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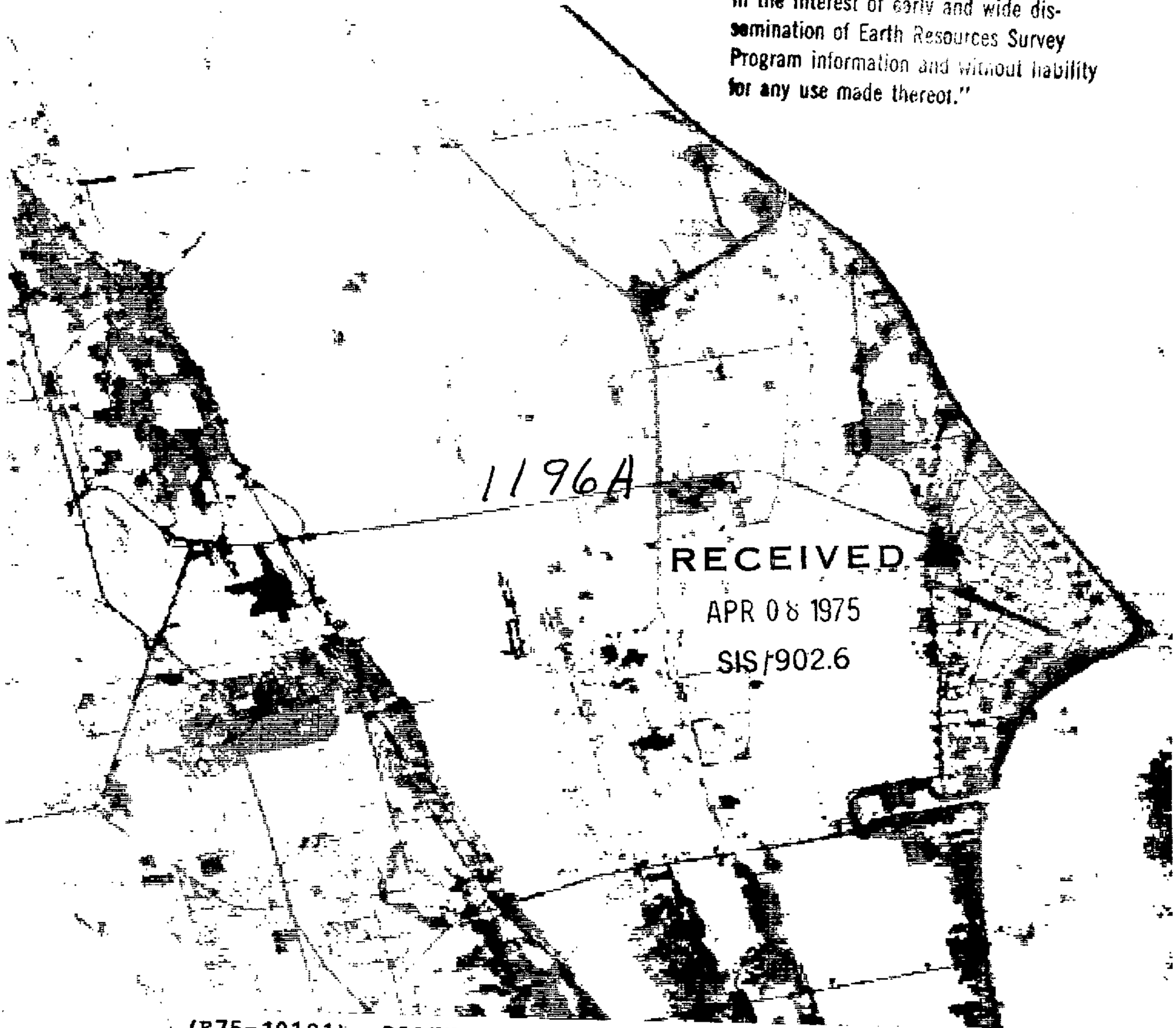
ERTS-1 FINAL REPORT

PLANNING APPLICATIONS IN EAST CENTRAL FLORIDA

PROPOSAL NO. Y-10-006-001

BREVARD COUNTY PLANNING DEPARTMENT

REPORT NO. BCPD L1-12



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PLANNING APPLICATIONS IN EAST CENTRAL FLORIDA

PROPOSAL NO. Y-10-006-001

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16. Abstract

This is a study of applications of ERTS data to planning problems, especially as applicable to East Central Florida. The primary method has been computer analysis of digital data, with visual analysis of images serving to supplement the digital analysis. The principal method of analysis was supervised maximum likelihood classification, supplemented by density slicing and mapping of ratios of band intensities. Land-use maps have been prepared for several urban and non-urban sectors. Thematic maps have been found to be a useful form of the land-use maps. Change-monitoring has been found to be an appropriate and useful application. Mapping of marsh regions has been found effective and useful in this region. Local planners have participated in selecting training samples and in the checking and interpretation of results.

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PREFACE

OBJECTIVE:

The general objective of this project has been the investigation of applications of ERTS data to planning problems, with emphasis on East Central Florida. These applications have been divided into three categories:

(1) land-use mapping

(2) change monitoring

(3) routine planning problems

SCOPE OF WORK:

Digital computer techniques using computer-compatible tapes have served as the primary analysis method, supplemented by visual observation of images. Computer techniques are primarily mapping based on maximum likelihood classification, density slicing, and band ratios.

The area under study has been that area comprising the domain of the East Central Florida Regional Planning Council and consisting of six counties: Brevard, Indian River, Lake, Orange, Osceola, and Seminole

Land-use and thematic maps of several urban and non-urban areas have been prepared and analyzed.

CONCLUSIONS:

Land-use mapping by computer classification techniques applied on a regional and county basis and, for some purposes, a city basis, is a useful application of ERTS data, particularly when oriented toward change-monitoring.

SUMMARY OF RECOMMENDATIONS:

Development of use of satellite data as a planning tool should continue on two fronts: (1) continued improvement of techniques for classification, mapping, and change-monitoring, and (2) increased involvement of practicing planners in use of the data.

Timeliness of data dissemination is less critical for most planning applications than for some other applications but is still important.

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PERSONNEL

The project has been under the general administrative supervision of John W. Hannah, Brevard County Development Coordinator. Garland L. Thomas has been responsible for the technical work.

Fernando Esparza has been responsible for the computer work and has done much of the program development. James J. Millard has done the bulk of the computer programming, has handled the details of the computer runs, and has participated in the interpretation of results.

Homer Royals, of the Florida Game and Fresh Water Fish Commission, collaborated in planning the lake eutrophication study, has done the sampling and analysis, and has participated in interpretation of results. He is a co-investigator for that part of the work.

OBJECTIVES

The general objective of this project has been the investigation of applications of ERTS data to planning problems, with emphasis on East Central Florida. These applications have been divided into three categories:

(1) land-use mapping

(2) change monitoring

(3) routine planning problems

METHODS

VISUAL INTERPRETATION

Visual interpretation has been used to a limited extent, mainly as a supplement to computer methods. Visual correlation with computer analysis is essential to provide guidance for the computer work and to help in providing interpretation.

Before our computer programs became operational, some analyses relating to variations in radiance were done on an I^2S Digicol instrument. We now find that most information of that kind can be obtained more accurately by computer methods, with visual observation and Digicol viewing used to supplement and guide the computer work.

COMPUTER DENSITY SLICING

The first stage of our computer work has been centered around density-slicing and mapping. While, for most purposes, it has been superseded by direct classification, density slicing is still useful for several purposes:
(1) making preliminary maps of an area for locating training samples.
(2) obtaining the integrated radiance for a specific band and area.
(3) observing patterns of intensity of development in urban areas, and
(4) obtaining patterns of reflectance in lake eutrophication studies.

COMPUTER CLASSIFICATION

In a late stage of the contract period, a maximum likelihood classification program was completed and put into operation. This program now serves as our primary means of obtaining land use information. Density-sliced maps or maps showing ratios of radiances in two bands are used to locate training samples for input into the classification program.

Fernando Esparza of Kennedy Space Center, has been in charge of the computer work and, in consultation with G. L. Thomas, has developed most of the flow schemes. The bulk of the programming has been done by James J. Millard, who also has been responsible for the individual runs and has participated in interpretation of results.

Programs developed during the period of this report and now operational are:

(1) Hex Data Dump

Prints out specified data from ERTS tape in hex format.

(2) Radiance Data Dump

Prints out specified data from an ERTS tape in radiance units (milliwatts/cm^2-s steradian)

(3) Histogram Program

Plots histograms (number of occurrences vs. count number) for each band or the ratio of the radiances in any two bands (number of occurrences vs. logarithm of ratio of radiances). Can be used for any designated polygon. For histograms of single bands, results are tabulated in terms of number of occurrences and fraction of total number of occurrences for each count number.

(4) Density-sliced mapping program

Assigns designated printer character to designated intensity ranges (specified in counts) for any band or the ratio of radiances in any two bands (logarithm of ratio of intensities) and produces a printer map of the resulting pattern. Up to nine intensity or ratio levels can be mapped. Since the designation of intensity levels or ratio values is arbitrary, this program has the capability of stretching any specified portion of the band(s).

(5) Classification Program

The principal feature of this program is the maximum likelihood classification procedure, which is based on the mathematical method outlined by Swain.[1] Since this method is rather costly in terms of computer time, two other alternatives were added to provide perhaps less exact results at reduced computer time. They are: (a) classification according to the class which has its centroid the least Euclidean distance from the point being classified, and (b) choosing the three nearest classes by the above distance measurement and then using the maximum likelihood method to make the final choice from among those three classes. For purposes of discussion, we shall refer to these three options as MAXLIK, MINDIST, and MAX/MIN, respectively.

After classification is concluded for each data sample, the appropriate class character is assigned for mapping. Concurrently, a character count for each class is maintained for tabulation and use during analysis of the requested rectangular area under investigation. Up to eight classes may be mapped at one time.

(6) Matrix Tape File Generation Program

This program computes the necessary parameters needed for classification by any of the above three methods from training data samples. Parameters include the covariance matrix for each class and the matrix determinant and centroid values of each band for each class. The parameters then are recorded on magnetic tape for use in the other programs described. Different files have been created for various areas under investigation as well

[1] Philip N. Swain. Pattern Recognition: A Basis for Remote Sensing Data Analysis. LARS Information Note 111572 (9/10/73)

as for each ERTS data set used due to differing radiance values caused by differing atmospheric conditions and sun angles.

(7) Character Counting Program

This program yields the character count and fraction of the total for each class with the added capability of examining any polygonal-shaped region. (The mapping program is restricted to rectangles). The logic of the classification program is used except for mapping output.

The programs are written for the GE-635 computer, and all computer work has been done on the GE-635 at Kennedy Space Center.

RESULTS

VISUAL INTERPRETATION

While it is perhaps trite to say, it is nevertheless true that planners and public officials can benefit from the general background information and perspective gained from looking at the "big picture", such as an enlargement of a Skylab photograph or an ERTS color composite. In addition, certain specific information can be obtained, such as: extent of urban growth, flood plains, transportation needs, appropriateness of regions for development, extent of marsh, and extent and location of marsh drainage and encroachment.

Machine-aided visual interpretation also has a place. In this project, an I^2S Digicol Viewer has been used to observe the relative intensities of development of sectors in individual cities, such as Orlando, where major "bright spots" were found to represent centers of industrial and commercial activity and one newly-developed residential sector.

Observations of several of the small cities along the Florida East Coast has brought out a characteristic development pattern, illustrated by Daytona Beach, Figure 1, in which the numbers represent the following typical features:

(1) intensely developed beach region.

(2) commercial spot development at the western edge of the city, at interstate highway exit.

(3) central business district, located along U. S. highway 1.

(4) residential sector, located mostly west of U. S. 1.

One unanticipated result brought out by both visual observation and computer maps is that residential developments having networks of streets but presently few residents have the appearance of cities. Examples are Deltona, Port St. John and the new section of Port Malabar.

