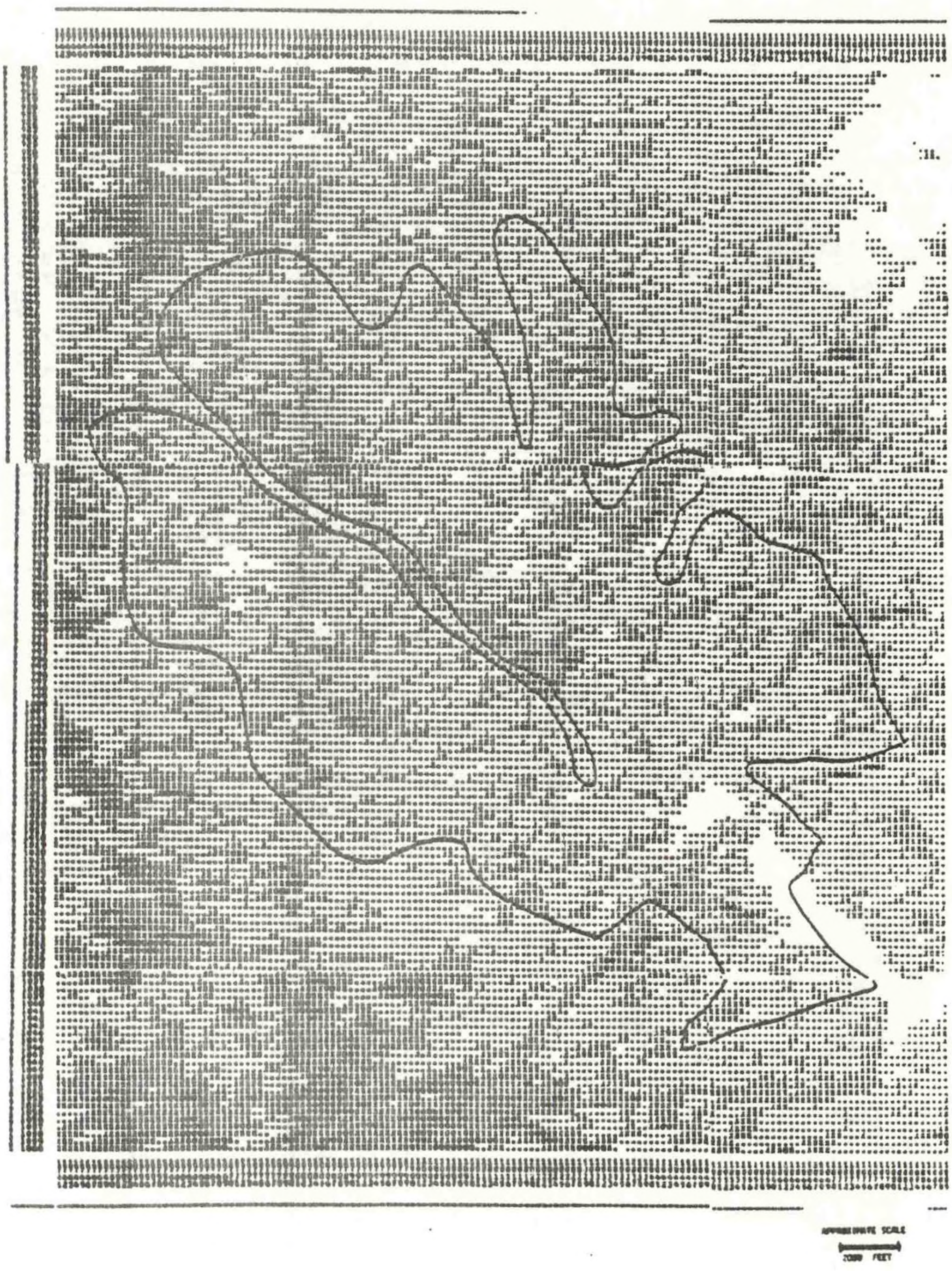


Figure A.7

Round Bay Bog (TN5)

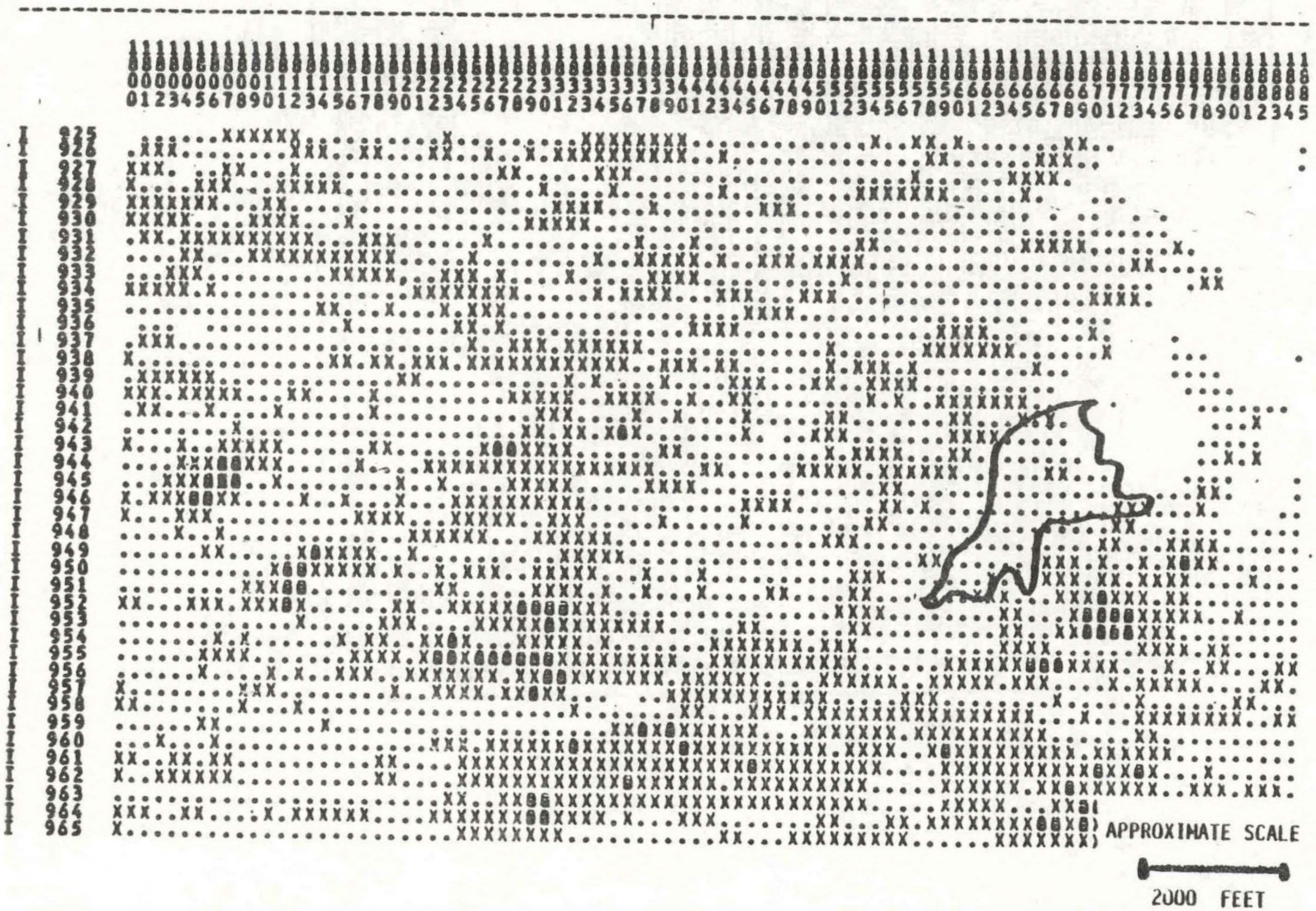


Figure A.8

Gunpowder Delta Marsh/Day's Cover (TN6)

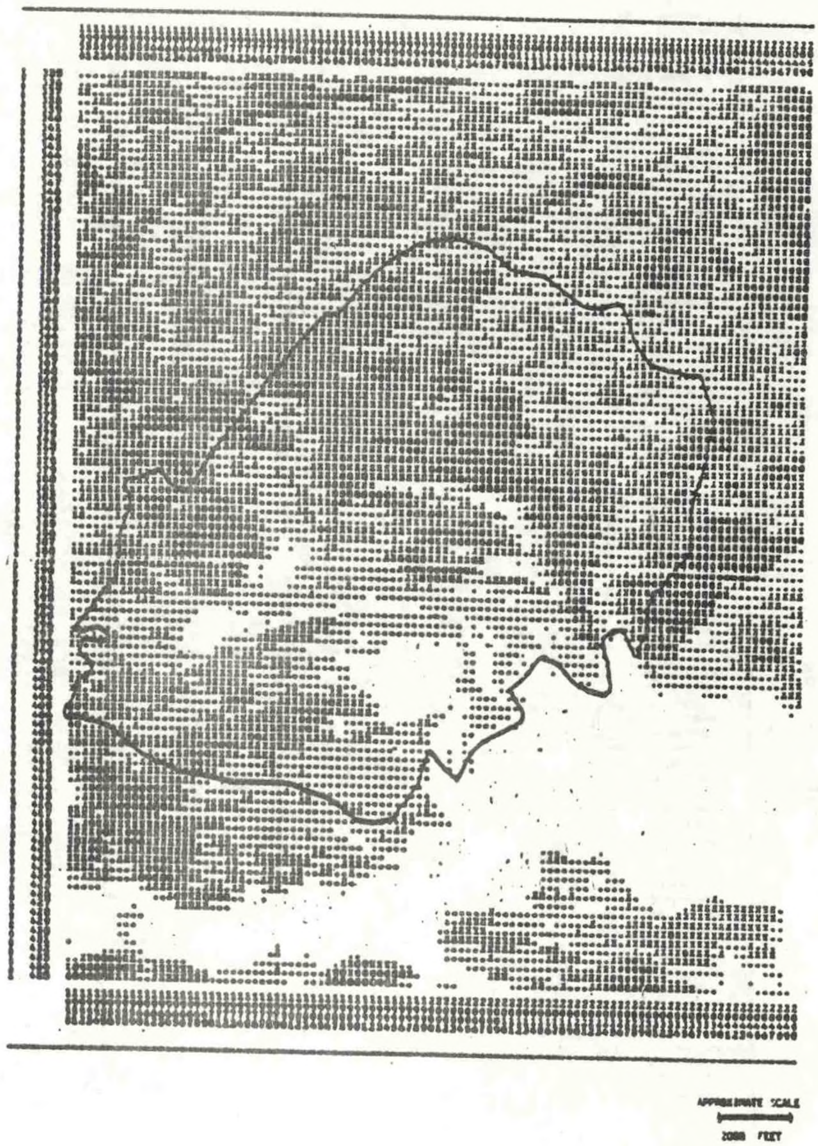


Figure A.9

Zekiah Swamp (TN7)

