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LANDSAT PLANNING APPLICATIONS
IN EAST CENTRAL FLORIDA

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CR-155028

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NASA, Kennedy Space Center

April, 1977
Final Report, Investigation #22670

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Prepared for:

Goddard Space Flight Center
Greenbelt, Maryland 20771

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BREVARD County
BOARD OF COUNTY COMMISSIONERS
COUNTY DEVELOPMENT DIVISION, 2575 N. Courtenay Parkway, Merritt Island, Florida 32952

SEAL OF BREVARD COUNTY FLORIDA

September 23, 1977

National Scientific and Technical
Information Facility
Attn: Earth Resources
P. O. Box 8757
BWI Airport
Baltimore, MD 21240

Gentlemen:

Enclosed is one (1) copy of the Final Report for ERTS
Follow-on Investigation No. 267 for Contract No. NAS5-20907.

Sincerely,

John W. Hannah

John W. Hannah
Development Division Coordinator
Principal Investigator

H/a
Enc. A/S
cc: Garland L. Thomas, Co-investigator
Edmund Szajna, Code 902, Goddard Space Flight Center

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16. Abstract

Land use maps have been prepared of Orange County and part of Brevard County using Landsat data. The method is computer classification and mapping followed by manual tracing of the patterns from the computer map.

A change map showing new construction in metropolitan Orlando over a seven month period has been prepared by manually comparing two computer-produced maps.

Several specific problems related to land use mapping have been studied.

Original photography may be purchased from:
EROS Data Center

Sioux Falls, SD

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[1]NASA, Kennedy Space Center

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PREFACE

(A) Objective

The general objective of this project was the study of ways in which Landsat-type data can be useful to local and regional planners. Specific objectives have been land use mapping and change monitoring.

(B) Scope of Work

The land use mapping has been accomplished by preparing computer line printer maps based on supervised maximum likelihood classification. Tracings of the patterns shown by those maps are then prepared manually.

Change monitoring has been accomplished for areas under development by manually comparing computer-produced land use maps for different dates.

(C) Conclusions

Land use maps made from Landsat data by computer classification, when corrected by local knowledge or by comparison with aerial photography or other sources of information, are sufficiently detailed and reliable to be useful to county and regional planners. Correction, as mentioned above, is essential, however, if the accuracy required for this purpose is to be attained. Preparation of such maps on a county-wide scale is feasible and cost-effective.

Change monitoring is an appropriate application of Landsat data.

(D) Summary of Recommendations

Education of planners in capabilities and applications of Landsat data should continue.

Operational systems should be the responsibility of state or regional data processing centers and commercial organizations.

CONTENTS

FIGURES

TABLES

I. PERSONNEL

The project has been conducted under the general administrative supervision of John W. Hannah, Principal Investigator and Brevard County Development Coordinator. Dr. Garland L. Thomas[1], Co-Investigator, has been responsible for the technical work.

Fernando Esparza, Co-Investigator, of NASA, Kennedy Space Center, has been responsible for the computer work and did some of the early programming. James J. Millard, of NASA, Kennedy Space Center, has done the bulk of the computer programming, and until the last four months of the program handled the details of the computer runs and sometimes participated in the interpretation of results. Four months prior to the completion of the project, the computer programs developed for this and the preceding Landsat project incorporated into the system of computer programs used by the Kennedy Space Center Earth Resources Group; at that time, Willie H. Green, of that group, assumed responsibility for the details of the computer runs. James Millard has continued to provide assistance with program interpretation and troubleshooting when needed.

Scott Henderson, Greg Adkins, and Richard MacMillan, all of the Orange County Planning Department, have contributed to that organization's part of the work. James Sellen has coordinated the work in that department, and Ron Manley has been helpful in discussions of land use inventory matters and environmental applications.

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[1] Report author.

Kenneth Sylvester, Hydrologist, and Marvin Miller, Biologist, both with Brevard County's Water Resources Program, have collaborated in the study of the St. Johns River marshes.

William C. Stimmel, Environmental Specialist with the St. Johns River Water Management District, collaborated in the Jane Green Reservoir Study .

II. FACILITIES

This project would not have been possible in its present form without the cooperation of the Earth Resources Group and the Computer Facility at Kennedy Space Center. As pointed out earlier, all of the programming was done by KSC personnel. In addition, the Honeywell 635 computer at that facility was used for the data processing.

The Earth Resources Group supported this project in many ways, including use of equipment in their Data Analysis Facility. Aerial photography of Brevard County provided by the Earth Resources Group has been very useful in developing training data and in comparison of results.

III. OBJECTIVES

There have been two major objectives of this project:

(1) Land use mapping in East Central Florida

(2) Change monitoring of key sectors.

IV. METHODS

GENERAL

The approach to land use mapping has been that of supervised computer classification followed by manual preparation of simplified versions of the computer maps. The maps so prepared are then corrected by application of local knowledge and comparison with existing aerial photography. Other specific problems are handled according to the circumstances of the problem.

COMPUTER PROGRAMS

The computer programs used in this project were mostly written in their basic form in a preceding Landsat project but have been revised and put in operational status during this project. The programs have been written almost entirely by James J. Millard (NASA, Kennedy Space Center), with some of the early programming having been done by Fernando Esparza (NASA, Kennedy Space Center) and with some input to the programming having been provided by Fernando Esparza and G. L. Thomas.

The programs are written for the Honeywell 635 computer. They are written approximately 90% in Fortran and 10% in KSC 635 Assembler Language. The Assembler Language is used mostly in data input, tape re-formulating, and data transfer. The programs could be run on another Honeywell 635 with minor modifications, but their modification for another computer would be a major task.

These programs have not been incorporated into the operational system of the KSC Earth Resources Group, where daily handling of computer details is the responsibility of Willie H. Green, whose collaboration for the last four months of this program is gratefully acknowledged.

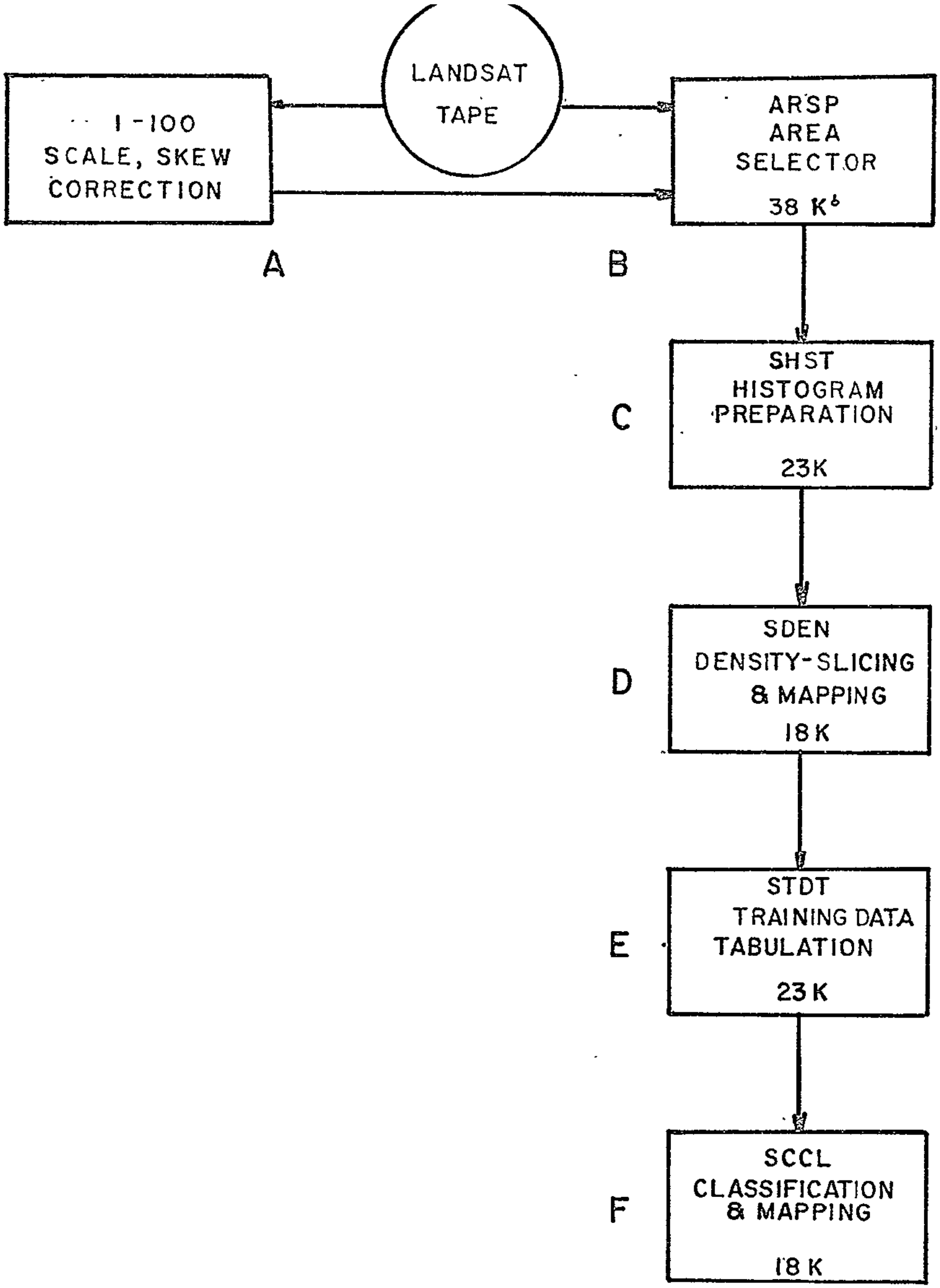
The programs are rather basic, leaving a relatively large amount of the work to manual methods, and are modular in form, so that the complete system need not be in the computer at one time. These features obviate the need for a dedicated or a large computer. We believe that such use of a system of modular programs and associated manual techniques is suited to use with a small computer.

The programs and a typical sequence of use are shown in Figure 1.

Step A, skew and scale correction, is being performed currently on the PDP 11/45 computer associated with the General Electric Image - 100 System because the appropriate programming was already in operation with that system. The output of step A is a 512 x 512 element tape. The skew and scale correction can readily be incorporated into step B, eliminating step A.

Step B produces an "area tape": a tape containing just the area to be studied, thereby reducing the amount of tape handling in future steps. In addition, step B changes the data format from the standard Landsat format (band-interleaved-by pixel) to a band-interleaved-by-line format which we have found to be easier and faster to process.

The Area Selector Program also has the capability of combining pixels by averaging their values. It can combine four pixels (2x2) into one or nine pixels (3x3) into one. This capability was introduced in order to evaluate its utility in regional mapping, producing a smaller scale map with less detail We have not yet used this feature enough to evaluate its utility. The Area



[b] COULD BE 24 OR 25 K WITHOUT 2 X 2 AND 3 X 3 OPTIONS

FIGURE 1
COMPUTER PROGRAMS

Selector Program will also accept data in the Skylab EREP S192 format or in the band-sequential format produced by a microdensitometer (Optronics). The output of Step A is normally put in the band-sequential format.

Step C produces histograms of the four bands or of ratios of any pair. In conventional land use mapping, it is our usual practice to prepare a histogram of the ratio (band 7 counts/band 5 counts) for the first area to be mapped. This program also has the capability of performing the classification described in F without mapping but with character counting (for area tabulation) for designated trapezoids.

In conventional land use mapping, the histogram produced in Step C is used to select the ranges for printer-character choices for a 7/5 map produced by program D. The eight line per inch map so produced is then used for location of training samples. (Two or three trials may be needed to obtain a map with suitable range-character combinations.) A non-supervised clustering program probably would be more useful at this stage, but the 7/5 mapping uses much less computer time (0.4 sec./km^2), and we have found it to be satisfactory. Local knowledge, aerial photography, or other information is, of course, necessary in choosing the training samples. Generally, we try to utilize local planners in the training sample selection process.

Training samples selected in the above process are then used in the Training Data Tabulation Program, E. Line and element numbers are read off the 7/5 map (Line numbers are printed on the map margin) and punched on cards. This is the slowest step in the process and fairly time-consuming but needs to be done relatively infrequently. It can, of course, be done faster on an interactive system; but the choice of training samples is the key to the success of the classification, and we feel that there is an advantage to being able to spread the map out on a tabletop and choose the training samples in a careful manner. Also, there is an advantage to being able to see the overall scene and individual pixels on the same map. Moreover, the scale of the computer map is 1/24,000, the same as that of the USGS 7.5' topographic maps, so that one can overlay the computer map on the topographic map (or photography, if available at that scale) on a light table to aid in choosing training samples. The Training Data Tabulation Program prints out for each training class the histograms in each band, "centroid" components, and covariance matrix data, from which the standard deviation in each band can be computed. The statistical characteristics of each training class are stored on punched cards.

The decision as to which class to use in the Classification Program is based primarily upon a separation distance defined as follows:

(1)

$$D = \left[\left(\frac{X_{11} - X_{12}}{\frac{\sigma_{11} + \sigma_{12}}{2}}\right)^2 + \left(\frac{X_{21} - X_{22}}{\frac{\sigma_{21} + \sigma_{22}}{2}}\right)^2 + \left(\frac{X_{31} - X_{32}}{\frac{\sigma_{31} + \sigma_{32}}{2}}\right)^2 + \left(\frac{X_{41} - X_{42}}{\frac{\sigma_{41} + \sigma_{42}}{2}}\right)^2\right]^{1/2}$$

$$= 2\left[\left(\frac{X_{11} - X_{12}}{\sigma_{11} + \sigma_{12}}\right)^2 + \left(\frac{X_{21} - X_{22}}{\sigma_{21} + \sigma_{22}}\right)^2 + \left(\frac{X_{31} - X_{32}}{\sigma_{31} + \sigma_{32}}\right)^2 + \left(\frac{X_{41} - X_{42}}{\sigma_{41} + \sigma_{42}}\right)^2\right]^{1/2}$$

In (1), the first subscript designates the band and the second subscript the class. The σ's are the "standard deviations" in the respective bands. The computation of D currently is being done manually, but computation of it or some other separate distance could readily be incorporated into the Training Data Program.

For evaluation, the values of D are tabulated as shown in the example in Table 1. A table of this type is then used as a guide in determining what classes to attempt to identify. Roughly, separation of classes is thought of as feasible for $D \geq 2$; but this is only a guide to be modified by the experience of a particular case and the need for separation of the classes under consideration.

The classification program, F, has three optional methods:

(1) MINDIST

In this option, the distance from the subject point to the centroid of each class is computed, and the class for which the distance is least is chosen as the class for that point. This is the fastest of the three classification methods.

(2) MAX/MIN

This option was written as a compromise between MINDIST and a maximum likelihood classification. Distances are computed as in option (1), then the three classes representing the shortest distances are chosen for a maximum likelihood calculation for the final classification. The time saving turns out to be not significant, and this method has not been used much.

(3) MAX. LIK.

This is the maximum likelihood option, which is used primarily. One modification has been added which reduces computer time somewhat without a significant decrease in classification accuracy. That is a table-look-up in a single band where it is justified by separability of the "signatures" of the class being considered. "Signature" data for the various classes can be prepared from the output of the Training Data Program, E, as shown in Figure 2. Currently, these plots are prepared manually, but they could be produced by the computer. The vertical lines represent the standard deviations

TABLE 1

DISTANCES BETWEEN TRAINING CLASSES

NORTH BREVARD DATA FOR MARCH 18, 1974

	WATER	HRWDS	PINE	MARSH	PINPAL	CYPRES	PLMOSO	SANPIN	URBAN	PASTUR	YNGCIT	MIDCIT	MATCIT	MOBHOM	PLMTTO
WATER	.	23.4	36.3	17.7	24.6	16.4	28.4	29.3	17.7	18.2	18.4	18.8	17.6	28.8	27.9
HRWDS	.	.	7.0	9.8	4.7	6.7	5.5	7.2	6.6	6.3	7.4	3.5	2.9	10.1	4.1
PINE	.	.	.	7.5	4.6	4.0	5.3	2.7	8.1	7.1	6.2	4.6	2.8	12.7	6.3
MARSH	.	.	.	.	6.7	2.7	7.3	5.7	8.1	7.1	6.4	6.2	5.8	12.2	8.6
PINPAL	.	.	.	.	.	3.6	1.4	4.4	6.0	5.0	3.7	1.6	1.0	9.3	1.6
CYPRES	.	.	.	.	.	.	4.2	2.5	7.4	6.4	5.3	4.1	3.1	11.1	3.8
PLMOSO	.	.	.	.	.	.	.	5.2	5.4	4.0	2.6	1.2	1.9	8.1	2.1
SANPIN	.	.	.	.	.	.	.	.	8.2	7.2	6.3	4.7	3.0	12.9	6.3
URBAN	.	.	.	.	.	.	.	.	.	1.5	2.8	4.2	5.7	0.6	5.6
PASTUR	.	.	.	.	.	.	.	.	.	.	1.5	3.1	4.8	2.5	4.6
YNGCIT	.	.	.	.	.	.	.	.	.	.	.	1.8	3.6	4.2	3.3
MIDCIT	.	.	.	.	.	.	.	.	.	.	.	.	1.7	6.0	1.0
MATCIT	.	.	.	.	.	.	.	.	.	.	.	.	.	7.8	1.6
MOBHOM	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8.6
PLMTTO	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

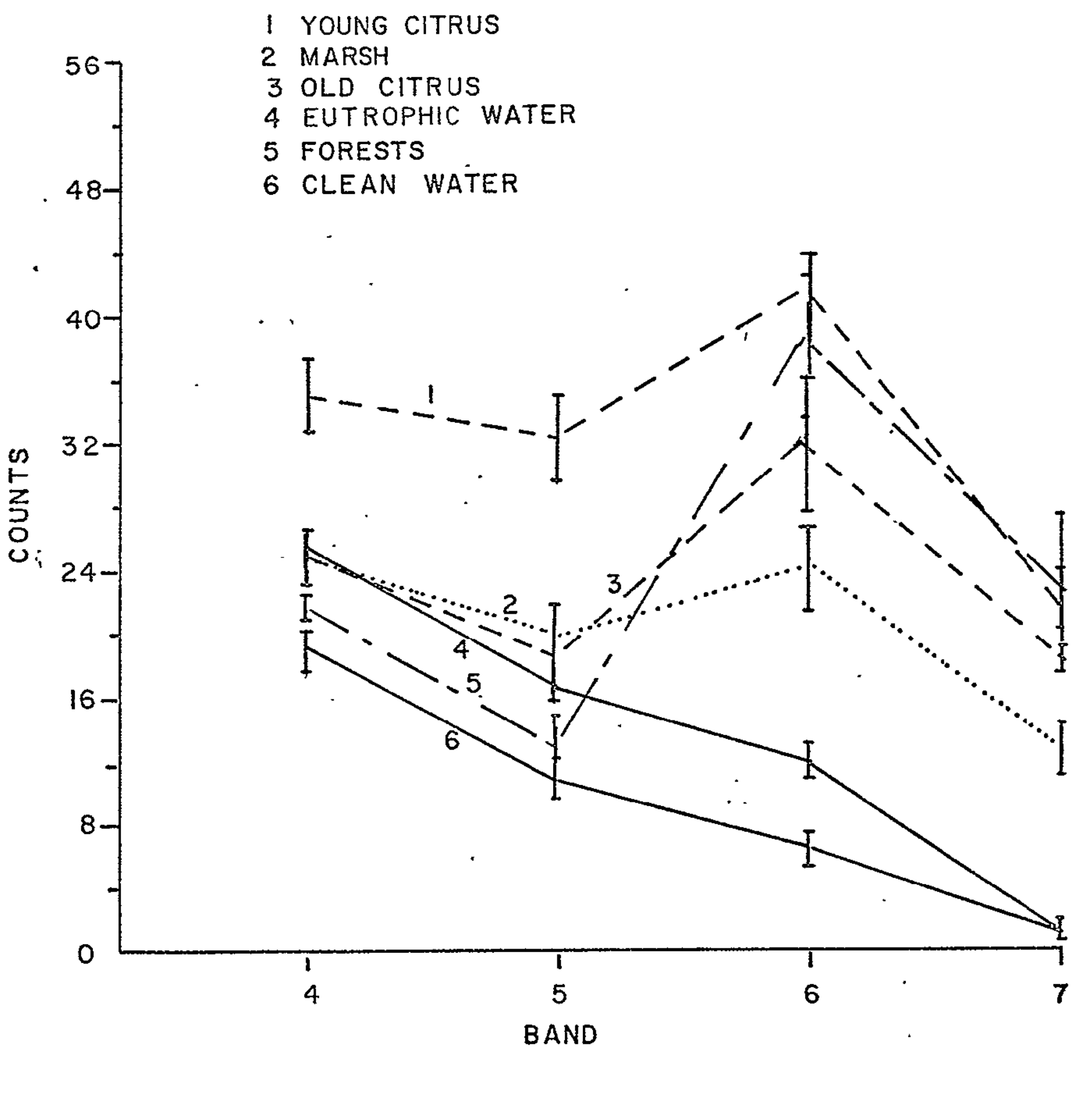


FIGURE.2
TRAINING CLASS "SIGNATURES"

for the individual bands. A plot of this type indicates which classes can be classified on a single-band table-look-up method. For example in Figure 2 (which has greater separations than most actual cases), water and marsh could be classified by table-look-up in band seven and young citrus in band four. In a typical case, water and perhaps one or two other classes can be classified by the single band table-look-up method. The computer procedure then is to first check each point for table-look-up possibilities in the designated bands; then, if table-look-up does not apply, perform a maximum likelihood classification. The table-look-up time is so small relative to the maximum likelihood classification time that the effect of this procedure on computer time is to reduce the effective number of classes considered by the number of classes for which table-look-up is used. In our case, the classification/mapping central processor time turns out to be approximately 0.37 sec./km^2/class classified by the maximum likelihood method (the table-look-up classes being "free").

Sometimes the order of consideration in the table-look-up is important. For example, in Figure 2, if water is considered first and thereby removed from further consideration, the forest class is left as a reasonable candidate for table-look-up in band 5.

In addition to the time-saving feature, it has been our experience that, under certain conditions, addition of the single band table-look-up feature to the classification scheme has increased the accuracy of the classification. This can be the case when the familiar striping effect is present in one or two bands of the data. In such a situation, the striping may be sufficiently serious to interfere with the classification by the maximum likelihood method but may permit accurate classification by table-look-up in a band which is free of striping. There may be cases where it would be advantageous to use this particular table-look-up "first pass" classification in more than one band per class, we have not yet done that.

If the single band table-look-up feature is added to the MINDIST classification scheme, option (1), a fast, reasonably accurate classification method is obtained. We tried this for one case and obtained a classification/mapping central processor time of .12 sec/km^2/class (two table-look-up classes, seven minimum distance classes).

The maximum likelihood program also has the capability of probability thresholding.

A maximum of 16 classes (including table-look-up classes) can be used.

Printer characters are assigned to the classes being mapped, and program F produces a line printer map at a scale of 1/24,000.

MAPPING METHODS

Since many people find a computer map difficult to interpret and since we do not have the capability of producing colored maps directly, our approach has been to simplify the computer maps and reduce the clutter by tracing the computer-produced land use patterns on a transparent overlay. The USGS numbering system, modified to fit the local situation, is used to designate the various land use classes.

The major effort in this program has been directed toward the production of a land use map of Orange County. In addition to the production of a useful land use map, a further aim has been a quantitative evaluation of Landsat data for that purpose. Hence, the procedure includes some extra steps directed toward that evaluation. The tracing produced as described above is compared with existing aerial photography (Real Estate Atlas) in the Orange County Planning Department. This comparison is done by one of the Orange County planners together with the co-investigator. The Landsat map is corrected to be consistent with the photography. A map showing the corrections is prepared, as is the final corrected map, which is prepared by the Orange County representative. The final map also contains traffic zone boundaries, as the immediate objective of the mapping was to produce a land use inventory tabulated by traffic zones. For purposes of that inventory, the Orange County representative then uses a portable type planimeter to determine the areas associated with the various land use categories in each traffic zone.

The co-investigator uses a planimeter to determine the areas for the various land use classes on the original land use map and the corrections, from which accuracy figures are determined. The histogram program, C, has the capability of counting characters and thereby obtaining automatically areas associated with the various land use classes. That capability is sometimes used for that purpose; but in this situation, we do not feel that the accuracy of the classification justifies use of that method, and we believe the measuring of patterns to be more appropriate.

CHANGE MAPS

Our present method of making change maps is manual comparison, by overlaying on a light table two computer-produced maps, one of which usually is a thematic map (commercial - industrial - new construction). This method seems to be effective in detecting substantial changes (two or more areas) which involve ground clearing or intentional or unplanned removal or killing of vegetation.

V. RESULTS

ANTICIPATED

Land Use Mapping

It was expected that land use maps would be prepared for Orange and Brevard Counties and other sectors selected on the basis of the existence of special problems.

Change-Monitoring

Change maps were planned for Orange County and the Kissimmee Basin.

OBTAINED

The major effort has been extended on the mapping of Orange County and evaluation of results. Only the northern portion of Brevard County has been mapped.

A change map has been prepared for the Orlando area.

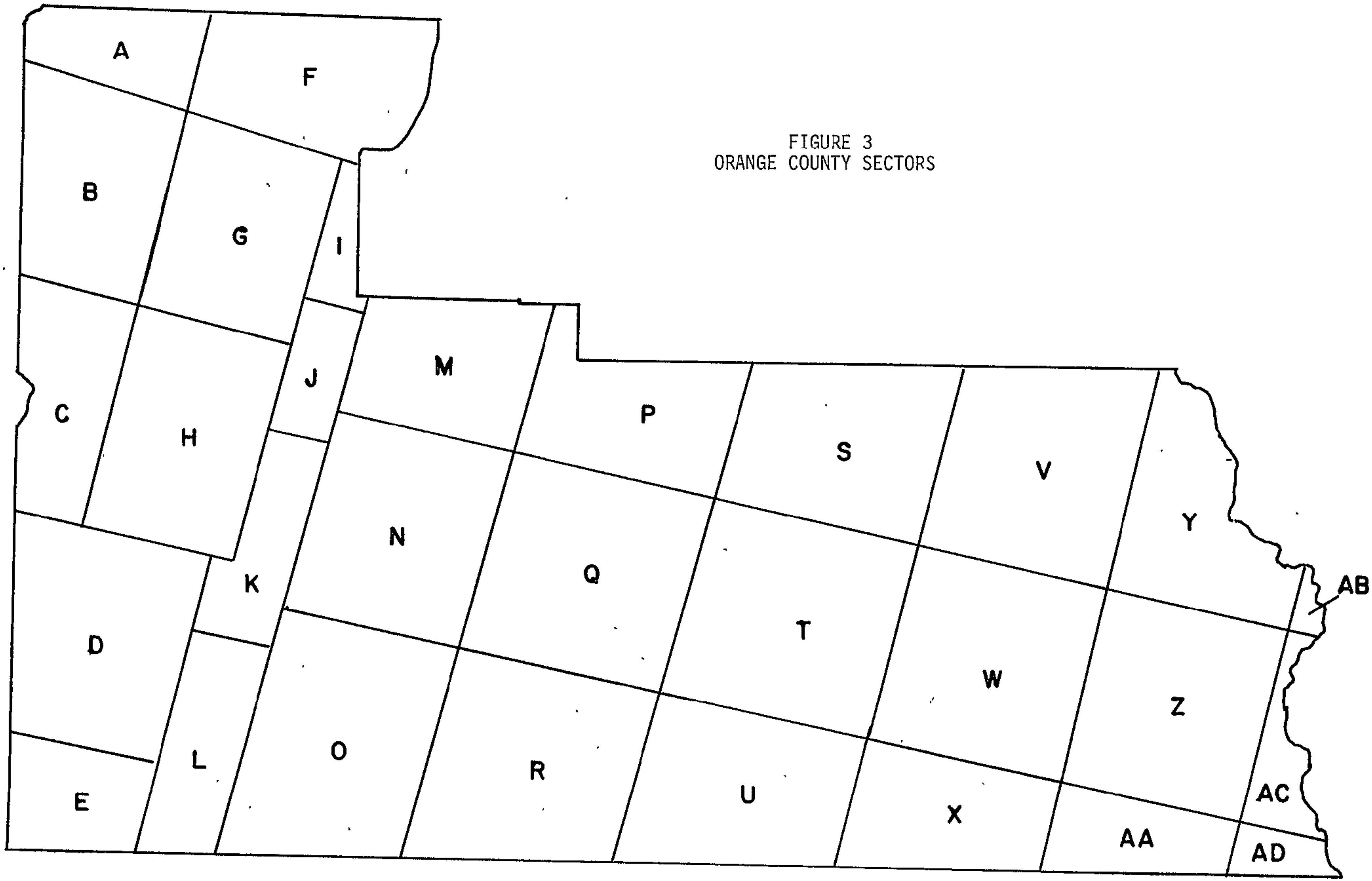
Because of a significant reduction in development activity in the Kissimmee Basin, study of that sector was deemed less critical than originally thought and a change map has not been prepared for that region.

Orange County

Land Use Mapping:

Using the method described above, land use maps of the County have been prepared. For this purpose, the County was divided into the sectors shown in Figure 3. The sector sizes were based on convenience in mapping and reproduction, the maximum size being that which could be accommodated by the camera used in preparing figures for reports.

FIGURE 3
ORANGE COUNTY SECTORS



It will be noted that the sectors in Figure 3 are slightly distorted. The mapping of Orange County was started before the scale-correction feature was added to our system; and, once the mapping was started, it was decided to continue without that correction. The difference in scale in the two directions is approximately 6%. For orientation purposes, a map of the County is included as Figure 4.

The original Landsat maps, as traced from the computer maps, are shown in Figures 5-34. For reproduction, the scale is reduced to one-half the original scale. The modified earlier version of the USGS classification system used for these maps is listed in Table 2.[2] The letter designators are the local modification.

Major highways and streets which are seen on the computer maps are drawn in manually (with occasional slight modifications based on photography) to improve the clarity and utility.

A limited amount of local knowledge was used in making the tracing from the computer map. That is, human interpretation was used where obvious to an observer with some knowledge of the County. We believe this to be a practical way to use Landsat data for United States observations; the computer map need not, and we think should not, be interpreted completely literally when it is not necessary to do so. The human intervention must, however, be kept in mind when reviewing accuracy figures. Examples of the "human intervention" are: most urban level 3 classifications, such as the identification of institutional features (Naval Training Center, Florida Technological University); location of airport boundaries;

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[2] James R. Anderson, Ernest E. Hardy, and John T. Roach, Land-Use Classification Systems for the Use with Remote-Sensor Data, Geological Survey Circular 671 (1972).