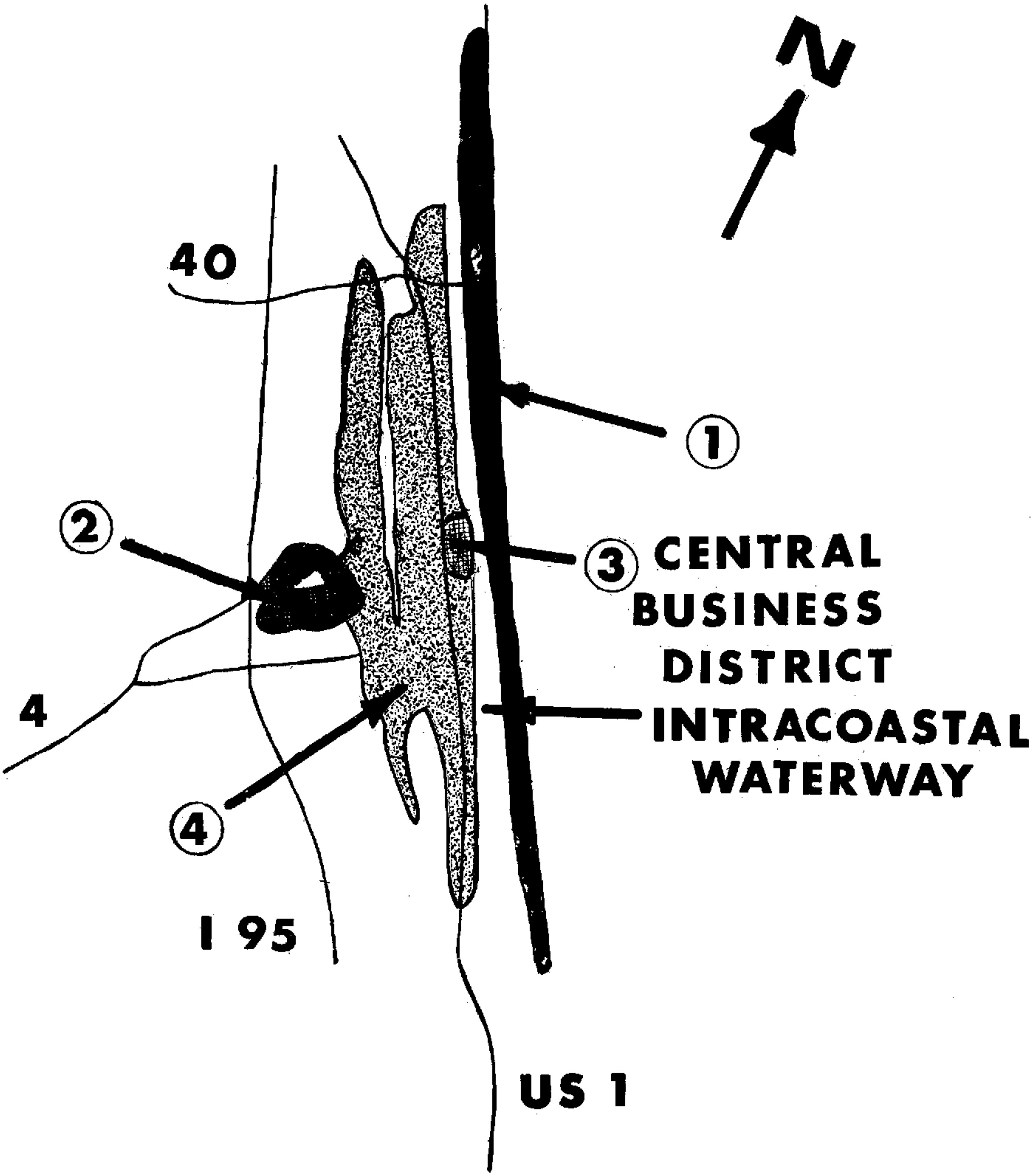

Figure 1

Daytona Beach

ENVIRONMENTAL INDICATOR

Due to the relatively high reflectance of concrete and asphalt in bands four and five and the relatively low reflectance of vegetation in those bands, it seems feasible to develop environmental indicators based on area/reflectance or population/reflectance. Using the Digicol densitometer and a band 5 image, we have made some test measurements of such a quantity, with the results shown in Table 1, where the numerical values are only relative. Since we think this measurement can be made more accurately by computer methods, we expect to continue the measurements in that way.

LAND-USE MAPPING

Non-urban

Some land-use mapping of non-urban areas has been done to illustrate its feasibility for this part of Florida. Figures 2 and 3 are an example for two adjoining sectors of the northwest corner of Brevard County. They were made by the maximum likelihood classification program, with a 7/5 ratio map used for locating training samples, and with identification of training samples based on photography and local knowledge. The north side of Figure 3 adjoins the south side of Figure 2. Water is represented by blank and marsh by S. Since the B's, which represent bare sand and man-made features, are easily mistaken for S's, groups of B's are outlined and numbered; (4) represents spots of bare sand, (5) represents an interstate exit with some commercial activity, (6) represents a mobile home park, and (7) represents residential sectors. Thus, un-outlined dark portions are marsh; and outlined dark portions are bare sand and man-made features. Outlined sectors designated as (1) are mixed palms-palmetto-hardwood. The extensive regions designated as (3) are difficult to classify by any method; they are mixed palmetto-pine-grasses, with occasional marshy spots. Outlined sectors designated as (2) are stands of cypress. The region designated as (8)

REGION OR CITY	RADIANCE	RADIANCE	(persons/ha)	(units/ha)	RADIANCE
Beach-dune area at New Smyrna Beach	.83				
Patrick Air Force Base	.65				
Industrial Area, Cape Kennedy Air Force Station	.58				
Port St. John	.58	1076	Area 2: 6.0 Total : 1.2	2.0 .4	1.6
Deltona	.60				
Vehicle Assembly Building, Kennedy Space Center	.54				
Merritt Island	.49	3933	4.0		8.1
Daytona Beach	.49				
Headquarters Area, Kennedy Space Center	.48				
Titusville	.49	1987	6.1		15.4
Cocoa	.48	2090	4.4		12.7
Cocoa Beach	.48				
Region south of Patrick Air Force Base	.41				
New Smyrna Beach	.39				

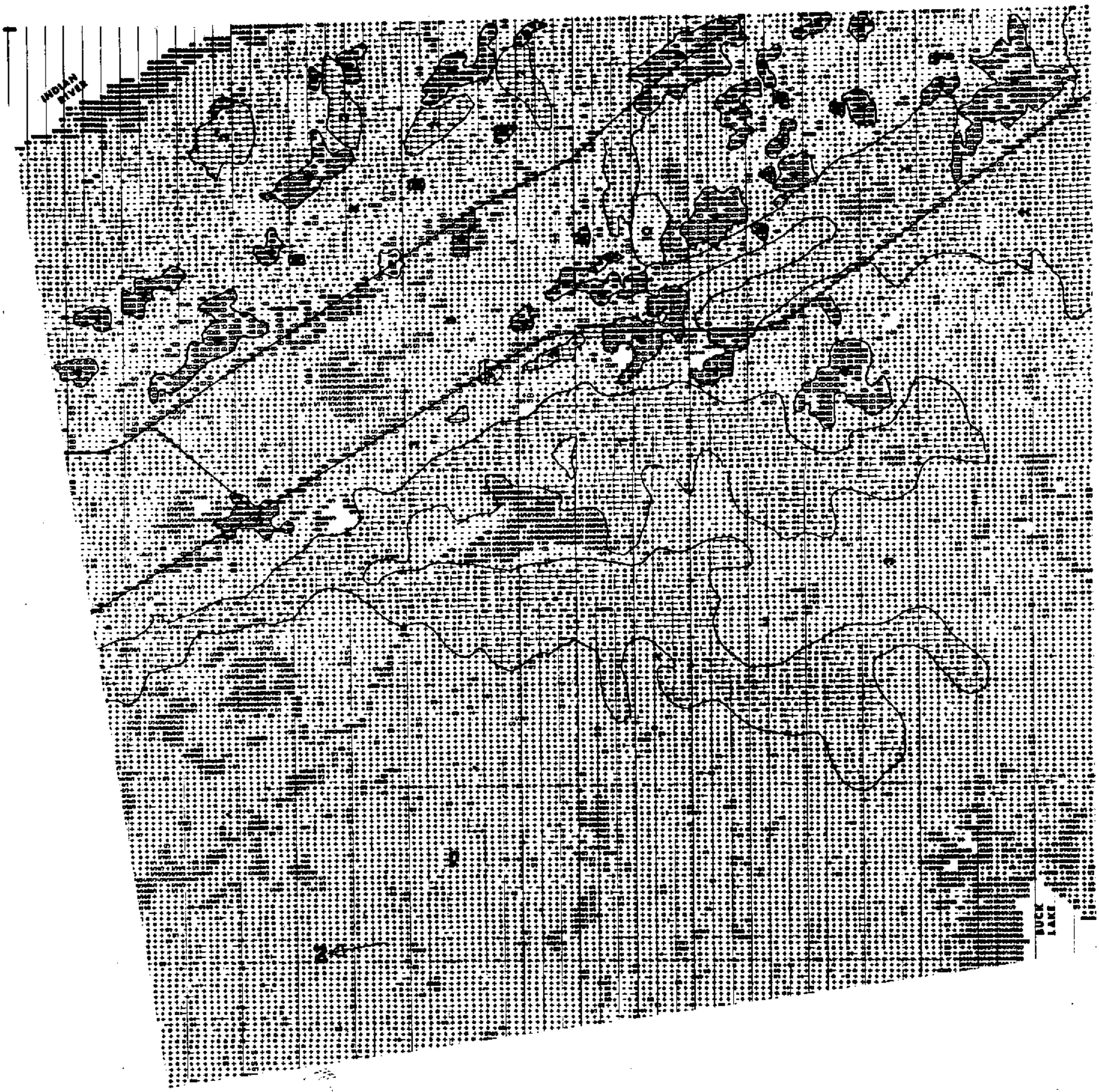

Figure 2

Northwest Corner, Brevard County

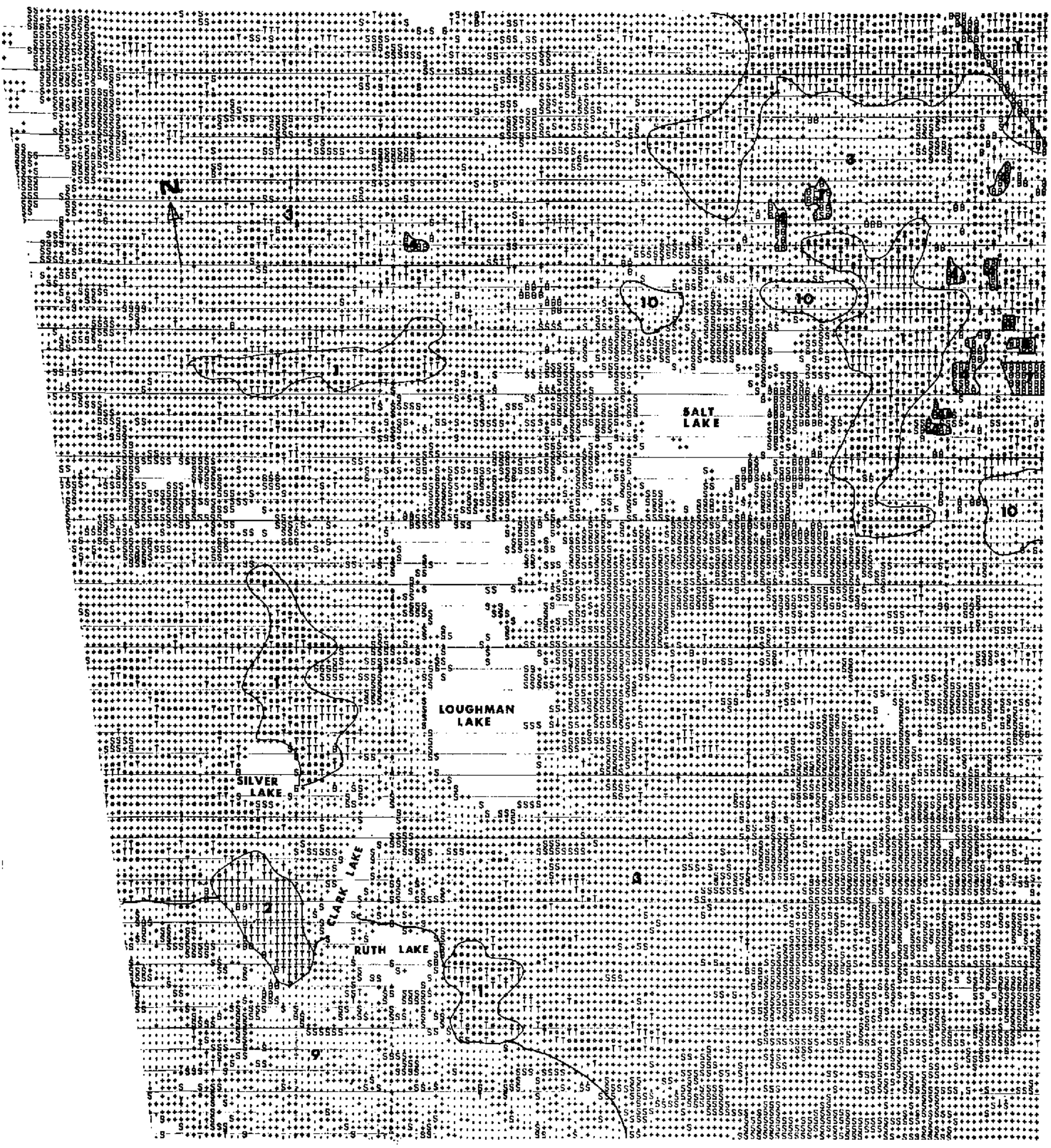

Figure 3

Section of Northwest Brevard County

is all of the area east of U. S. highway 1 and is predominately citrus, which is not well identified in this classification; its identification in this case is based on photography. Spots identified as bare sand in this sector are mostly newly-cultivated citrus groves with small trees. (9) identifies a portion of the St. Johns River flood plain; marsh grasses elsewhere are identified by (10).

Urban

Maximum likelihood land-use maps have been made of Titusville, Orlando, and Cocoa-Rockledge-Merritt Island, shown in Figures 4, 5, and 6, respectively.

The Titusville map was used as a test for the relative times and accuracies of the three classification methods described earlier.

The time-saving value of the two alternate methods is indicated by the following figures on central processor time on the GE-635 computer for six-class maps of the Titusville area (72,240 pixels, 129 mi.^{2}).

METHOD	TIME
MAXLIK	16.9 min.
MAX/MIN	12.6
MINDIST	5.8

Accuracy Of Results

As indicated above, the program computes the fraction of the total area represented by each class being considered. When these results are compared for the three alternatives, some differences are found, as indicated by the figures of Table 2. Those figures apply to the total region shown in the MAXLIK map of Figure 4.