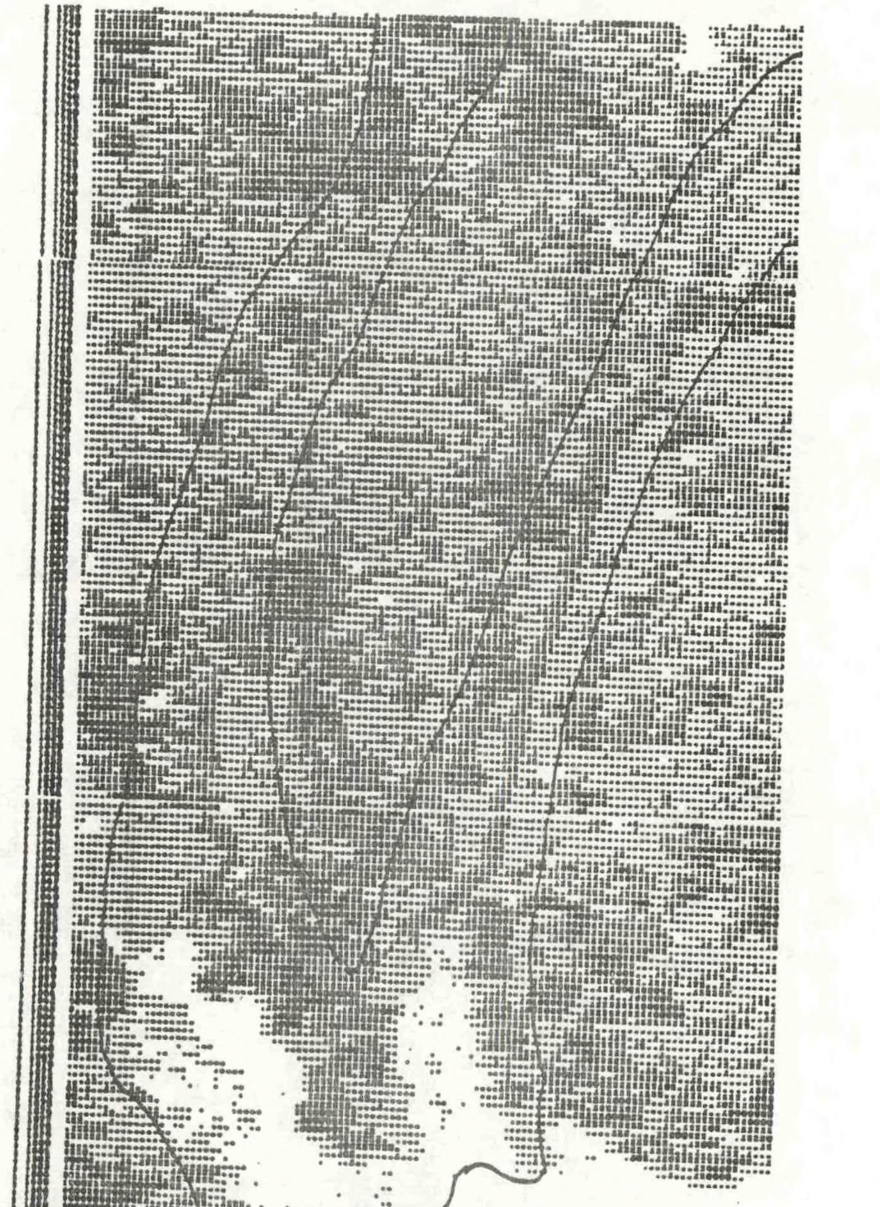


Figure A.10
Mattawoman Creek (TNB)

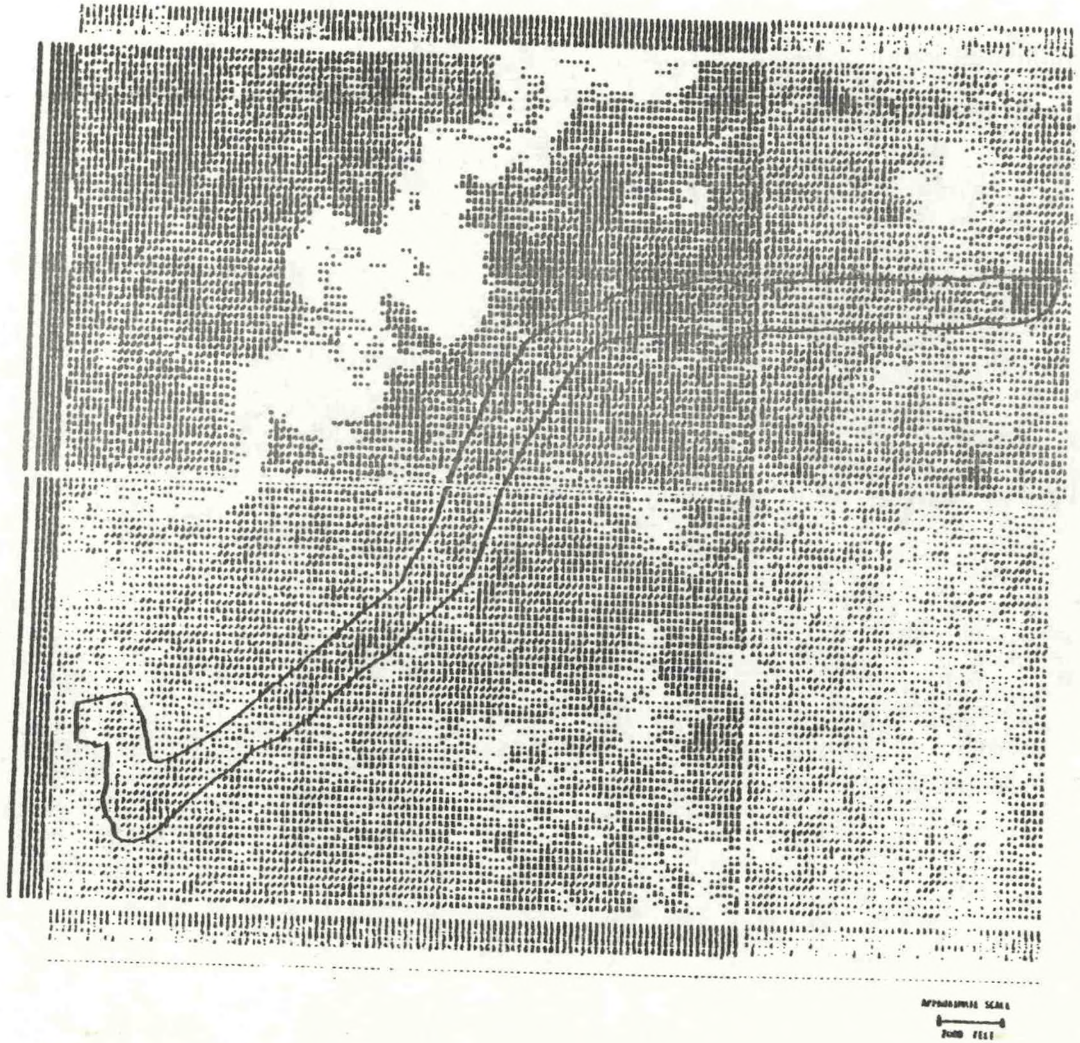


Figure A.11

Big Marsh/Howell Point (TNB)

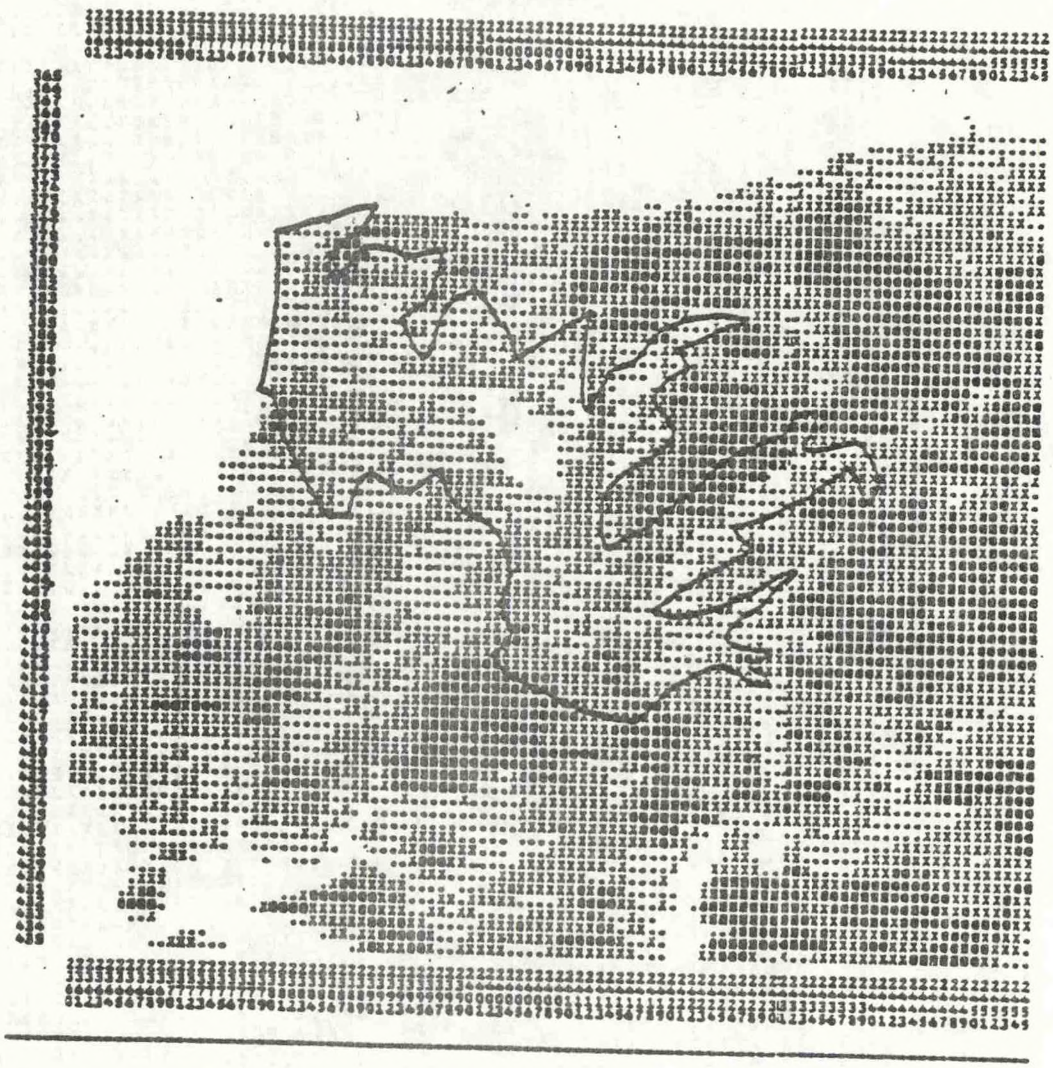


Figure A.12

Broad/Henson Creek Marsh (TN10)