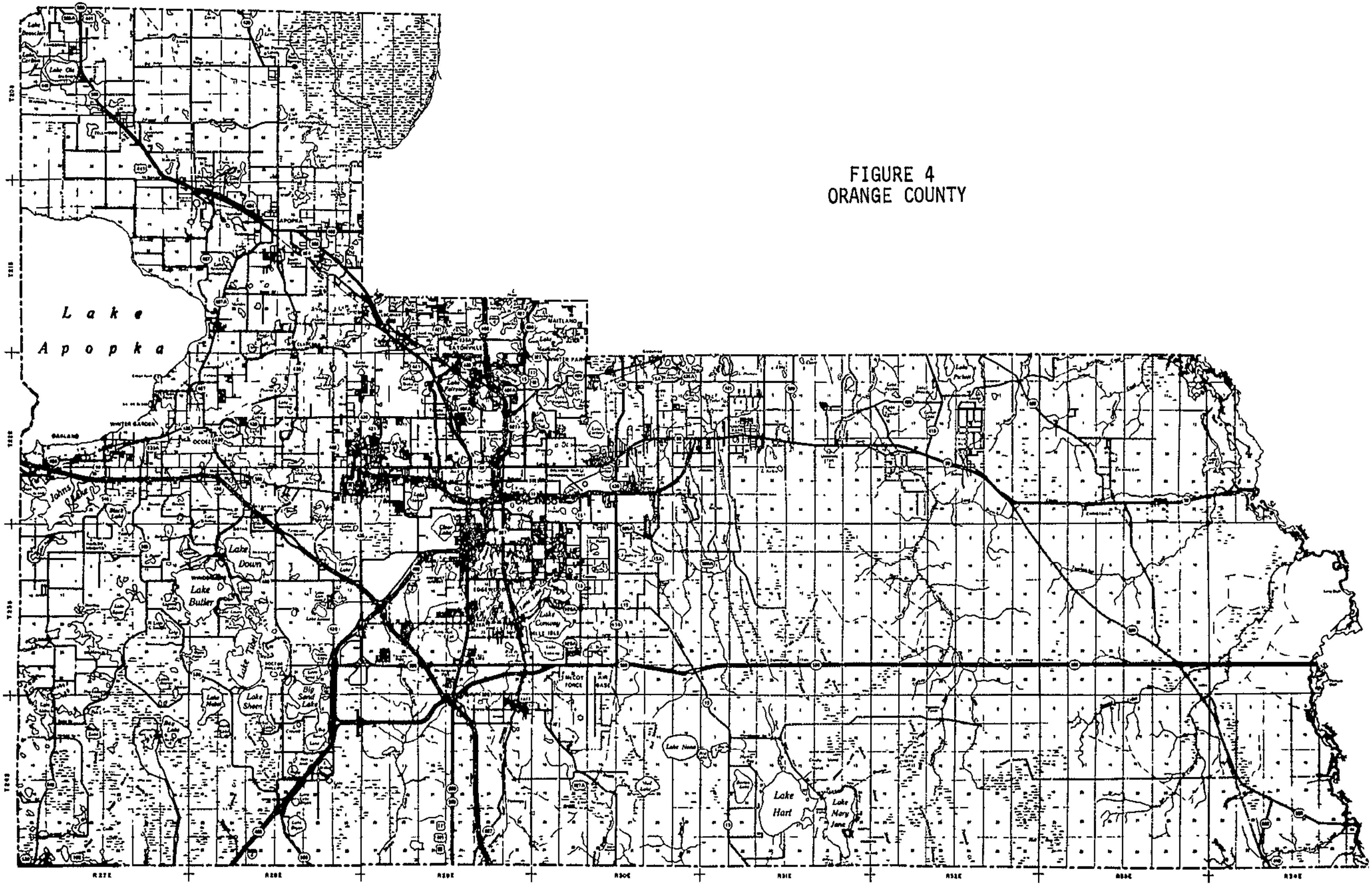


FIGURE 4
ORANGE COUNTY

LAND-USE CATEGORIES:

Level 1	Level 2
1. Urban and built-up land	1. Residential a. Wooded residential b. Non-wooded residential c. Rural residential d. Mobile-home parks e. Bare sand (non-landscaped) 2. Commercial and services 3. Industrial 4. Extraction a. Phosphate mines b. Reclaimed phosphate mines c. Clay mining 5. Transportation 7. Strip 9. Open 10. Institutional & Recreational 11. New construction 12. Tended grass
2. Agricultural land	1. Cropland and pasture a. Muck farms (vegetable) b. Vegetable farming c. Pasture 2. Groves a. Primarily citrus 3. Bare sand in agricultural sector 4. Cleared
3. Rangeland	1. Grass 2. Palmetto 3. Brush
4. Forest land	1. Deciduous a. Cypress b. Hardwoods 2. Evergreen (pine) 3. Mixed a. Pine and Palmetto b. Palmetto and Scrub Oak
5. Water	1. Streams and waterways 2. Lakes 3. Other (Gulf of Mexico)
6. Non-forested wetland	1. Vegetated 2. Bare
7. Barren land	3. Sand other than beaches

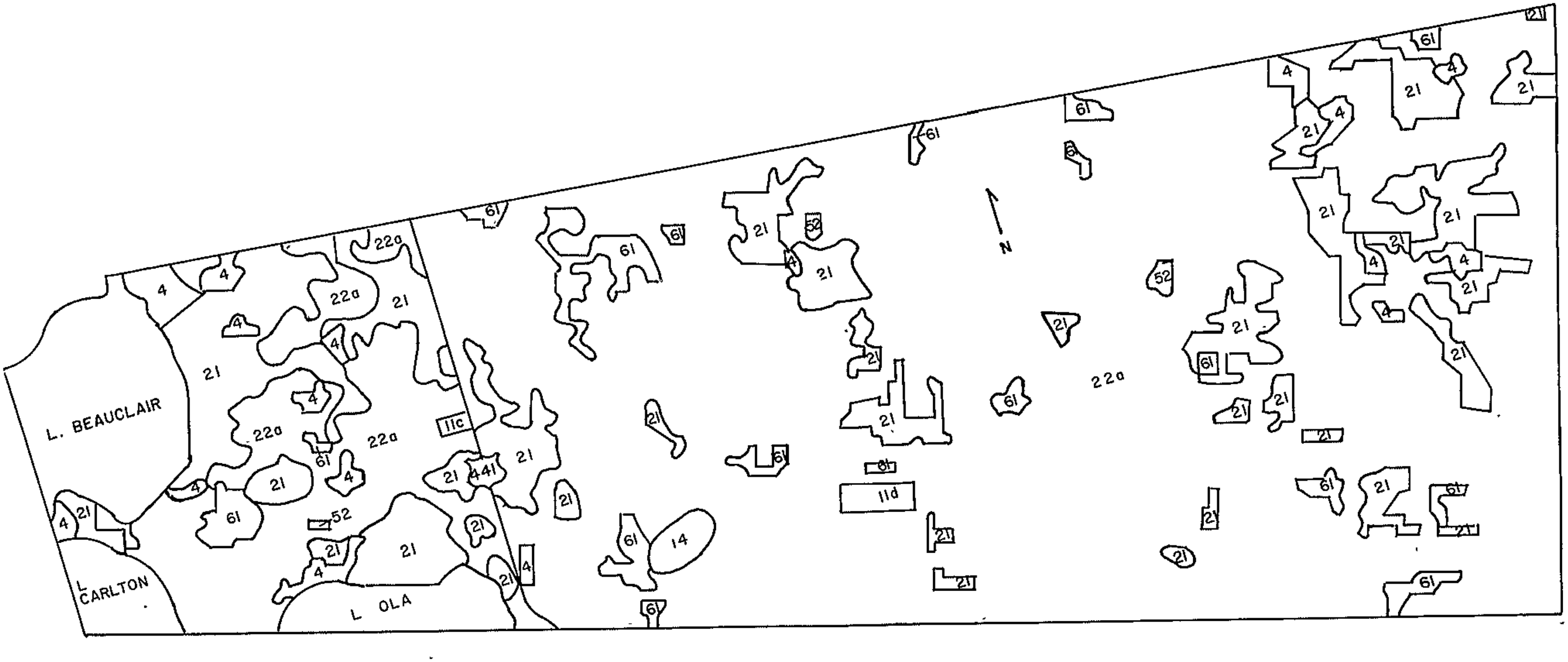


FIGURE 5
LANDSAT MAP
SECTOR A, ORANGE COUNTY

SCALE ∼ 1/48,000

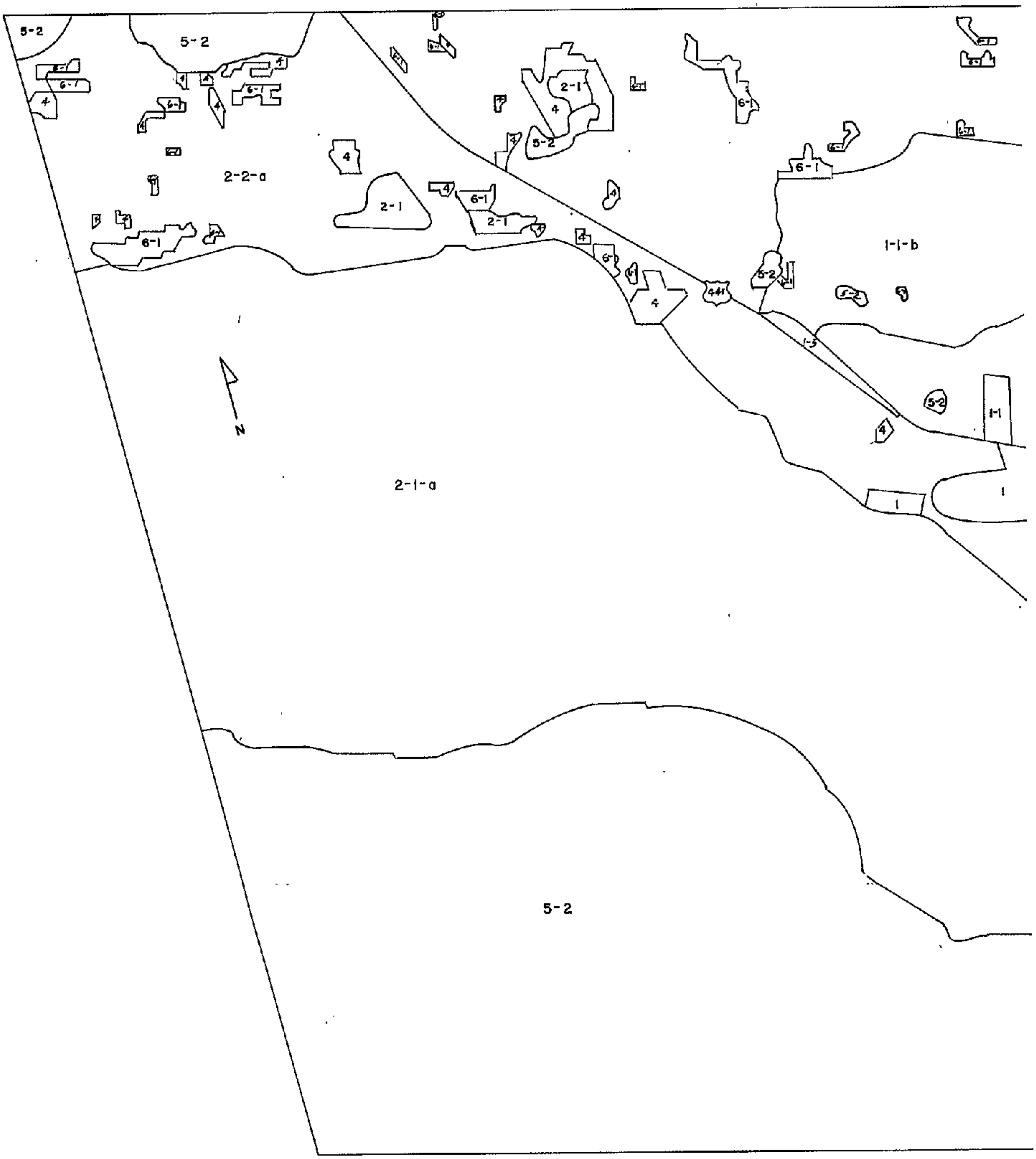


FIGURE 6
LANDSAT MAP
SECTOR B, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1
FOLDOUT FRAME 2

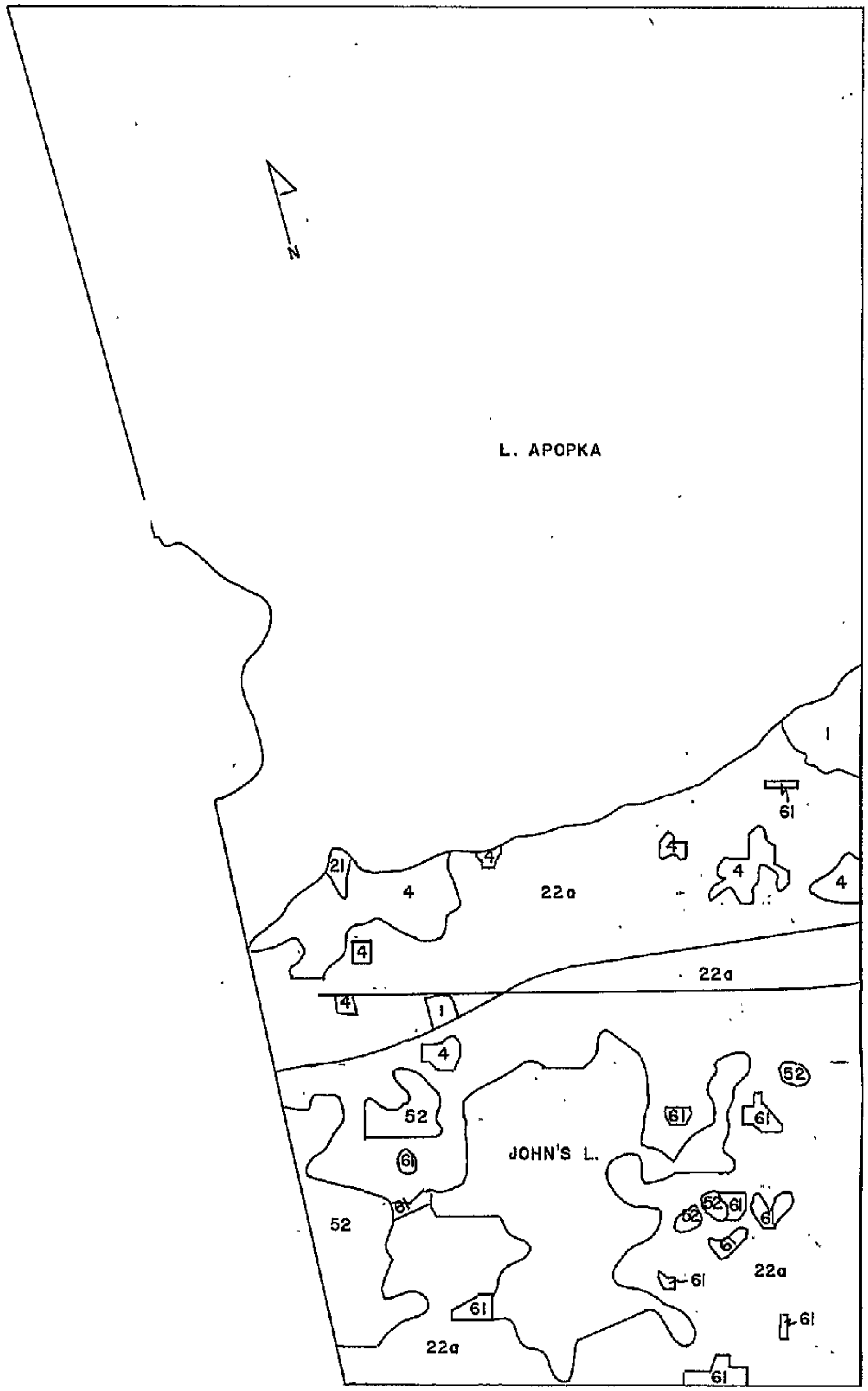


FIGURE 7
LANDSAT MAP
SECTOR C, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1
FOLDOUT FRAME 2

FOLDOUT FRAME 1

FOLDOUT FRAME 2

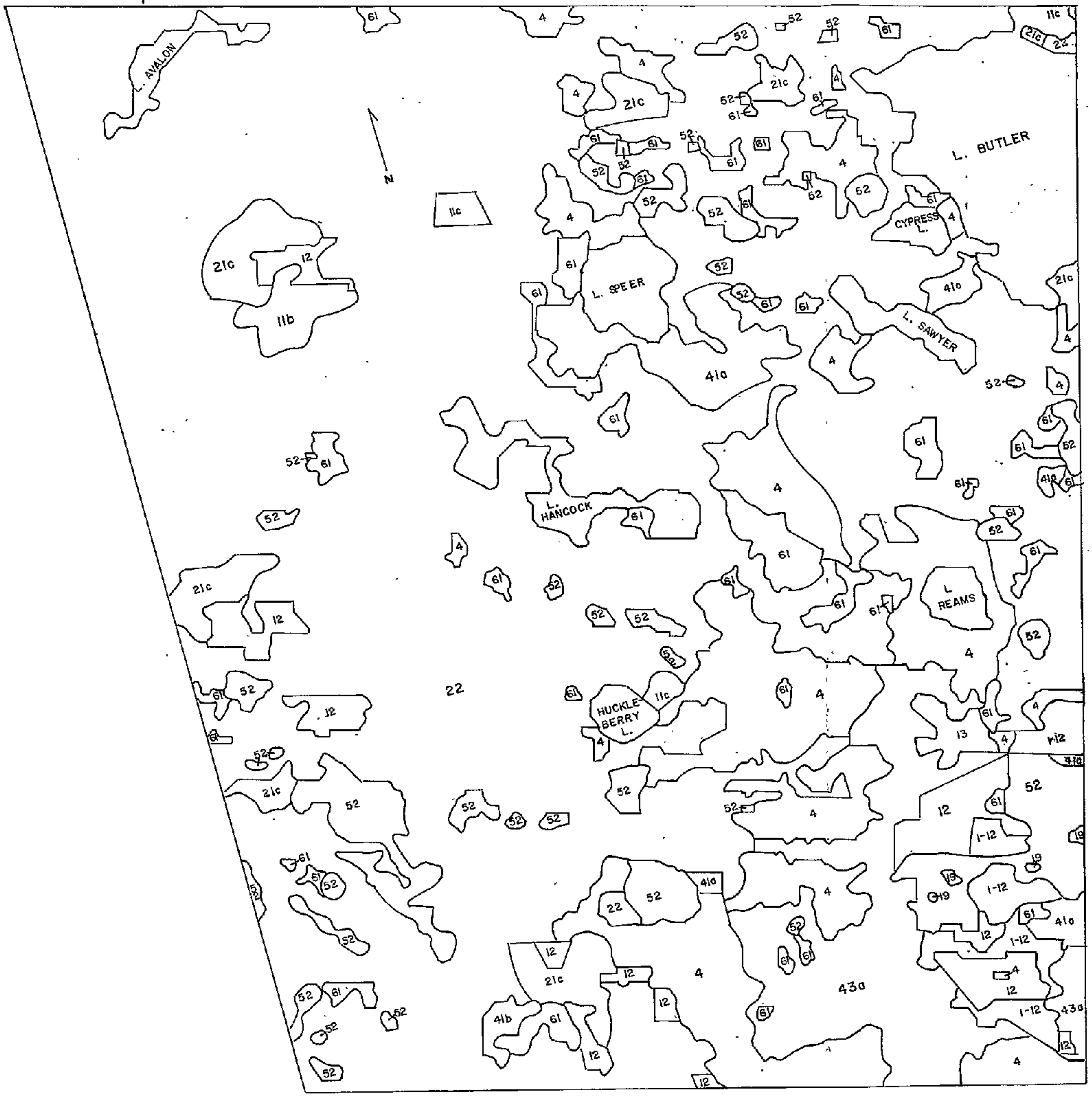


FIGURE 8
LANDSAT MAP
SECTOR D, ORANGE COUNTY

SCALE ~ 1/48,000

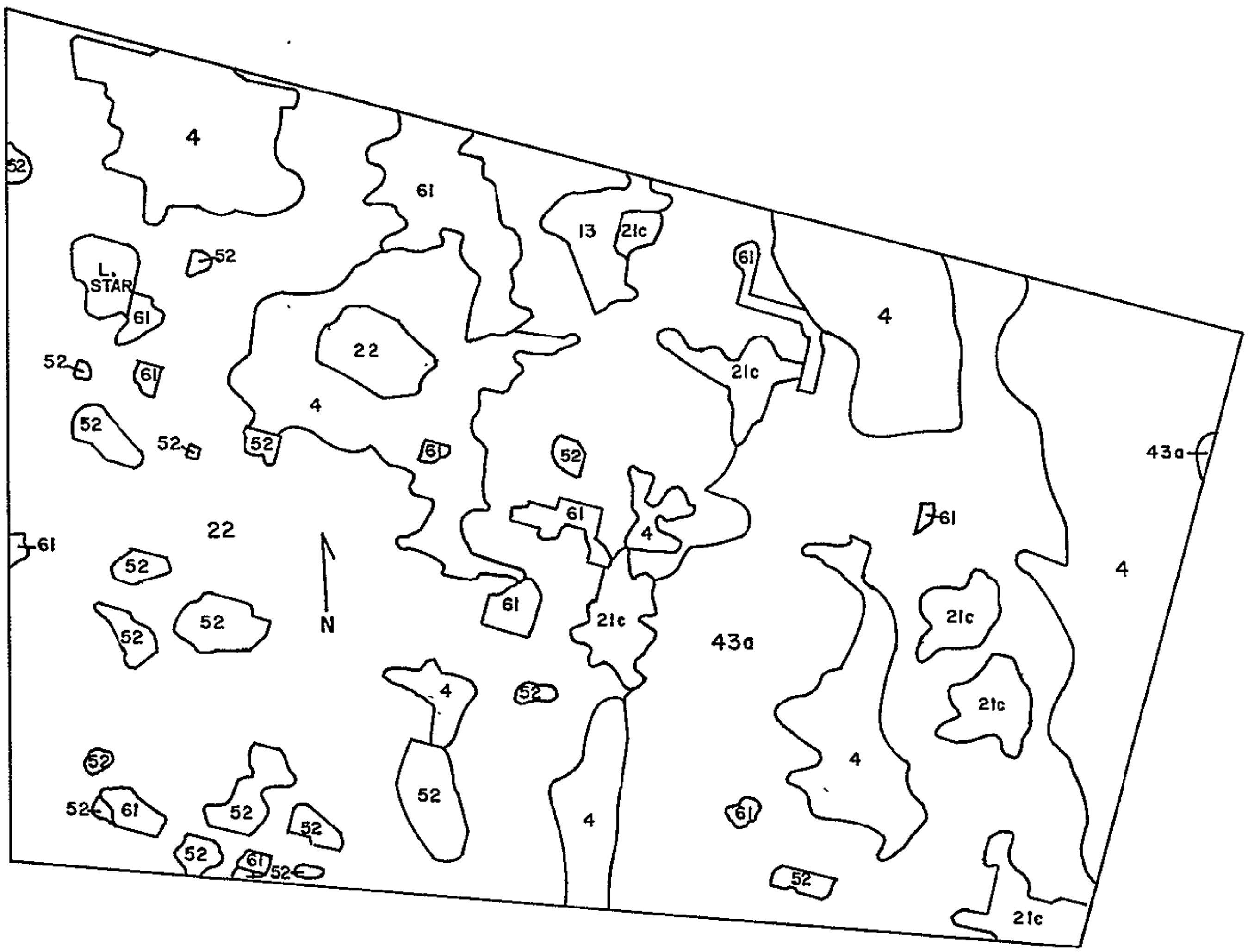


FIGURE 9
LANDSAT MAP
SECTOR E, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

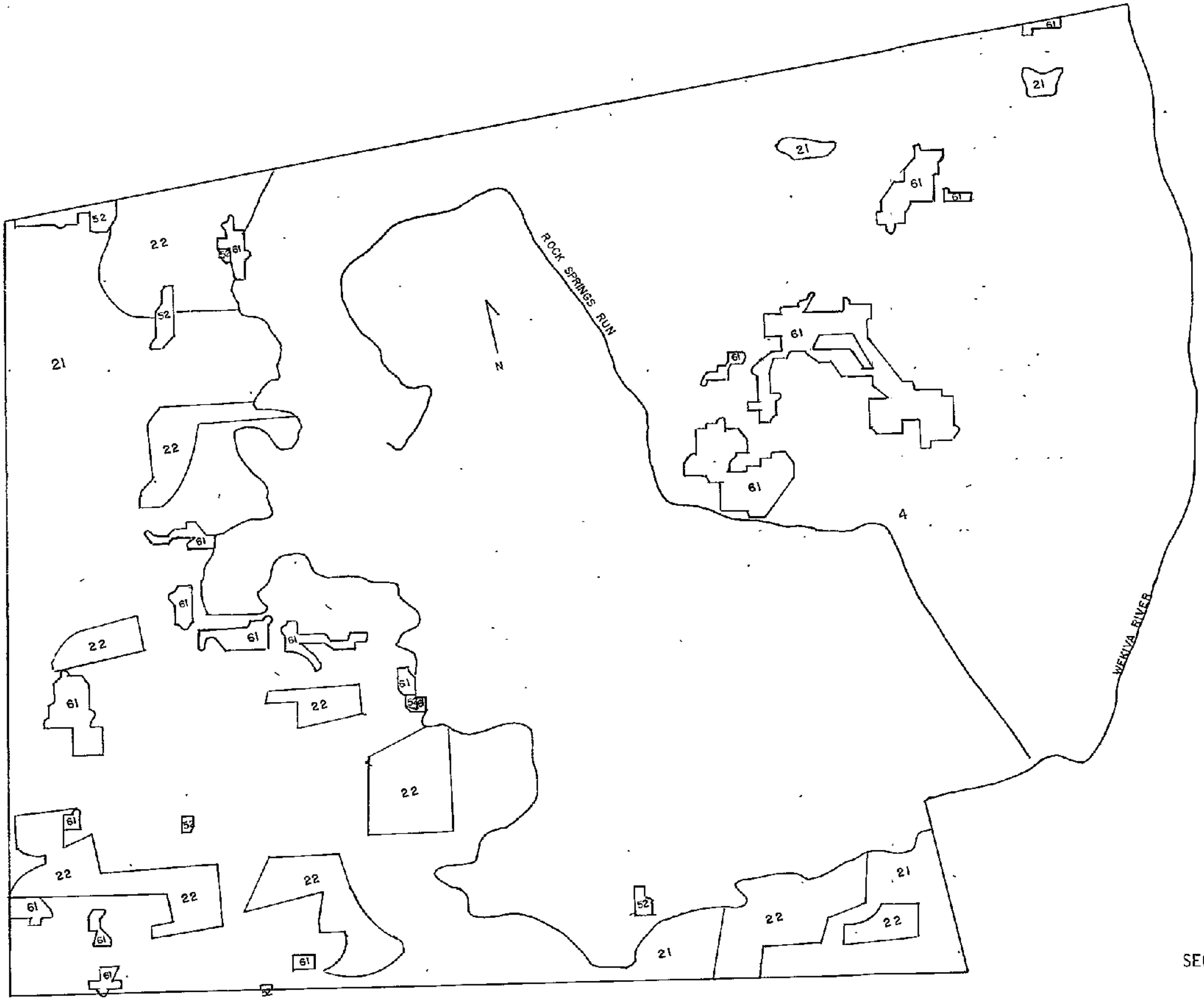


FIGURE 10
LANDSAT MAP
SECTOR F, ORANGE COUNTY

SCALE ∼ 1/48,000

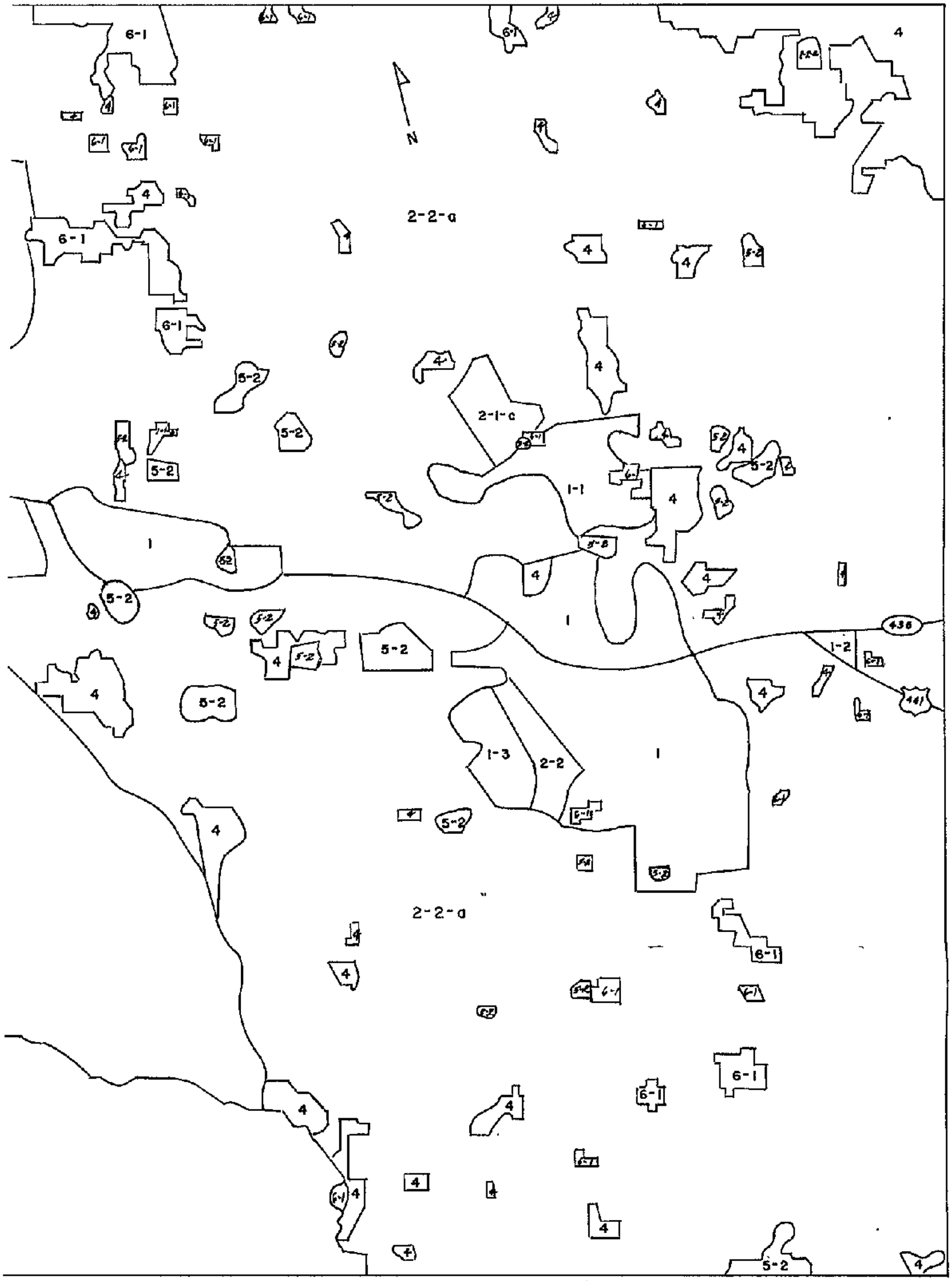


FIGURE 11
LANDSAT MAP
SECTOR G, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