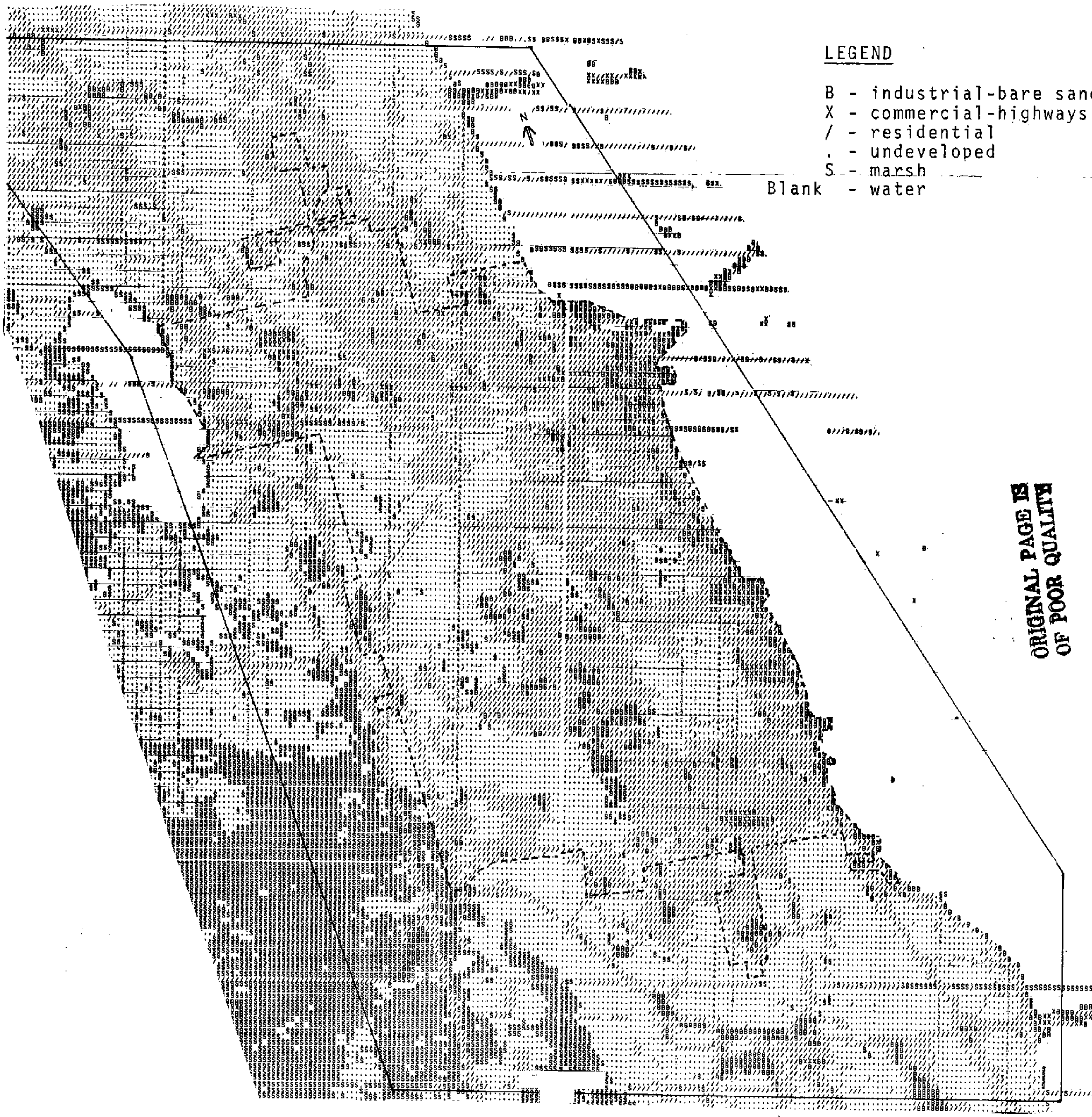

Figure 4

Land Use Classification of Titusville

LEGEND

B - industrial
* - commercial
/ - wooded residential
X - non-wooded residential
. - undeveloped
T - trees
Blank - water

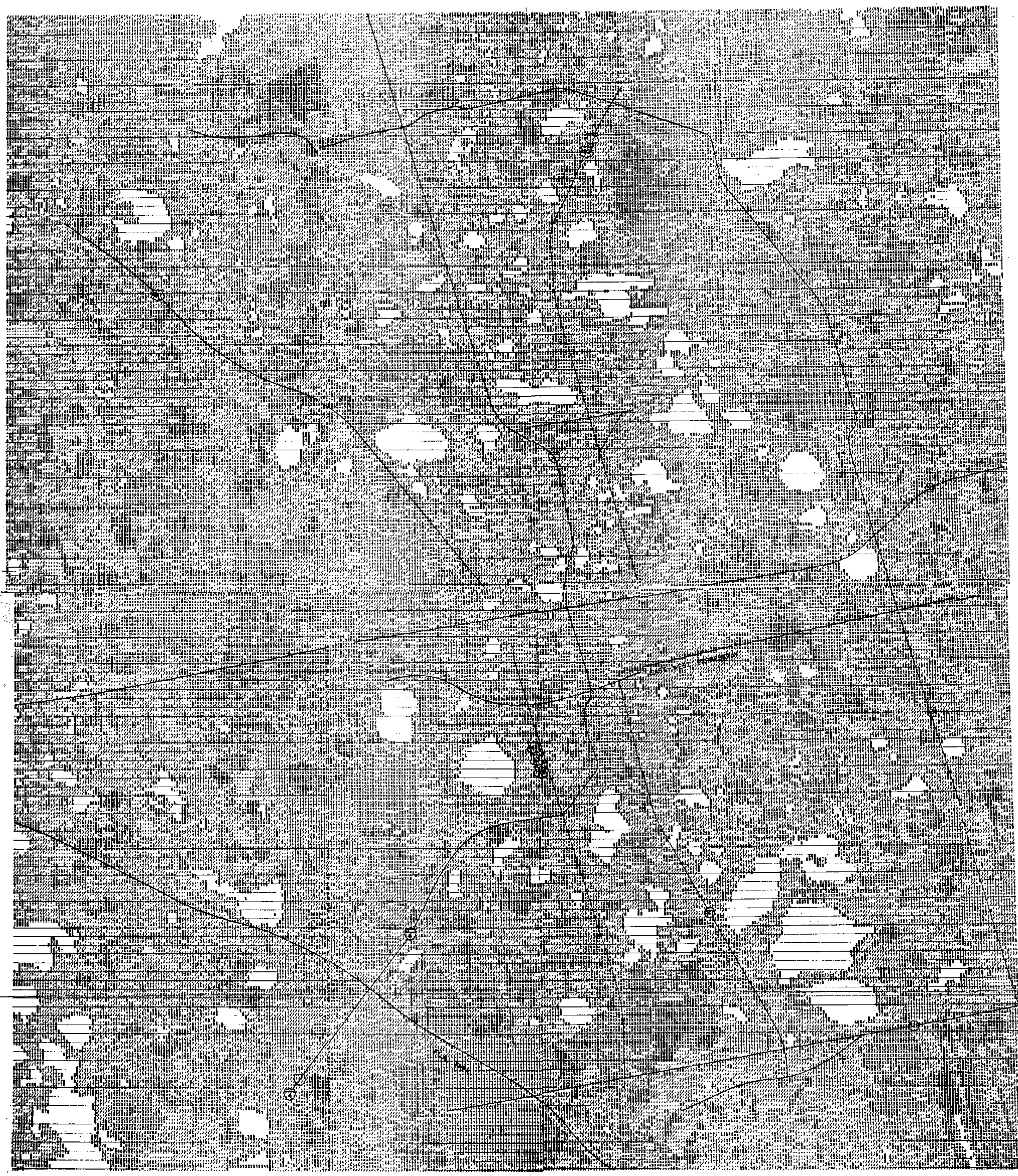

Figure 5

Land Use Classification of Orlando

LEGEND

* - industrial-bare sand

X - commercial

/ - residential

. - undeveloped

S - marsh

Blank - water

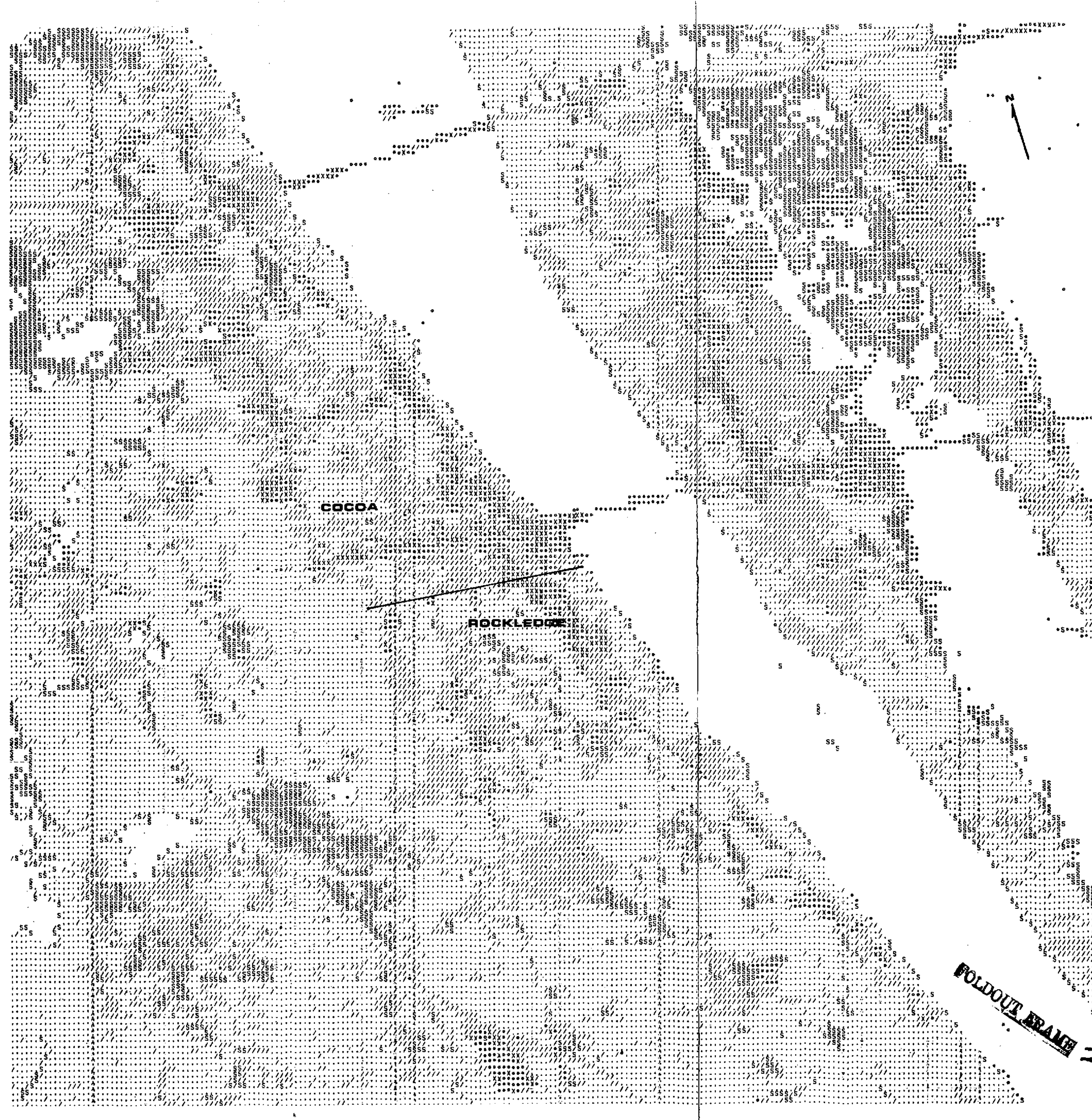

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Figure 6

Cocoa-Rockledge-Merritt Island

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TABLE 2

CLASS	CHARACTER REPRESENTATION	FRACTION OF TOTAL MAX LIK	MAX/MIN	MIN DIST
water	blank	34%	34%	37%
undeveloped	.	26%	25%	28%
marsh	S	20%	22%	22%
residential	/	18%	17%	10%
commercial	X	1%	1%	2%
industrial new construction bare sand	B	2%	1%	00

Table 2 shows that the minimum distance method, compared to the maximum likelihood method shows significantly reduced residential area and slightly increased water, marsh, and undeveloped areas. Some basis for the higher number of residential choices made by the maximum likelihood method may lie in the wider spread of the residential histograms as compared to the histograms for the water, marsh, and undeveloped classes. An example of a test area which did fit neatly into a classification was a sector which was classified as undeveloped by the minimum distance method and as residential by the maximum likelihood method. The sector actually is undeveloped with relatively sparse vegetation so that some sand shows through.

In an attempt to evaluate the accuracy of the three classification methods, a check was made of individual characters (pixels) by simple random sampling using a random number table to choose the line and sample number for samples within the solid lines of Figure 4 (Titusville and immediate environs). Aerial photography (color infrared and panchromatic) was the primary source of ground truth information, reinforced by local knowledge and the Titusville City Planner's land use map. One percent of the total number of points was checked, with the results shown in Table 3. The overall accuracy figures can be changed by the choice of boundaries - in this case by the amount of marsh and open water included within the boundaries - but the relative accuracies of the three methods are not changed. If the "safe" classes of open water and marsh are excluded, the accuracy figures for the three methods become 90, 87 and 89 percent, respectively.

In the sampling results, 56 points were not counted as either correct or incorrect because of the difficulty of making a clear-cut decision. Most of these uncertainties were due to geometric uncertainties at class boundaries; others applied to locations which were mixtures of two classes. Points in this uncounted group included:

Golf courses, which usually were classified as residential.

One high density residential (apartment) point which was classified as commercial.

Major highways which were usually classed as residential.

Five points which were identified as marsh by MINDIST and as undeveloped by MAXLIK and MAX/MIN. The states of those points at the time of the ERTS pass is not known.

Schools and school yards which were usually classed as residential.

How the uncertain points are counted and how much "safe" area is included in the area under consideration have important effects on accuracy figures.

A few other points are worth noting:

Urban classes can be expected to be less homogeneous than, say, agricultural classes and, therefore, more difficult to classify accurately.

Citrus varies widely in spectral pattern due, at least in part, to variations in the amount of sand seen between the trees. In these maps, citrus was sometimes classed as residential.

Separation of commercial and industrial is, in this case, not reliable. Reliable results are obtained if they are combined into a single class.

TABLE 3

CLASS	MAX LIK			MAX/MIN			MINDIST		
	Number Correct	Number Incorrect	% Correct	Number Correct	Number Incorrect	% Correct	Number Correct	Number Incorrect	% Correct
Water	40	0	100%	40	0	100%	40	0	100%
Marsh	31	0	100	29	0	100	29	0	100
Undeveloped	81	8	88	83	11	88	90	4	96
Residential	29	1	97	30	0	100	25	4	86
Commercial	1	1	50	1	1	50	2	0	100
Industrial - new construction - bare sand	7	0	100	2	5	29	1	4	20
OVERALL	189	13	94	185	17	92	187	14	93

Some of the B's shown on Figure 4 are bare sand in fairly new residential areas with sparse vegetation. Some others represent areas denuded of vegetation by motorbikes.