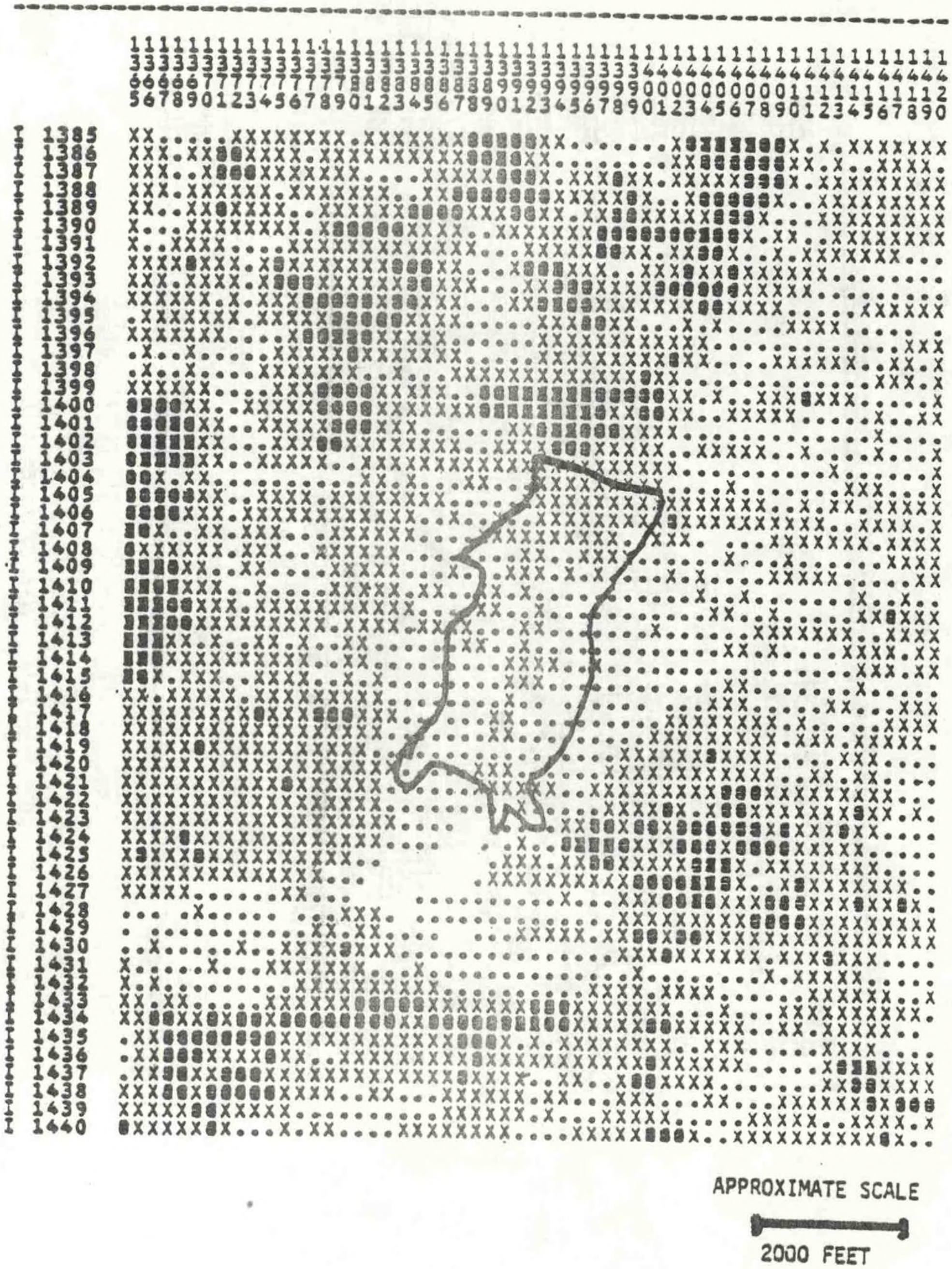
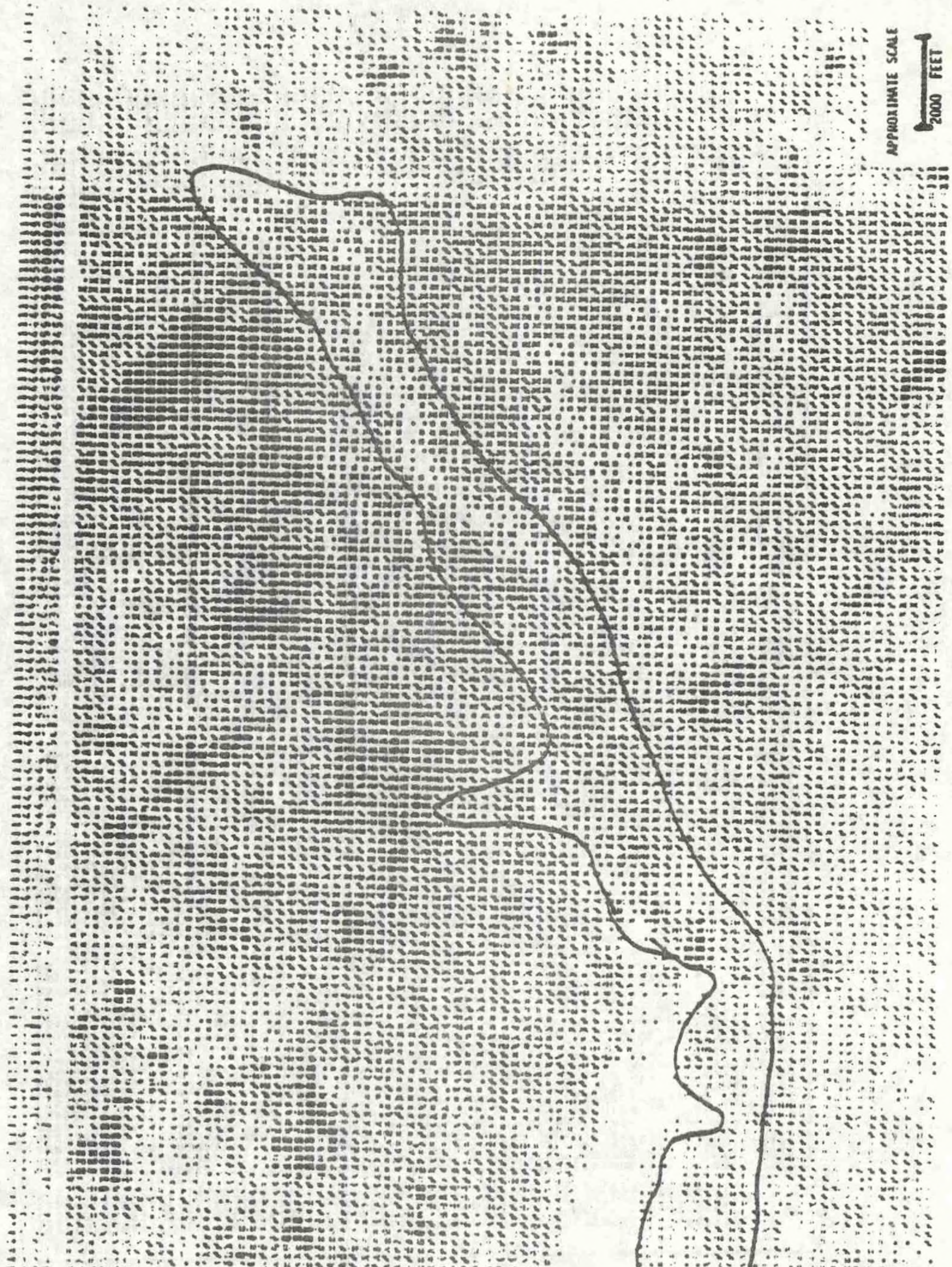


Figure A.13



Piscataway Creek (TN11)

Fisure A.14

Chaptico Run (TN12)

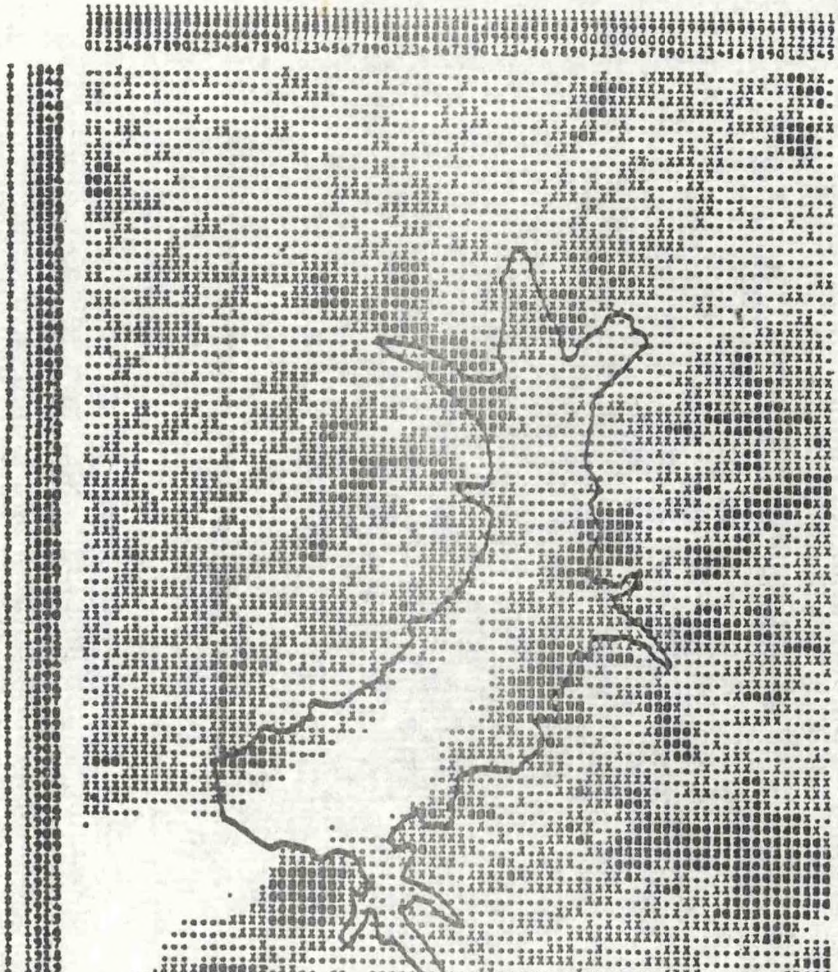


Figure A.15

Killpeck/Trent Hall Creeks (TN13)