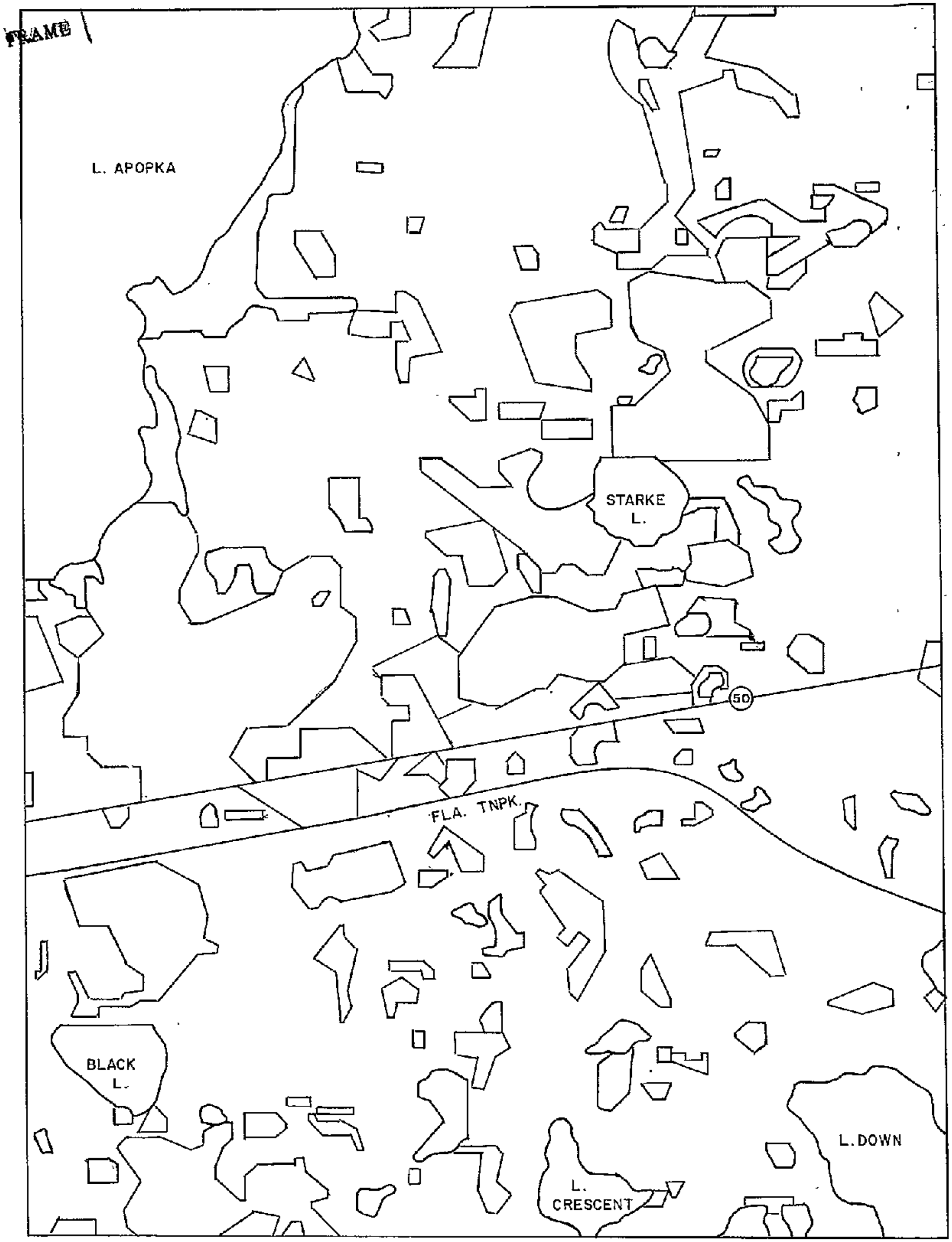


FIGURE 12
LANDSAT MAP
SECTOR H, ORANGE COUNTY

SCALE ~ 1/48,000

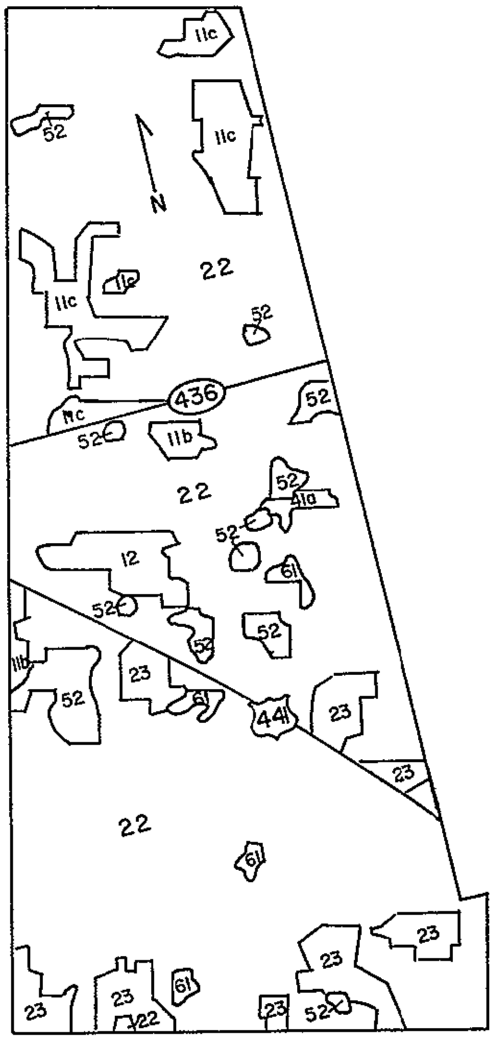


FIGURE 13
SECTOR I, ORANGE COUNTY

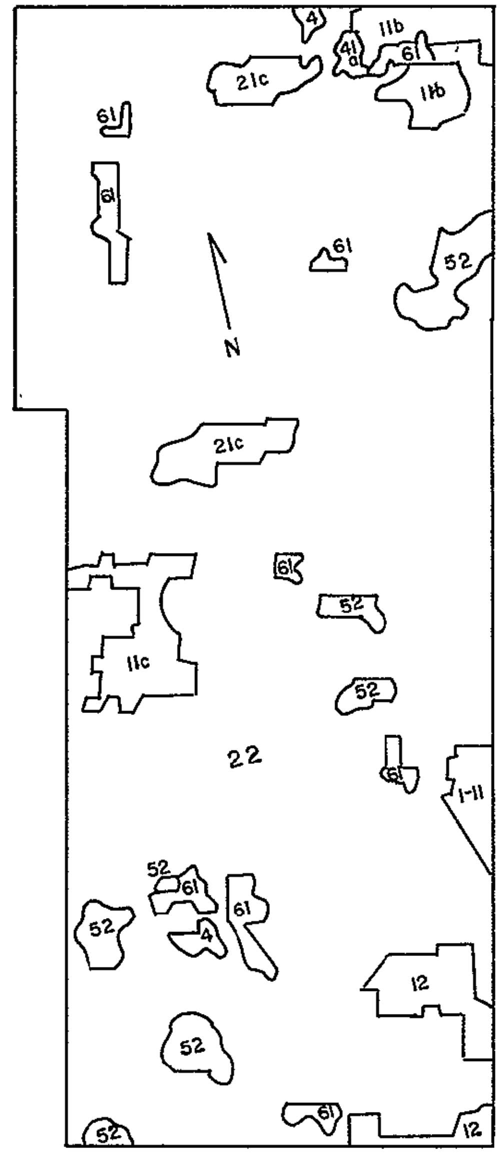


FIGURE 14
SECTOR J, ORANGE COUNTY

LANDSAT MAP
SCALE ∿ 1/48,000

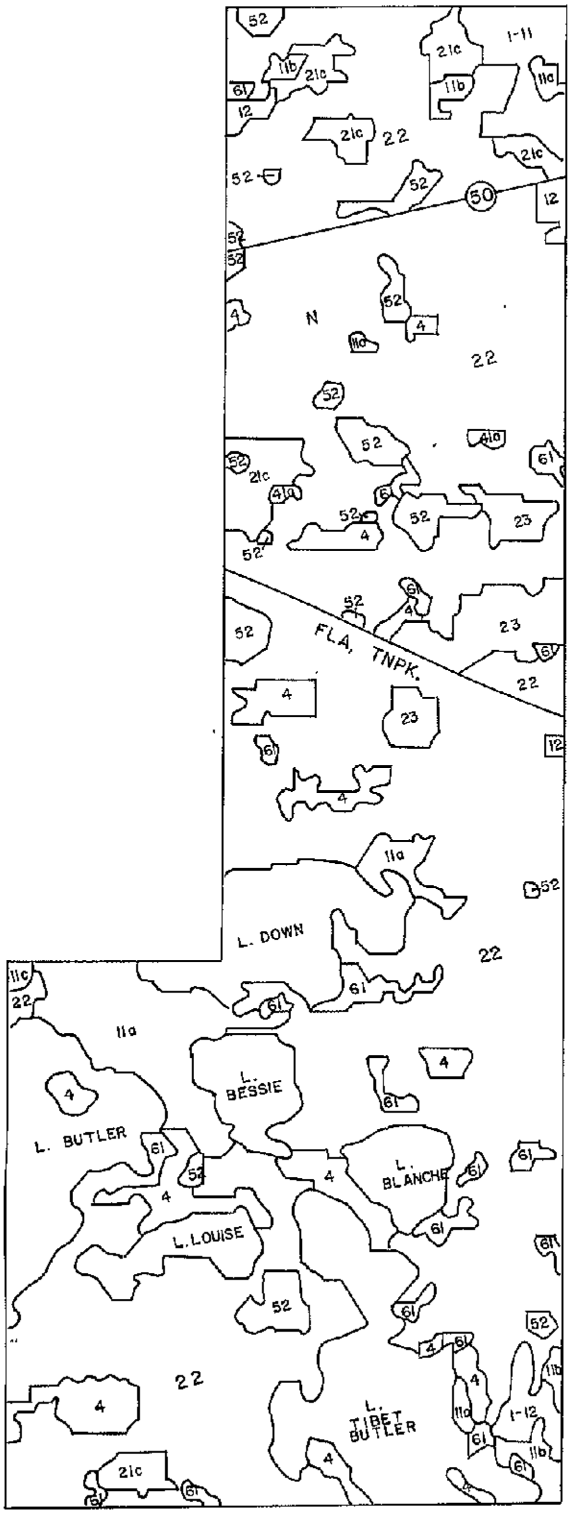


FIGURE 15
SECTOR K, ORANGE COUNTY

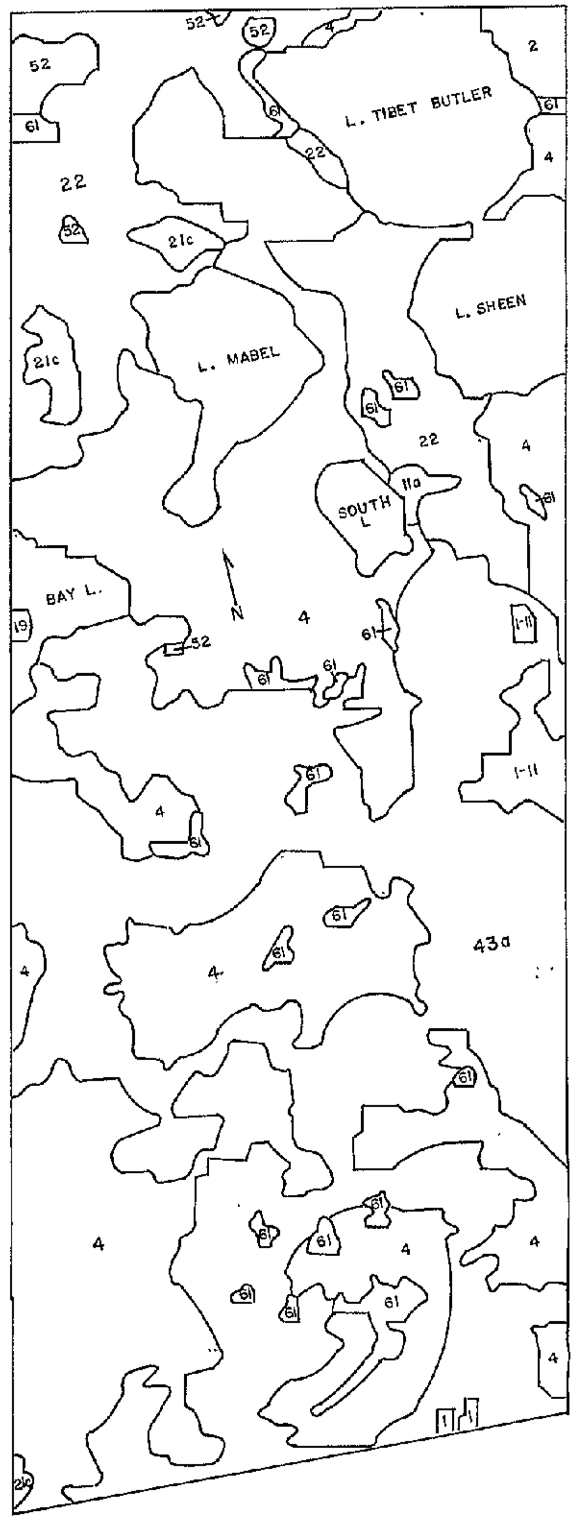


FIGURE 16
SECTOR L, ORANGE COUNTY

LANDSAT MAP
SCALE ~ 1/48,000

FOLDOUT FRAME 1
FOLDOUT FRAME 2

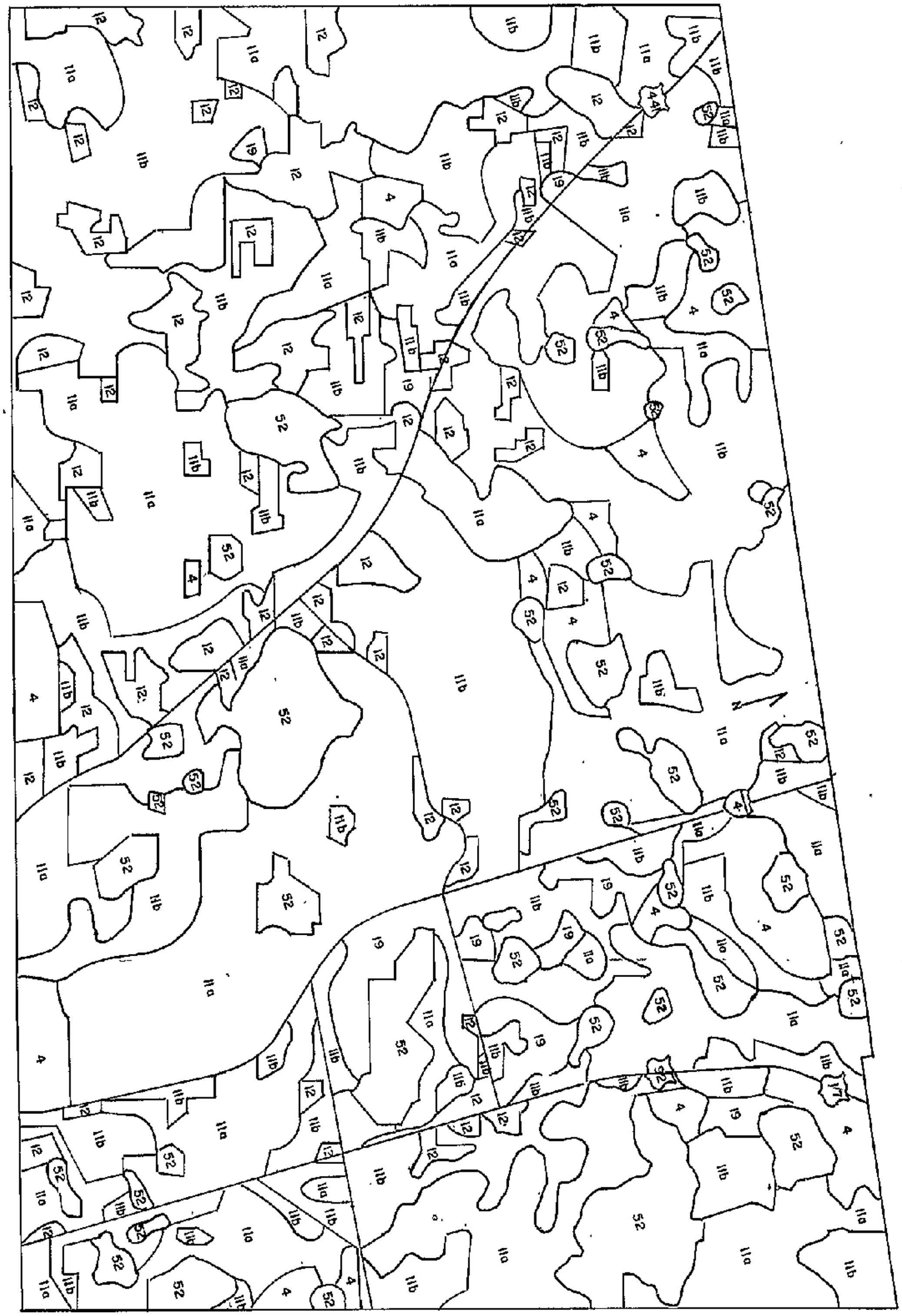


FIGURE 17
LANDSAT MAP
SECTOR M, ORANGE COUNTY

SCALE ∿ 1/48,000

FOLDOUT FRAME 1
FOLDOUT FRAME 2

FOLDOUT FRAME 1

FOLDOUT FRAME 2

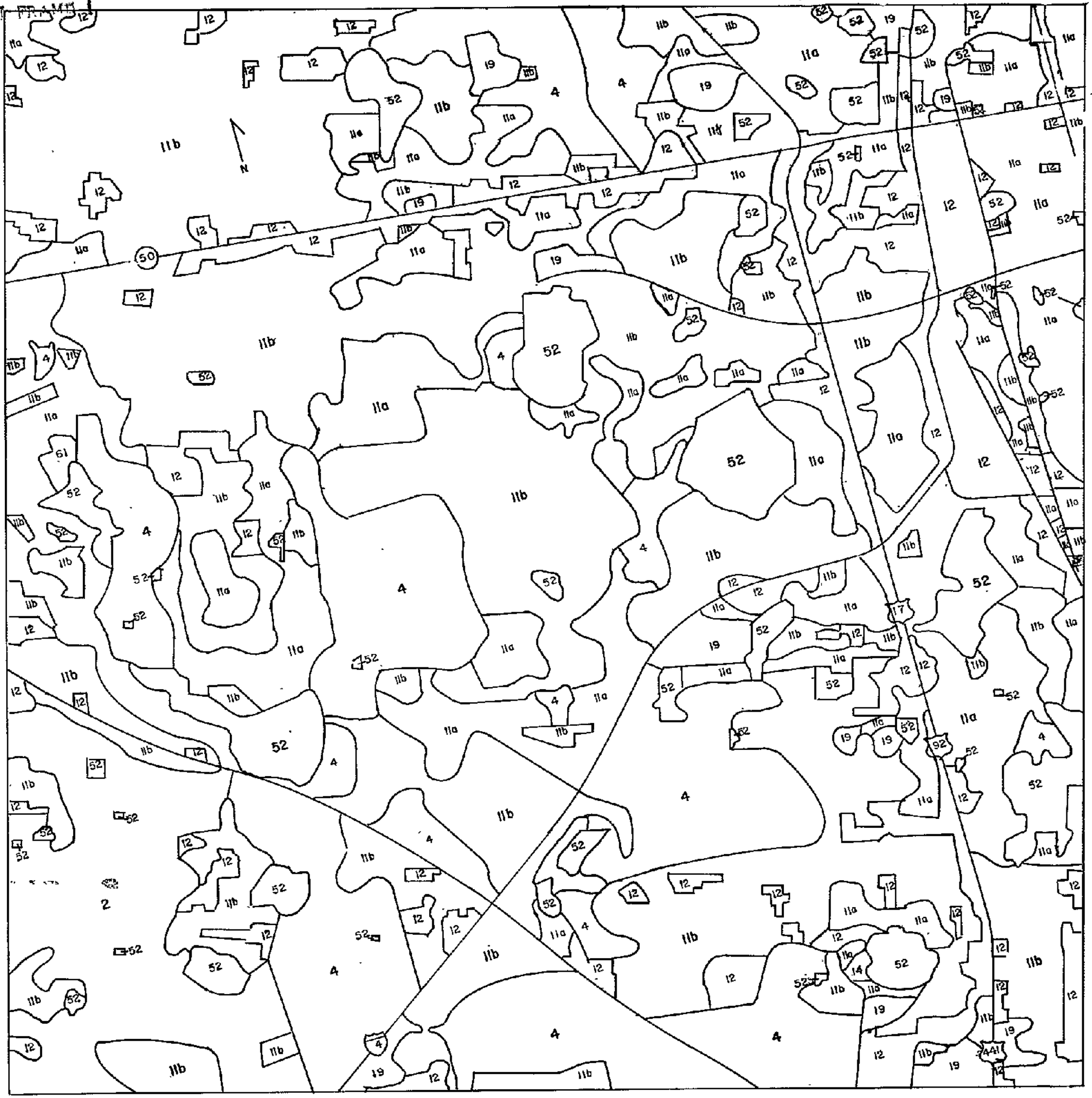


FIGURE 18
LANDSAT MAP
SECTOR N, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

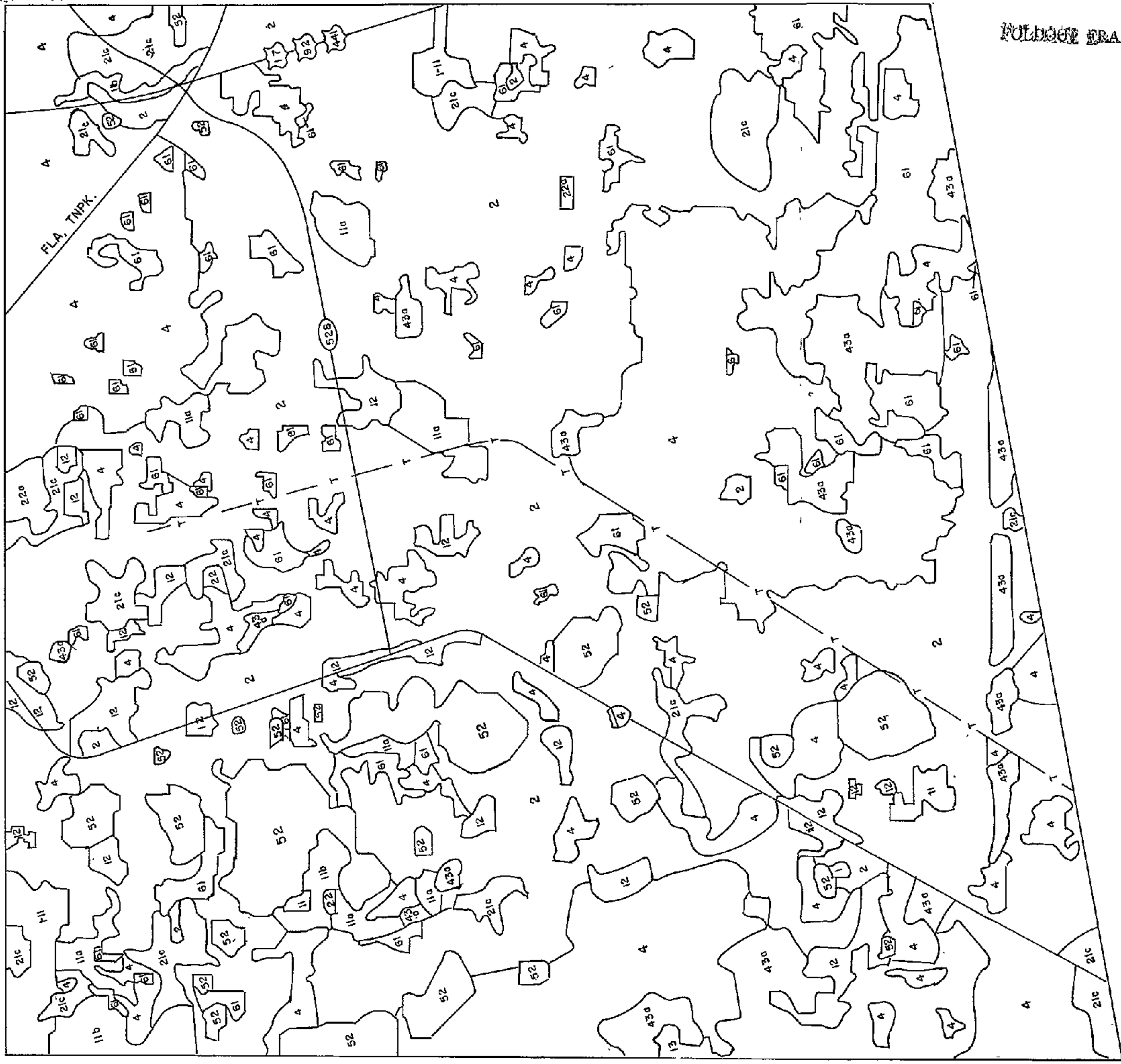


FIGURE 19
LANDSAT MAP
SECTOR 0, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 20
LANDSAT MAP
SECTOR P, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

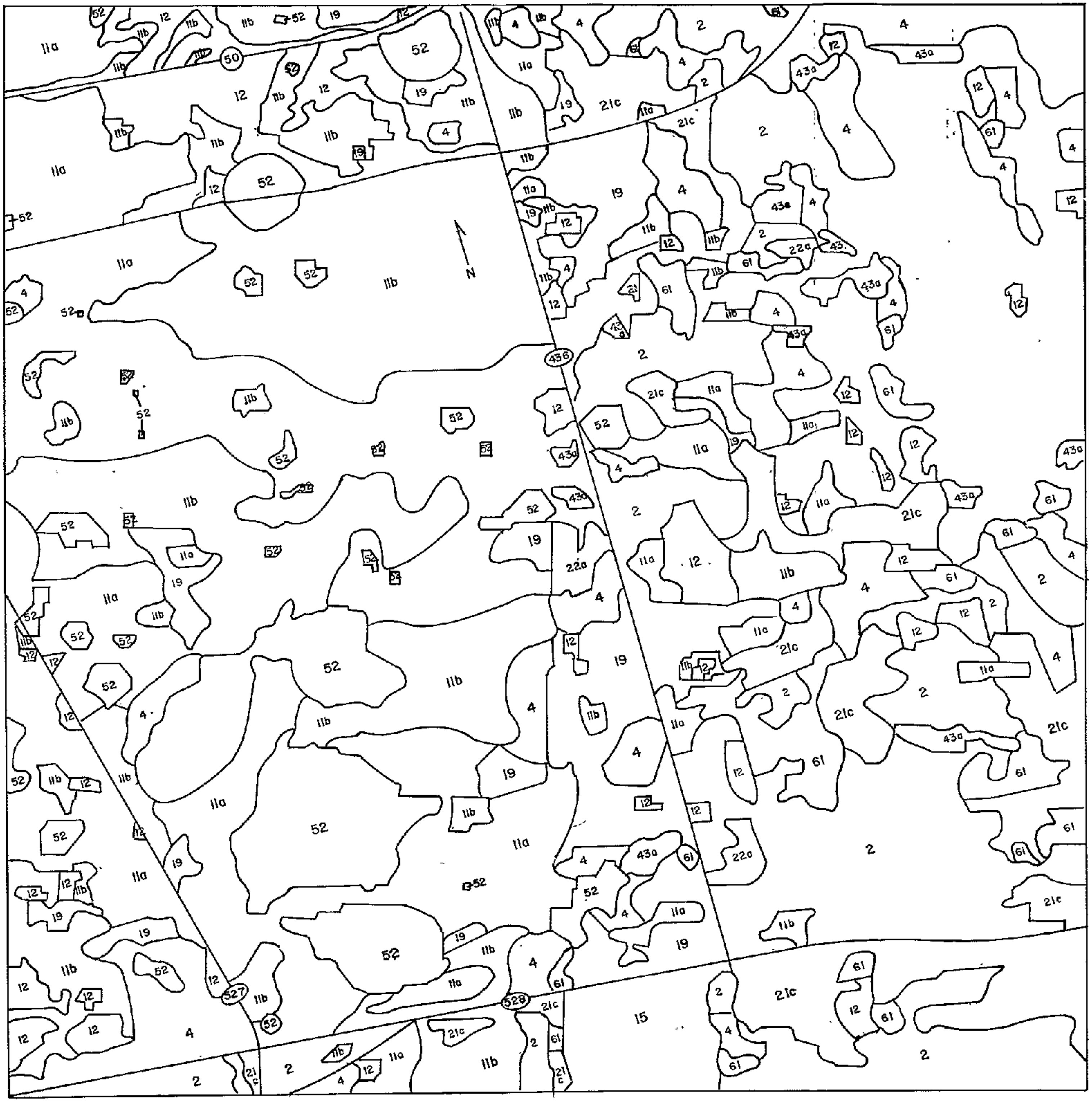


FIGURE 21
LANDSAT MAP
SECTOR Q, ORANGE COUNTY

SCALE ~ 1/48,000

FIGURE 22
LANDSAT MAP
SECTOR R, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 2