At this time we are not able reliably to separate industrial, new construction, and bare sand.

Titusville

The city limits of Titusville are shown as the dashed line on Figure 4. A character count for the City of Titusville, uncorrected for bad scan lines, gives the results shown in Table 4, along with data prepared by conventional methods by the Titusville Planning Department.

The total areas for the City are in good agreement, indicating that character-counting is a suitable method of determining areas.

The ERTS map, since it is based on physical characteristics, provides some information not normally available on planners' conventional land-use maps: e.g., water and marsh areas, in this case. Table 3 indicates that the figures for marsh and water areas are quite reliable. On the other hand, the conventional land-use map, taking into account economic, political and social factors, provides some classifications which an ERTS map cannot provide, e.g., utilities, public, and institutional uses. Thus, a complete correspondence between the two sets of figures is not possible. Some classes can be grouped for comparison, as shown in Table 4.

The residential area on the ERTS map includes essentially everything in the residential area: residences, streets, vacant lots, golf courses, schools, and other features with similar spectral characteristics when integrated over a resolution element and, therefore, must be compared with item 7 from the planners' figures. The planners' residential figure applies only to lots containing residences.

TABLE 4

CLASS	TITUSVILLE PLANNING DEPARTMENT			ERTS MAP			PER-CENT DIFFERENCE
	AREA		% OF TOTAL	AREA		% OF TOTAL	
	ACRES	HECTARES		ACRES	HECTARES		
(1) Water				34	14	0	
(2) Marsh				300	120	3	
(3) Undeveloped				3573	1429	33	
(4) Residential	2222	888	21	5744	2298	53	
(5) Commercial	329	131	3	424	170	4	+ 29
(6) Industrial	68	27	1	467	187	4	+587
(7) Residential, Streets, Rights-of-Way, Utilities Transportation, Public, Institutional	4611	1844	43	(5744)	2298		+ 25
(8) Commercial and Industrial	397	159	4	891	356	8	+124
(9) Water, Marsh and Undeveloped	5730	2292	53	3907	1563	36	- 32
(10) Residential and Highway				5809	2324	54	
(11) Bare Sand				234	94	2	
Total	10,738	4295		10,841	4336		+ 1

As pointed out above, the ERTS map does not give reliable separation between commercial and industrial classes; hence, for comparison purposes, those two classes are combined into a single class. This figure is approximately twice the planners' figures; this difference can be explained on a basis of classifying as industrial-commercial, some regions which are not commercial or industrial but nevertheless have high light reflectance, e.g., apartment houses, apartment house parking lots, and regions barren of vegetation. B's on the computer map which were believed to be due to bare sand were subtracted from the character count to give the industrial figures quoted. The result indicates that Titusville has 234 acres of bare sand, of which 86 acres are denuded of vegetation by motorbike usage (determined by ground observations).

For the same reasons that the ERTS residential figure is higher than the corresponding planners' figure, the ERTS area for (water and marsh and undeveloped) is lower.

A 1973 conventional land-use map of Titusville is included as Figure 7, for comparison with Figure 4.

Thematic Maps

Thematic maps can be made with the classification program by "printing" undesired classes as blanks. An example is Figure 8, which shows the commercial, industrial sectors of Orlando, with the lakes (dotted) included for orientation. A map of this type is useful for showing development patterns, particularly when repeated periodically to show changes. This map, for example, shows the central business district (1), a large commercial region (2); a smaller commercial region (3); an industrial sector (4); a commercial strip(5); McCoy Airport (7); a "belt" highway running from McCoy Airport to the commercial sector at the top of the map (8). This highway (#436) is undergoing rapid growth of commercial and high density residential growth. Area 8 (Altamonte Springs), which is building up rapidly, not only is outside Orlando, but also is outside Orange County. A map of this type provides an excellent means of studying the develop-

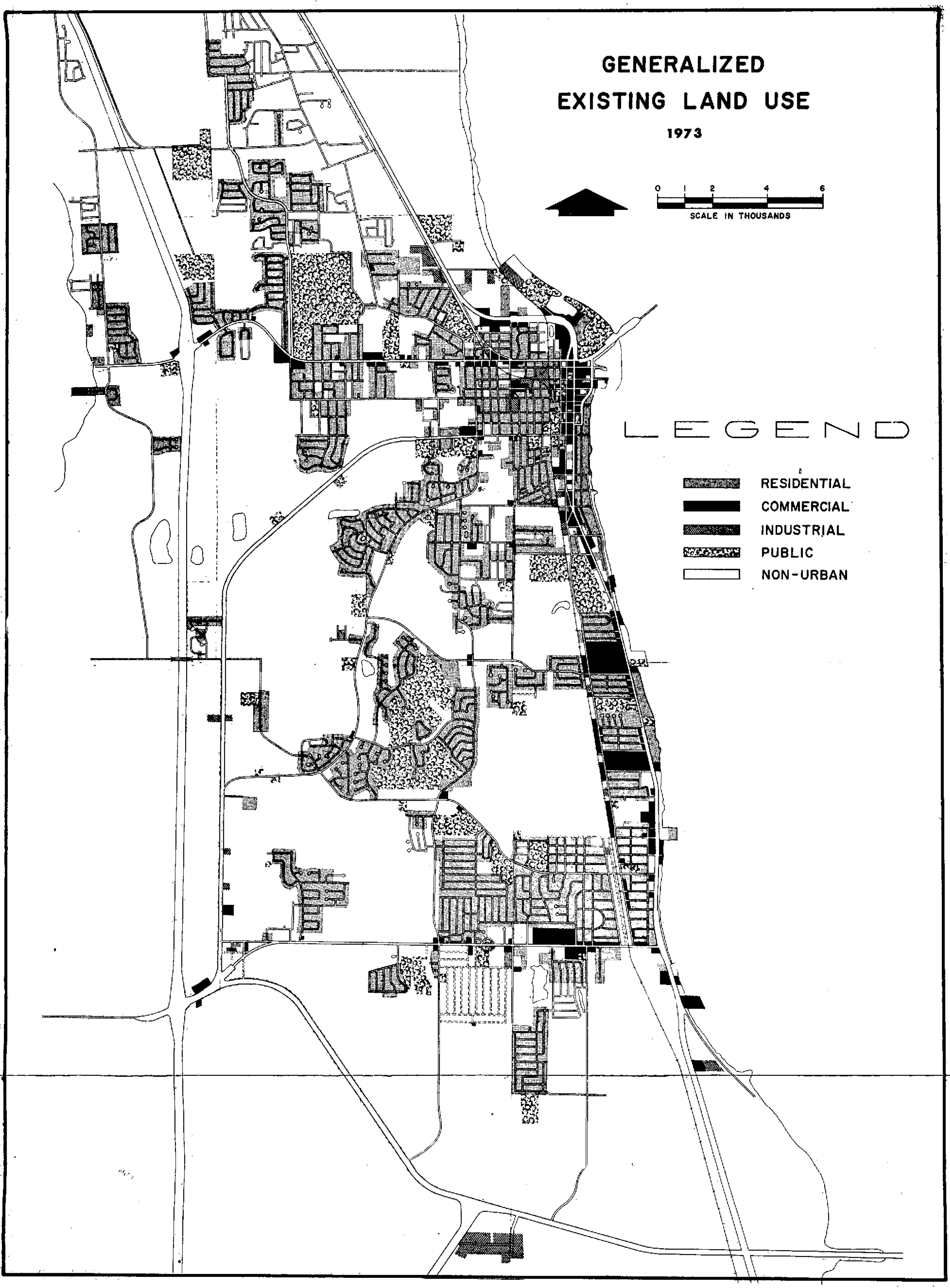

Figure 7

Planners' Land Use Map of Titusville

LEGEND

B - industrial-commercial

. - lakes

Everything else blank

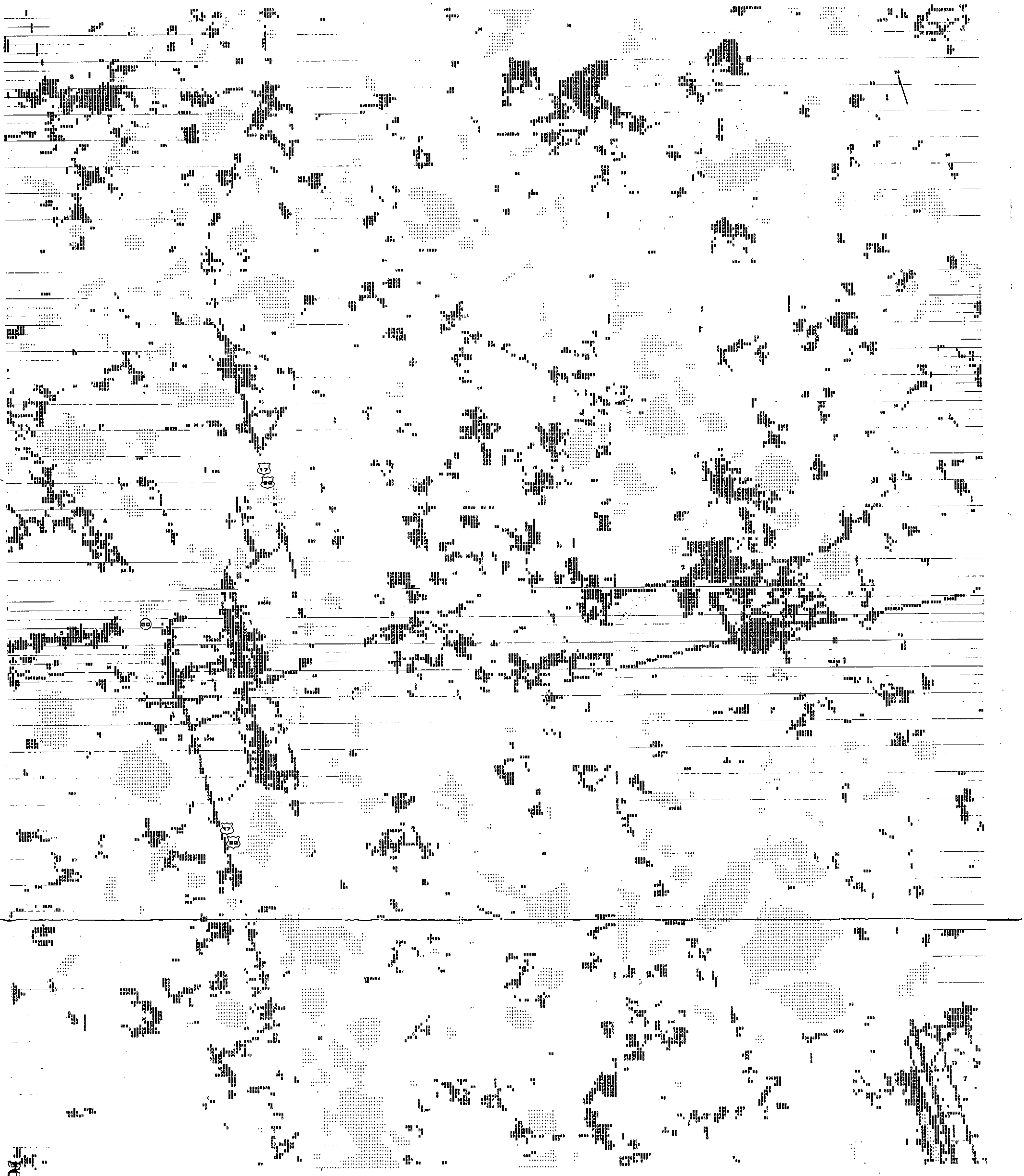

Figure 8

Orlando Industrial/ Commercial

ment pattern of a city. If the development pattern is compared with the classic textbook pattern (Concentric Zone, Sector, and Multiple Nuclei)[2] some differences and some features of correspondence are seen. Orlando has some aspects of all three patterns, probably falling closest to the multiple nuclei pattern with the addition of a "belt" feature which has some resemblance to a concentric zone feature. The belt is highway 436. The regions of rapid development are roughly equidistant from the central business district with access aided by freeways and with much of the development outside the taxing jurisdiction of the community which provides the reason for the development. Figure 8 clearly illustrates the need for planning and control which supersedes city and county boundaries. Computer maps clearly point out other cases where political boundaries are unrelated to physical development: for example, the separation of Cocoa and Rockledge, Figure 6.

Figure 5 illustrates the method's capability of distinguishing two types of residential sectors: (a) the older sector with an abundance of large trees which essentially surrounds the central business district and extends northeastward into Winter Park and Maitland and (b) newer residential sectors lying outside the older sector and having fewer and smaller trees. A thematic map showing this effect is shown as Figure 9, in which only these two residential classes are shown.

The density-slicing program can be used to produce some types of useful thematic maps, also, e.g., Figure 10, which shows the sectors of Orlando with relatively high reflectivity (band 5), which is normally associated with concrete, roof tops, bare sand, parking lots - generally, non-landscaped regions. Study of such a map can tell a planner what sections

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[2] F. Stuart Chapin, Jr., Urban Land-Use Planning. University of Illinois Press, Urbana (1965)

LEGEND

/ - wooded residential

X - non-wooded residential

. - lakes

Everything else blank

Figure 9

Orlando Residential and Wooded Residential

LEGEND

B - highest radiance (band 5)

* - 2nd highest radiance

/ - medium radiance

Blank - lowest radiance

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Figure 10

Intensity of Development in Orlando

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of the city need attention. It also can give him a picture of the pattern of high-intensity development in his city, for example, in Figure 10, four levels of intensity of development are shown, the degree of shading being the indicator of the degree of development.

Maps delineating visible water surface are easy to prepare by either density-slicing or the maximum likelihood method, but density-slicing requires appreciably less computer time. Figure 11, a map of Orlando's lakes, is an example.