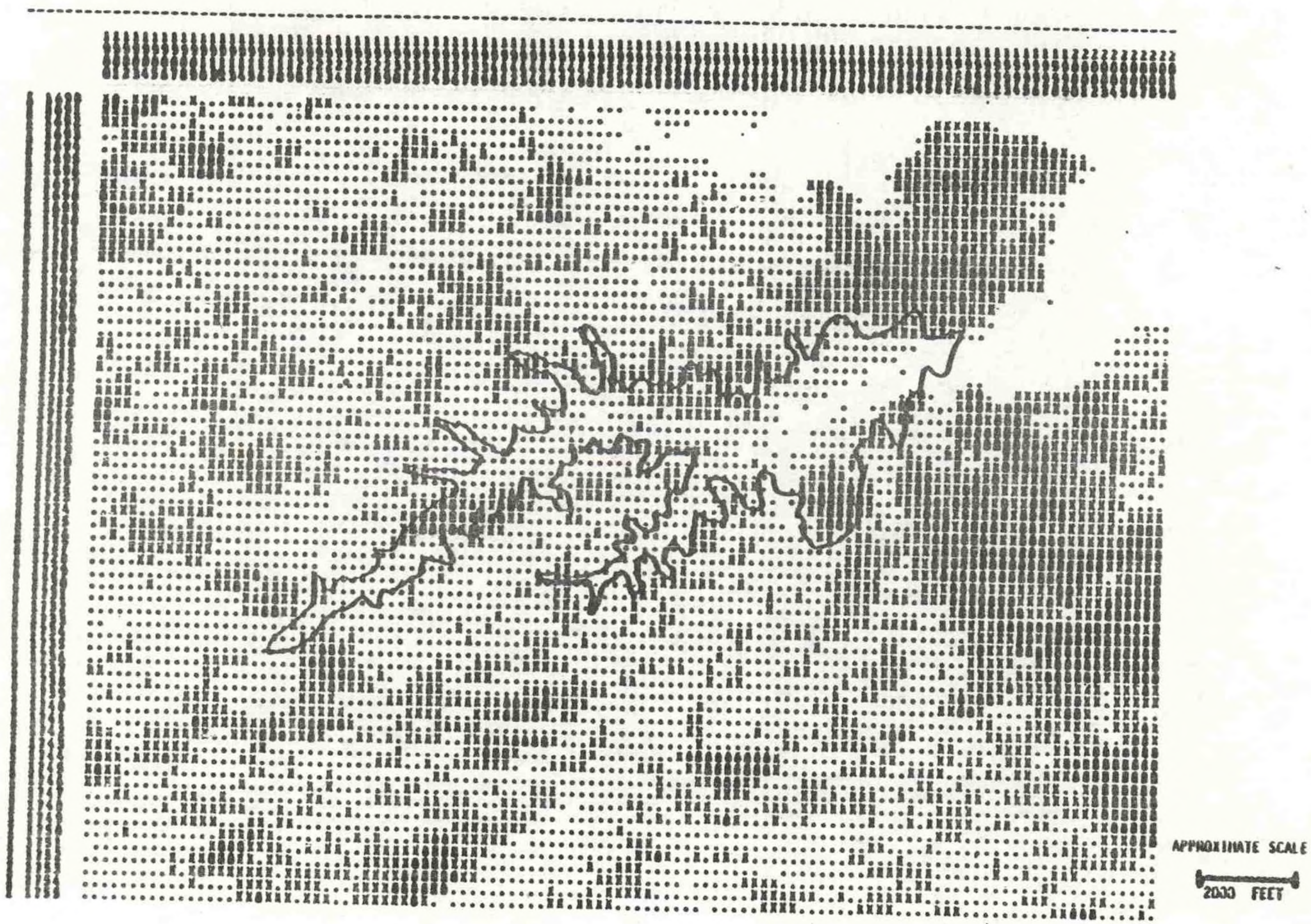


Figure A.16

Pocomoke River (TN14)

Pocomoke City Subarea

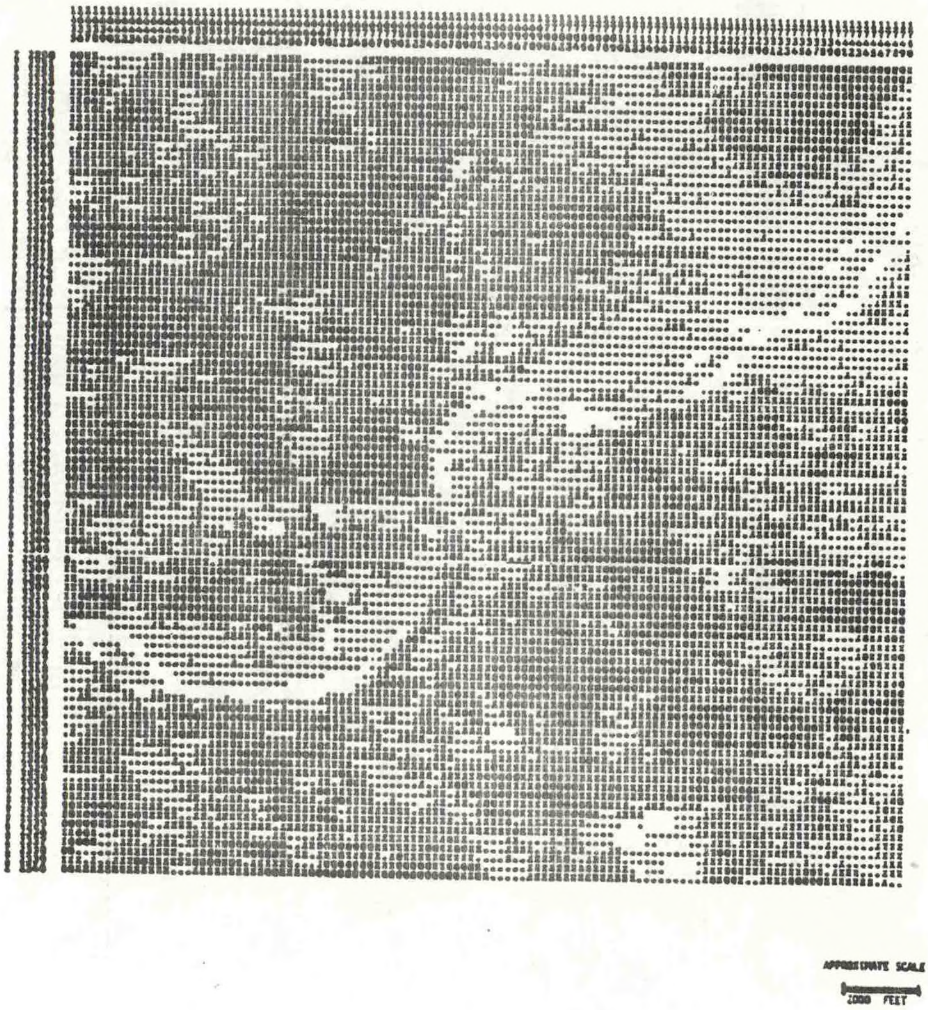
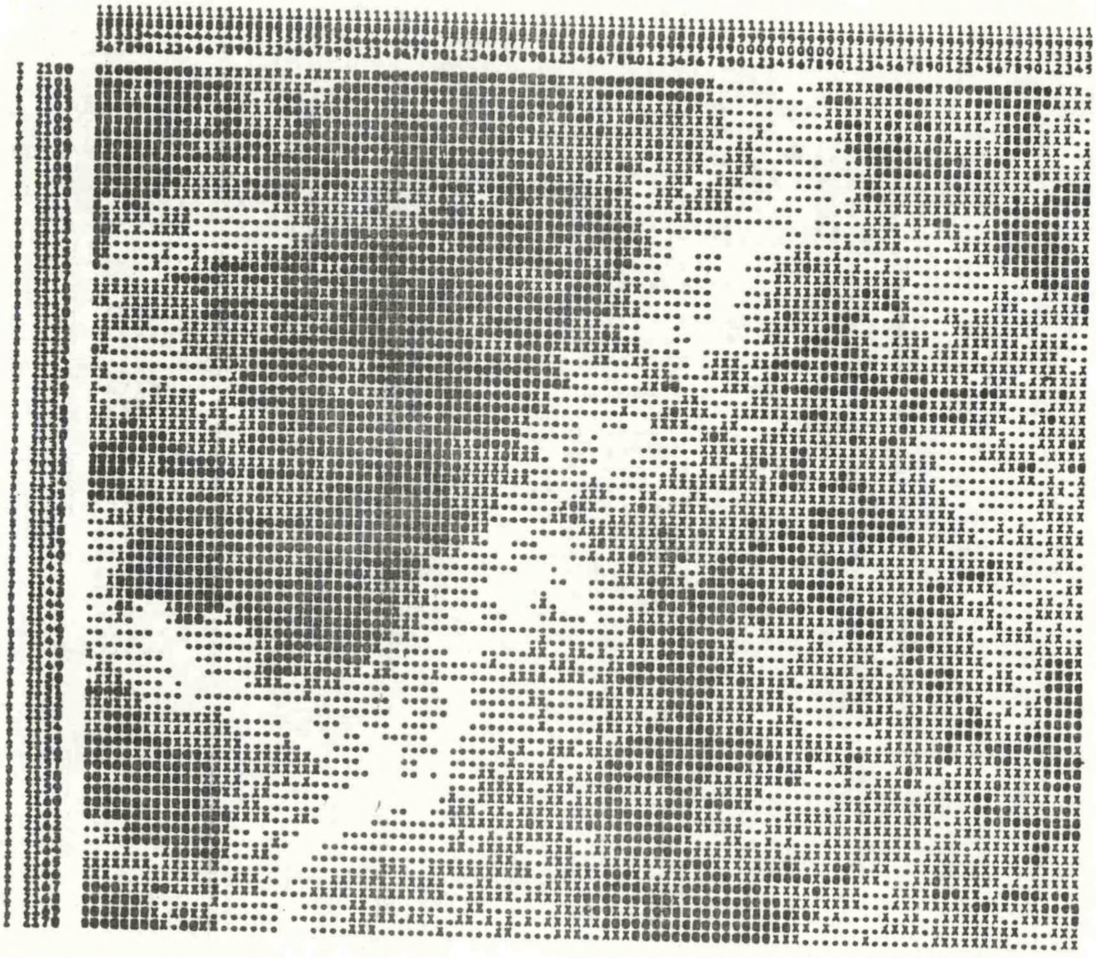


Figure A.16

Pocomoke River (TN 14)

Snow Hill Subarea



APPROXIMATE SCALE

2000 FEET

Figure A.17

Sullivan's Cove Marsh (T15)