FOLDOUT FRAME 1

FOLDOUT FRAME 2

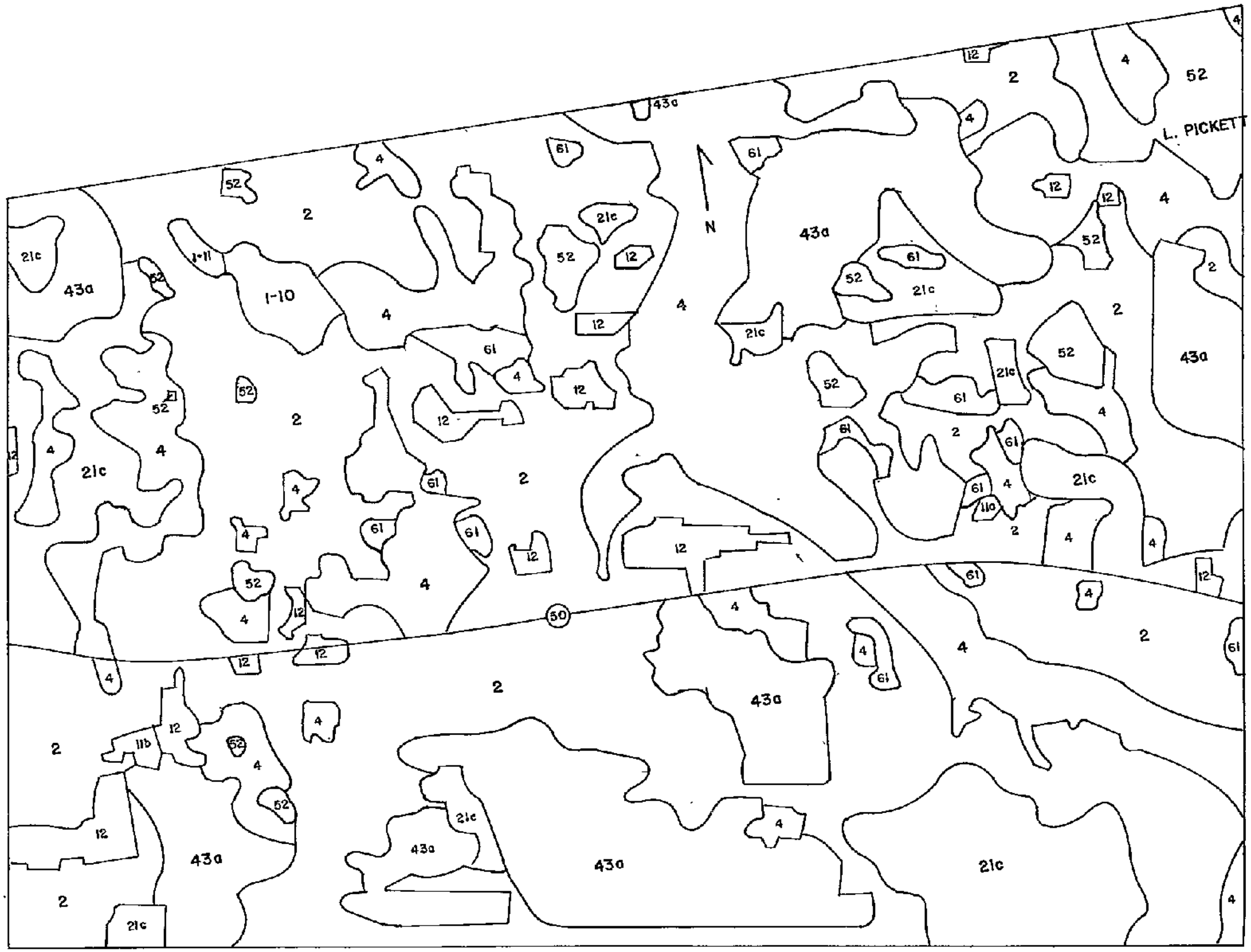


FIGURE 23
LANDSAT MAP
SECTOR S, ORANGE COUNTY

SCALE ∿ 1/48,000

FOLDOUT FRAME 2

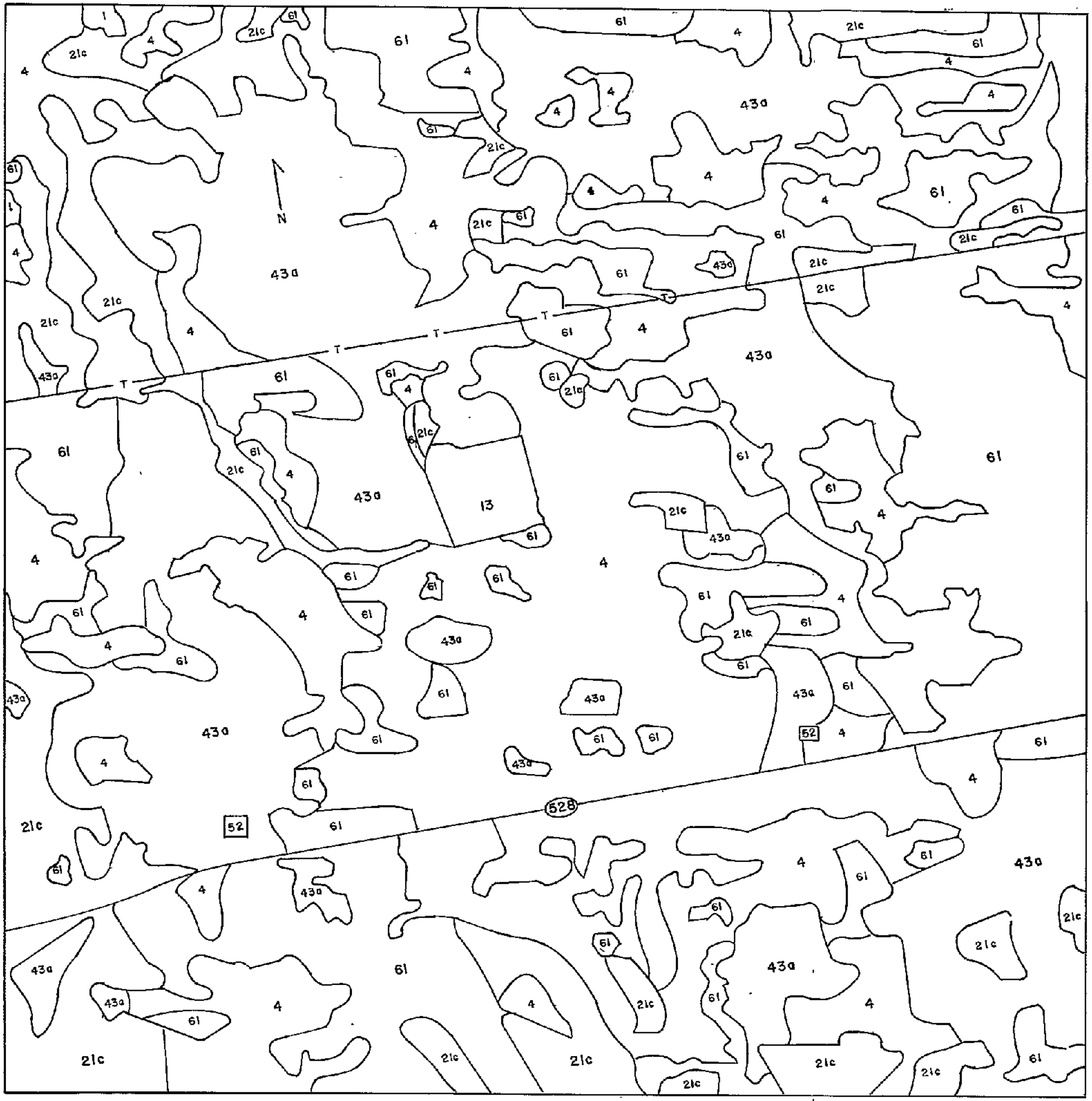


FIGURE 24
LANDSAT MAP
SECTOR T, ORANGE COUNTY

SCALE ~ 1/48,000

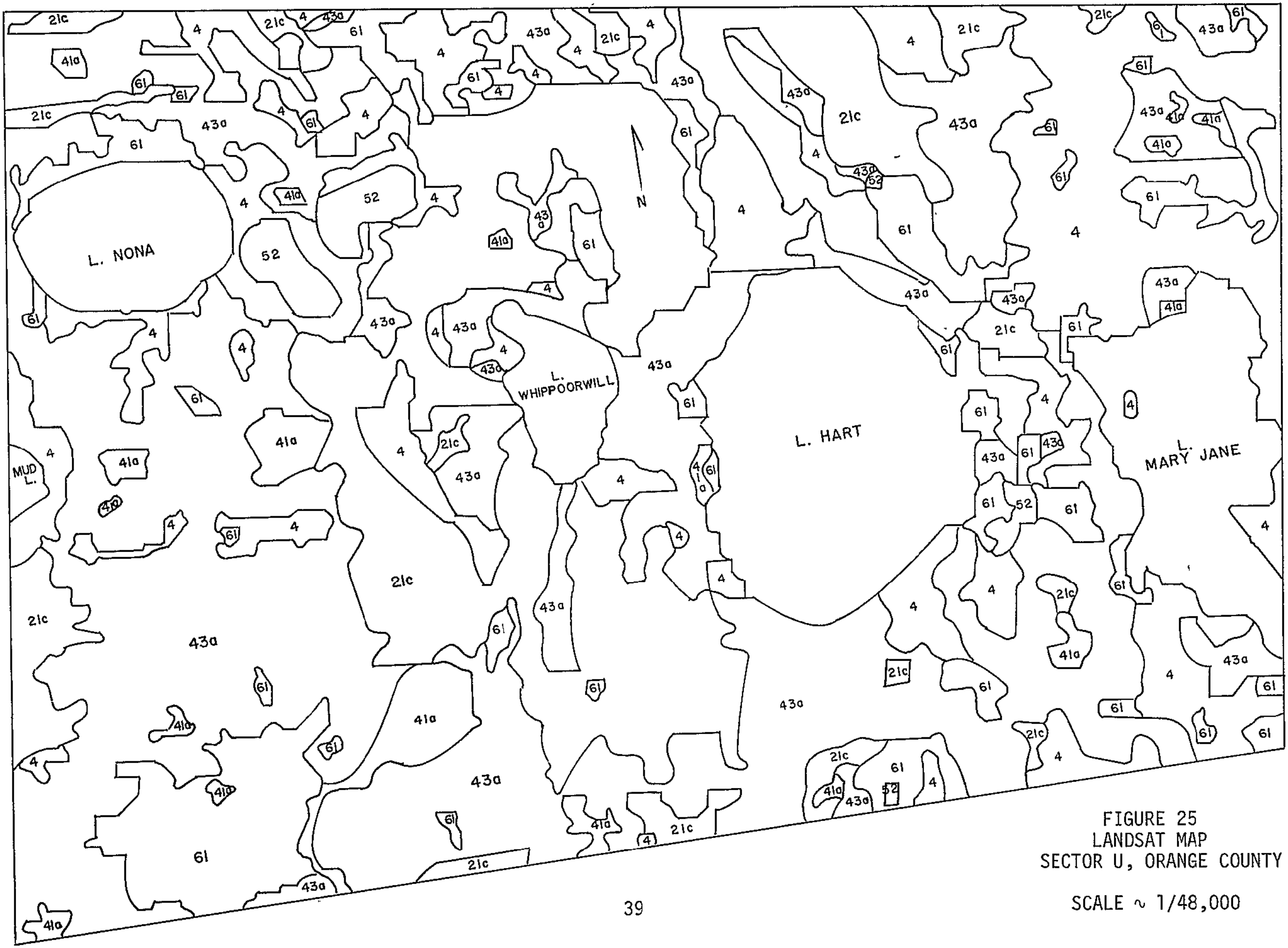


FIGURE 25
LANDSAT MAP
SECTOR U, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

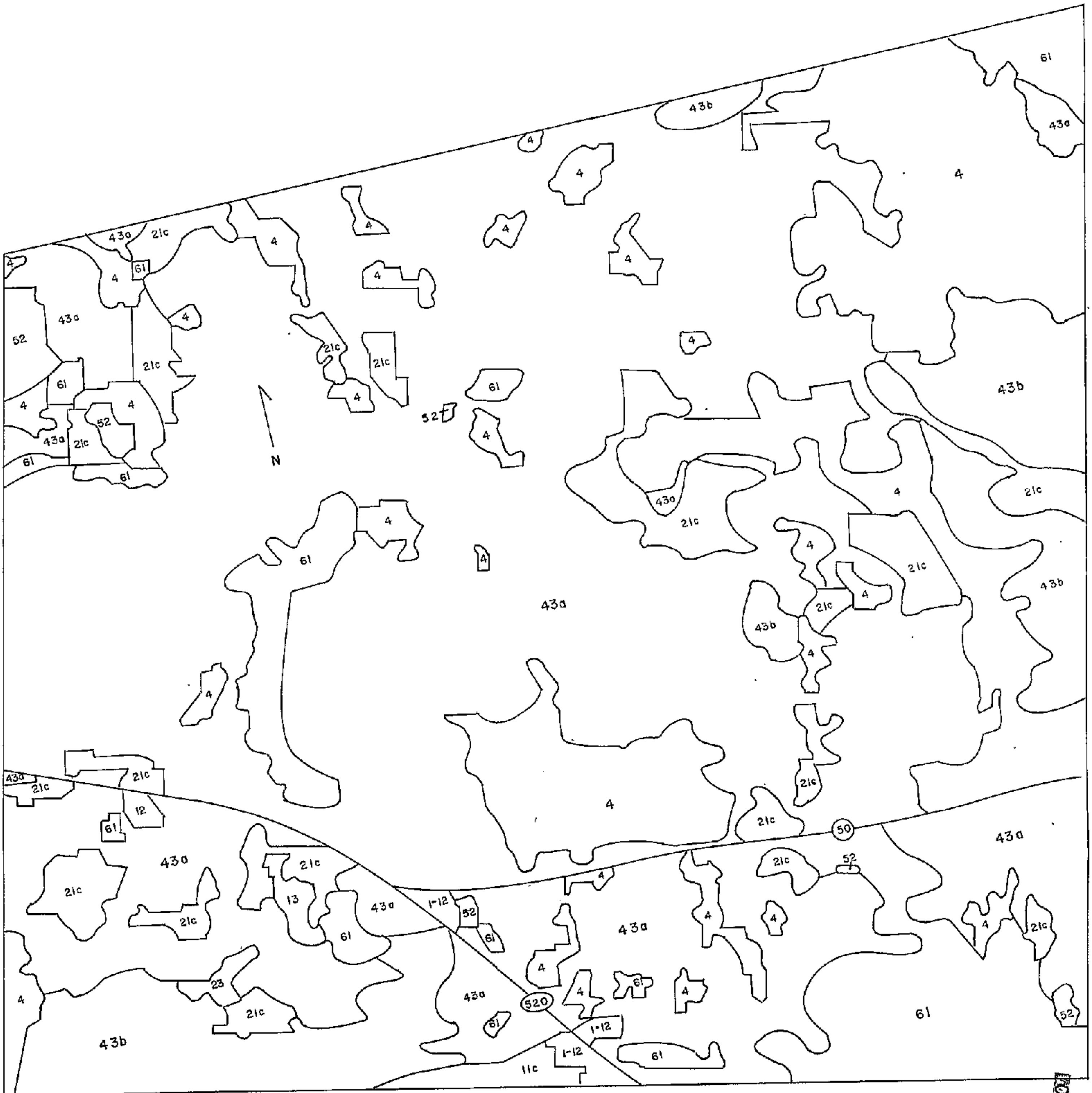


FIGURE 26
LANDSAT MAP
SECTOR V, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 2

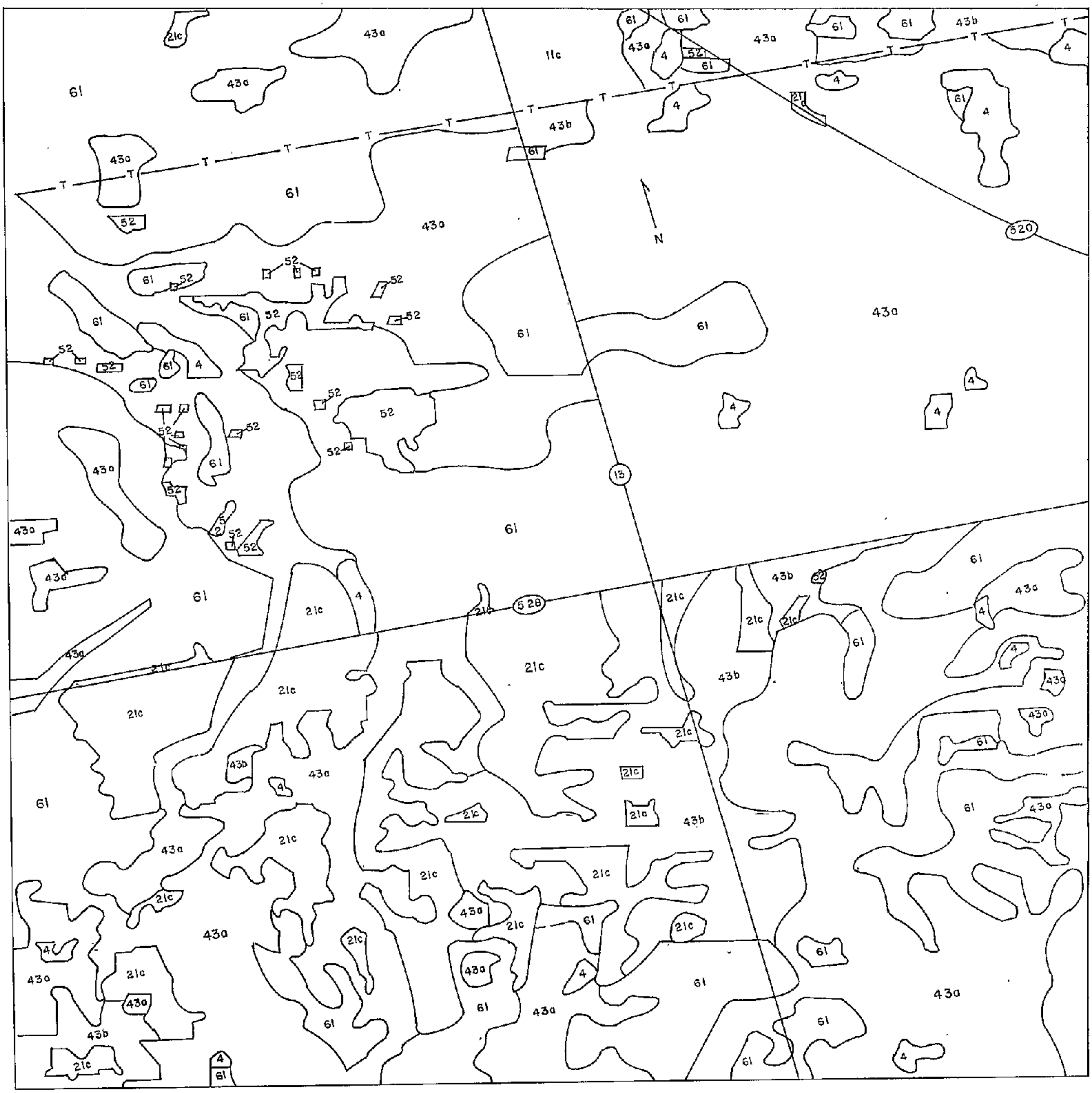


FIGURE 27
LANDSAT MAP
SECTOR W, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1
FOLDOUT FRAME 2

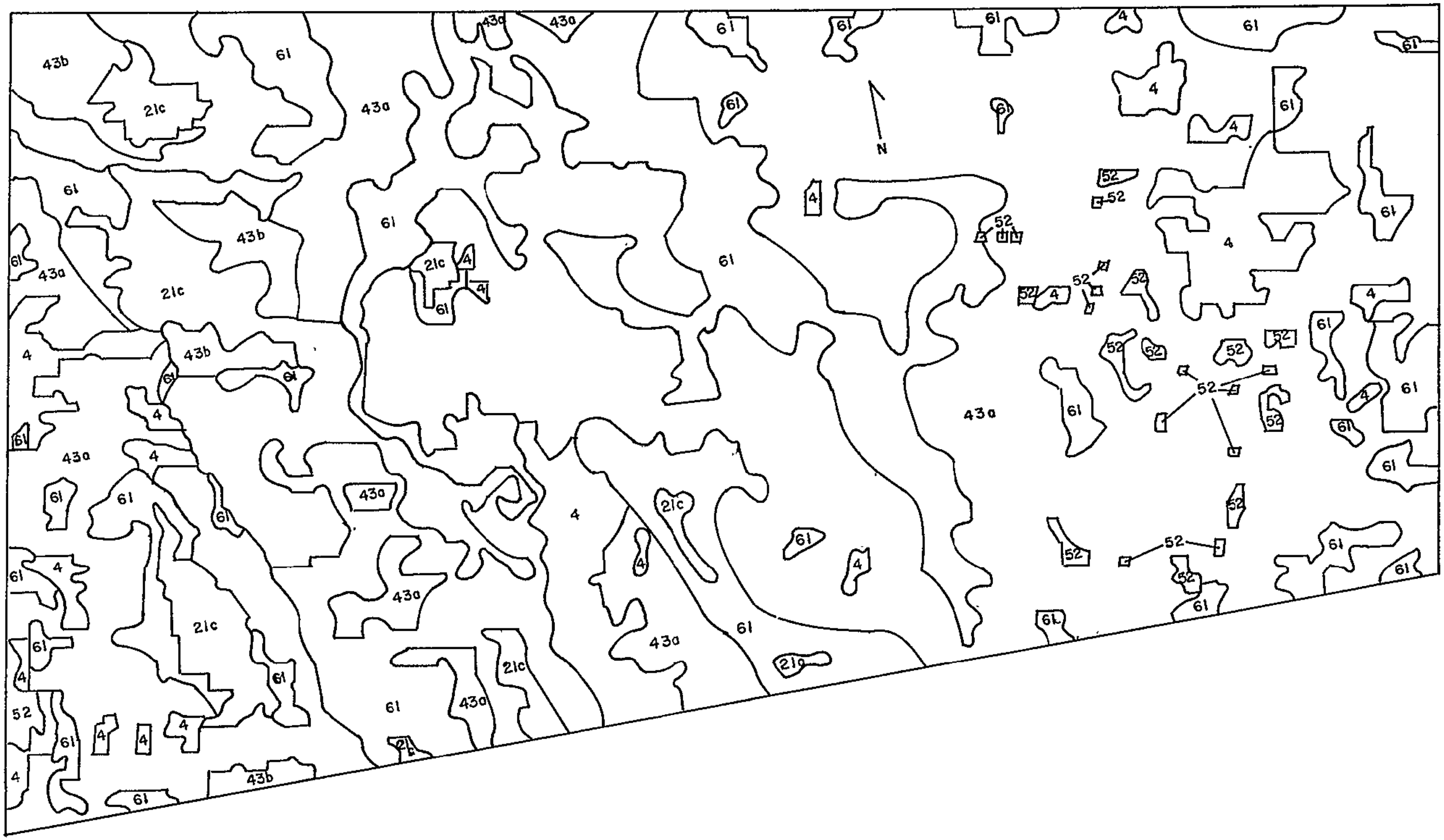


FIGURE 28
LANDSAT MAP
SECTOR X, ORANGE COUNTY

SCALE ∿ 1/48,000

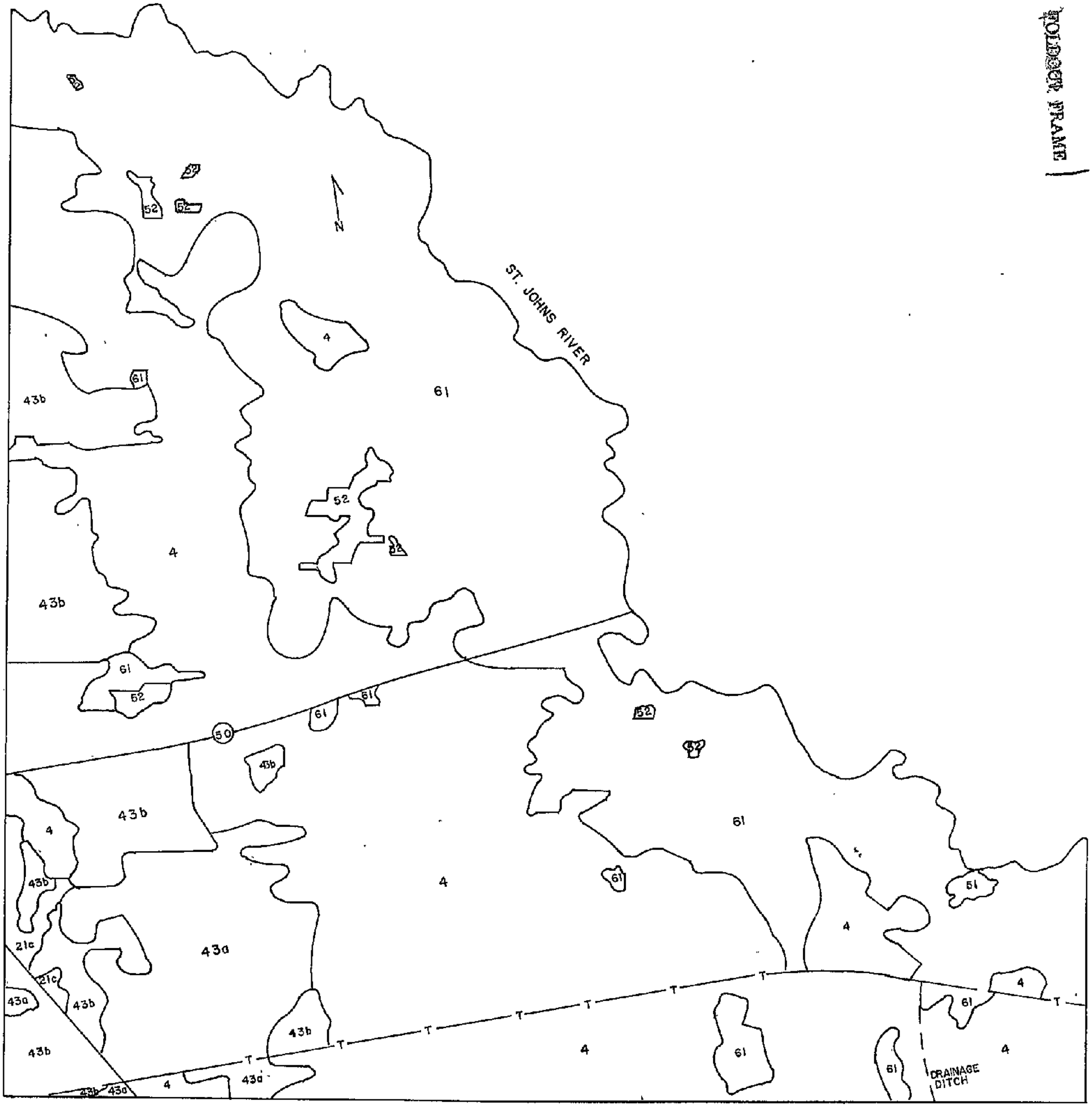


FIGURE 29
LANDSAT MAP
SECTOR Y, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1
FOLDOUT FRAME 2