Another useful thematic map is the marsh map, an example of which will be presented later.

CHANGE MONITORING

It appears that one of the most important planning applications of satellite data will be in change monitoring - the updating of land use maps. The periodicity of ERTS is, of course, an important advantage for this use.

Most of our change monitoring work was done before our classification program became operational and is, therefore, based on density-slicing methods. We believe that use of maximum likelihood classification will improve the accuracy but not change the general method or results.

In using density-slicing or band ratios for change monitoring, corrections must be made for radiance difference between passes. The method used by us to date to normalize the data has been to make the choice of character levels for mapping the second set of data such that certain commercial regions which were known to have remained constant during the period, appeared the same (same characters and same area) on the second map as on the first. Due to differences in positioning of the sensor resolution element on the different passes, at least, there will be minor differences in the computer maps even where there have

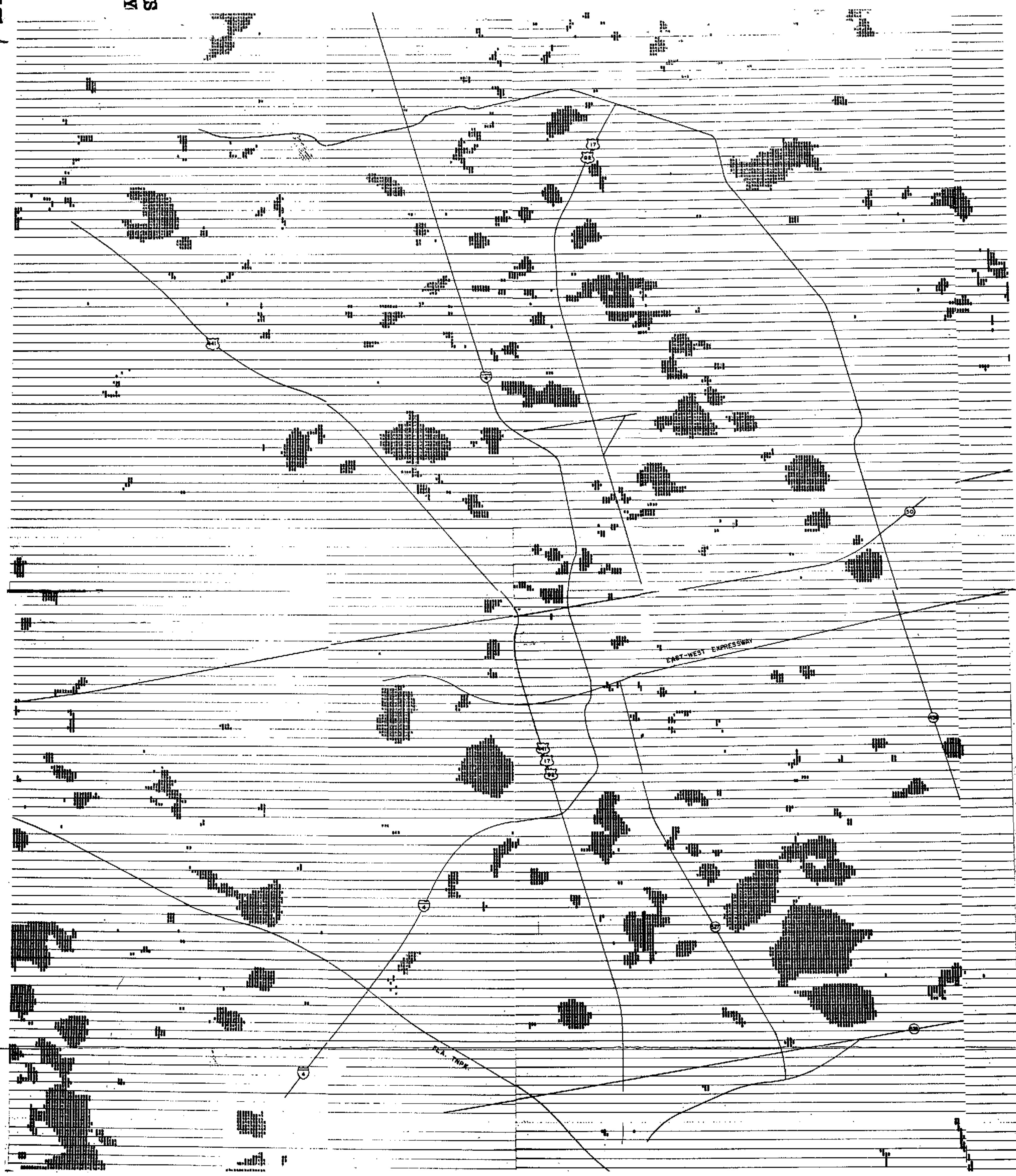


Figure 11

Orlando Lakes

been no changes in the scene, so that a change of one character, for example, on the map often is not significant; but, as a rule of thumb, a change of two or more characters usually is significant and should be checked.

Two types of map were used in making the comparison: band 5 density and the ratio of bands 7/5. The results described below for Titusville (September 6, 1972 and April 28, 1973) use the combined information available from the two types of maps, some of the changes were observable on one of the map types, some on the other, and some on both.

Certain obvious changes are readily observable (For reference purposes, we shall refer to them as Class A changes):

(1) construction of a new motel

(2) grading associated with construction of a new high school

(3) grading at an industrial park

(4) construction of 3 single-family houses adjacent to each other

(5) construction of two single-family houses adjacent to each other

(6) construction of a new single-family house

(7) street construction

(8) sand quarry in initial stage of development

Most of these changes caused a change in several map characters (resolution elements). A check with the City Building Department indicated several other construction projects which had some activity during the period under construction. These locations were checked against the computer maps with the following results (Call these Class B changes):

(9) enlargement of parking lot -- in central business district -- not distinguishable on ERTS maps

(10) construction of church -- small -- one lot -- believed seen on ERTS map.

(11) construction of addition to school -- seen on ERTS maps but not noticed as Class A because it is adjacent to a shopping center.

(12) 8 new single-family houses in a single subdivision -- scattered -- not observed on ERTS maps

(13) condominium additions -- observable on ERTS maps

(14) condominium construction -- observable on ERTS maps

(15) 5 single-family residences in the same general area -- observable on ERTS maps

(16) 9 single-family houses in same addition but mostly scattered -- not observed on ERTS maps

(17) 3 single-family homes adjacent to each other -- not observed on ERTS maps

(18) construction of small commercial building -- not observed on ERTS maps

(19) 6 single-family homes in same general area -- observable on ERTS maps

(20) construction of a small commercial building -- possibly observable on ERTS maps but indistinguishable from (7)

(21) construction of 4-unit condominium -- observable on ERTS map

(22) addition to condominium -- not observable on ERTS maps

(23) construction of small commercial building -- observed on ERTS maps

(24) construction of an additional building in an industrial complex located on bare sand -- not observed on ERTS, as the complex and surrounding sandy area already showed a maximum level of radiance.

It will be noted that of the sixteen Class B changes, nine were observable on the ERTS maps. With more careful analysis, they could, then, have been detected from the ERTS maps, followed by ground checking; however, such a procedure would involve checking out a comparable number of "false leads." The remaining six Class B changes could not be detected by the ERTS analysis techniques used by us to date.

Major changes can be detected almost automatically, but the monitoring of minor changes (of the order of size of a resolution element) is not yet an automatic process. Results to date indicate that, when supplemented by appropriate ground checking, this can be a useful tool.

Figure 12 shows the locations of the changes observed on the ERTS maps as described above.

A similar study to evaluate the Disney World impact in terms of commercial growth in the surrounding region, is shown in Figure 13. The existing development includes commercial and industrial development only; the added development also includes new residential development.

DAILY PLANNING PROBLEMS

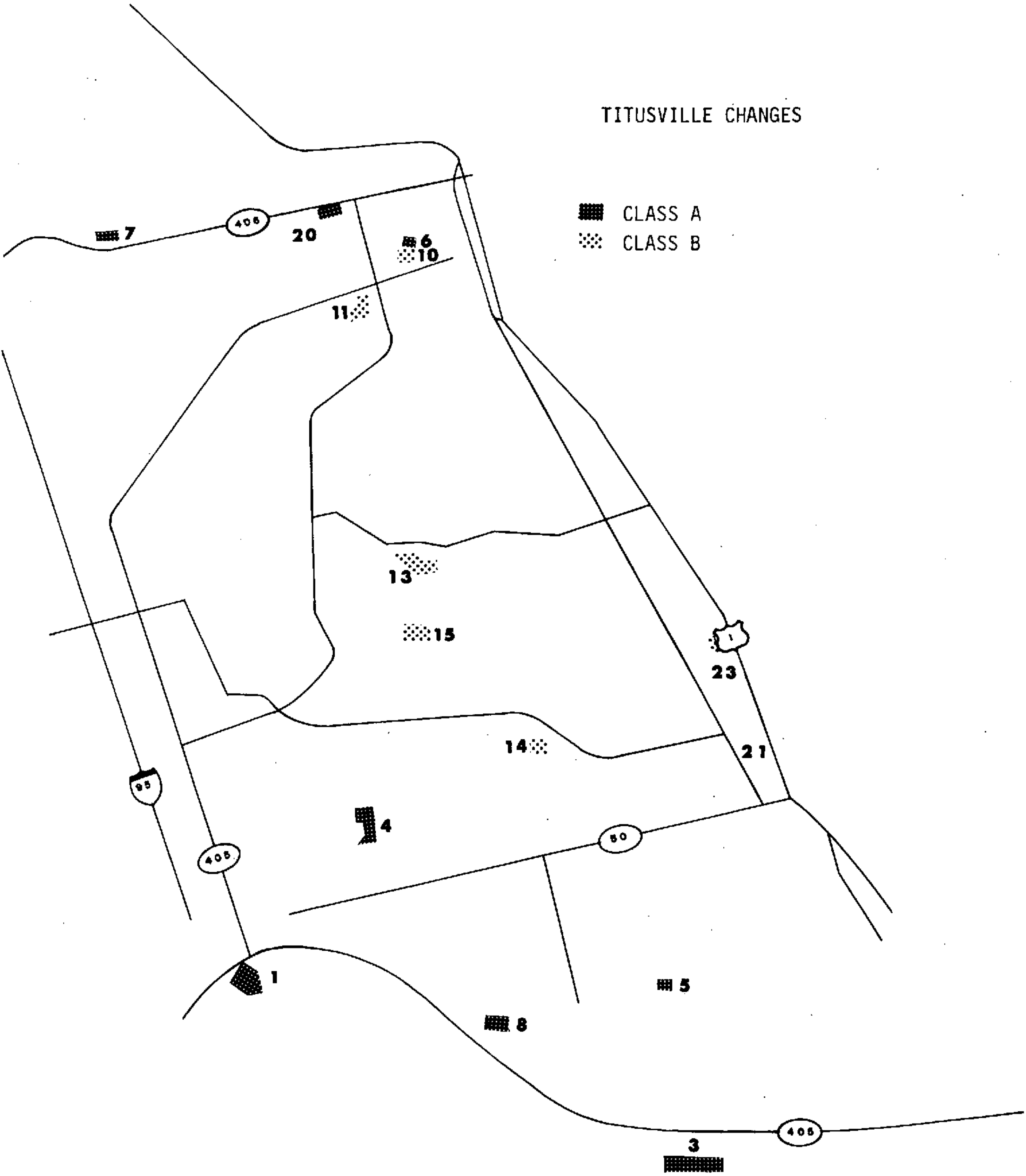
In addition to the applications mentioned above, it is our experience that having ERTS data available and having the planners aware of its capability facilities their handling of a variety of routine planning problems:

Visual Impact

Having a visual image, preferably an enlarged color composite print, helps one obtain a perspective view of his county and region. It provides an insight into which sectors are suitable for development and which are not and shows lakes and general drainage patterns, flood plains, marsh areas, and the extent of urbanization.

Neighborhood Analysis

The radiance of a region in one of the visible bands gives a clue to the nature of the region, particularly with regard to the amount of asphalt, concrete, and bare sand in relation to the amount of vegetation. This information has been used qualitatively by James Delcamp, Lakeland Planner, in neighborhood analysis; and the possibility exists for using it in a quantitative way in a manner similar to that discussed above for the environmental indicator.