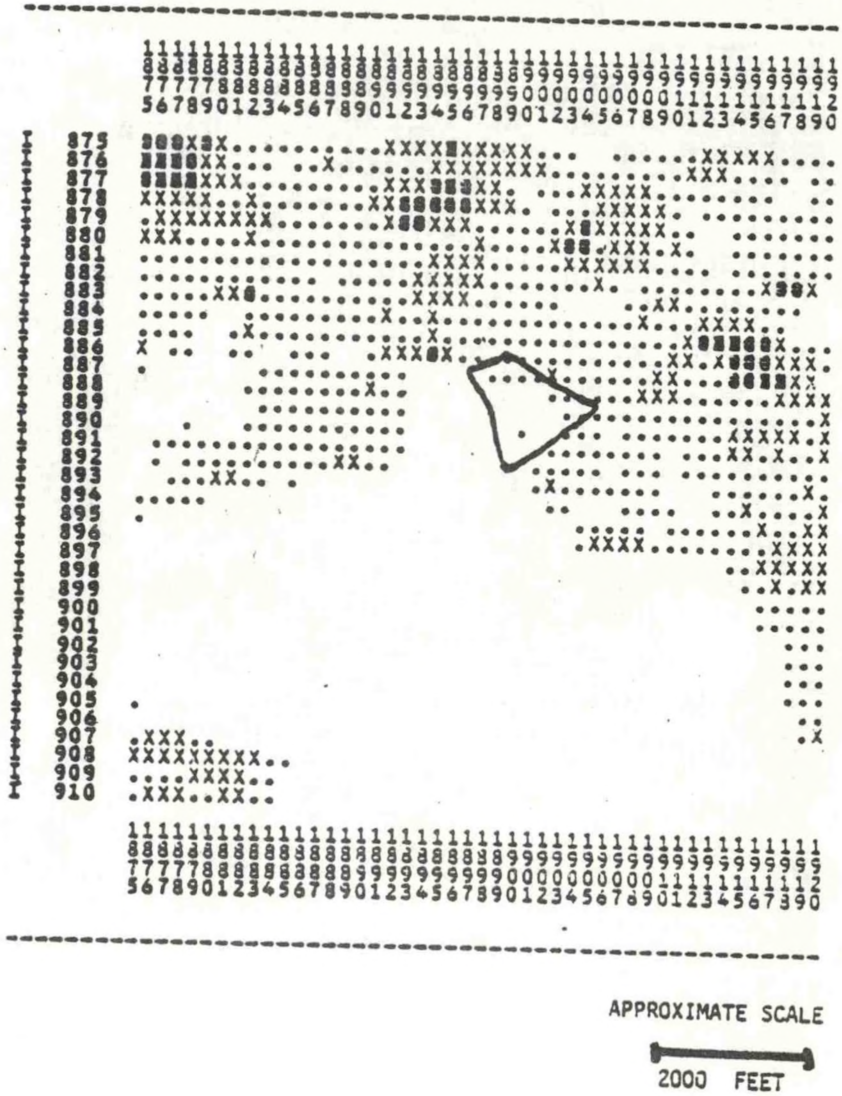


Figure A.18

Deep Pond/Beverly Beach (T16)

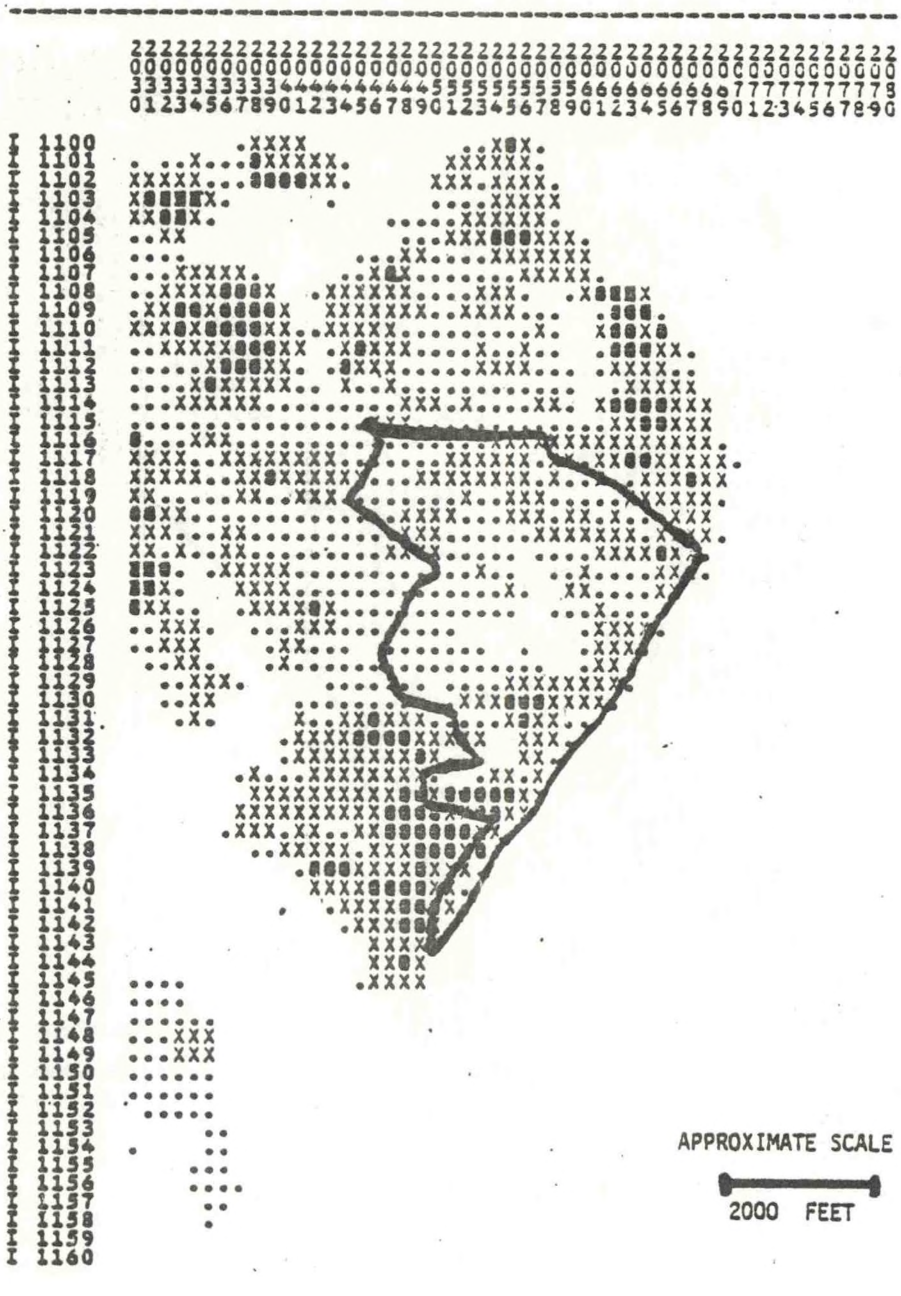


Figure A.19

Black Marsh (T17)

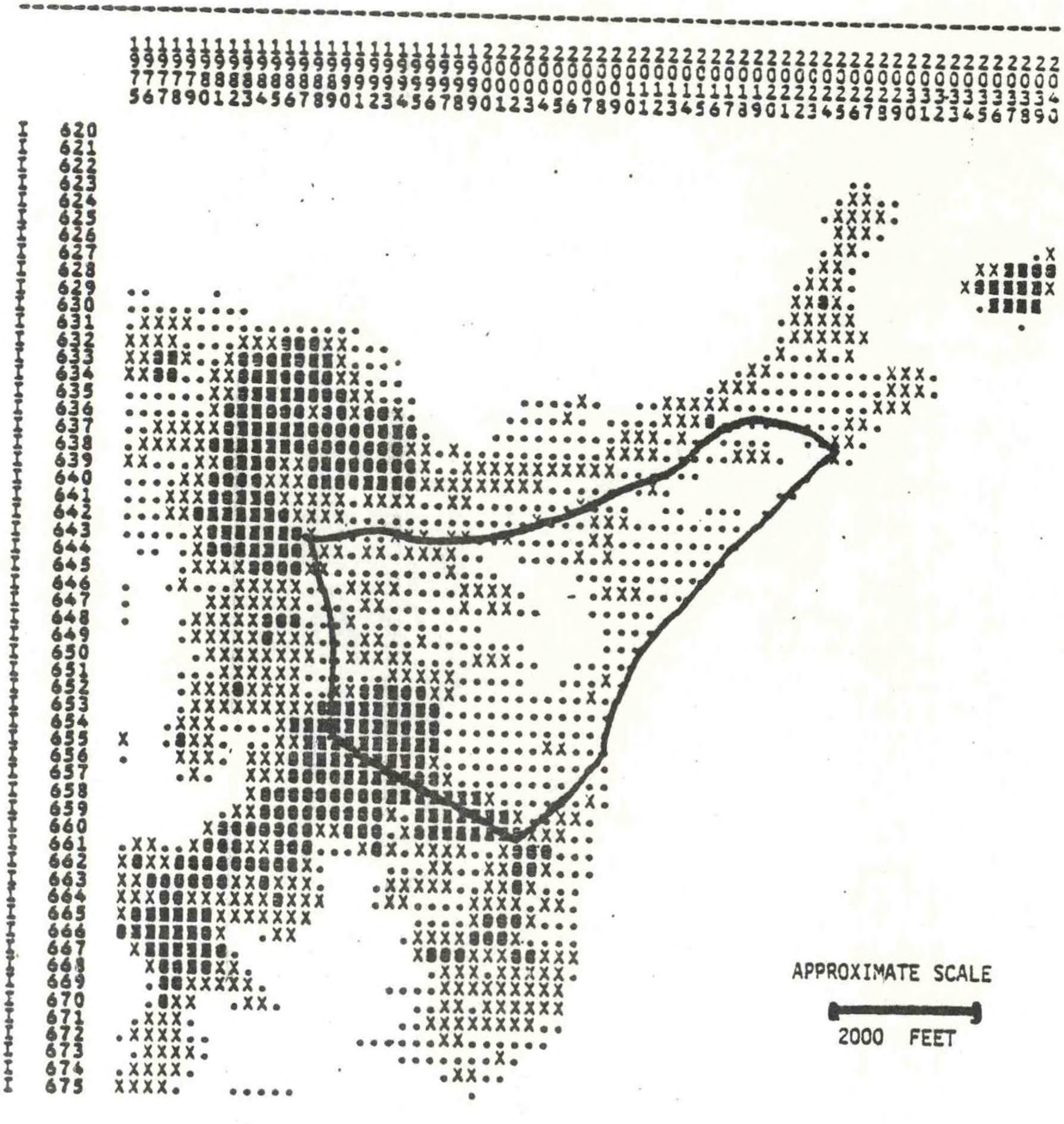


Figure A.20

Bush Creek Marsh (T18)