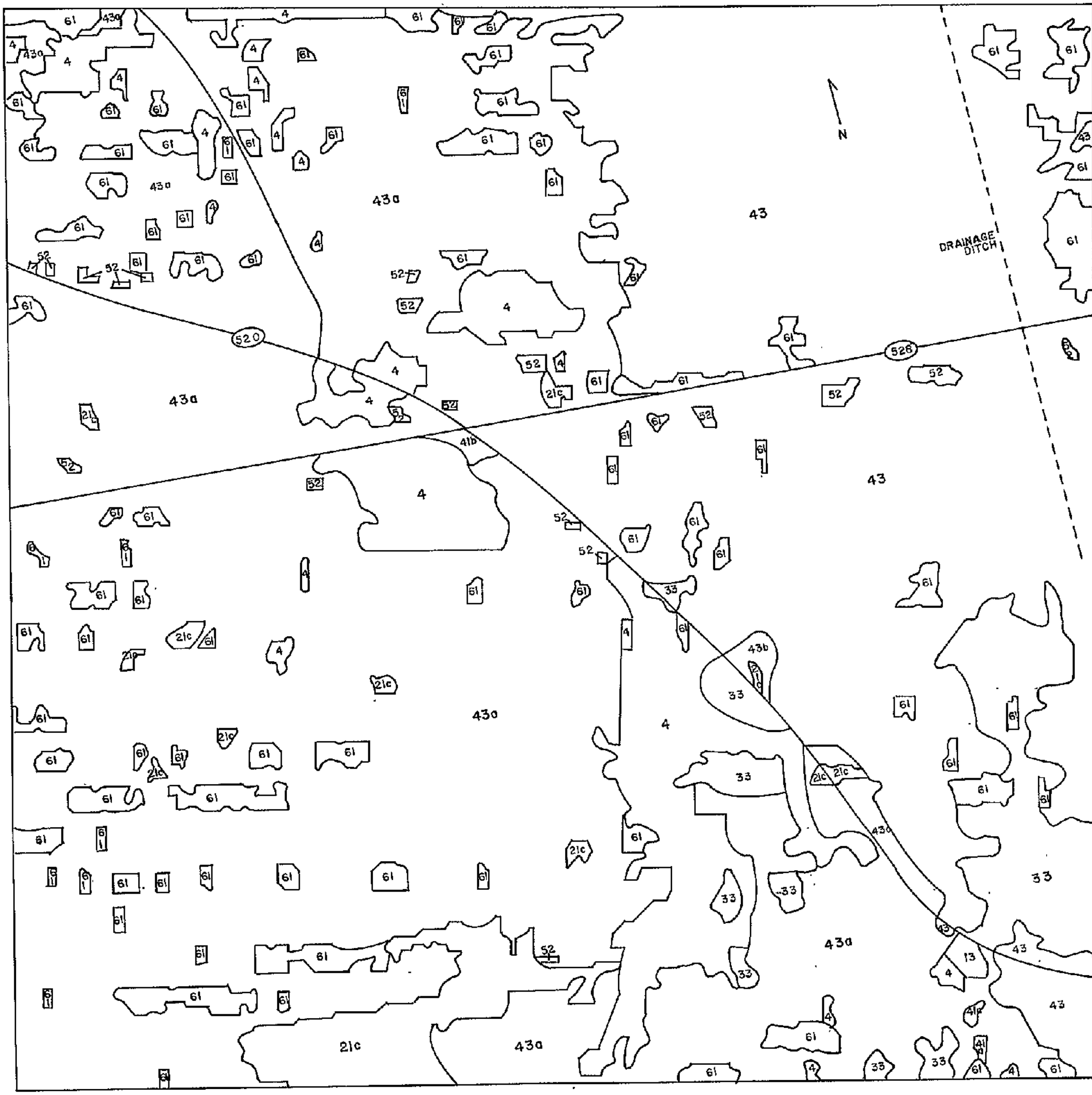


FIGURE 30
LANDSAT MAP
SECTOR Z, ORANGE COUNTY

SCALE ∿ 1/48,000

FOLDOUT FRAME
FOLDOUT FRAME

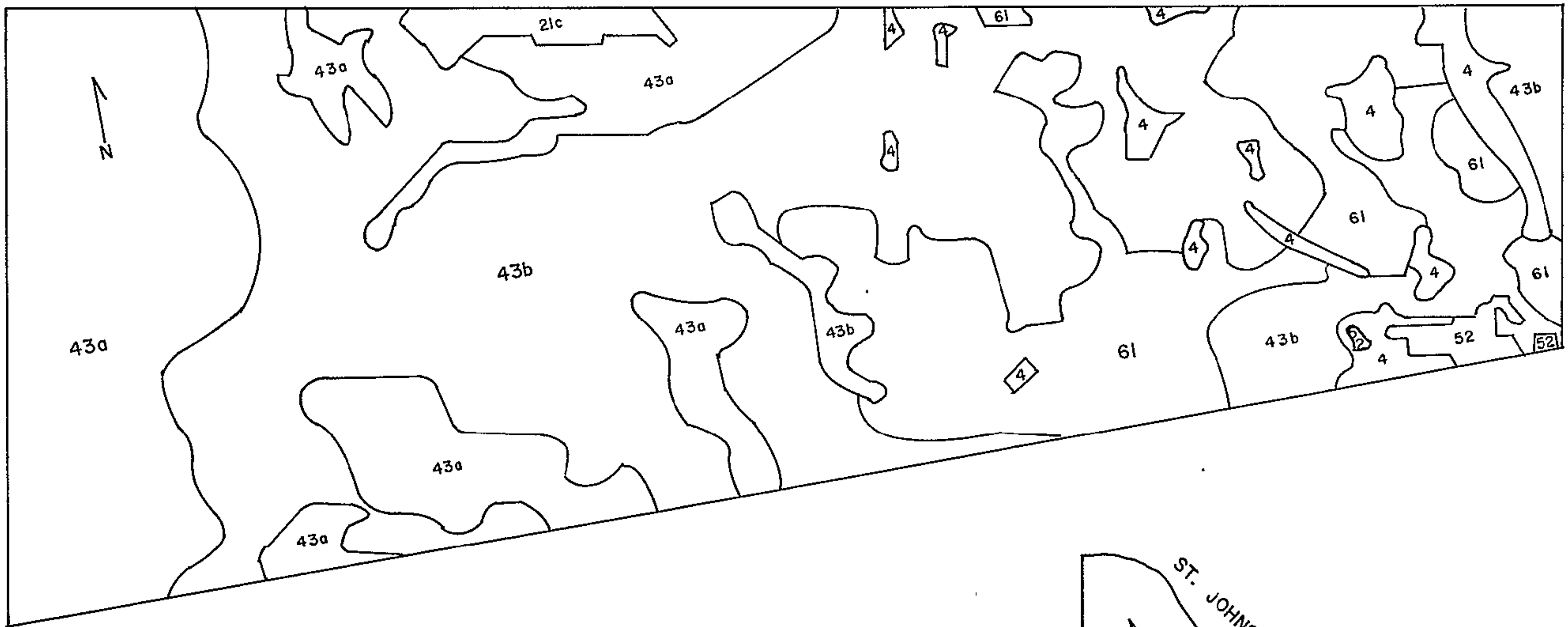
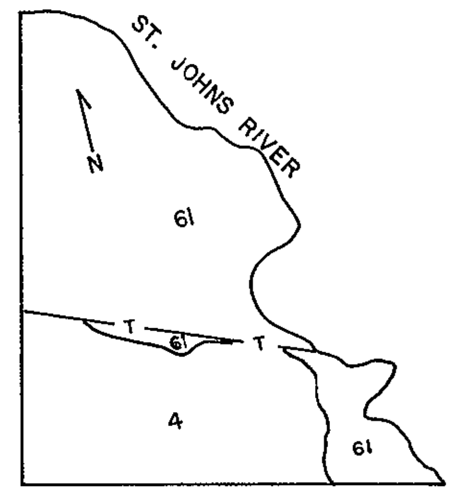


FIGURE 31
SECTOR AA, ORANGE COUNTY



LANDSAT MAP
SCALE ~ 1/48,000

FIGURE 32
SECTOR AB, ORANGE COUNTY

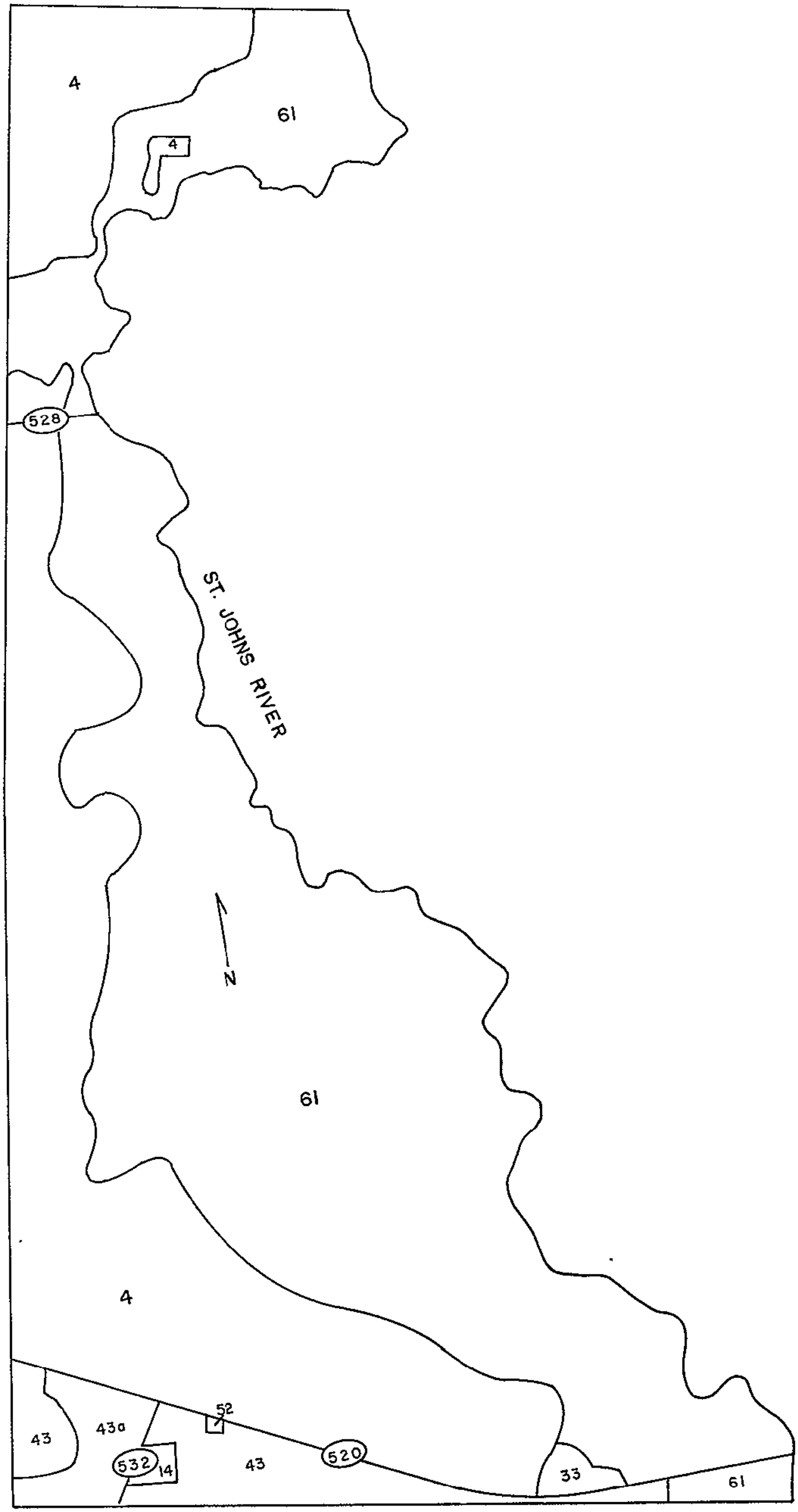


FIGURE 33
LANDSAT MAP
SECTOR AC, ORANGE COUNTY

SCALE ~ 1/48,000

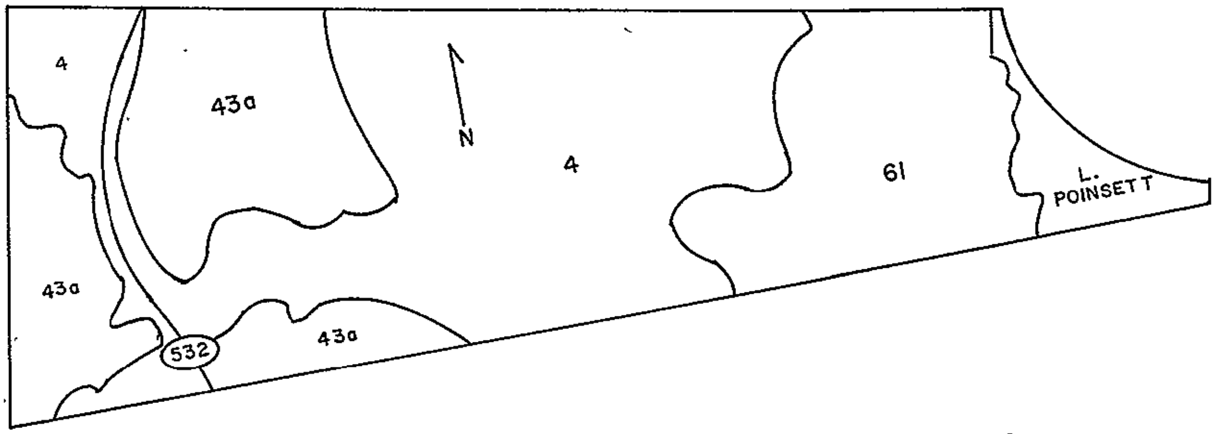


FIGURE 34
LANDSAT MAP
SECTOR AD, ORANGE COUNTY

SCALE ~ 1/48,000

some forest patterns compared to those of small scale photography. No special classes were attempted for the vegetable farms north of Lake Apopka (Sectors B and G); that classification in Figures 6 and 11 is based on the characteristic geometric patterns shown on the computer map.

No attempt was made to separate commercial and industrial classes in the computer classification; the two were combined into a single class at that stage and then divided into two classes by the planner.

It will be noted that not all classifications are given to the same degree of precision. While the general level of classification is Level 2 the designation may vary from Level 1 to Level 3. That is because we chose to designate each small sector to the degree of precision deemed justified by the data - primarily by the uniformity of the characters within a bloc. For example: (1) in some cases, only the urban category - 1 - is designated, while in others, 11a may be indicated; (2) the general agricultural designator - 2 - was used when the printer characters were so mixed as to prevent more exact classification. A similar situation exists with forest classification.

In addition to urban growth in metropolitan Orlando, there are several regions in the County in which there is special environmental interest:

(1) The Econlockhatchee and Little Econlockhatchee Rivers, Sectors P, S, T, and W (seen as forest strips in Figures 20, 23, 24, and 27) are under consideration as preservation areas.

(2) The forested Wekiva River region (Sector F, Figure 10) is the subject of a three-county attempt as a state designation as a scenic and

wild river. The adjacent Rock Springs Run is under consideration as a preservation area by the County.

(3) The Shingle Creek Swamp, the forested region in the lower center of Sector O, Figure 19, is under consideration for designation as an open space due to its capability of retention of water in alleviation of flooding problems.

(4) Rapid development in the vicinity of the Butler Chain of Lakes (Lakes Butler, Down, Louise, Big Sand, Tibet Butler, and others, Sectors D, H, K, L, O, Figures 8, 12, 15, and 19) has caused concern with regard to maintenance of the present high quality of the water in the lakes of this prime water recharge area. Hence, this is a region that will be watched carefully.

(5) The Tootoosahatchee Game Preserve (forested area, eastern edge of the County, Figures 29-34, Sectors Y, Z, AB, AC, and AD, extending from the St. Johns River approximately six miles westward), has recently been purchased by the State for a preservation area.

Corrections based on comparison with photography are shown in Figures 35-60. The number outside the parenthesis represents the classification based on the aircraft photography, and the number inside the parenthesis represents the classification from the tracing of the Landsat computer map. Sectors AA, AB, AC, and AD had no corrections. Problems can be seen to include:

Difficulty in distinguishing between citrus and urban, pasture, or forest, depending upon the age and degree of cultivation of the grove;

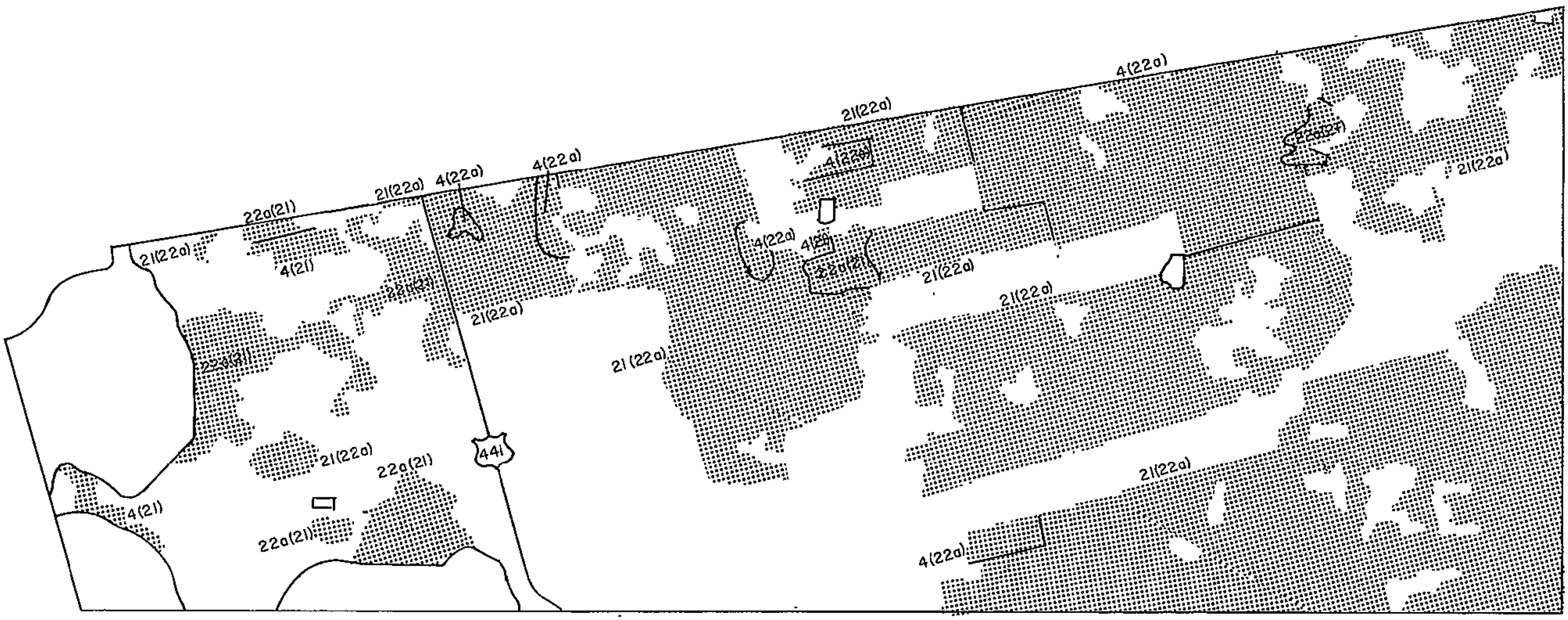


FIGURE 35
CORRECTIONS
SECTOR A, ORANGE COUNTY

SCALE ~ 1/48,000

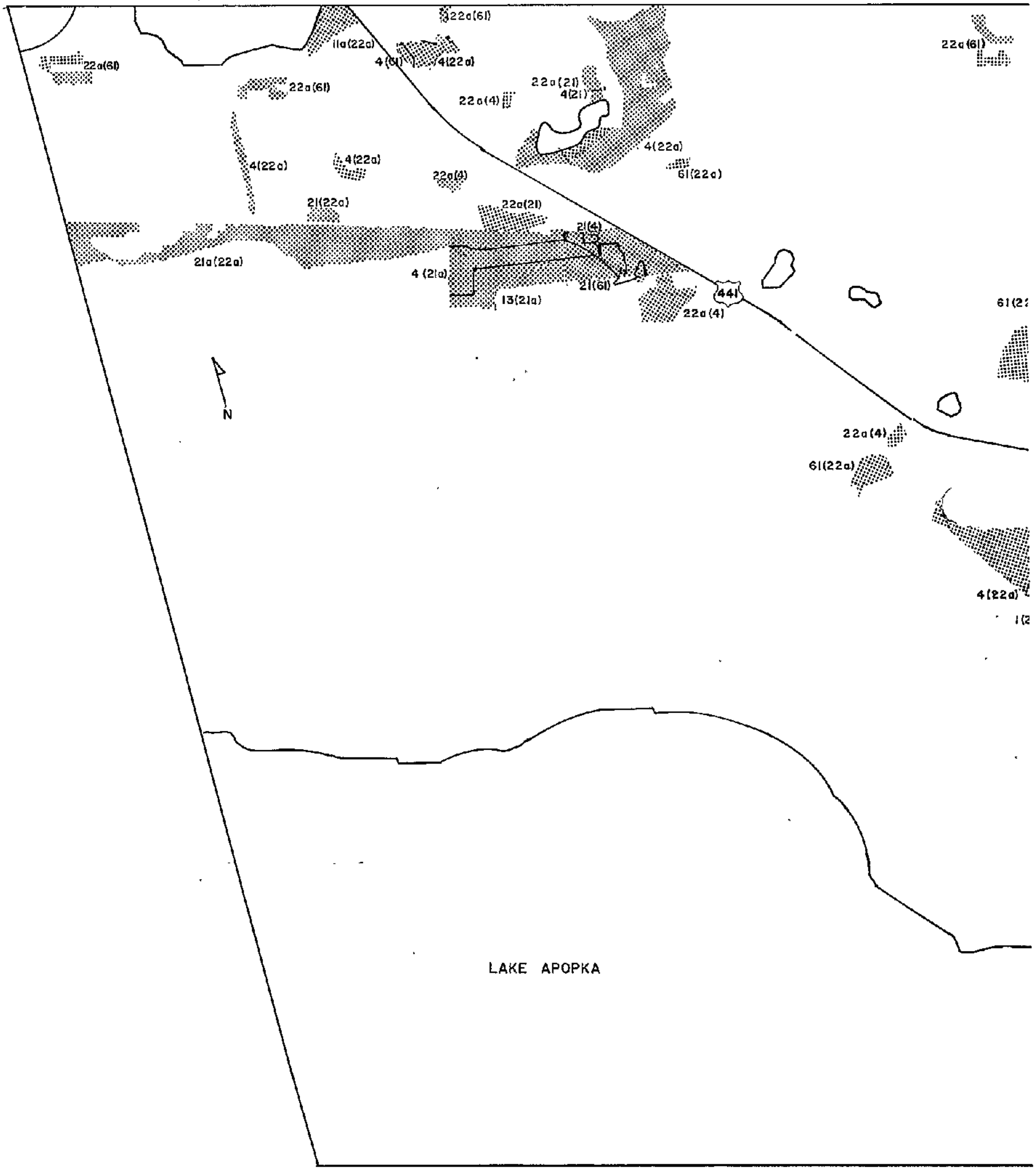


FIGURE 36
CORRECTIONS
SECTOR B, ORANGE COUNTY

SCALE ∿ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

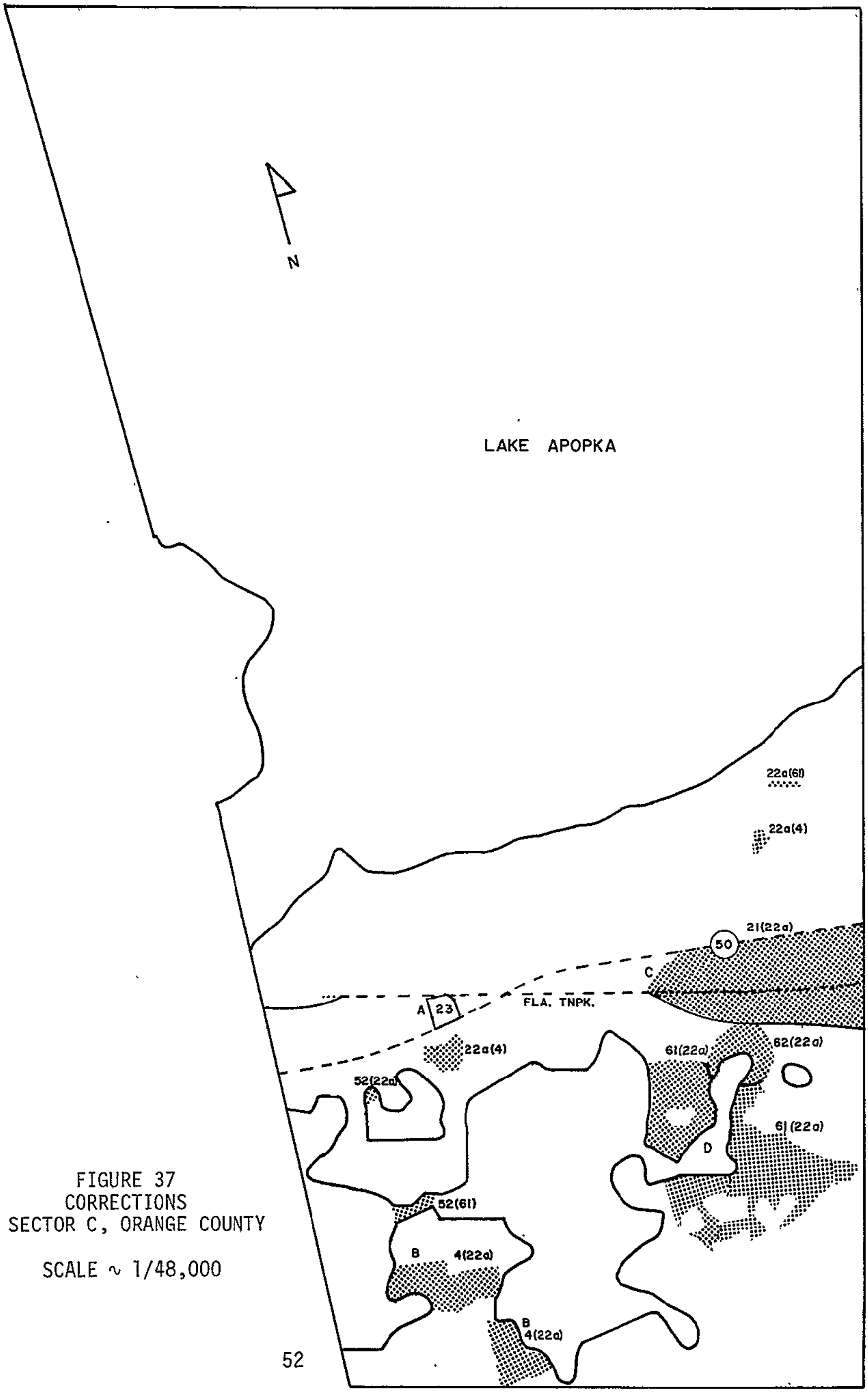


FIGURE 37
CORRECTIONS
SECTOR C, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

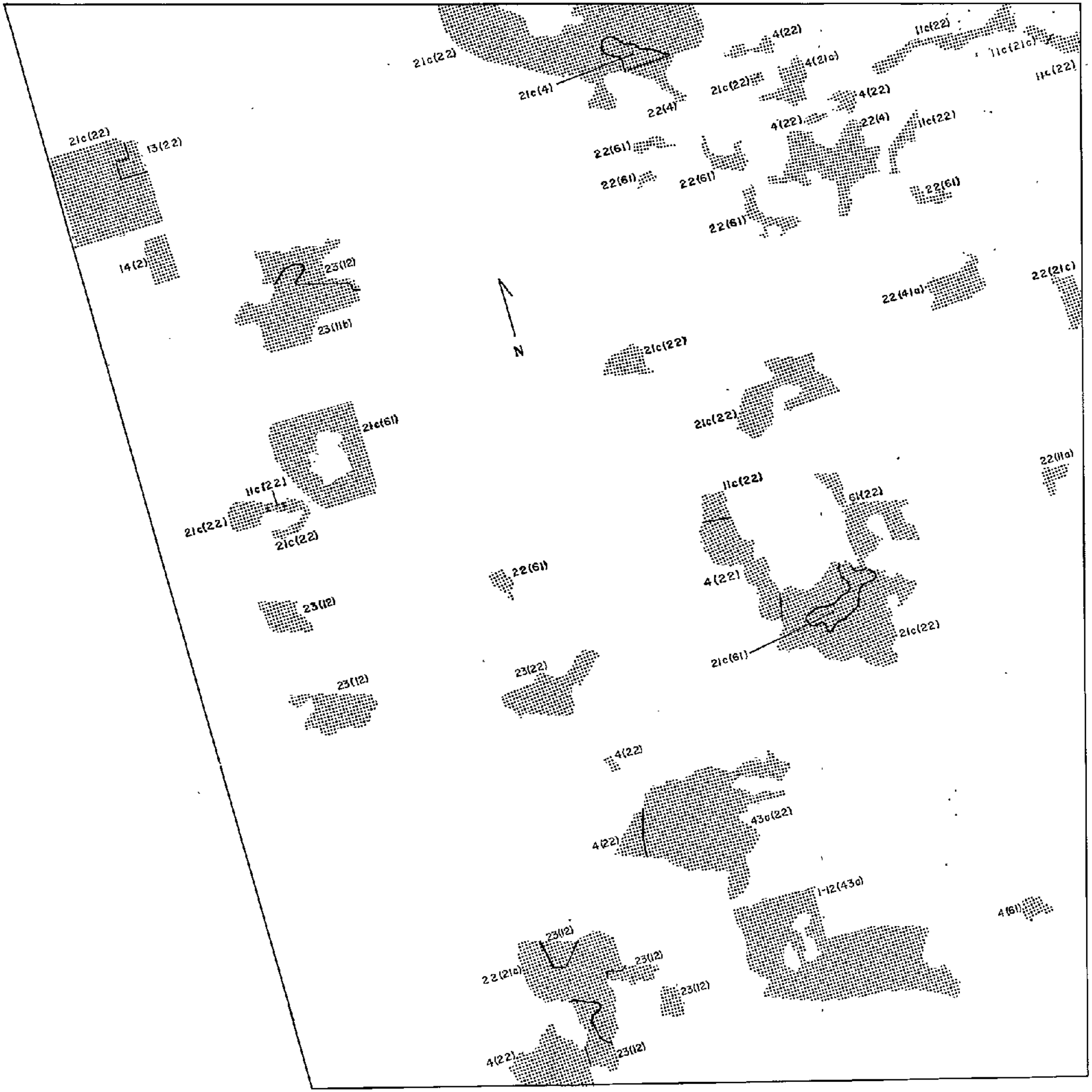


FIGURE 38
CORRECTIONS
SECTOR D, ORANGE COUNTY

SCALE ~ 1/48,000

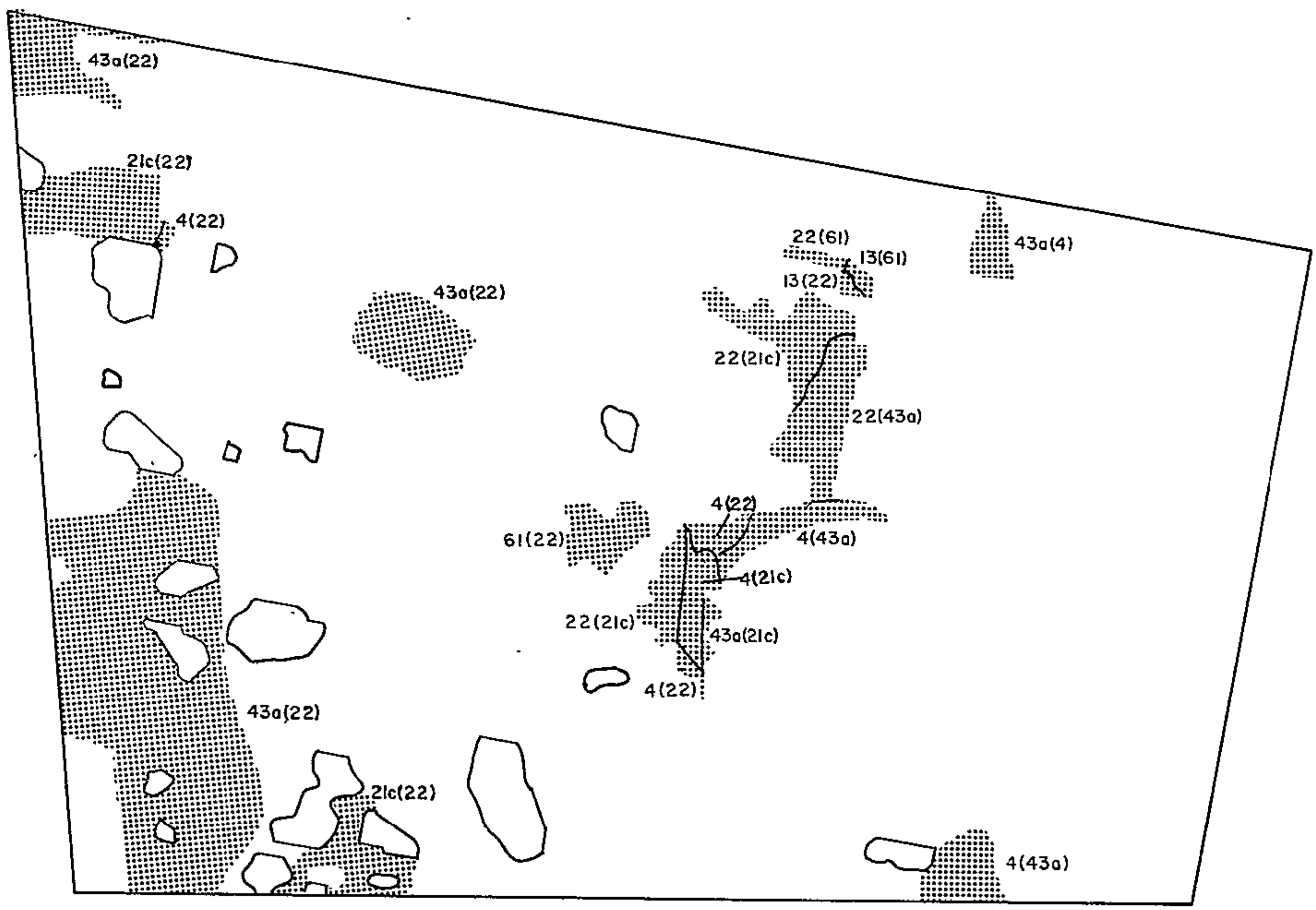


FIGURE 39
CORRECTIONS
SECTOR E, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