TITUSVILLE CHANGES
CLASS A
CLASS B
405
7
20
6
10
11
13
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23
1
14
21
95
4
50
405
1
5
8
3
405

Figure 12

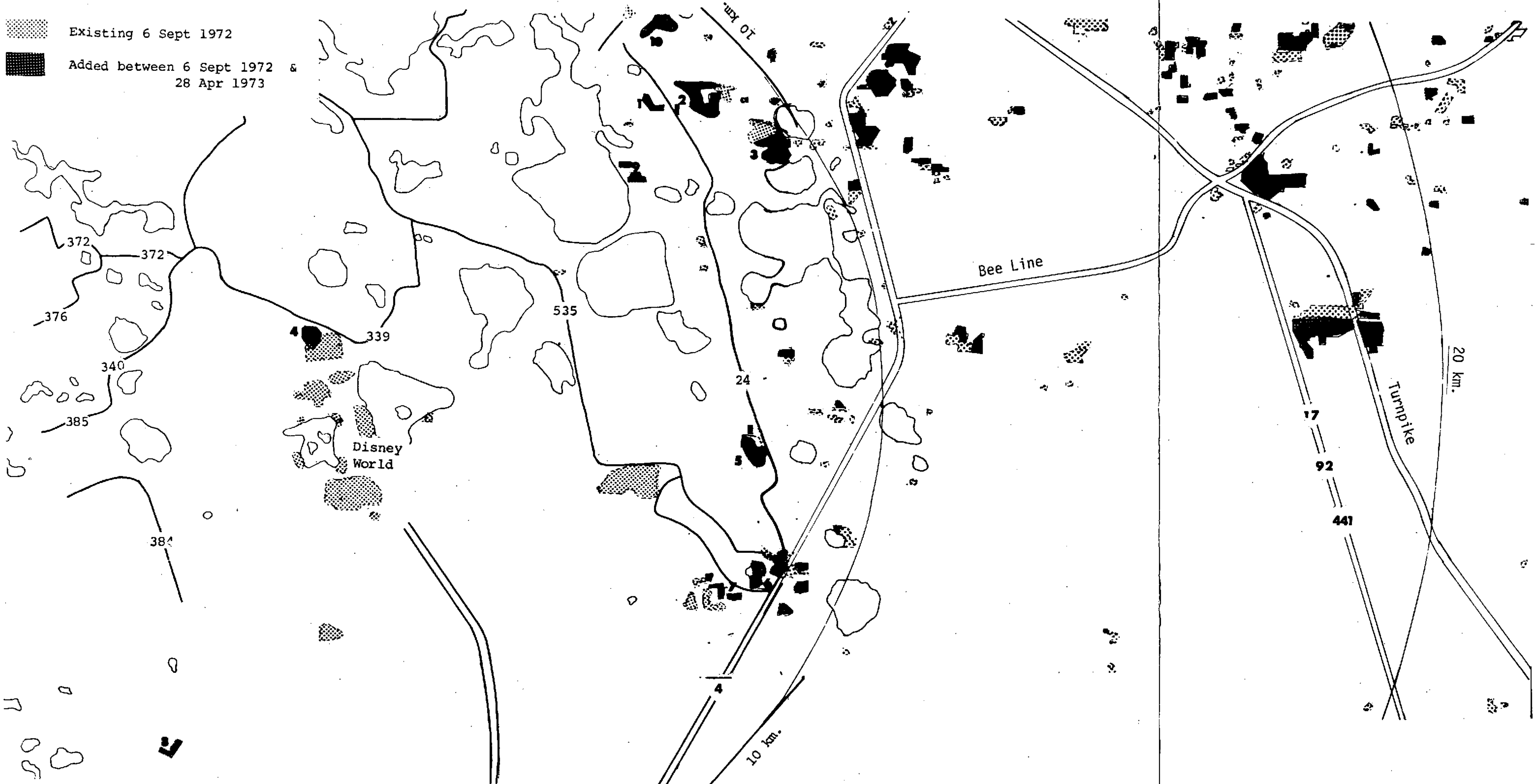

Figure 13

Changes in Disney World Vicinity

Visual Interpretation

Due to their timeliness, band 5 images have been observed visually by Brevard County planners to determine whether further development had occurred recently in a particular area undergoing large-scale residential development.

Transportation

General transportation perspective can be obtained from a computer map of the type shown on the cover of this report, a band 5 density-sliced map with parometers chosen to show only man-made development. We believe the potential exists for more specific transportation analysis, but have not followed through on this as yet.

Flood Plains

A problem of current concern to local and regional planners is that of delimiting flood plains. This problem is of concern for two reasons: (1) in regions experiencing rapid population growth, there is increasing pressure for development of undeveloped land, and (2) federal flood insurance regulations require that local governments know the location of the 1/100 annual flood probability line.

It has been noted that band 7 images show a moderately-to-well defined gray area in the vicinity of the St. Johns River. In some sectors, this gray sector is difficult to delineate; in others it is quite sharply defined.

The St. Johns is unusual in that it lies on a flat region with large marsh areas and relatively few large trees, at least in this section of the basin. Aerial photography and satellite images, therefore, give a relatively unobstructed view of the basin except in some places where a canopy of willow and other trees obscures the river and its immediate ground environs.

The sector of the river studied for this purpose is that running along the western edge of Brevard County, where the river approximates the western boundary of the county. Figures 14 to 16 show the southern, central and northern sectors, respectively, with some overlap; these are enlargements of band 7 images (for different dates) enhanced to bring out this effect. The river runs from south to north. Figure 14 shows the origin of the river; it also shows the effect of drainage of the marsh, which formerly occupied an appreciably larger area than it does now. The light-colored, rectangular sectors are drained sectors, mostly converted to pasture; much of the drainage water is carried by ditches eastward to the Indian River. Lake Washington, located approximately one inch from the top of Figure 14, is the major source for the water supply of the southern portion of the county, which now has a population of 106,000 projected at 262,000 in 1995. Water supply is generally regarded as the limiting factor on population growth in this part of the county.

Several sources of information have been used to obtain evidence leading toward an interpretation of the gray areas: color infrared aerial photography, panchromatic aerial photography, discussions with persons familiar with the river basin, comparison with known marsh regions in the Merritt Island Wildlife Refuge, comparison with ERTS images of coastal wetlands, comparison with topographic maps, and walking selected sectors. The evidence from these sources has led us to the conclusion that the gray area in these images represents marsh and semi-marsh. Where we have checked it, this conclusion is consistent with results obtained from the maximum likelihood classification program. The appearance on the image is similar to that of coastal wetlands areas on ERTS images of other regions, e.g., the west coast of Florida. Color infrared and panchromatic aerial photographs show a vegetation and soil moisture pattern which corresponds approximately to the subject pattern. The most persuasive argument is presented by comparing the ERTS pattern to topographic maps, where a general correspondence is seen between the gray ERTS area and the marsh area shown on the topographic maps (making allowance for the fact that the topographic maps are somewhat outdated and some of the marsh shown thereon has been removed

Figure 14

Image of Marsh, St. Johns Headwaters

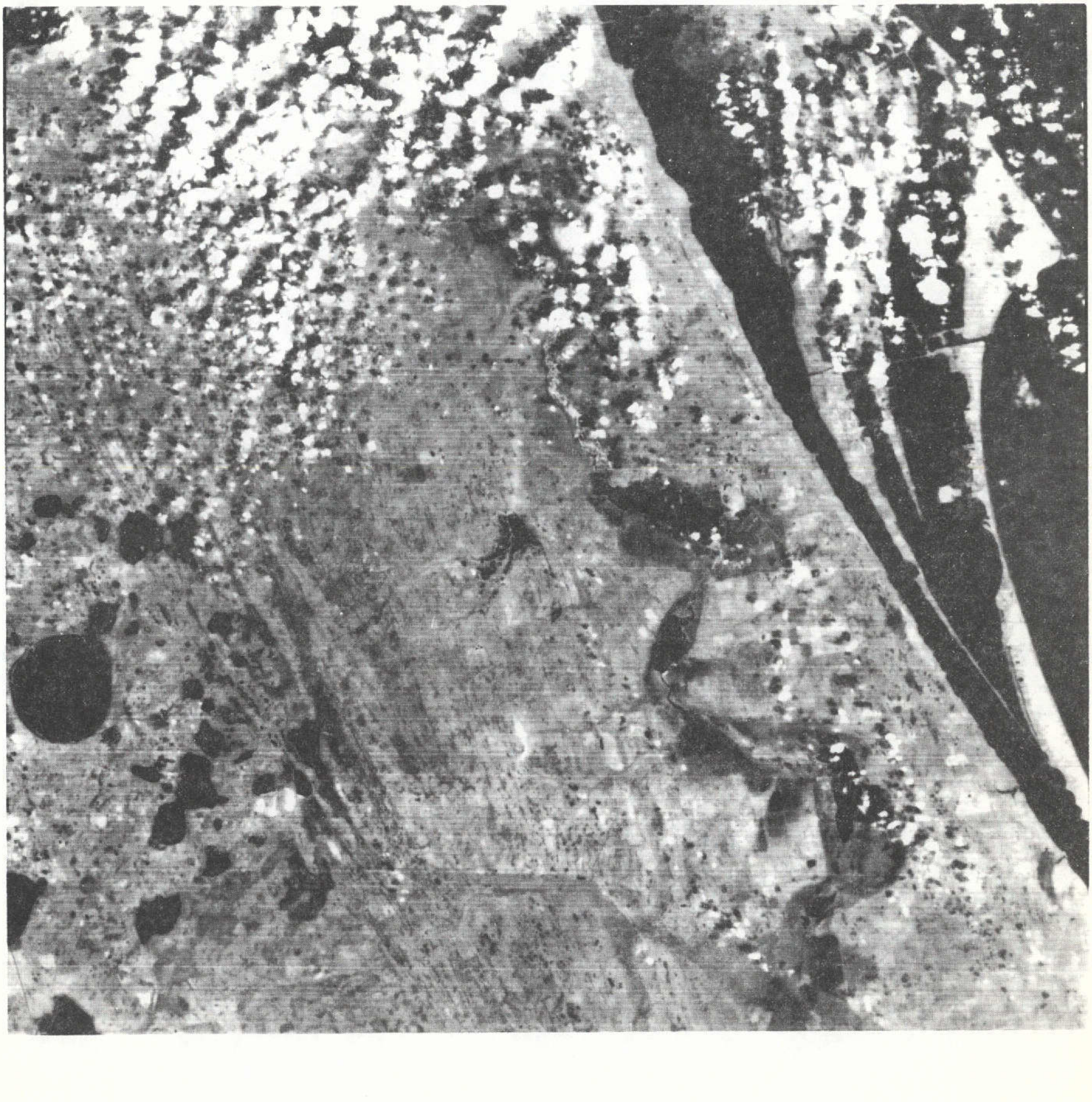

Figure 15

Image of St. Johns Marsh, Central Brevard County

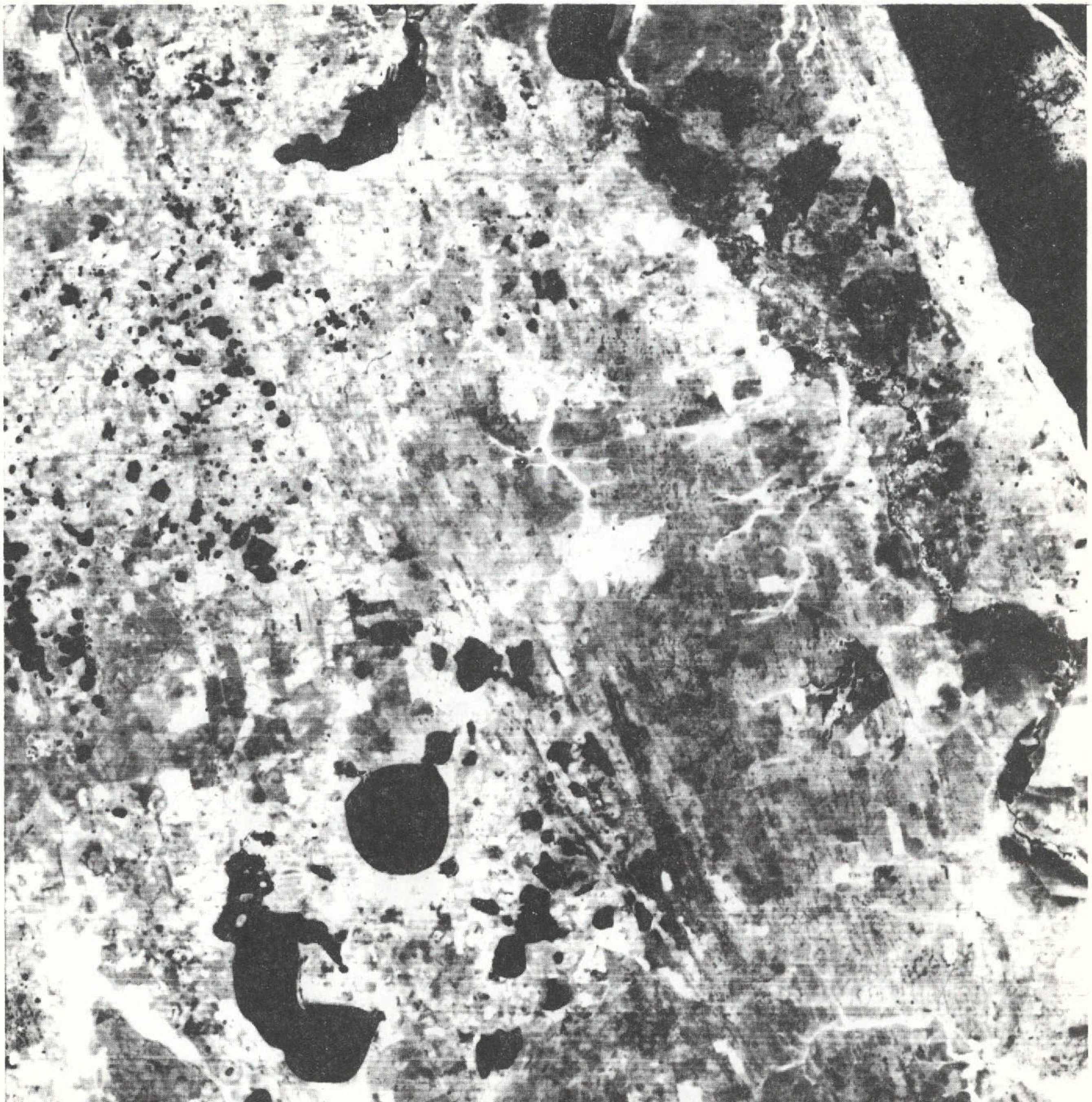

Figure 16

Image of St. Johns Marsh, Northern Brevard County by drainage).

The boundary of the gray area varies somewhat with the amount of rainfall. In most places, the variations are small; an exception is the wide gray area in the top half of Figure 16, for which the changes are significant. This area was abnormally wet at the time of the pass shown.

A band 7 density-sliced computer map shows the pattern in useful detail. Photographic reproductions of this map are shown in Figures 17 to 20, which represent south-to-north sectors, respectively, with overlap at one interface. The map shows water surface as dark, marsh and semi-marsh as gray, and everything else blank. Major highways (obtained from a band five map) and the county line have been drawn in. The water surface running along the eastern edge of the figures is the Indian River. We feel that in the original scale of 1/24,000, maps of this type represent sufficiently accurate and detailed maps of marsh areas to be useful for planning purposes. These data were taken on September 6, 1972, which is during the wet season.

Again, it will be noted that many dikes are seen clearly. Study of this map indicates which dikes are accomplishing their intended purpose and which are not.