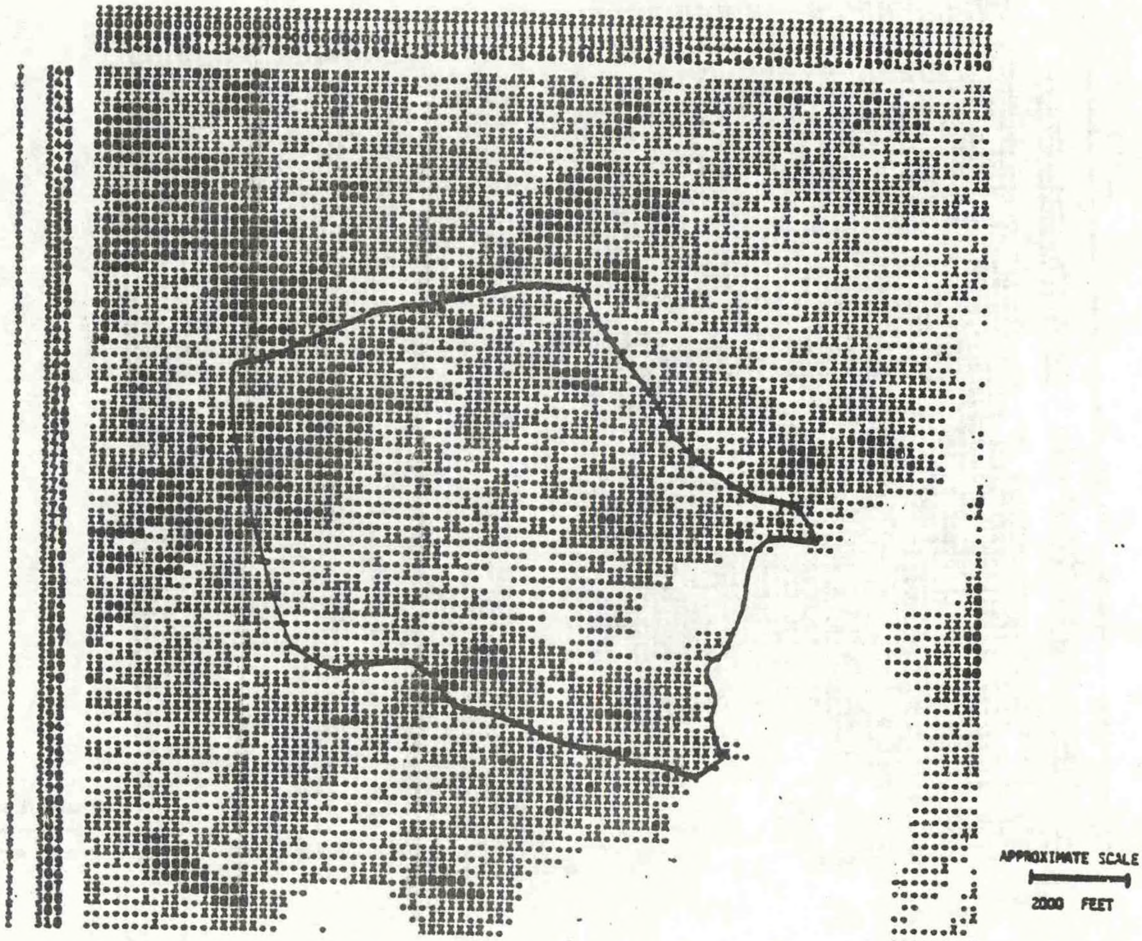


Figure A.21

Church Creek Marsh (T19)

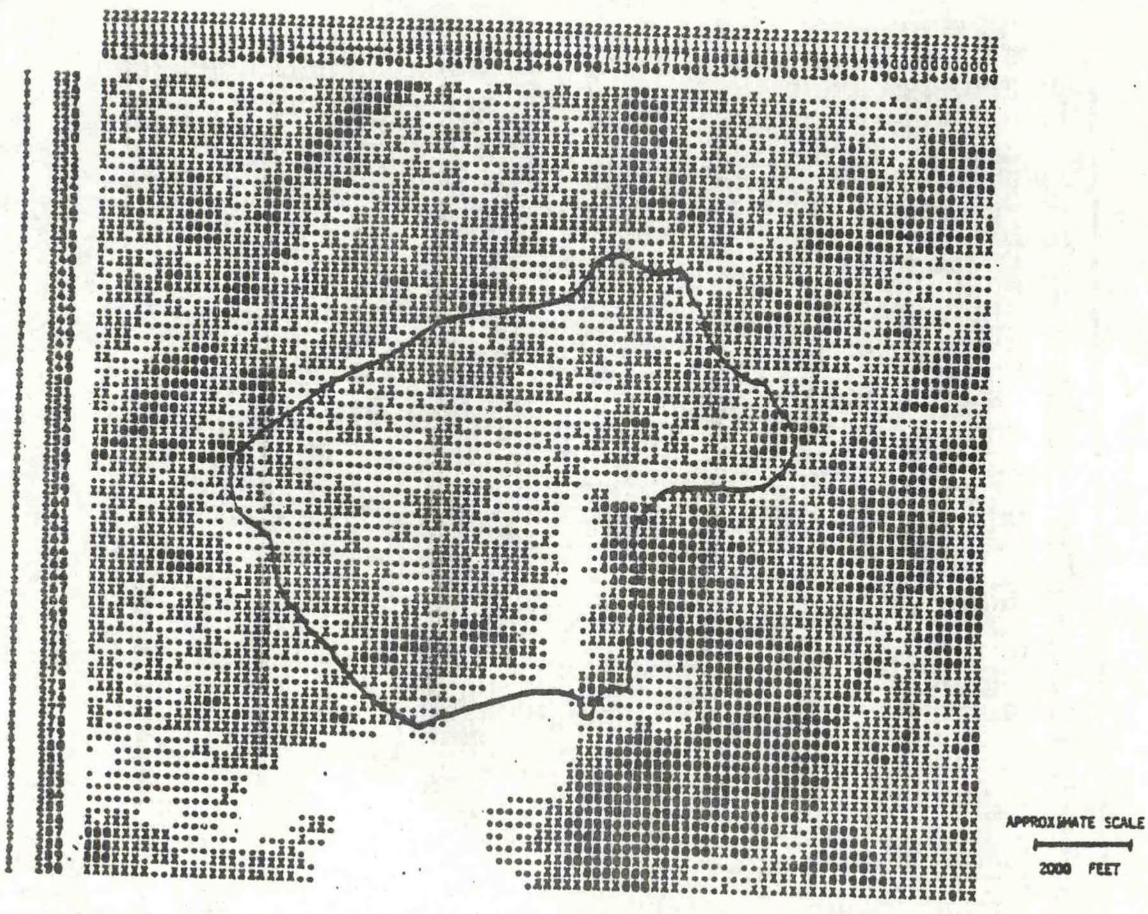


Figure A.22

Otter Point Creek Marsh (T20)

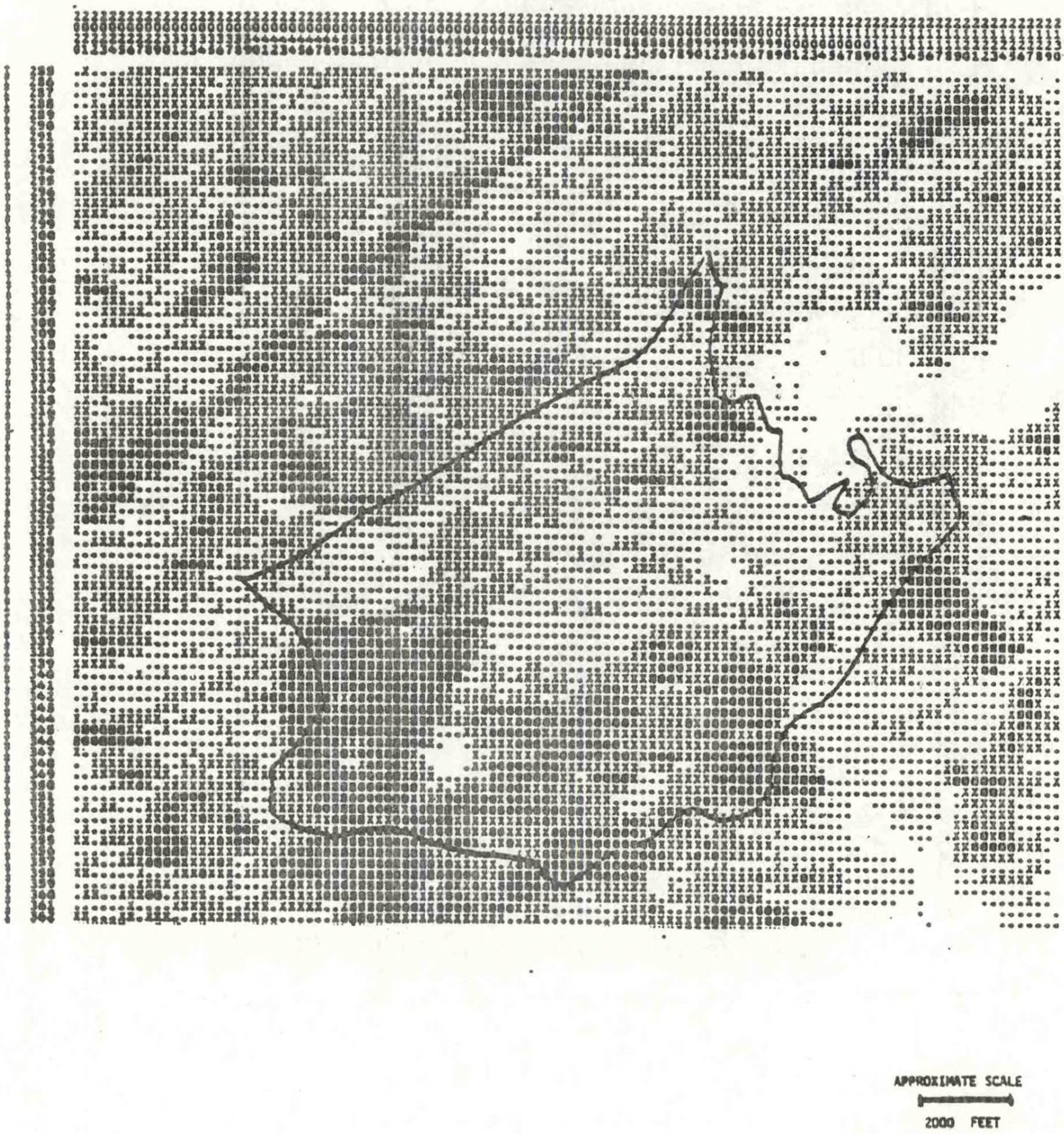


Figure A.23

Swan Creek Marsh (T21)