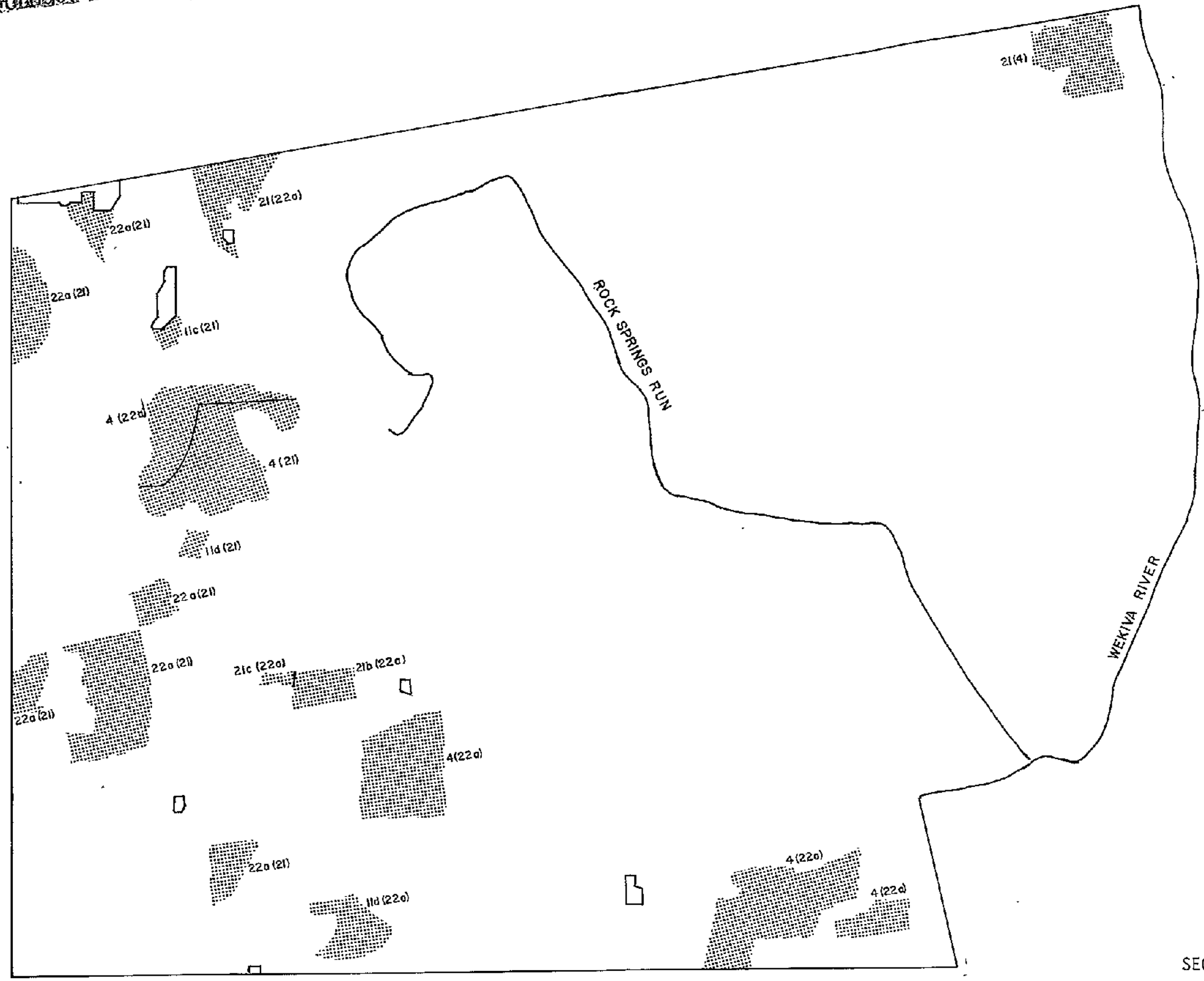


FIGURE 40
CORRECTIONS
SECTOR F, ORANGE COUNTY

SCALE ∿ 1/48,000

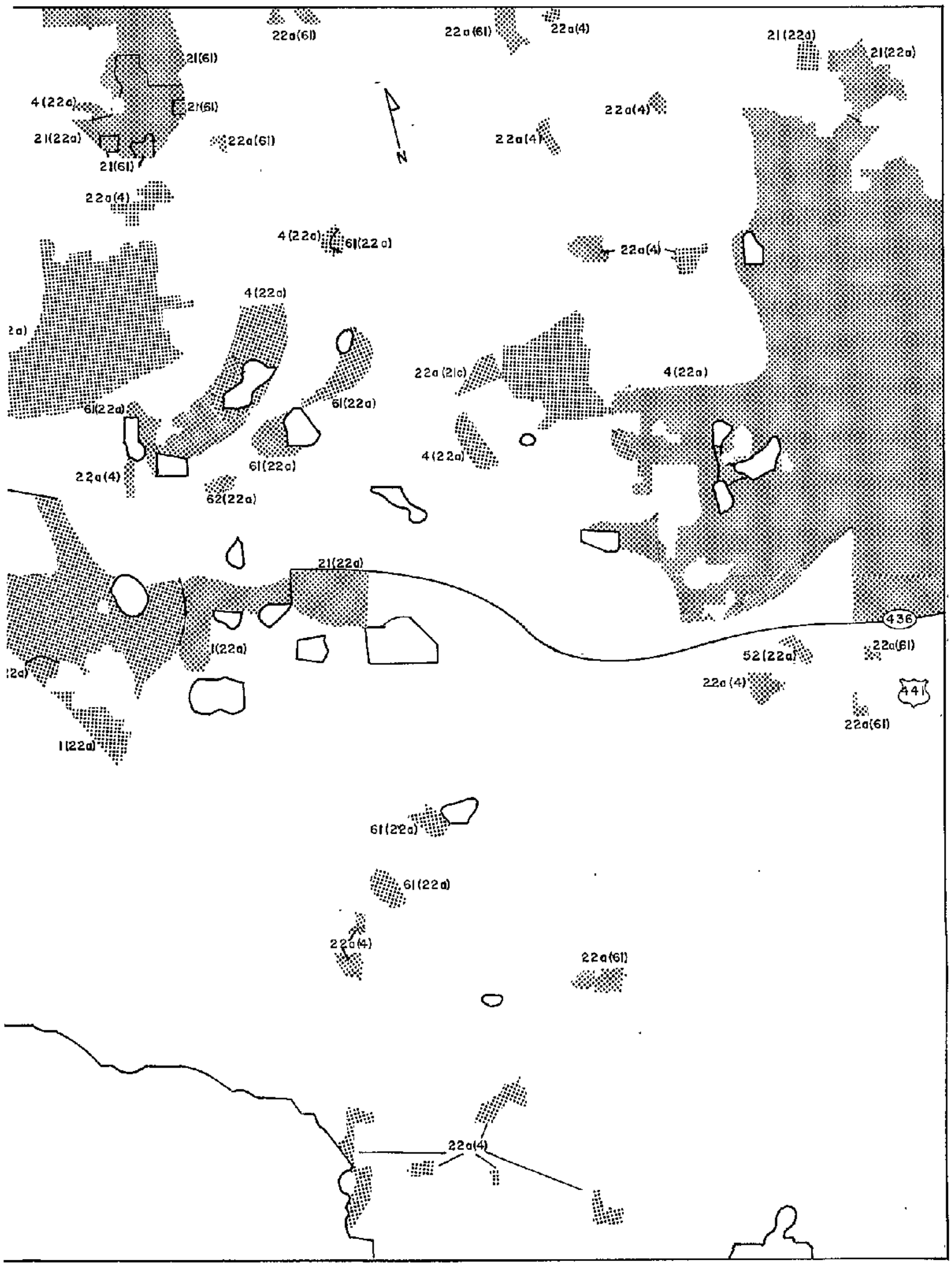


FIGURE 41
CORRECTIONS
SECTOR G, ORANGE COUNTY

SCALE ~ 1/48,000

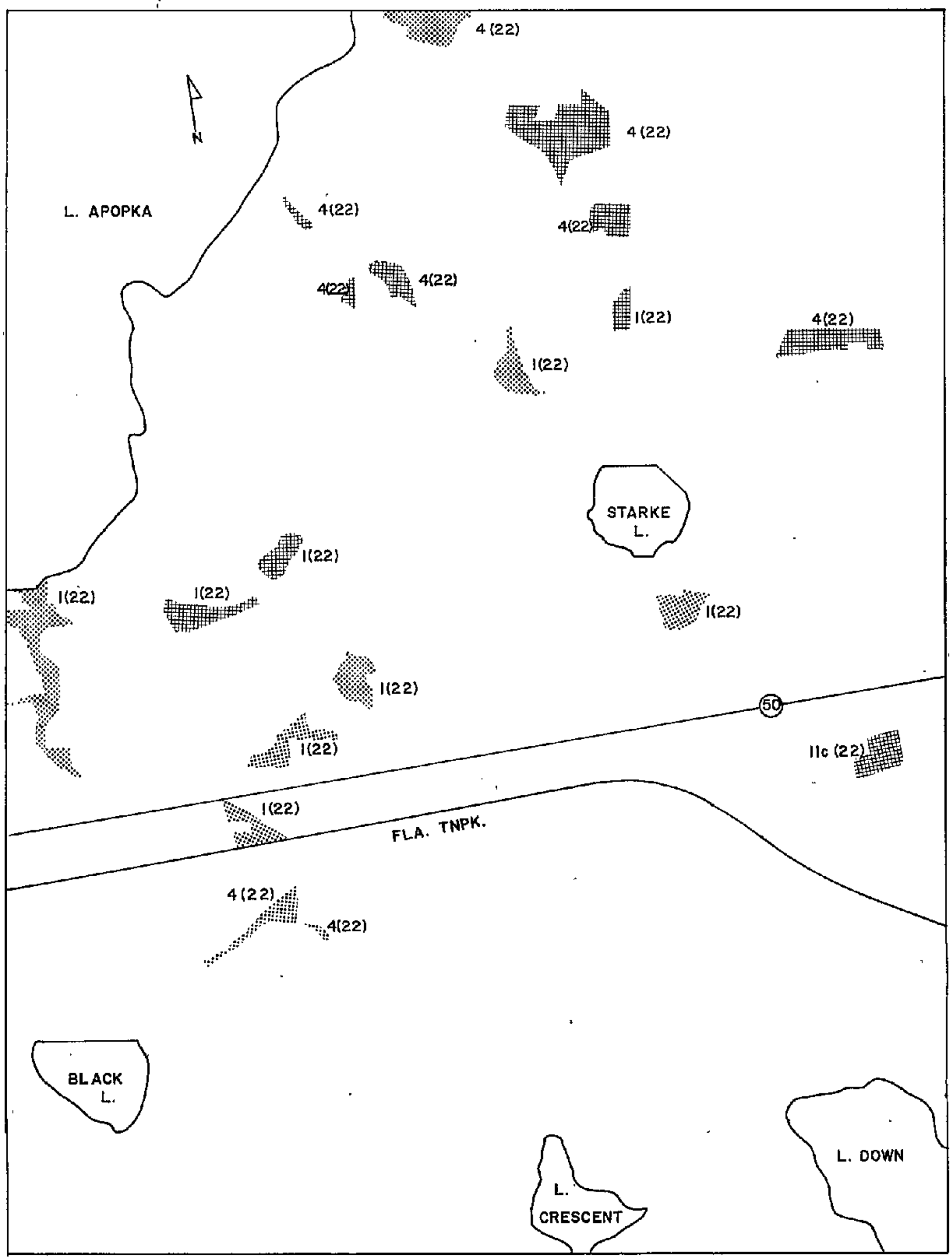


FIGURE 42
CORRECTIONS
SECTOR H, ORANGE COUNTY

SCALE ~ 1/48,000

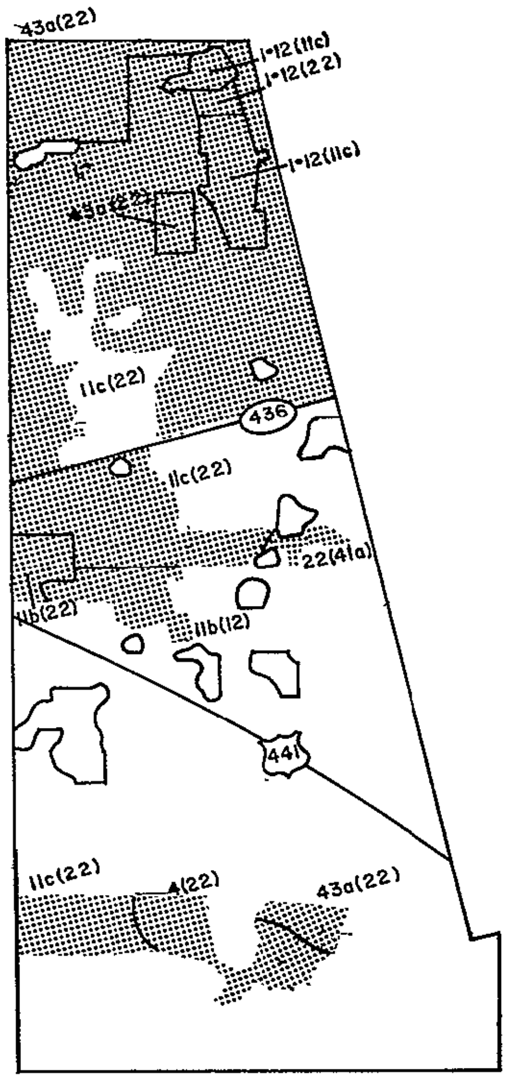


FIGURE 43
SECTOR I, ORANGE COUNTY

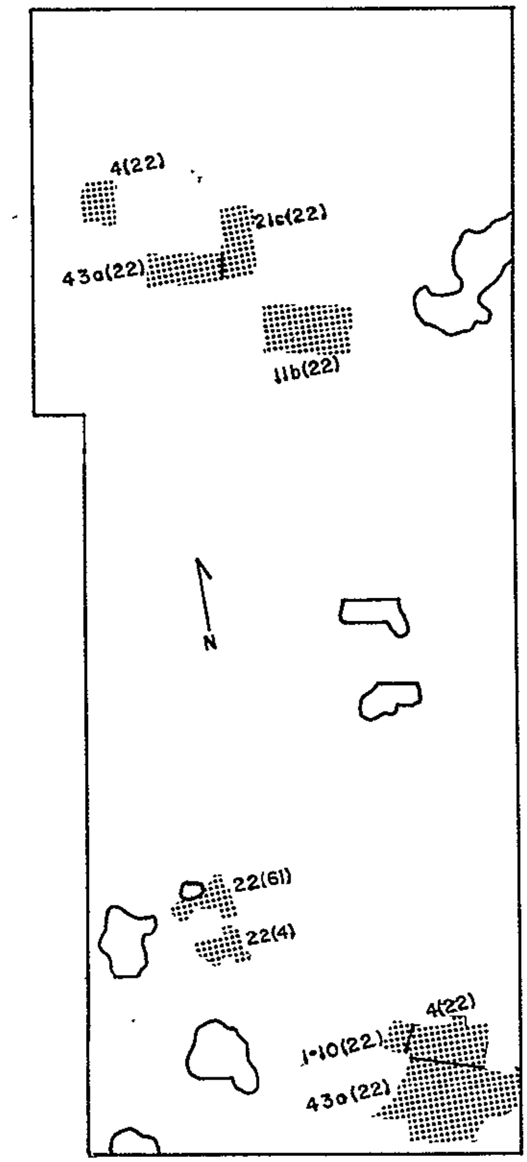


FIGURE 44
SECTOR J, ORANGE COUNTY

CORRECTIONS
SCALE ∿ 1/48,000

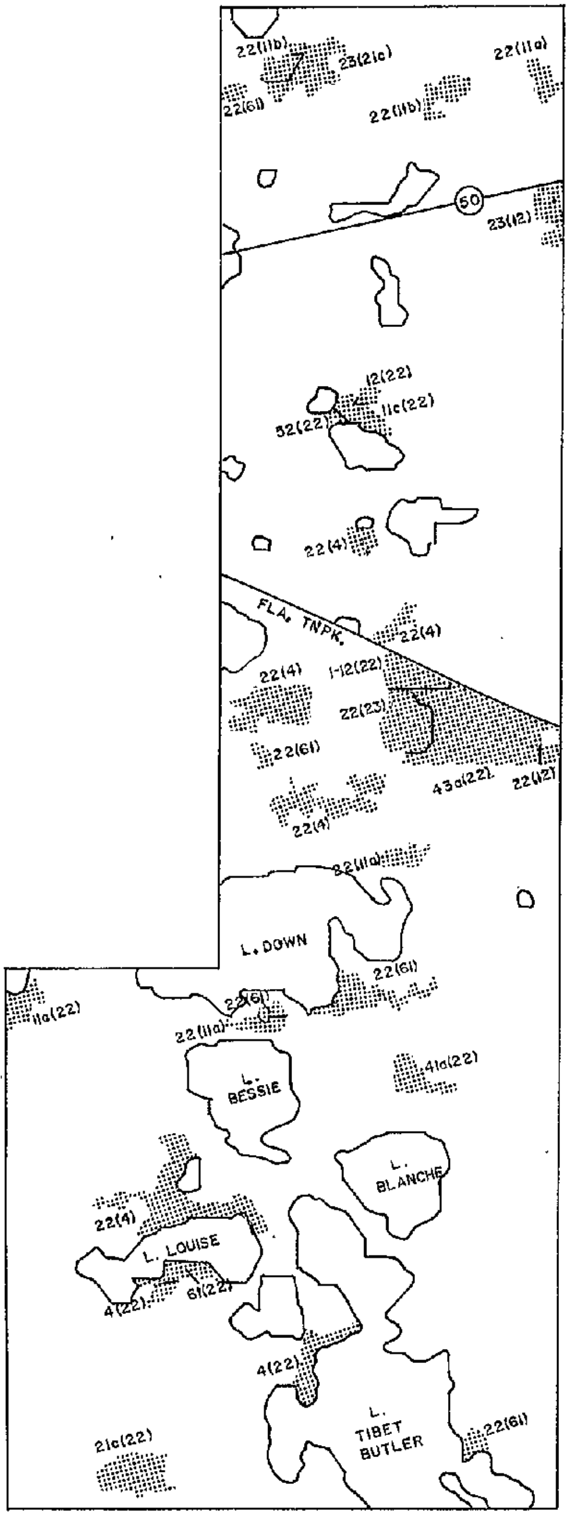


FIGURE 45
SECTOR K, ORANGE COUNTY

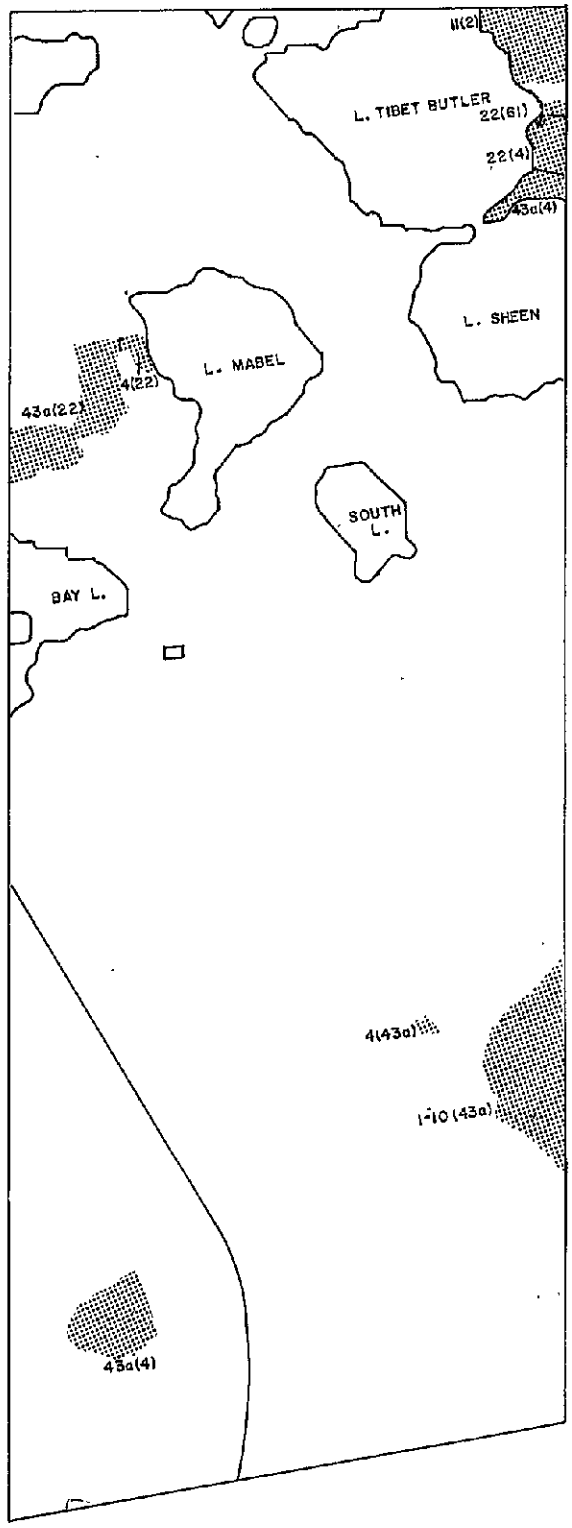


FIGURE 46
SECTOR L, ORANGE COUNTY

CORRECTIONS
SCALE ~ 1/48,000

FOLDOUT FRAME 1
FOLDOUT FRAME 2

FOLDOUT FRAME 1

FOLDOUT FRAME 2

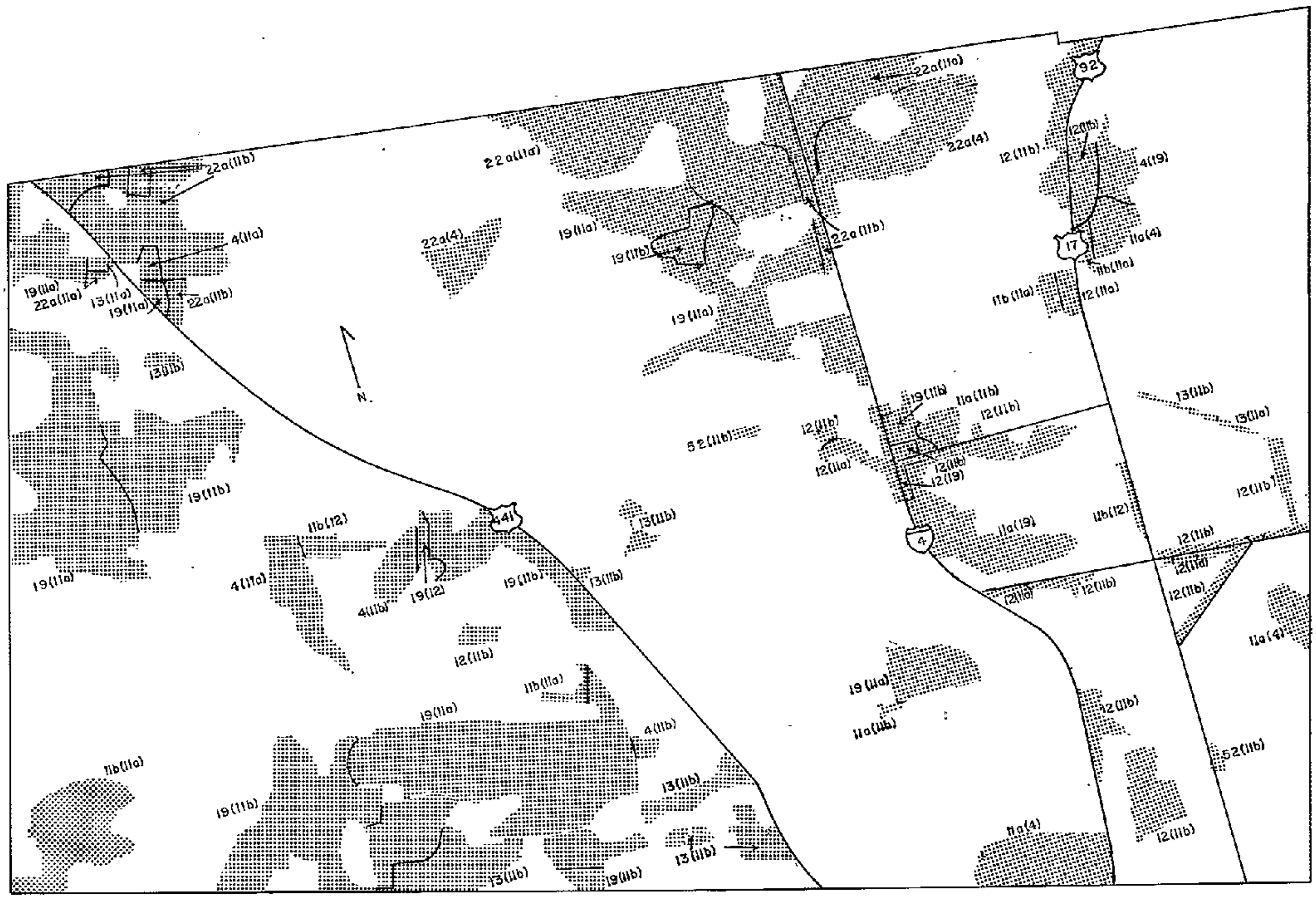


FIGURE 47
CORRECTIONS
SECTOR M, ORANGE COUNTY

SCALE ∿ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 48
CORRECTIONS
SECTOR N, ORANGE COUNTY

SCALE ~ 1/48,000

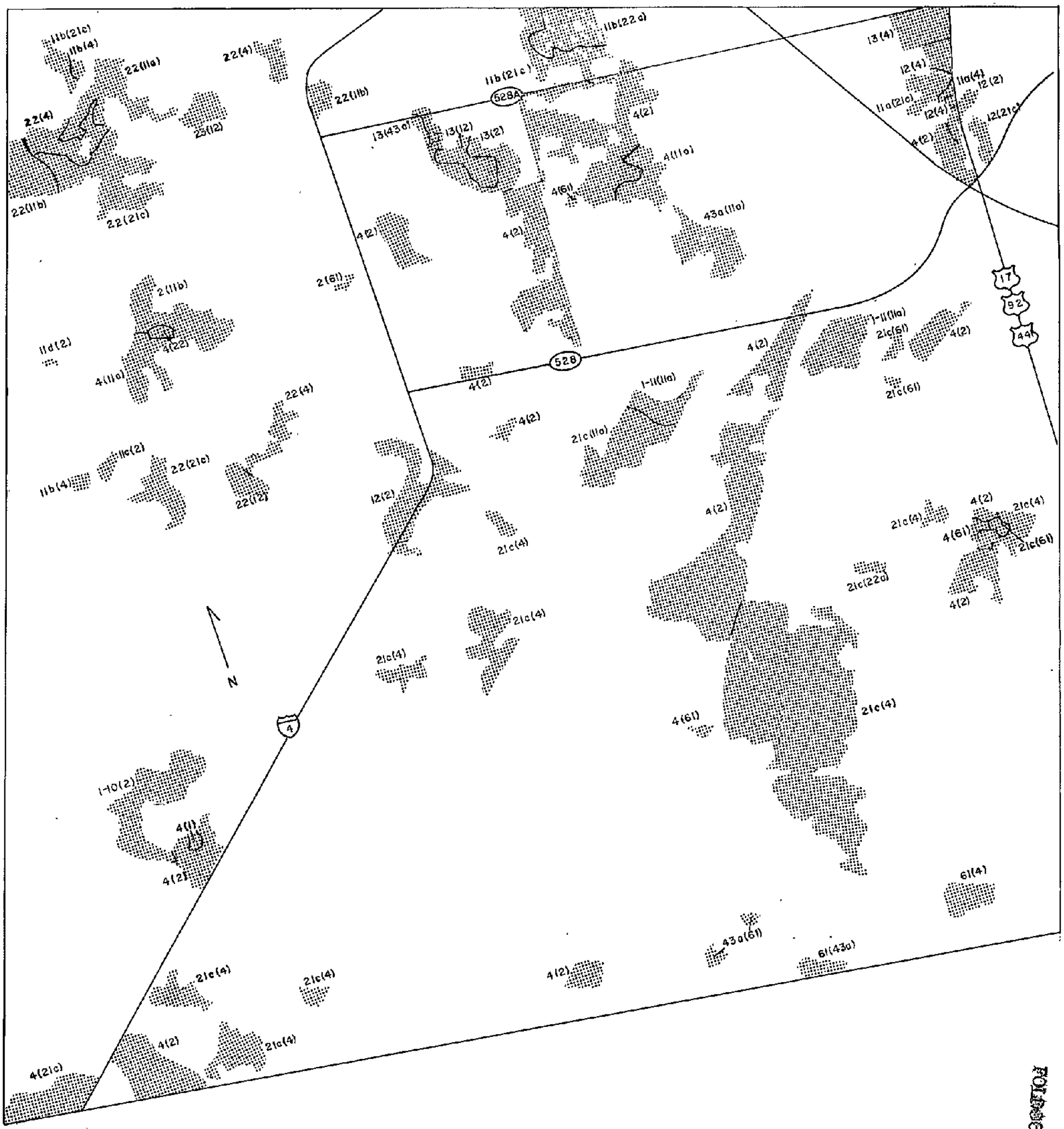


FIGURE 49
CORRECTIONS
SECTOR O, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