Another way to present this result is shown in Figure 21, which is an image made by scanning, quantizing, and enlarging the ERTS band 7 image, using an Optronics International drum-type microdensitometer. As in the computer map, black represents visible water and gray represents marsh and semi-marsh. Since both this method and the computer density-sliced mapping method are quantizing methods, they require proper setting of gray scale parameters to obtain the proper image; but this can be done readily by referring to the ERTS band 7 image, which shows relatively continuous density variation. The gray scale parameters are adjusted to match the gray pattern in the ERTS band 7 image.

Figure 17

Marsh Map, St. Johns Headwaters

Figure 18

Map of St. Johns Marsh, Central Brevard County

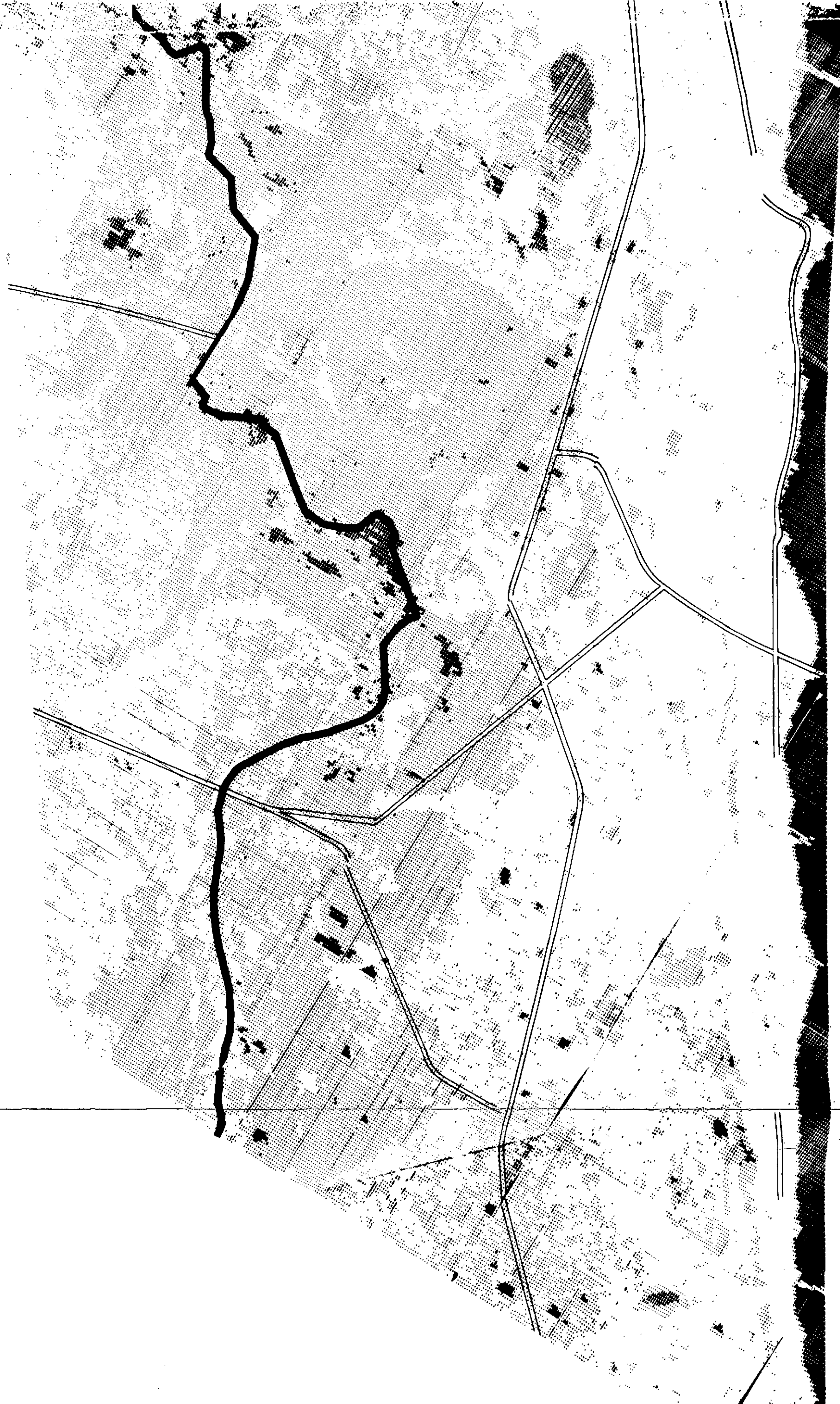

Figure 19

Map of St. Johns Marsh, North-Central Brevard County

Figure 20

Map of St. Johns Marsh, Northern Brevard County

Figure 21

Quantized Image of St. Johns Marsh

Figure 22 shows the relations between three different lines having significance with regard to the St. Johns flood plain. The solid line represents a tracing of the boundary of the gray area of Figures 14 to 16 as projected on a map by means of a Bausch and Lomb Zoom Transfer Scope. The dashed line delimits the flooded area (at least 30 day duration) of a 1953 flood as drawn by the U. S. Army Corps of Engineers. The dotted line represents a generalization of the 1/100 annual flood probability line as developed by the U. S. Geological Survey. When the ERTS marsh line generally falls inside the other two lines, which is generally the case, it does not change any conclusions but does provide further information. In a couple of spots, however, the ERTS marsh line lies outside the other two lines; those spots should be investigated further. These three lines have been used as background information by Brevard County planners in arriving at recommendations regarding areas which should be regarded as developable and areas which should be preserved in an undeveloped state. Those recommendations are contained in a new land use plan recently approved by the County Commission.

One advantage of the ERTS marsh line map is the repetitive nature of its availability, making possible the observations of seasonal effects and determining areas which are flooded or marsh part of the time.

Heavy tree canopy obscures the ERTS view of ground level and complicates the problem, requiring greater reliance upon vegetation maps and other indicators.

<u>Suburban Planning</u>

The Titusville planners have found the ERTS land-use maps useful in observing and projecting development for the purpose of planning utilities for regions outside the city limits, for which they do not have detailed land-use maps. Similarly, the ERTS maps have potential use, also, in the anticipation of transportation and commercial needs in the city due to development outside it.

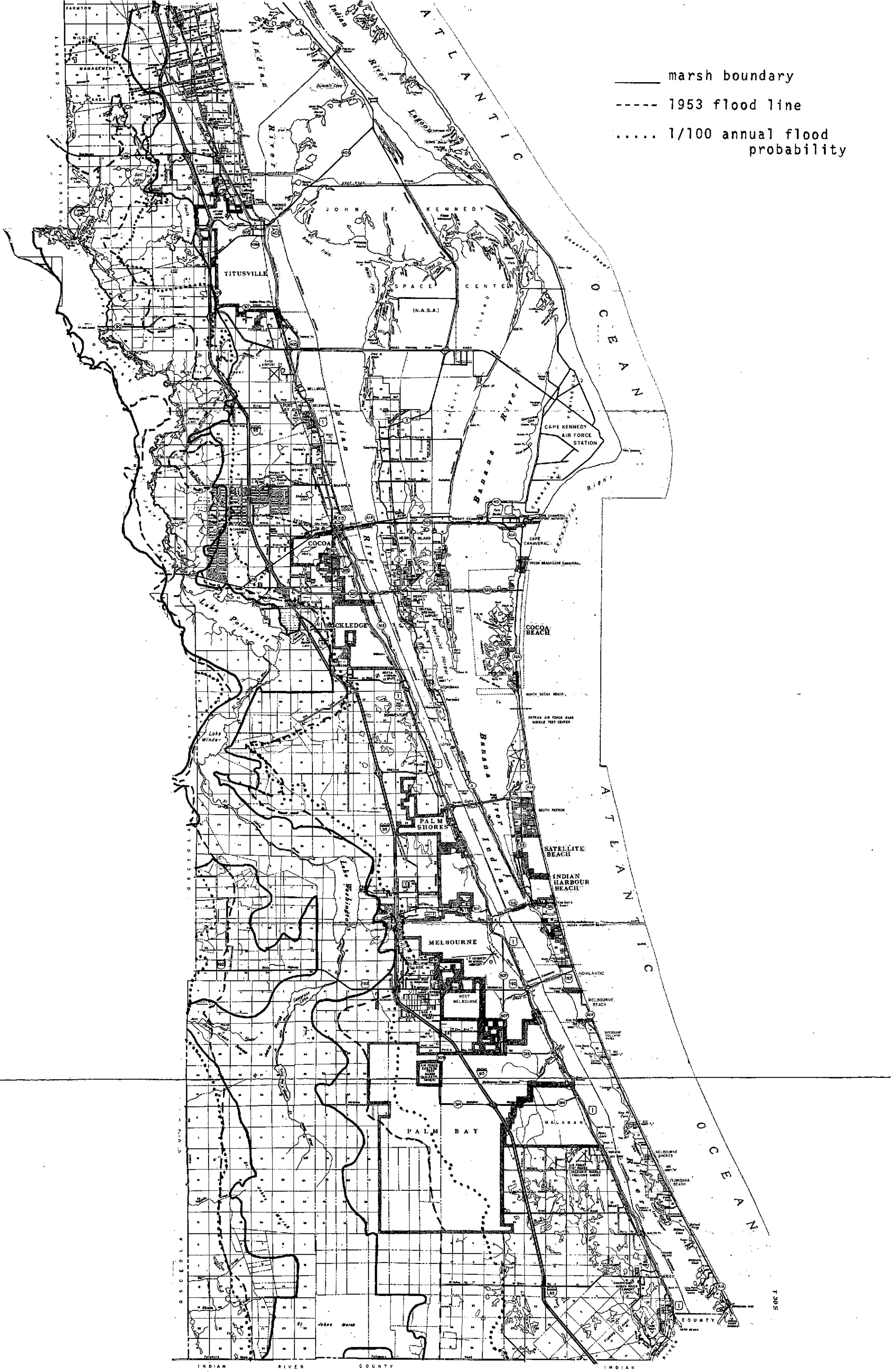

Figure 22

St. Johns River Flood Plain

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Residential Developments

The residential developments of Port St. John, Port Malabar, and Deltona have in common the feature of large platted areas with streets built but few houses in the larger portion and a concentration of houses at present in a relatively small area. The street density causes these developments to appear as cities on satellite images and computer maps. This effect is striking and significant in the case of Port Malabar, which occupies most of the city of Palm Bay, which borders the commercial center, Melbourne. A computer map of this area, such as Figure 23, illustrates, when one realizes that he is looking at a network of presently largely unoccupied streets in Port Malabar, that major problems and major changes in the nature of the southern portion of Brevard County, are coming. This portion of the county presently has a population of 69,000 projected at 185,000 in 1995.

New residential construction in the "new city" of Poinciana, in Osceola and Polk Counties, shows clearly on ERTS images and computer maps, leading to easy monitoring of its growth.

Phosphate Mining

Phosphate mining activity, a strip mining process, which is extensive in Polk County, can be readily and accurately monitored by ERTS images and computer maps, as can the land reclamation process.

Lake Eutrophication

ERTS images, computer maps, and Skylab EREP photography have led us to the conclusion that the state of lake eutrophication in Florida lakes can be evaluated, at least roughly, from satellite data. Lakes in an advanced state of eutrophication are found to have a different color than do clean lakes, the eutrophic lakes reflect light in bands 4 and 5 more strongly. This has led, in the later stages of our program, to a lake sampling program to attempt to correlate water parameters with light reflectivity in ERTS bands 4 and 5.

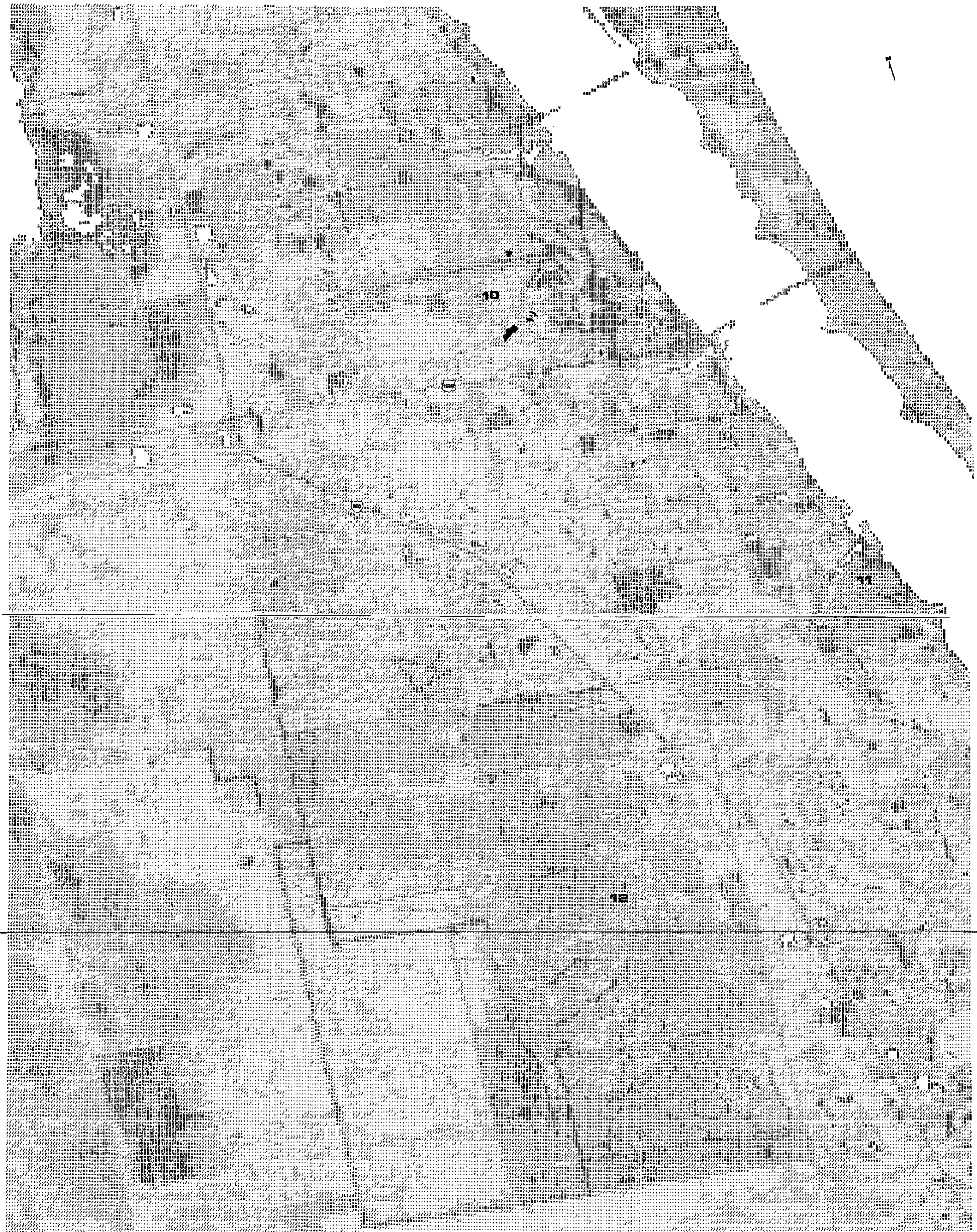

Figure 23

Melbourne-Palm Bay Development

Figure 24 is an EREP photograph in the wave length range corresponding to ERTS band 4; Lakes Apopka (1), Beauclair (3), Dora (4), Eustis (5), and Griffin (6) are highly eutrophic, while Harris (7), Yale (8), Louisa (10) Minnehaha (11) and Minneola (12) are relatively clean.