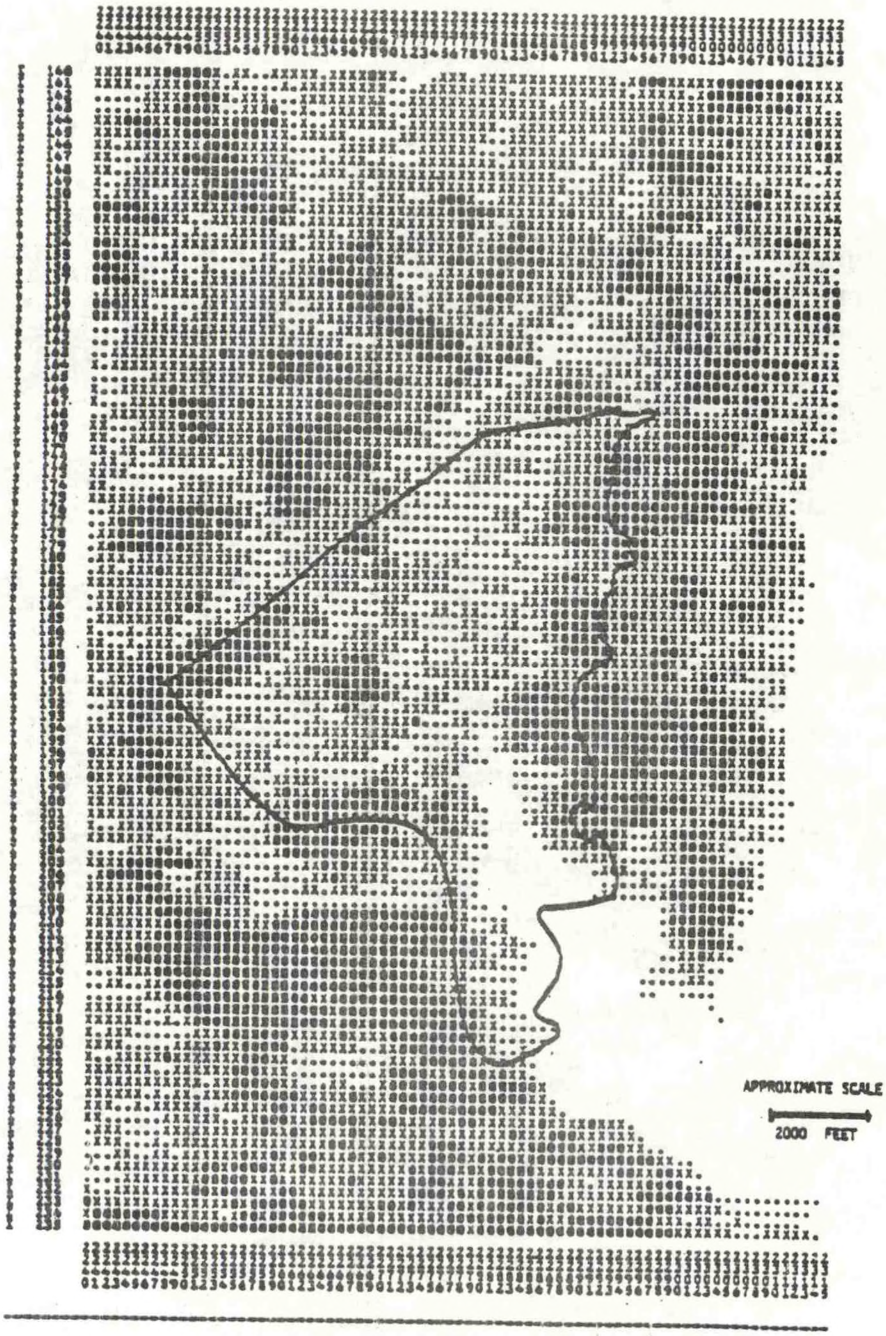


Figure A.24

Fresh Pond/Ansel's Bog (N13)

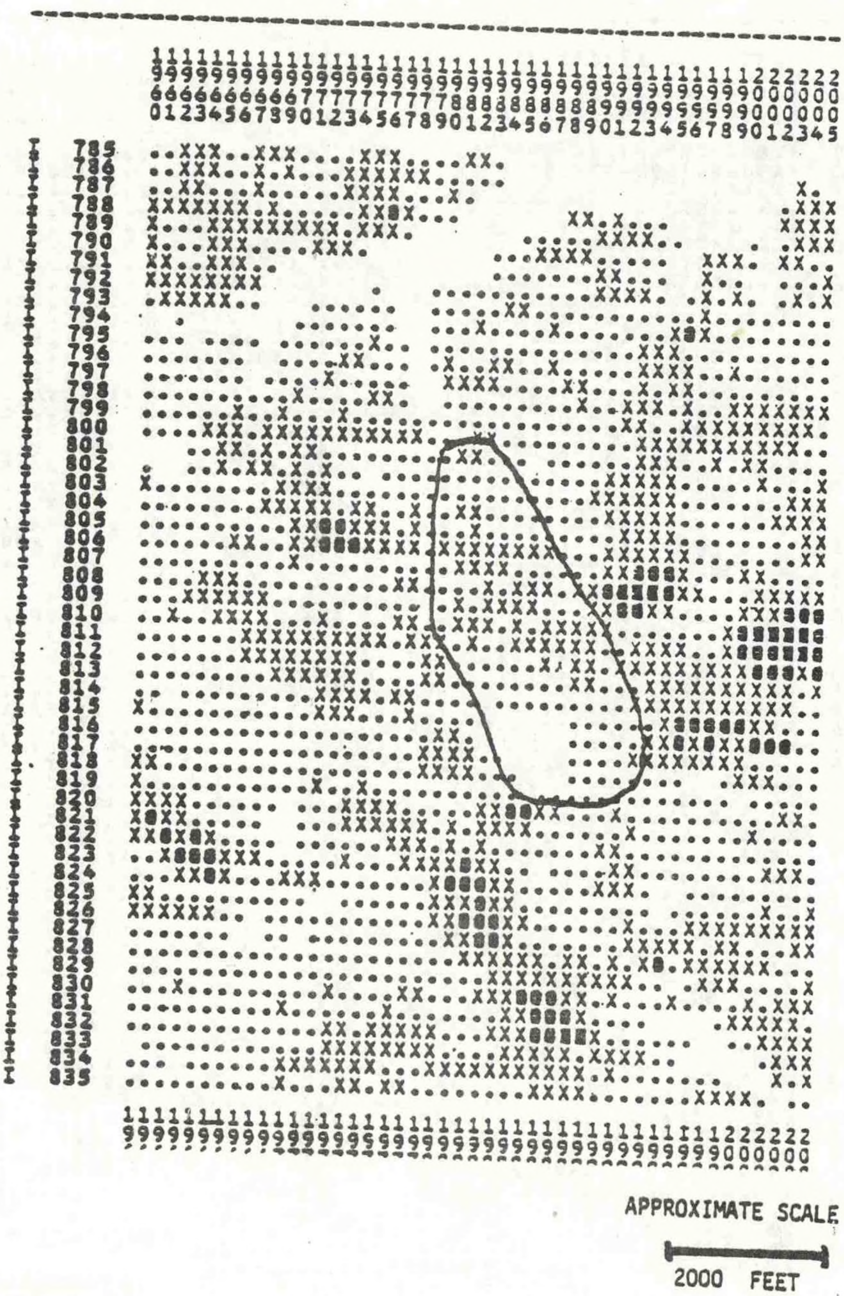
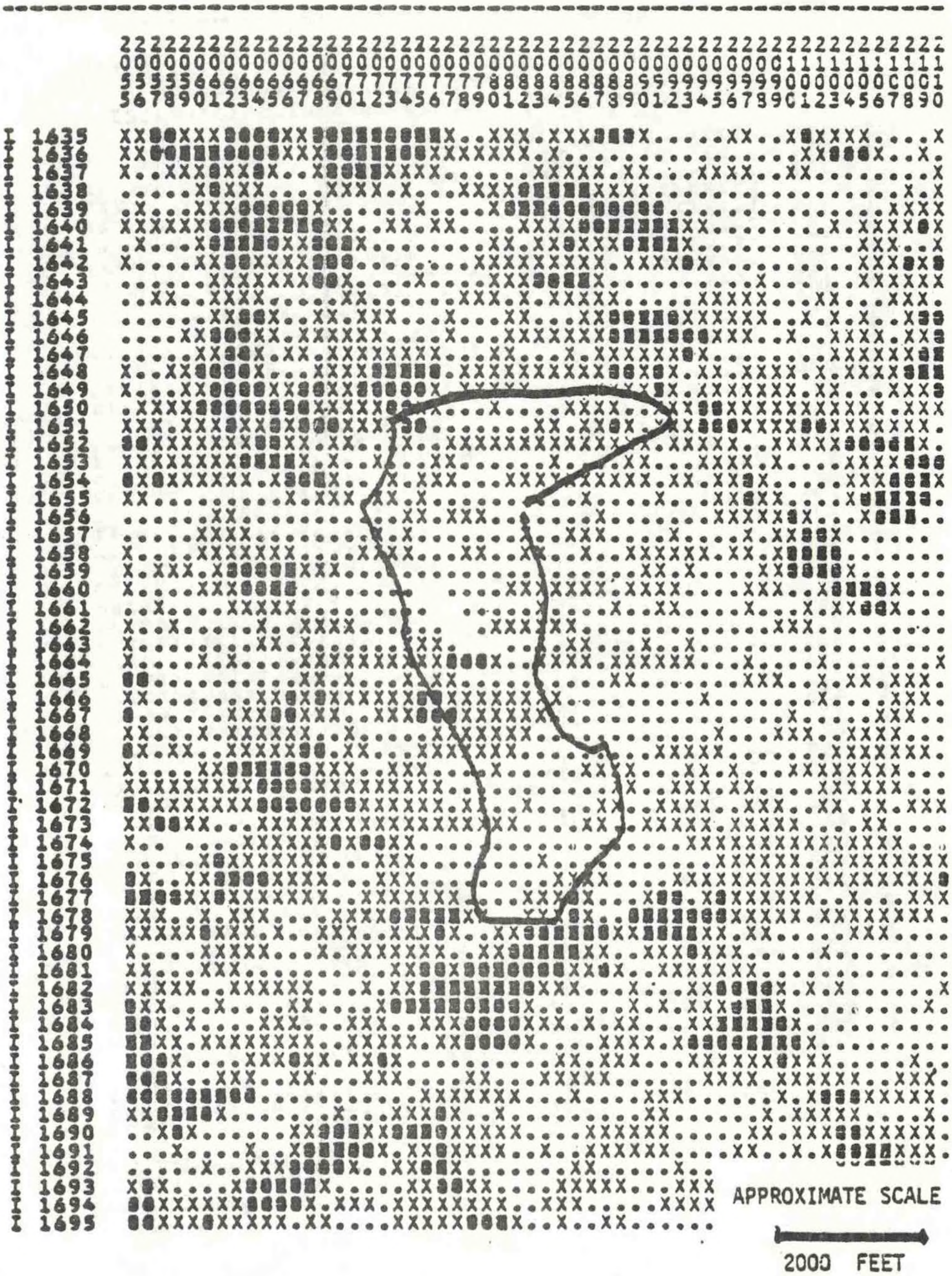


Figure A.25

Battle Creek Cypress Swamp (N16)



APPENDIX B - GLOSSARY

Active Sensor - A remote sensing system that transmits its own electromagnetic emanations at an object(s) and then records the energy reflected or refacted back to the sensor.