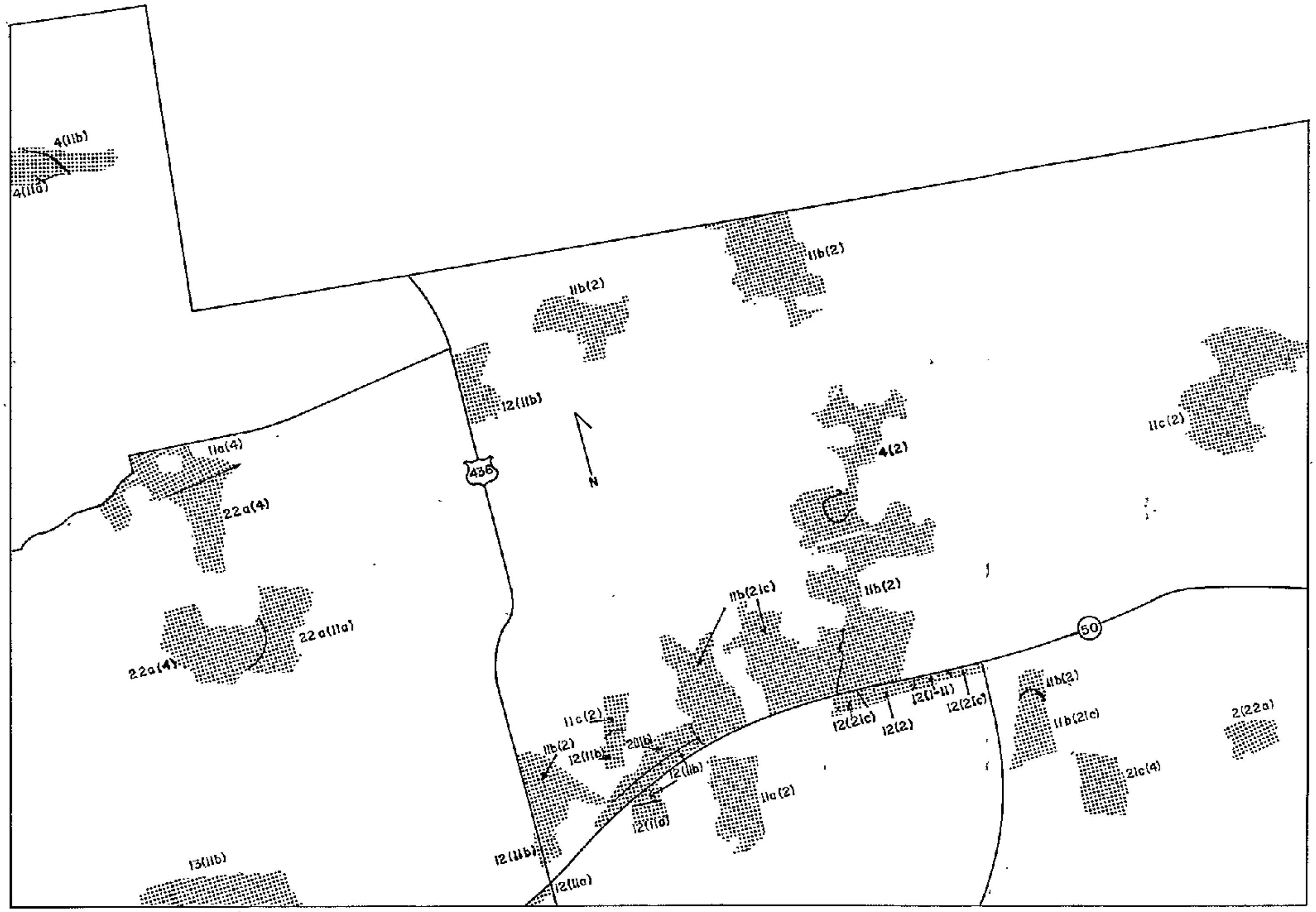


FIGURE 50
CORRECTIONS
SECTOR P, ORANGE COUNTY

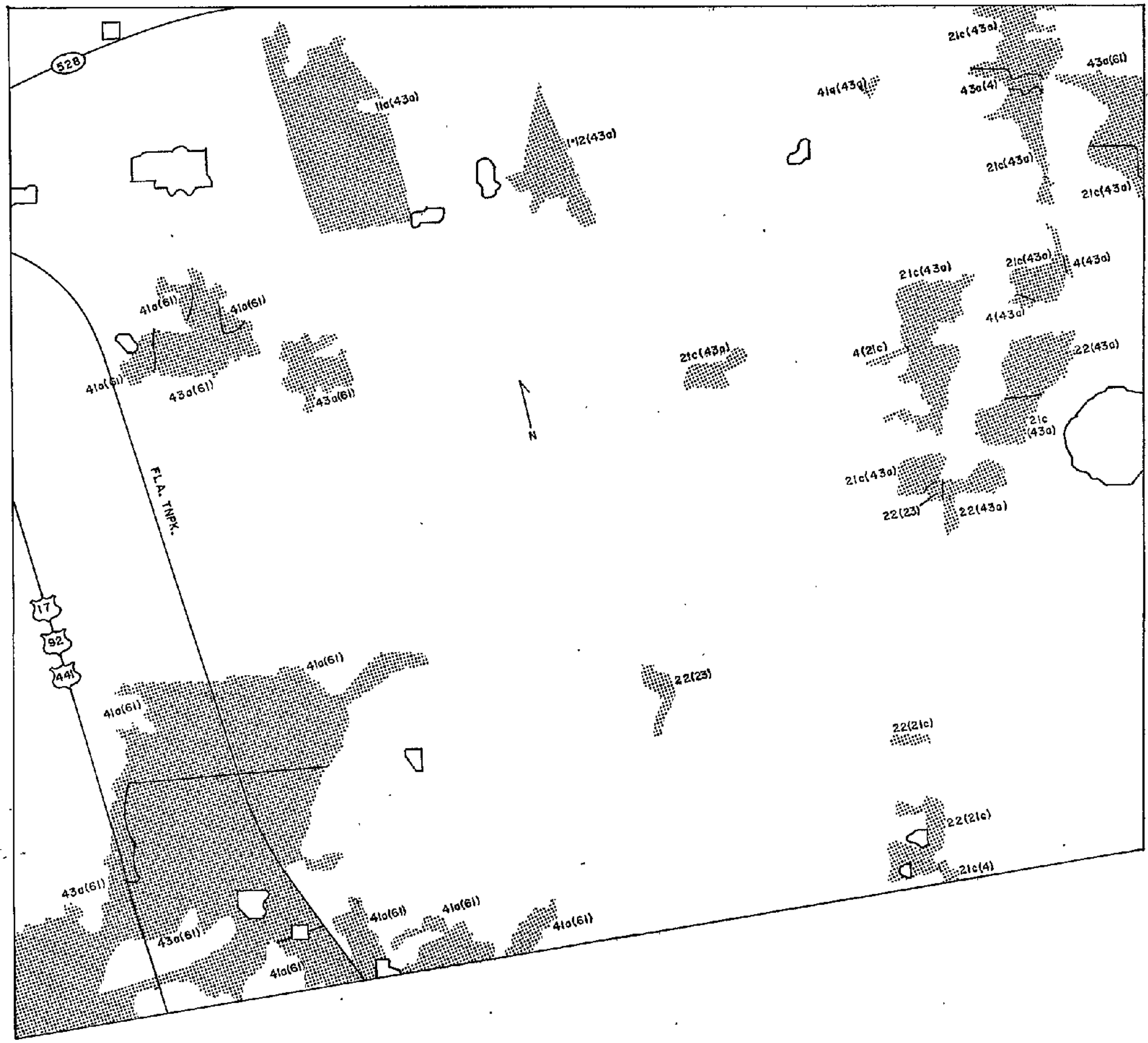
SCALE ∿ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 51
CORRECTIONS
SECTOR Q, ORANGE COUNTY

SCALE ~ 1/48,000



FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 52
CORRECTIONS
SECTOR R, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME

FOLDOUT FRAME

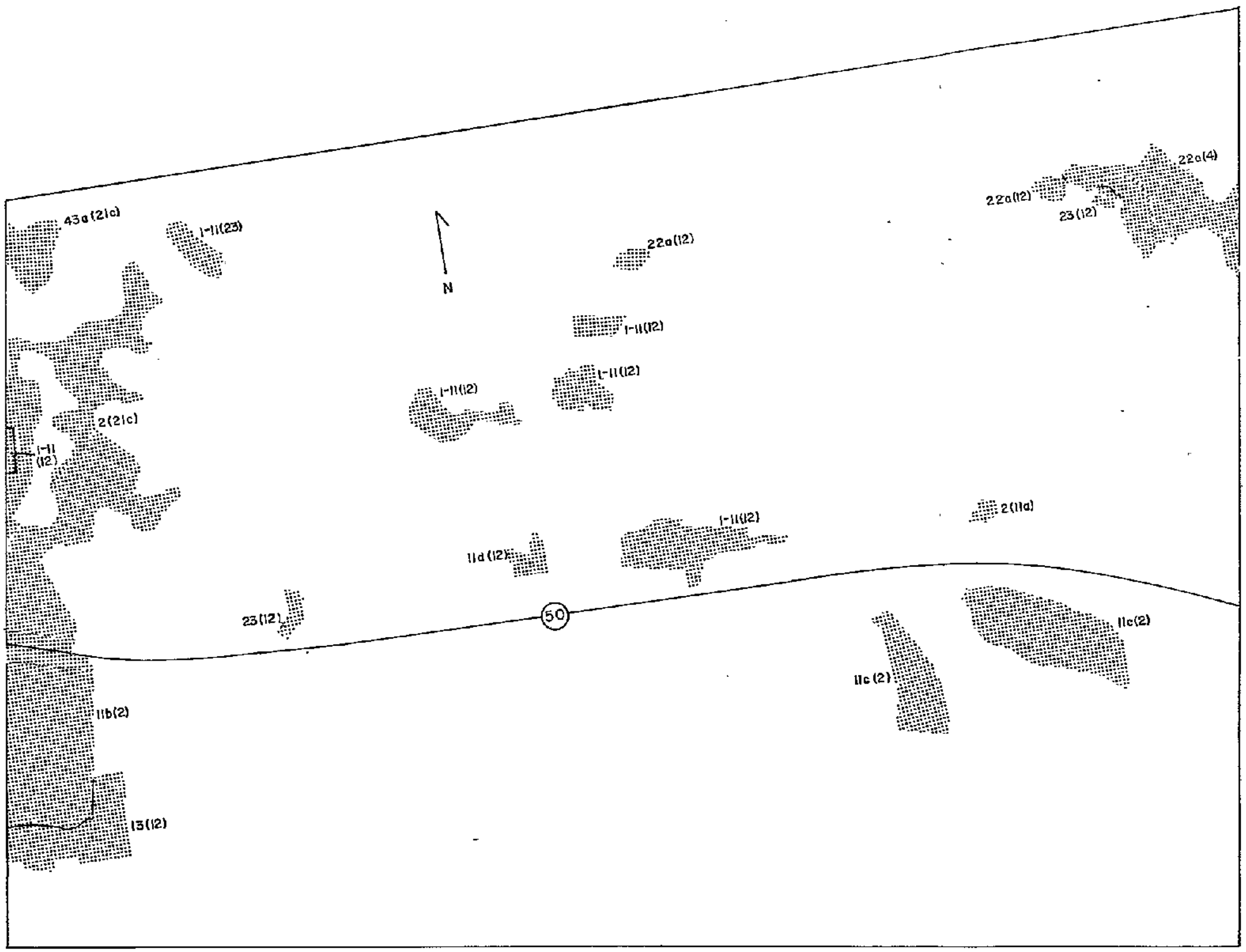
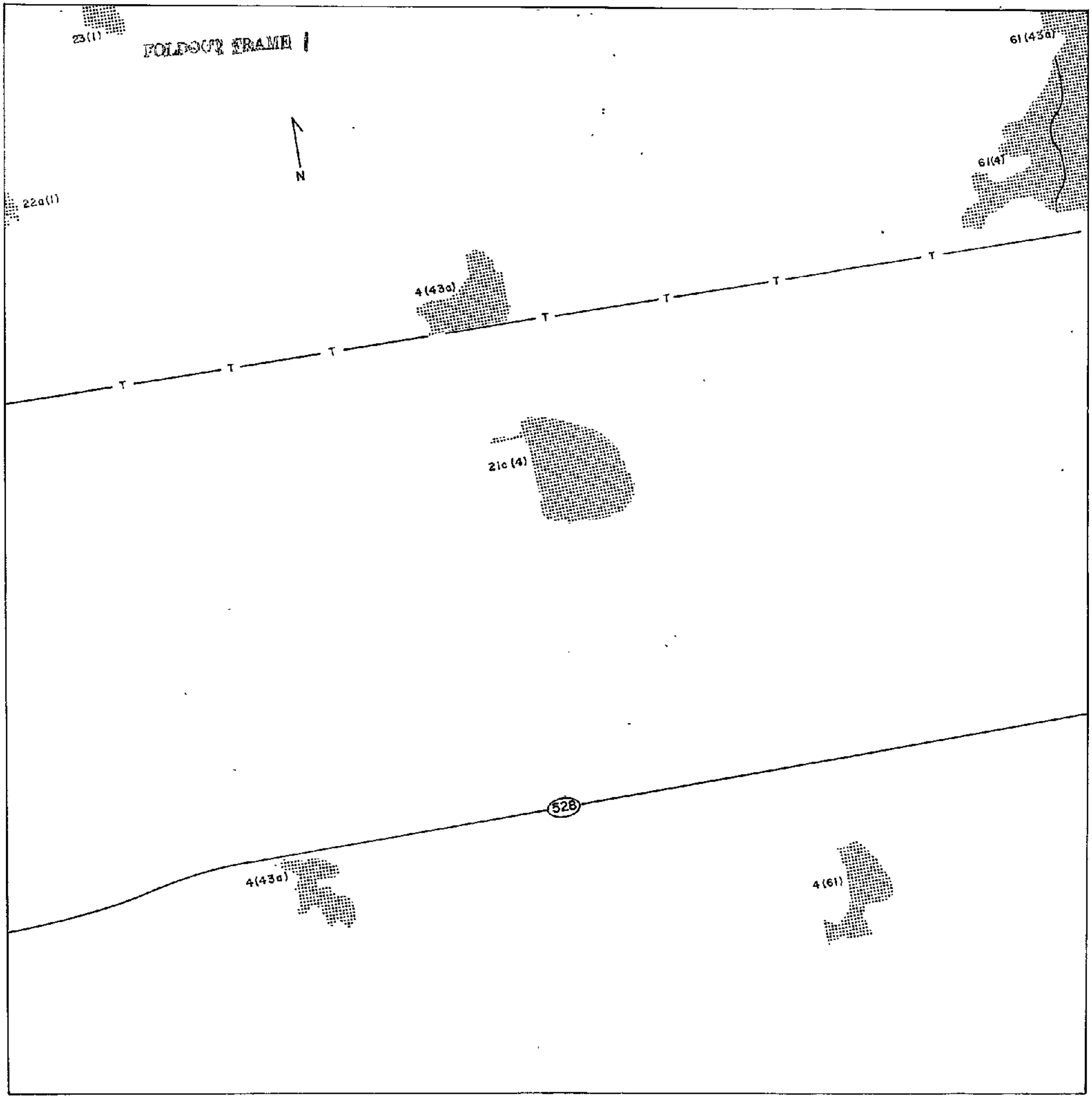


FIGURE 53
CORRECTIONS
SECTOR S, ORANGE COUNTY

SCALE ~ 1/48,000



FOLDOUT FRAME 2

FIGURE 54
CORRECTIONS
SECTOR T, ORANGE COUNTY

SCALE ~ 1/48,000

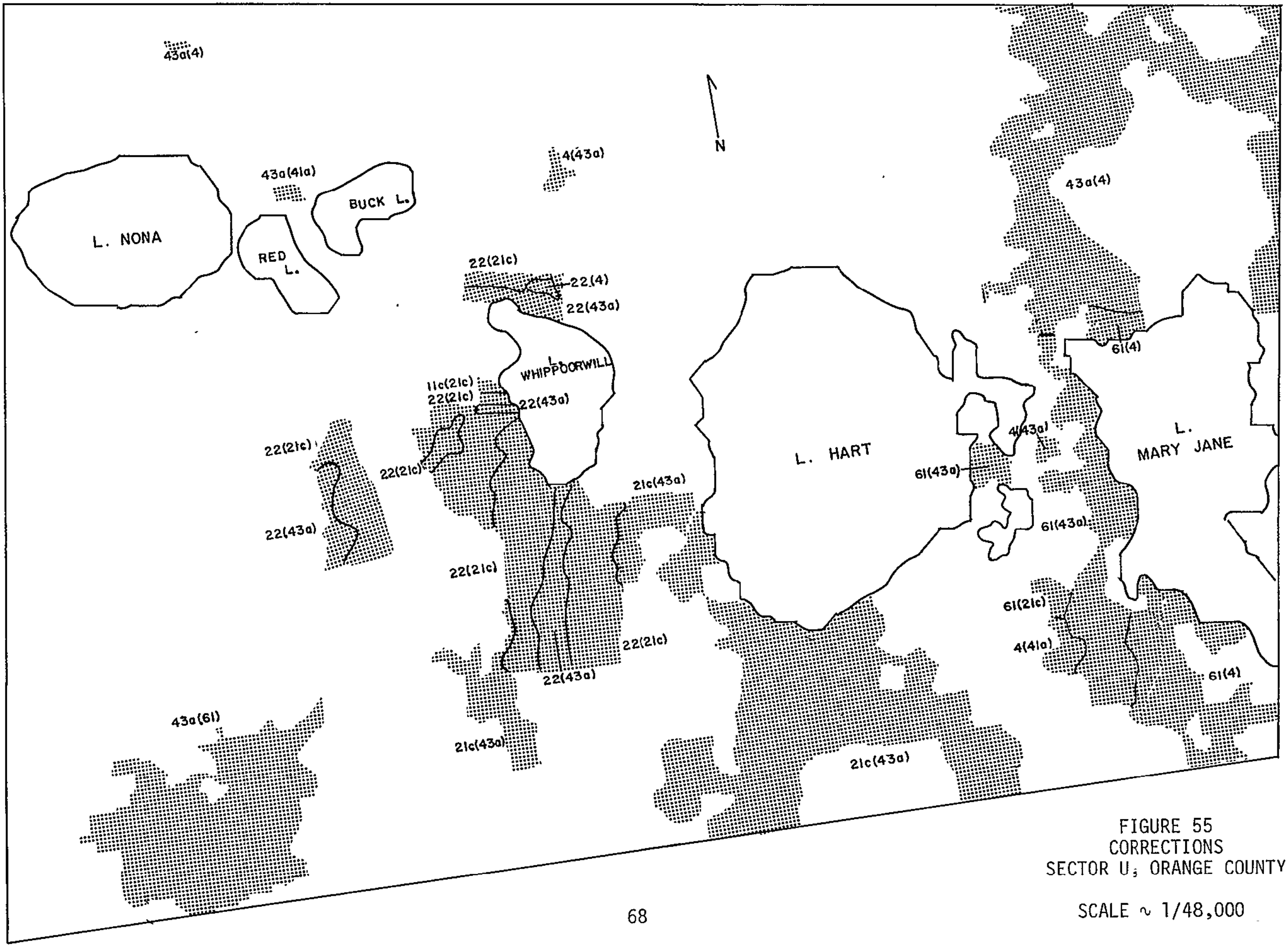
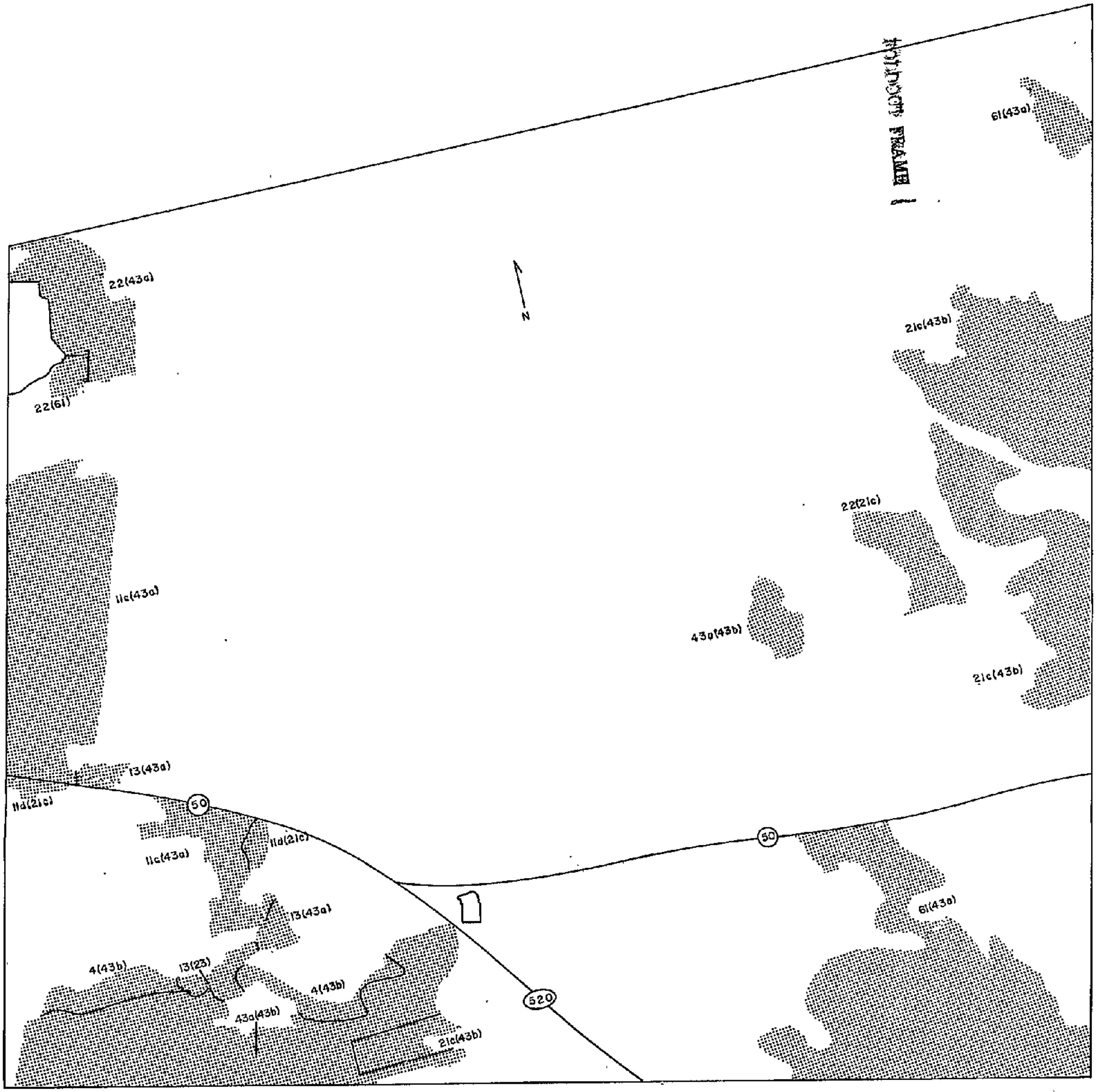


FIGURE 55
CORRECTIONS
SECTOR U; ORANGE COUNTY

SCALE ∿ 1/48,000

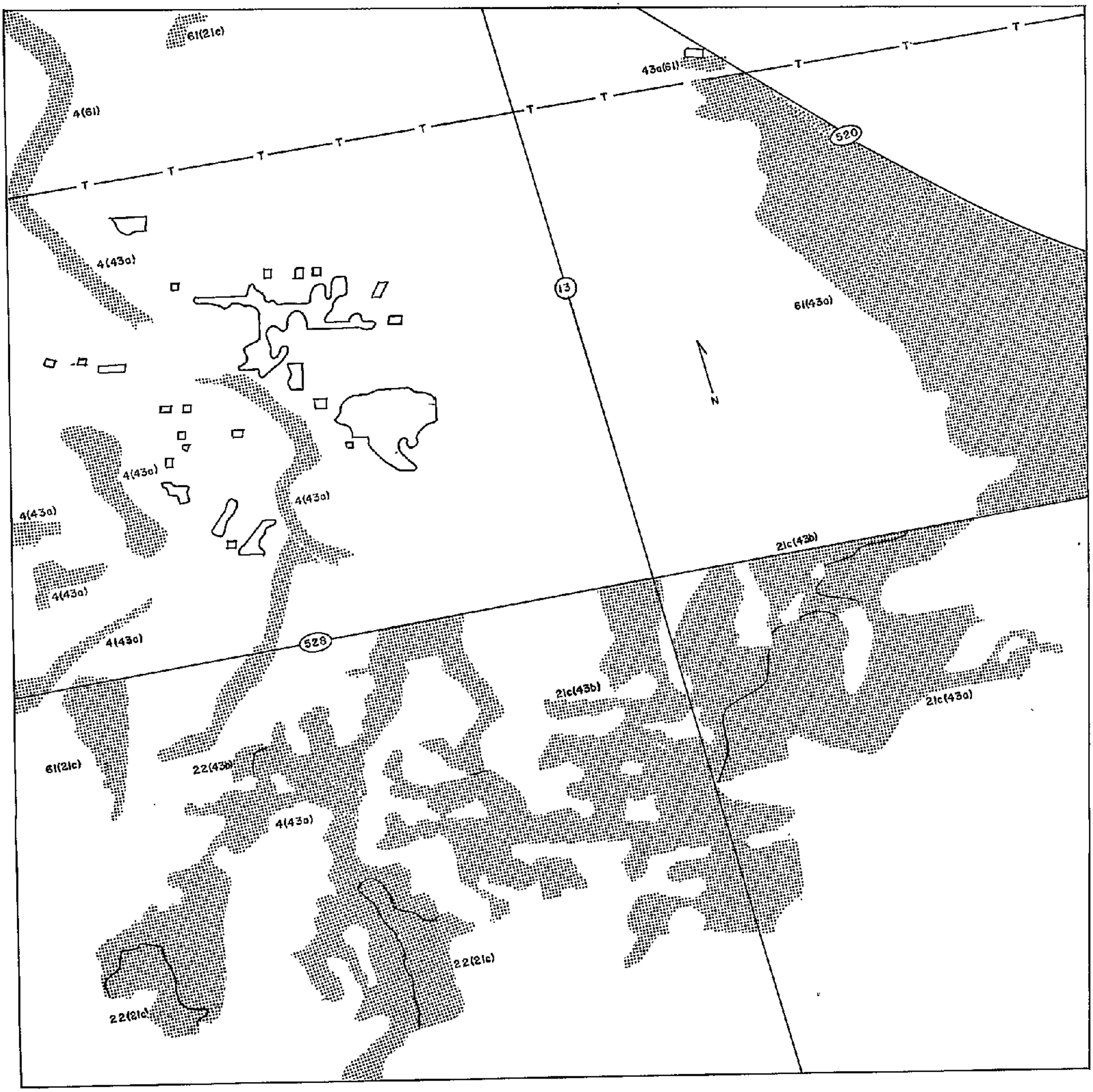


FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 56
CORRECTIONS
SECTOR V, ORANGE COUNTY

SCALE ~ 1/48,000



FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 57
CORRECTIONS
SECTOR W, ORANGE COUNTY