Figures 25 and 26 are ERTS band 4 density-sliced computer maps to illustrate variations in reflectivity. It will be noticed that the variation in color between the two ends of the lake can be seen clearly in Lake Griffin.

Homer Royals, of the Florida Game and Fresh Water Fish Commission has undertaken a sampling and analysis program for Lakes Eustis, Yale, and Griffin; and Mike Marshall, of the Central and South Florida Flood Control District is doing similar work for several locations in Lake Okeechobee. We do not yet have results to report.

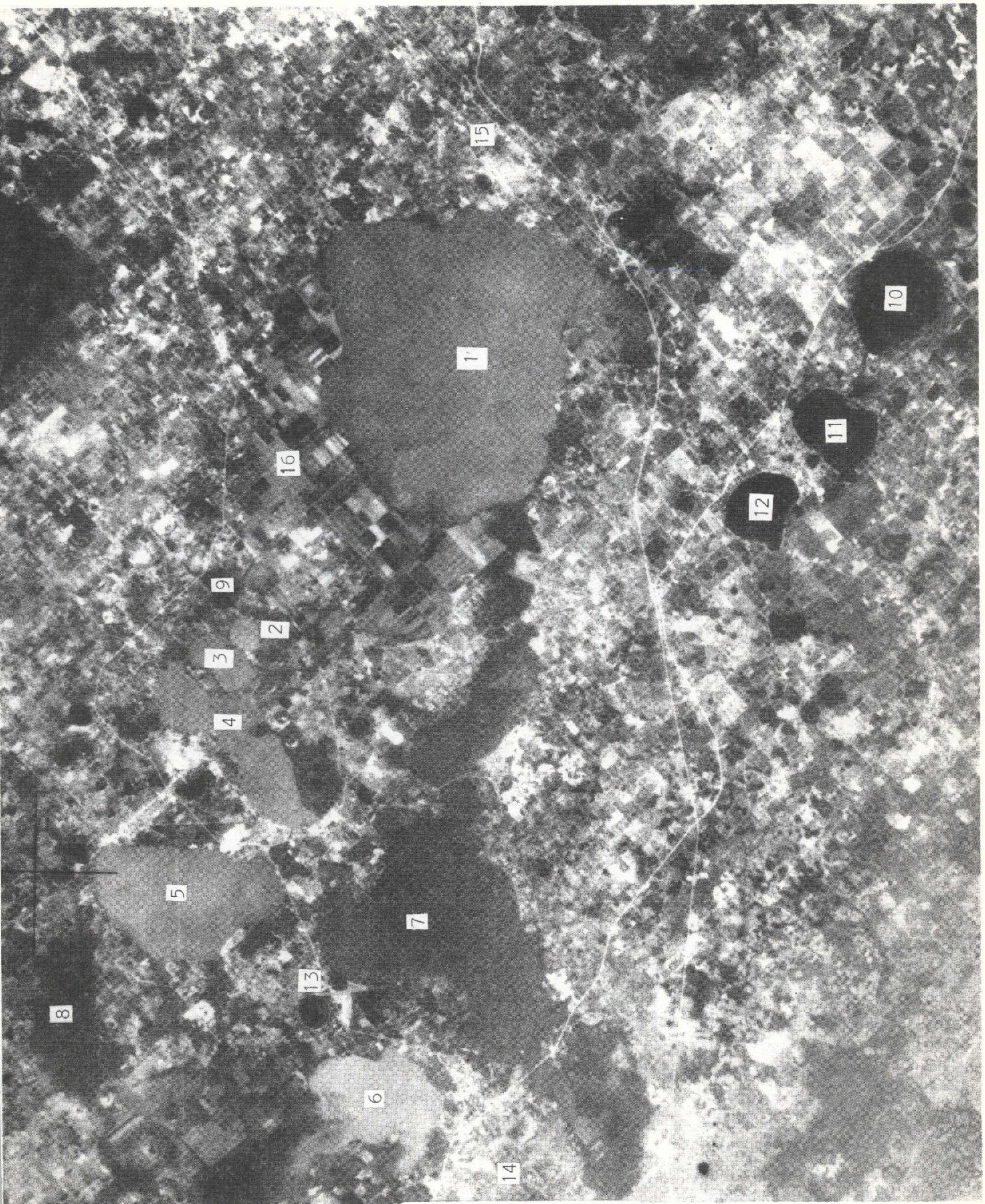

Figure 24

EREP Photograph of Central Florida Lakes

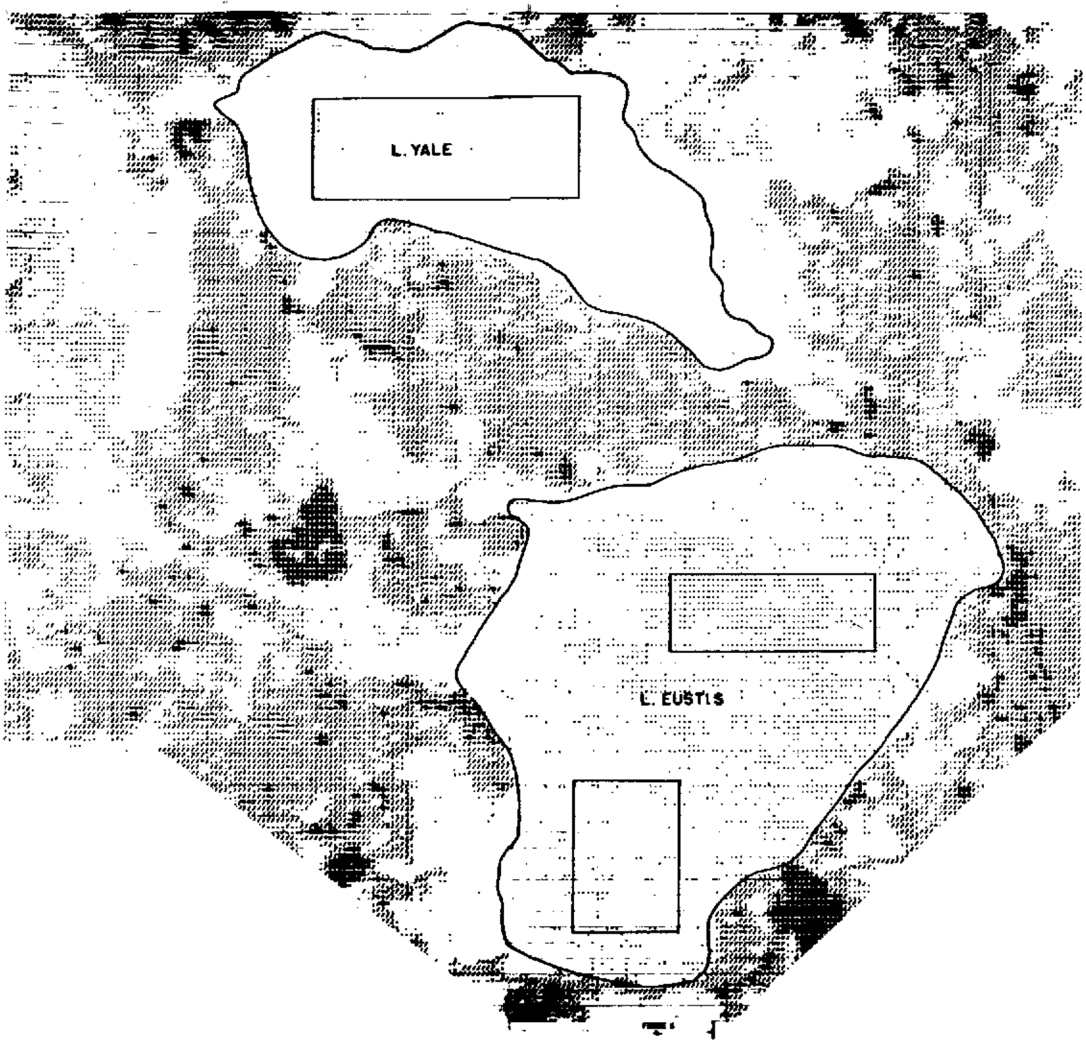

Figure 25

Band 4 Radiance, Lakes Yale and Eustis

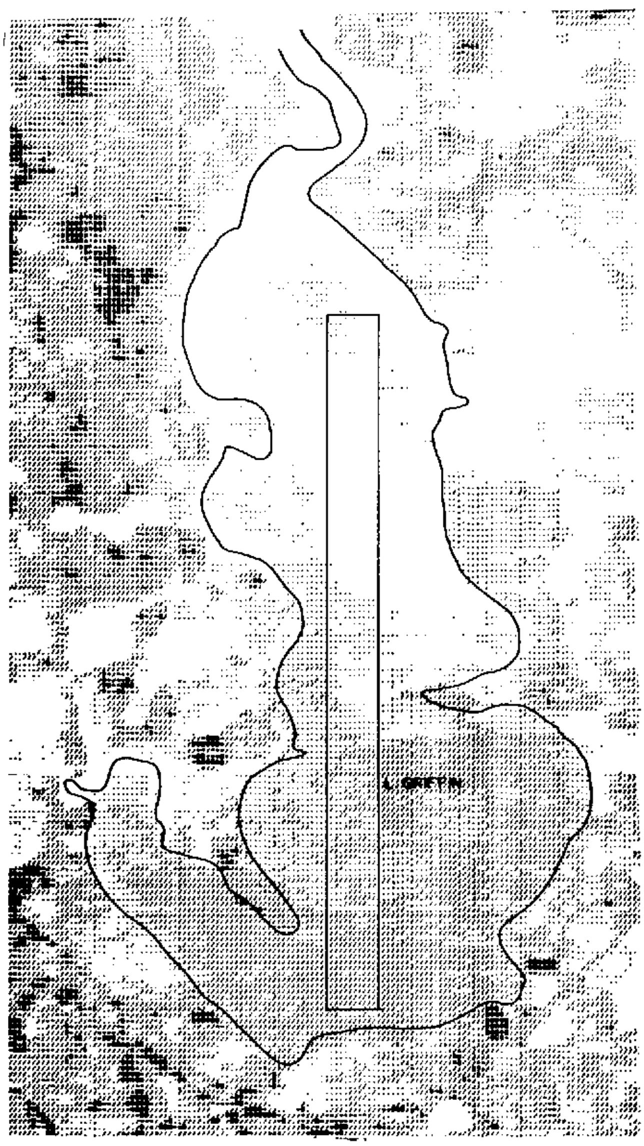

Figure 26

Band 4 Radiance, Lake Griffin

CONTACTS WITH PLANNERS

It has been our intention to work as closely as possible with the planners in the region, keeping them informed of developments, and seeking input from them. Discussions have been held with planners of the East Central Florida Regional Planning Council; planners of Brevard, Orange, Osceola, Polk, and Lake Counties; and with city planners of Titusville, Cocoa, Rockledge, Melbourne, Lakeland, and Leesburg.

Results of this work have been presented at a Regional Sciences and Applications Symposium at Kennedy Space Center, a meeting of the American Association of Geographers, and a meeting of the Titusville Planning and Zoning Board.

ACKNOWLEDGMENTS

Without the collaboration and help of various Kennedy Space Center personnel, this work could not have been done in this way. The computer program development and programming by Fernando Esparza and James J. Millard and the use of a KSC computer have been the heart of this project. J. P. Claybourne and the personnel of the Earth Resources Branch at KSC have made their facilities available, have provided photography of Brevard County for ground truth purposes, and have cooperated in every way that we could have asked. The Photographic Laboratory at KSC has been most helpful in doing special photographic work for us.

The Brevard County Reproduction and Printing Department has cooperated in doing special photographic and reproduction work in connection with the preparation of reports.

Various individuals not already mentioned have made contributions. Brett Horsely, formerly of the Brevard County Planning Department, has contributed to most of the work involving environmental matters. Gerald S. Langston, Jr., of the Brevard County Planning Department,has contributed helpful information regarding planning methods; and Timothy L. Lemper, of that organization, has helped with training samples.

Thomas C. McCollum and James L. Quinn, Titusville planners, have contributed to the work on their city.

James Delcamp,of Lakeland, and Robert M. Stark, of Orange County, have prepared training sets.

David Cox, Dennis Auth, and Dennis E. Holcomb, of the Florida Game and Fresh Water Fish Commission, have contributed in various ways.

Robert Yoder and Dr. James L. Baker, of the U. S. Fish and Wildlife Service, have collaborated in marsh and vegetation studies in the Merritt Island and St. Johns Wildlife Refuges, respectively.

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INDEX (continued)