Adaptive Clustering (ADPCLU) - ADPCLU is a fast clustering algorithm that may be used as a starter for iterative clustering or as a separate classification/data analysis algorithm. This procedure makes extensive use of the stripping algorithm and requires only two passes through the data. During the first pass, the clusters are formed, split, and merged. During the second pass, the pixels are assigned to individual classes.

Algorithm - (1) A fixed step-by-step procedure to accomplish a given result; usually a simplified procedure for solving a complex problem; also a full statement of a finite number of steps. (2) A computer-oriented procedure for resolving a problem.

Band, Spectral - An interval in the electromagnetic spectrum defined by two wavelengths, frequencies, or wave numbers.

Buffer Area - That area immediately adjacent to an area of critical State concern which is vital to the integrity of the area, but does not contain the specific features or characteristics for which the site has been designated. It may be necessary to manage a buffer area, though less intensively than a designated critical area.

Channel, Spectral - ASTEP-II uses this term to denote the spectral values associated with each pixel. Thus, if the user selected LANDSAT MSS Bands 4, 6, and 7 for analysis, ASTEP-II subsequently refers to these as channels 1, 3, and 4, respectively.

Classification - The process of assigning individual pixels of a multispectral image to categories, generally on the basis of spectral-reflectance characteristics. Digital classification involves computer manipulation of LANDSAT MSS digital values singly or in combination including spatial, temporal, and spectral band relationships for the purpose of representing aggregates of pixels as specific surface features.

Clustering - Mathematical procedure for organizing multispectral data into spectrally homogeneous groups. Clusters require identification and interpretation in a post-processing analysis.

Computer Compatible Tapes - Tapes containing digital LANDSAT data. These tapes are standard 19-cm (71/2-in) wide magnetic tapes in 9-track or 7-track format. Four tapes are required for the four-band multispectral digital data corresponding to one LANDSAT scene.

Contrast Stretching - A mathematical procedure usually performed by a computer to artificially increase the contrast in an image by expanding the range of digital values to utilize the full contrast range of the display device, thus making certain features stand out sharply.

Critical Limit - A statistically allowable distance from a known class spectral signature mean that an unknown pixel must fall within in order to be identified with that class.

Data Preprocessing - Manipulating or reformatting of raw, uncorrected data for standardization purposes prior to further analysis.

Density (Level) Slicing - The process of converting the continuous gray tone of an image into a series of density intervals, or slices, each corresponding to a specific digital range or feature of interest.

Deskewing - Data preprocessing procedure by which image geometry is corrected by resampling or reformatting the raw data set.

Digital Image Processing - Encompasses all the various operations that can be applied to digital image data. These include, but are not limited to, image compression, image restoration, image enhancement, preprocessing, quantization, spatial filtering and other image pattern recognition techniques.

Electromagnetic Spectrum - the ordered array of known electromagnetic radiations extending from the shortest cosmic rays, through gamma rays, X-rays, ultraviolet radiation, visible radiation, infrared radiation, and including microwave and all other wavelengths of radio energy.

Geocorrected Data - Image data sets that have been adjusted to change their geometrical character, usually to improve their geometrical consistency or cartographic utility.

Ground Control Point - An identifiable ground feature (e.g., a road intersection) which can be located in LANDSAT data and on a map, and referenced to a coordinate system. A series of these points can be used to geographically reference the LANDSAT data.

Ground Truth - Term coined for data obtained on surface or subsurface features to aid in interpretation of remotely sensed data. Information concerning the actual state of the environment at the time of a remote sensing overflight.

Image - (1) The recorded representation of an object produced by optical, electro-optical, optical mechanical, or electronic means. It is the term generally used when the radiation emitted or reflected from a scene is not directly recorded on film. (2)

The optical counterpart of an object, produced by a lens, mirror, or other optical system.

Image Enhancement - Any one of a group of operations that improve the detectability or interpretability of earth features or categories. These operations include, but are not limited to, contrast improvement, edge enhancement, spatial filtering, noise supression, ratioing, image smoothing, and image sharpening.

Impact Area - The area where activity and uses, if not properly managed, could have an adverse impact on the designated area or the buffer area.

Infrared - Pertaining to energy in the 0.7-100 um wavelength region of the electromagnetic spectrum. For remote sensing, the infrared wavelengths are often subdivided into near infrared (0.7-1.3 um), middle infrared (1.3-3.0 um), and far infrared (7.0-15.0-um). Far infrared is sometimes referred to as thermal or emissive infrared.

Iterative Process - A computational procedure in which replication of a cycle of operations produces results which approximate the desired result more and more closely.

Micrometer
- Formerly called a "micron," equals one-millionth of a meter; symbol um.

Multispectral Scanner - A line-scanning sensor which uses an oscillating or rotating mirror, a wavelength-selective dispersive mechanism, and an array of detectors to measure simultaneously the energy available in several wavelength bands, often in several spectral regions. The movement of the platform usually provides for the along-track progression of the scanner.

Numerical Analysis - Computer-assisted analysis techniques by which digital remote sensing data may be analyzed and classified quantitatively, as opposed to optical or manual remote sensing image analysis.

Passive Sensors - Remote sensing systems which detect radiant energy emitted or reflected from targets. The source for this radient energy comes from the general environment, and not from the remote sensing system itself.

Path/Row
- A worldwide reference system for nominal LANDSAT frame locations. Used to reference data at EROS Data Center.

Photo - A photographic picture produced directly and simultaneously on a film emulsion from reflected electromagnetic radiation of wavelengths in the visible and near infrared portions of the spectrum; compared to an electronically-scanned image.

Photogrammetry - The art or science of obtaining reliable measurements by means of photography.

Pixel - (Derived from "picture element.") A data element having both spatial and spectral aspects. The spatial variable defines the apparent size of the resolution cell (i.e., the area on the ground represented by the data values), and the spectral variable defines the intensity of the spectral response for the cell in a particular channel. The size of a pixel is determined by the altitude of the remote sensing system and the instantaneous field of view of the detector. One LANDSAT MSS pixel covers an approximately 57-by-79 meter or 1.1 acre rectangular geographic area.

Polygon - The perimeter of a training area whose row/column coordinates are fed into the computer during the signature extraction phase of a supervised classification.

Quad - Short for a U.S. Geological Survey 7.5 or 15 minute topographic quadrangle map.

Ratioing - A statistical data enhancement procedure of dividing spectral values for one channel by those from another channel, thus giving the investigator additional statistical information about an earth feature's spectral signature.

Registration - The process of geometrically aligning two or more sets of image data such that reference points can be digitally or visually superimposed. Data being registered may be of the same type, from very different kinds of sensors, or collected at different times.

Remote Sensing - In the broadest sense, the measurement or acquisition of information of some property of an object or phenomenon under study; for instance, the utilization at a distance (as from aircraft, spacecraft, or ship) of any instrument and its attendant recording and display devices for gathering information pertinent to the environment, such as measurements of force fields, electromagnetic radiation, or acoustic energy. The technique employs such devices as the camera, lasers, and radio frequency receivers, radar systems, sonar, seismographs, gravimeters, magnetometers, multispectral scanners, and scintillation counters.

Resampling - Involves statistical techniques for reorienting or geo-referencing remote sensing data to a coordinate map system.

Resolution - The smallest unit of measure or distance which can be discerned from remote sensed data, determined by the ability of a remote sensing system to distinguish signals that are close to each other spatially, spectrally, temporally, or radiometrically. A ground resolution unit is the smallest area on the surface of a feature which is remotely sensed for which discrete spectral data can be acquired. (see pixel.)

Spectral Reflectance - The reflectance of electromagnetic energy at specified wavelength intervals.

Spectral Signature - Quantitative measurement of the properties of an object at one or several wavelength intervals. A specific feature or field of LANDSAT data has an associated mean and covariance matrix is the signature of that feature or field.

Supervised Classification - Classification of images using statistics developed from training sites. A computer-implemented process through which each measurement vector is assigned to a class according to a specified decision rule, where the possible classes have been defined on the basis of representative training samples of known identity.

Thematic Mapper - A new remote sensing system on LANDSAT-4 with more and different wavelength detectors than the standard multispectral scanner (MSS) system.

Topo - Short for topographic, as in topographic quadrangle map or "topo quad."

Training - Informing the computer sytem which sites to analyze for spectral properties or signatures of specific land cover classes; also called signature extraction.

Training Areas - Also referred to as training sites, training fields, or training samples. Recognizable areas on an image with distinct (spectral) properties useful for identifying other similar areas. A training area that is a relatively small subset of a larger field is selected in order to develop unique feature signatures. Each training area should contain a single homogeneous feature, and all training areas should be sufficiently heterogeneous to be identifiable as distinguishable categories.

Unsupervised Classification - Computer classification of digital images by placing similar pixels into categories without the aid of training-site data. (See Clustering.)

Vegetative Index - A spectral data enhancement measure based on the addition, subtraction, multiplication, and/or division of spectral values from two or more channels. Ratioing is a good example.

Wetlands - Land areas containing excessive moisture or hygrophytic conditions, including forested swamps, vegetated marshes, and exposed mudflats. Distinguished in this study as tidal or non-tidal.

Window - An intensive study area or portion of a LANDSAT data tape to be analyzed and classified.

A C R O N Y M S

ADPCLU - Adaptive clustering algorithm in ASTEP.

ALLSIG - An ASTEP program which compiles all training area polygon data for a given land cover class and computes a spectral signature for that class.

ASTEP - Algorithm Simulation and Test Evaluation Program, a menu-oriented, interactive, and conversational system of over 100 programs and subroutines designed to lead the user through the analytic process of interpreting remotely sensed multispectral data.

CCT - Computer compatible tape

DCLASS - An ASTEP program for a supervised classification that classifies unnormalized data minimizing the distance of separation.

DNR - Maryland Department of Natural Resources.

DSP - Maryland Department of State Planning.

EPA - U.S. Environmental Protection Agency.

EROS - Earth Resources Observation Systems program, centered at Sioux Falls, South Dakota.

MCZMP - Maryland's Coastal Zone Management Program.

MSS - Multispectral scanner.

NASA - National Aeronautics and Space Administration.

NHAP - National High Altitude Photography Program, which provides a data base for mapping and resource management.

NOAA - National Oceanic and Atmospheric Administration.

QUANTZ - An ASTEP program which produces an image of a single channel of spectral data, based upon density slicing of spectral reflectance histograms.

SCS - Soil Conservation Service.

USDA - U.S. Department of Agriculture.

USFWS - U.S. Fish and Wildlife Service.

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