SCALE ~ 1/48,000

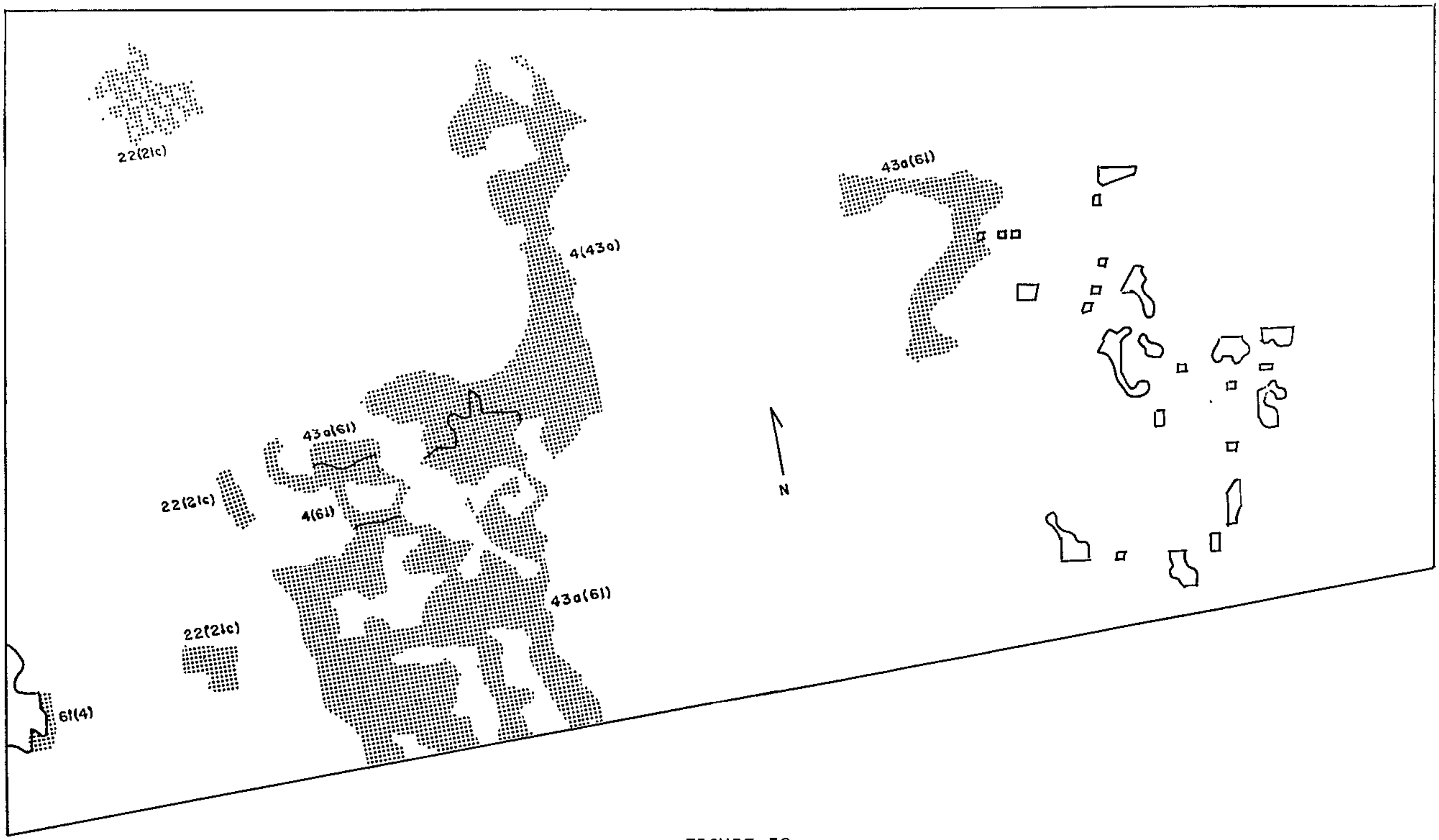


FIGURE 58
CORRECTIONS
SECTOR X, ORANGE COUNTY

SCALE ∿ 1/48,000

FIGURE 59
CORRECTIONS
SECTOR Y, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1
FOLDOUT FRAME 2

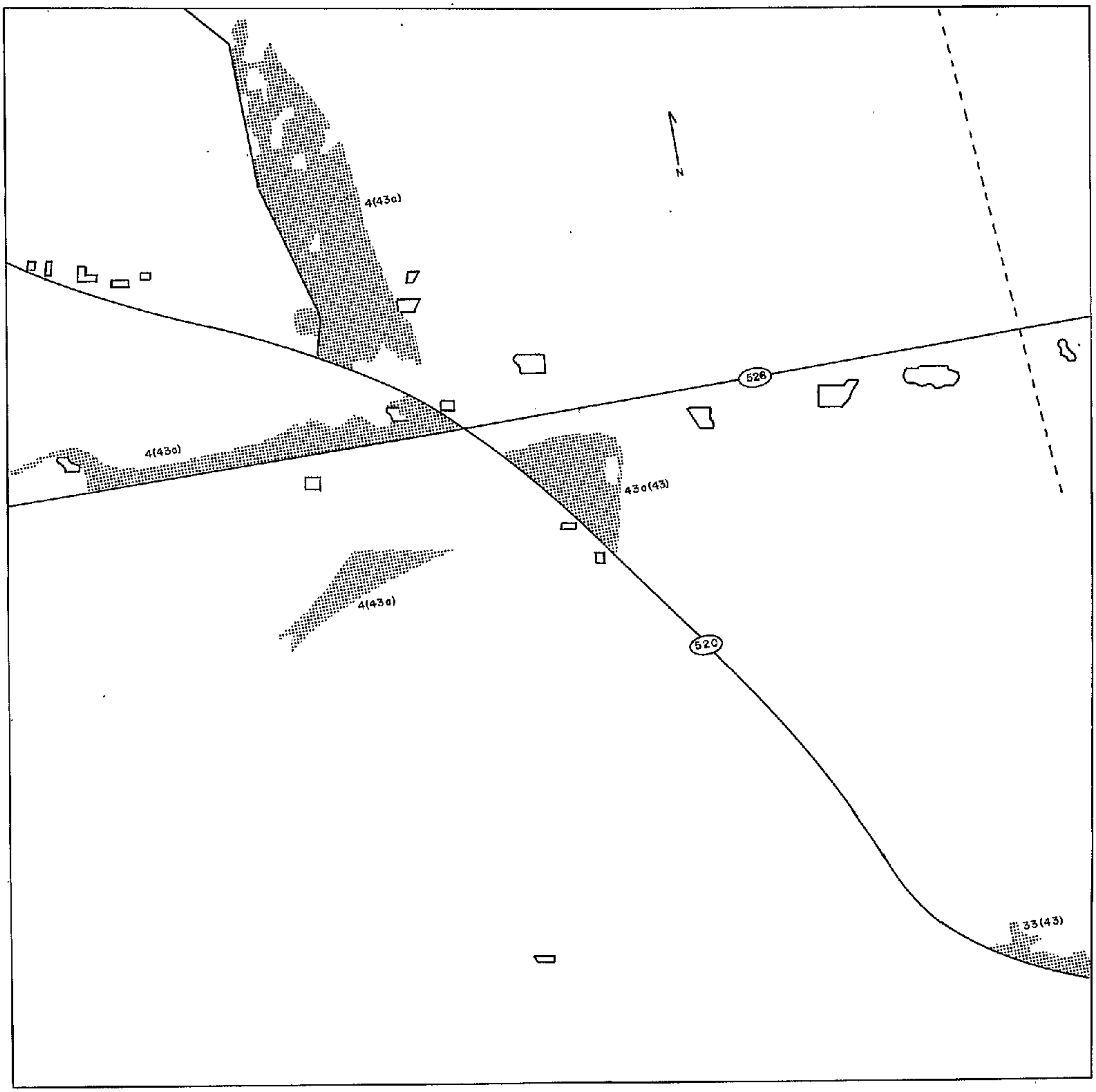


FIGURE 60
CORRECTIONS
SECTOR Z, ORANGE COUNTY

SCALE ~ 1/48,000

Difficulty in classifying forest of marginal density. (The same principle applies to other classes);

Reading some cypress forests as non-forested marsh. Cypress trees are not all in full leaf at the date of the satellite pass used (March 18, 1974). For example, a large cypress marsh in the lower left corner of Sector R appeared as marsh, while data for a pass later in the Spring or Summer would show it as cypress.

I will be noted that Figure 48 (Sector N) shows a significant error area shown by a different pattern and identified as citrus. A significant amount of citrus was not expected in that portion of the map and a citrus class was not sought; hence, the error is human rather than system. The error table presented later (Table 4) does not consider this as error. Its inclusion as error lowers the overall classification accuracy by approximately 0.5%.

Orange County is a major citrus-producing region. Unfortunately, citrus is difficult to identify from Landsat data because of the wide variation in the spectral appearance of the groves as seen from above. Our practice has been to divide citrus groves into three classes: young, middle-aged, and mature, depending mainly upon the amount of sand between the trees. This is not very successful; young groves are often confused with commercial/industrial, and mature groves may be confused with certain types of forest, especially oak. In the western part of the county, (e.g., Figure 12), where citrus groves are strongly predominant, our practice has been to classify as citrus everything which is not clearly classified otherwise or known to be something else. In other parts of the county, local knowledge is relied upon to some extent.

Due to the difficulty of distinguishing between commercial and industrial use in Landsat data, they were presented as a single class and the separation was made by the planner on the basis of his local knowledge and, where necessary, aerial photography.

The areas indicating errors in Figures 35-60 have been measured by planimeter to provide an indication of the accuracy of the classifications of Figures 5-34. The results are given in Table 3, which, then, shows the accuracy for the particular mixture of classification levels used in those maps, those levels which correspond to the degree of accuracy attainable by this method. In Table 3, a unit is counted as incorrect if its designation is changed, whatever the level of its original designation (i.e., a change from 1 to 2 or from 11a to 11b). The column labeled Accuracy is a measure of the probability that a given small area will be classified correctly.

It may be noted that Table 2 and Figures 5-34 include a few categories which cannot be distinguished from landsat data alone but require local knowledge. Those categories are not listed separately in Table 3. New construction, bare sand, extraction, institutional and transportation features are included in commercial/industrial. Mobile home parks are included in non-wooded residential.

As pointed out earlier, accuracy figures such as those of Table 3 should not be over-emphasized because they depend upon a number of factors,

TABLE 3

CLASSIFICATION ACCURACY

CLASS	AREA PRIOR TO CORRECTION		AREA	
	HECTARES	ACRES	INCORRECT HECTARES	ACCURACY (PER CENT)
1 Urban	1,363	3,368	18	99
11 Residential	632	1,562	0	
11a Wooded Residential	10,528	26,015	2,089	80
11b Non-wooded Residential	12,814	31,664	1,477	88
11c Rural Residential	312	771	32	90
12 Commercial/Industrial	5,956	14,718	283	95
19 Urban Undeveloped	1,277	3,156	216	83
2 Agriculture	22,071	54,539	1,974	91
21c Pasture	14,509	35,853	2,269	84
22 Citrus	37,584	92,872	6,706	82
23 Bare Sand in Agricultural Sector	227	561	68	70
33 Brush	529	1,307	0	
4 Forest	47,913	118,396	2,243	95
41a Cypress	622	1,537	42	93
41b Hardwoods	35	86	0	
43a Pine and Palmetto	45,914	113,456	5,793	87
43b Palmetto and Scrub Oak	5,218	12,894	2,417	54
51 Streams	13	32	0	
52 Lakes	23,329	57,647	0	100
61 Marsh	18,791	46,434	2,084	89
TOTALS	249,637	616,868	27,711	89

especially the extent to which local knowledge is used. They are presented here simply to provide a rough indication of the accuracy to be expected under similar circumstances. It should be pointed out, further, that those figures do not represent the accuracy of the final, corrected map, but rather the map made directly from Landsat data. The accuracy of the final map is higher. These figures are based on the counting of incorrectly designated sectors, independent of the area of the sector. The fractional occurrence is the number of times the particular error occurred divided by the total number of errors.

Frequency of occurrence of the various types of errors has been checked, with the most frequently occurring errors listed on Table 4.

A complete listing of errors is given in Table 5.

Results of accuracy measurements based on a Level 1 classification are given in Table 6.

A Level 2 classification is much less accurate in this case because some urban regions and a large amount of forest area were classified only to Level 1 precision. Separation of forest types was not a prime concern for this map.

The corrected maps with traffic zone boundaries are shown in Figures 57-82 (except for Sectors AB and AD, which have no corrections or traffic zone boundaries). As mentioned earlier, one of the immediate purposes of this map was production of a land use inventory to meet transportation planning needs. For that purpose, some of the classes shown on the original map, Figures 5-31, were not needed; hence, the corrected map, Figures 56-79, shows some of those classes combined. For example, it does not make a

TABLE 4

MOST FREQUENTLY OCCURRING ERRORS

Error Type Correct (Incorrect)	Fractional Occurrence
4 (22)	9%
22 (4)	8
22 (21c)	7
21c (22)	5
22 (43a)	4
19 (11a)	4
12 (11b)	4
21c (4)	3
43a (22)	3
61 (22)	3
4 (2)	3
22 (11a)	3
13 (11b)	3

TABLE [illegible]

Errors

Original Classification	Incorrect Classification	Area (Hectares)
1	22	4
	23	11
	4	3
11		0
11a	11b	182
	12	31
	13	15
	19	1,061
	1-11	52
	2,21c	48
	22	537
	4	123
	43a	39
	52	1
11b	11a	73
	12	622
	19	484
	2	92
	22	108
	23	60
	4	33
	52	5
11c	1-12	32
11d		0
12	11b	86
	11d	9
	19	5
	2	14
	22	25
	23	144
19	11a	120
	11b	25
	12	3
	21b	51
	4	17
1-12		0
2	11	32
	11a	153
	11b	372
	11c	203
	11d	1
	12	64
	13	30
	14	12
	1-10	55
	4	1,052
21c	11a	16
	11b	250
	11c,11d	40
	12	33
	2	430
	22	1,195
	23	14
	4,43	207
	43a	1
	61	77
22	1	223
	11a,11b,11c,11d	571
	12	28
	1-12	14
	21c	2,176
	223	70
	4,41a	2,083
	43a	624
	52	21
	61	896

TABLE 5
(continued)

Errors

Original Classification	Incorrect Classification	Area (Hectares)
23	13	24
	1-11	14
	22	30
33		0
4	11a	128
	11b	6
	12	11
	13	27
	19	71
	21c	595
	22	642
	43a	423
	61	227
41a	22	27
	4	12
	43a	3
41b		0
43	33	22
	43a	91
43a	11a	192
	11c	431
	13	31
	1-10	67
	1-12	221
	21c	1,099
	22	356
	4	1,774
	41a	2
	61	1,620
43b	11c	181
	21c	1,707
	22	30
	4	78
	43a	421
52		0
61	12	2
	2	2
	21c	140
	22	144
	4	103
	41a	379
	43a	1,310
	52	4

TABLE 6

LEVEL 1 CLASSIFICATION ACCURACY

CLASS	AREA PRIOR TO CORRECTION Hectares	AREA PRIOR TO CORRECTION Acres	AREA INCORRECT (Hectares)	ACCURACY (Percent)
1. Urban	32,882	81,253	1,315	96
2. Agriculture	74,391	183,824	7,102	90
3. Brush	529	1,307	0	
4. Forest	99,702	246,369	7,691	92
5. Water	23,342	57,679	0	100
6. Marsh	18,791	46,434	2,084	89
TOTALS	249,637	616,866	18,192	93

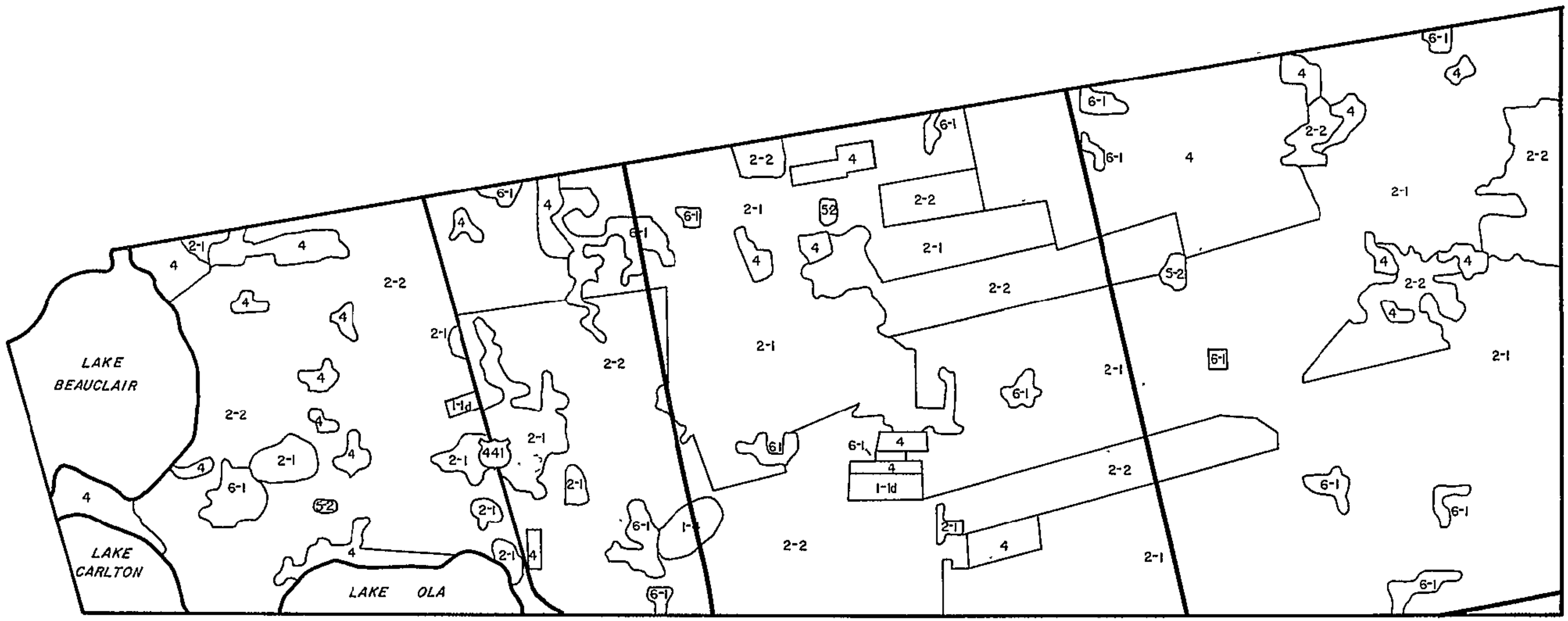


FIGURE 61
CORRECTED MAP
SECTOR A, ORANGE COUNTY

SCALE ∿ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

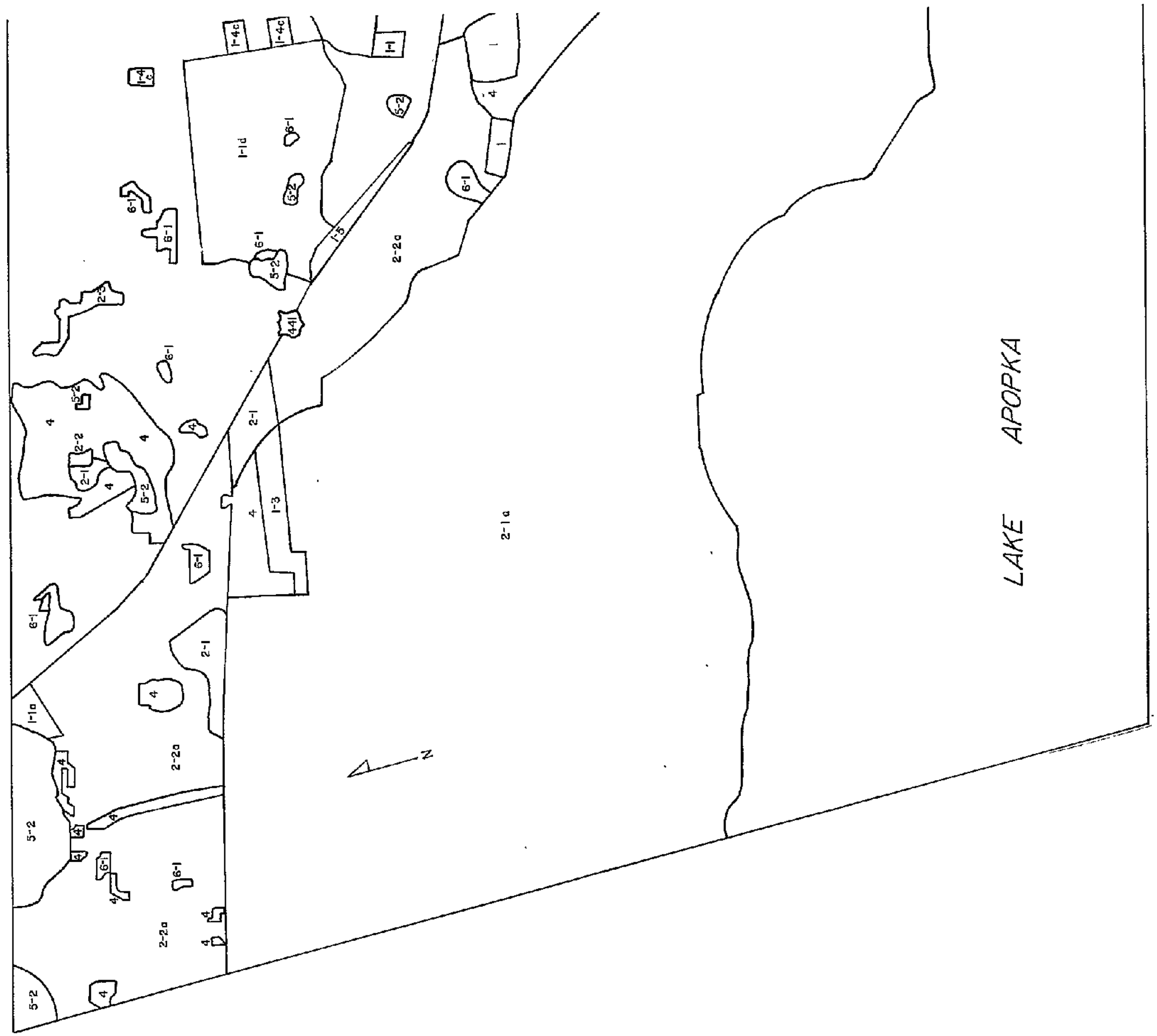


FIGURE 62
CORRECTED MAP
SECTOR B, ORANGE COUNTY

SCALE ~ 1/48,000

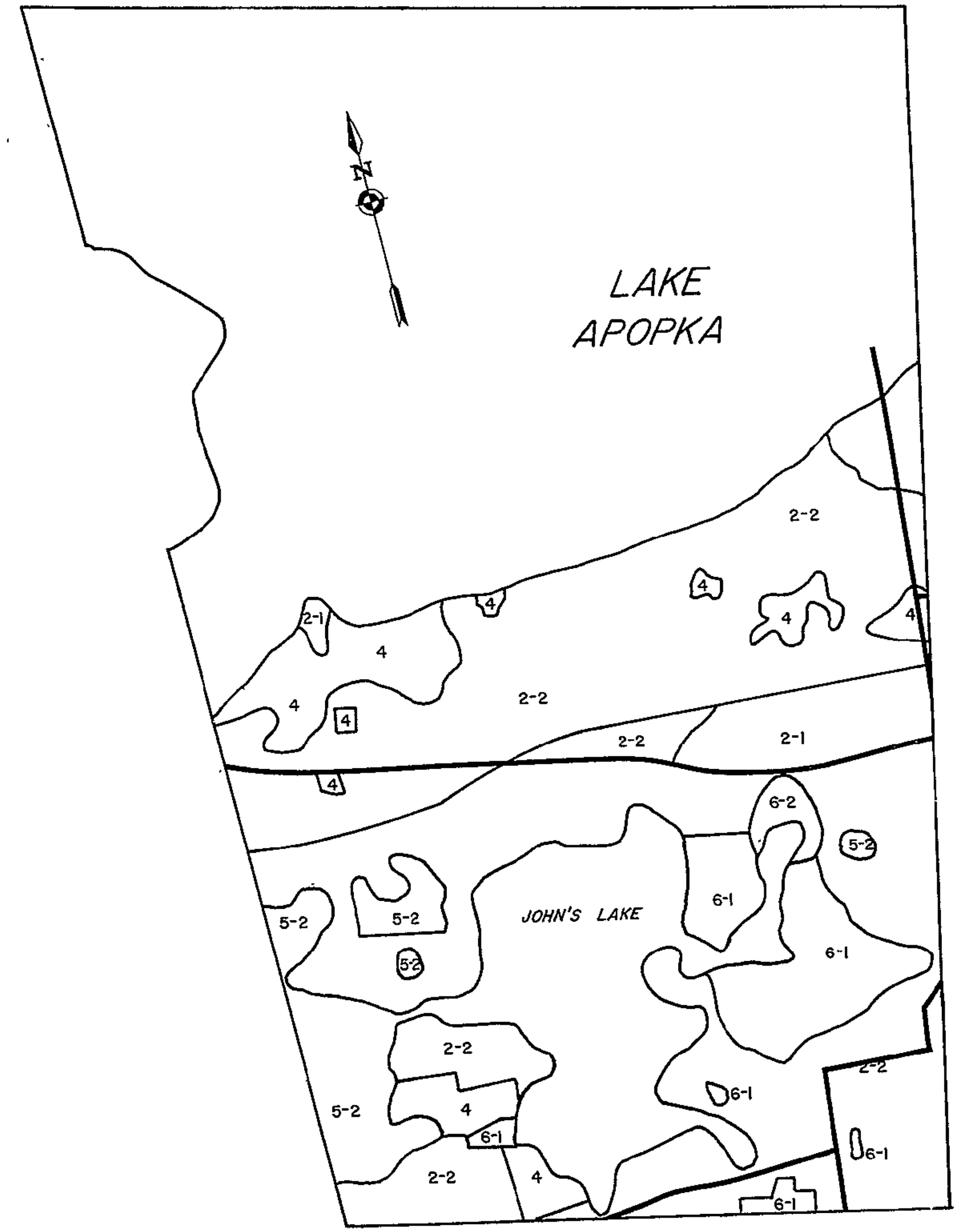


FIGURE 63
CORRECTED MAP
SECTOR C, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

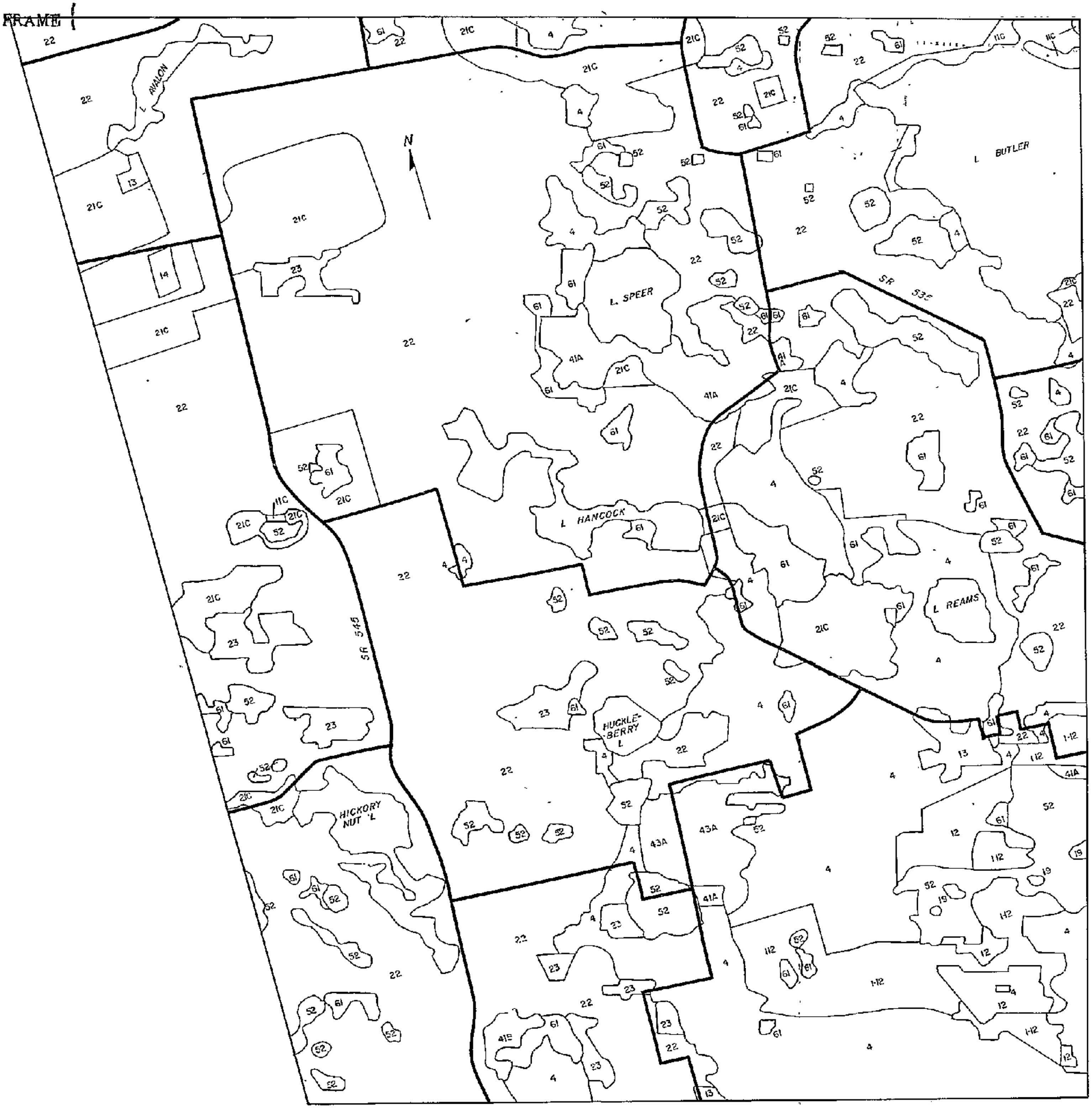


FIGURE 64
CORRECTED MAP
SECTOR D, ORANGE COUNTY

SCALE ~ 1/48,000

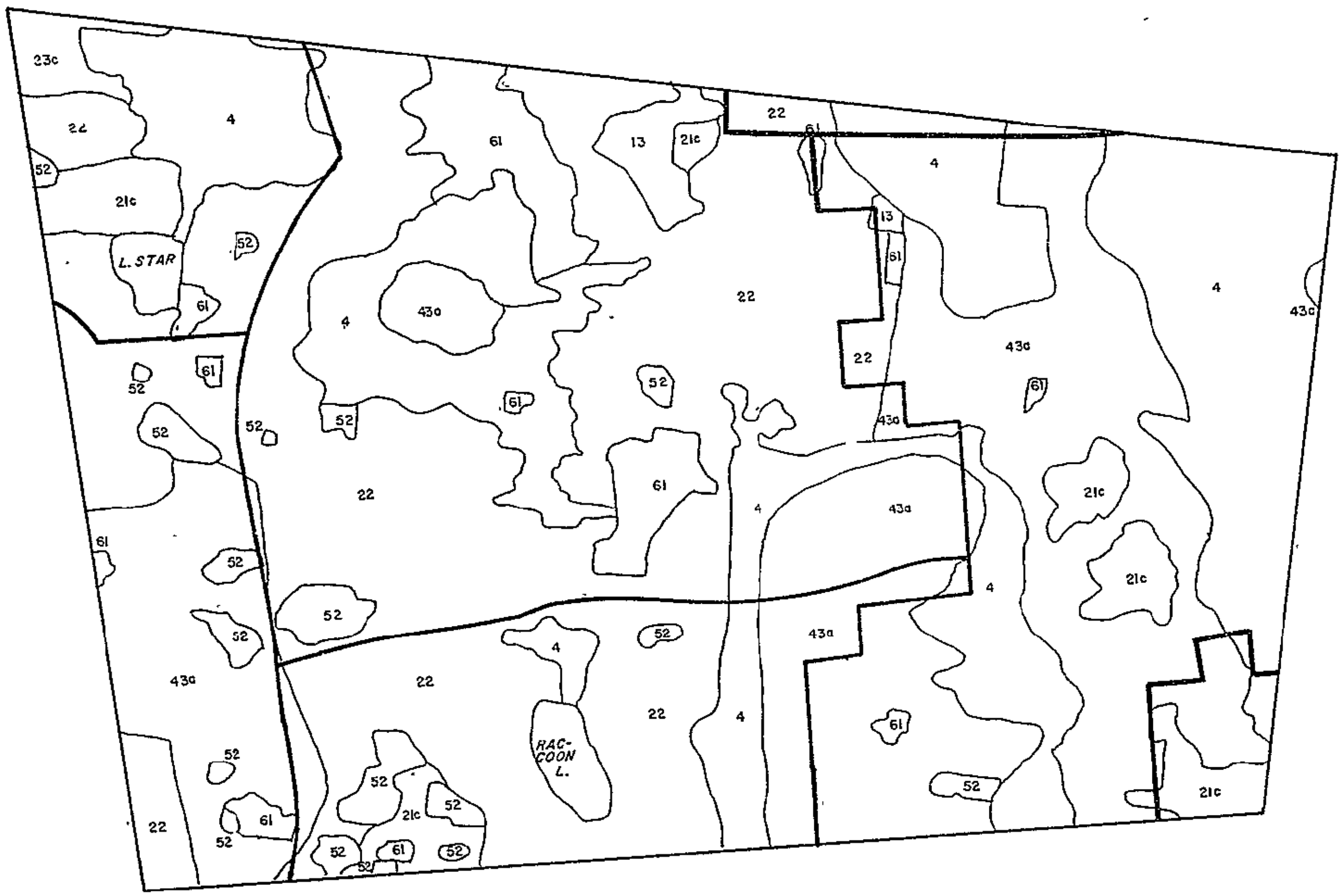


FIGURE 65
CORRECTED MAP
SECTOR E, ORANGE COUNTY

SCALE ∿ 1/48,000

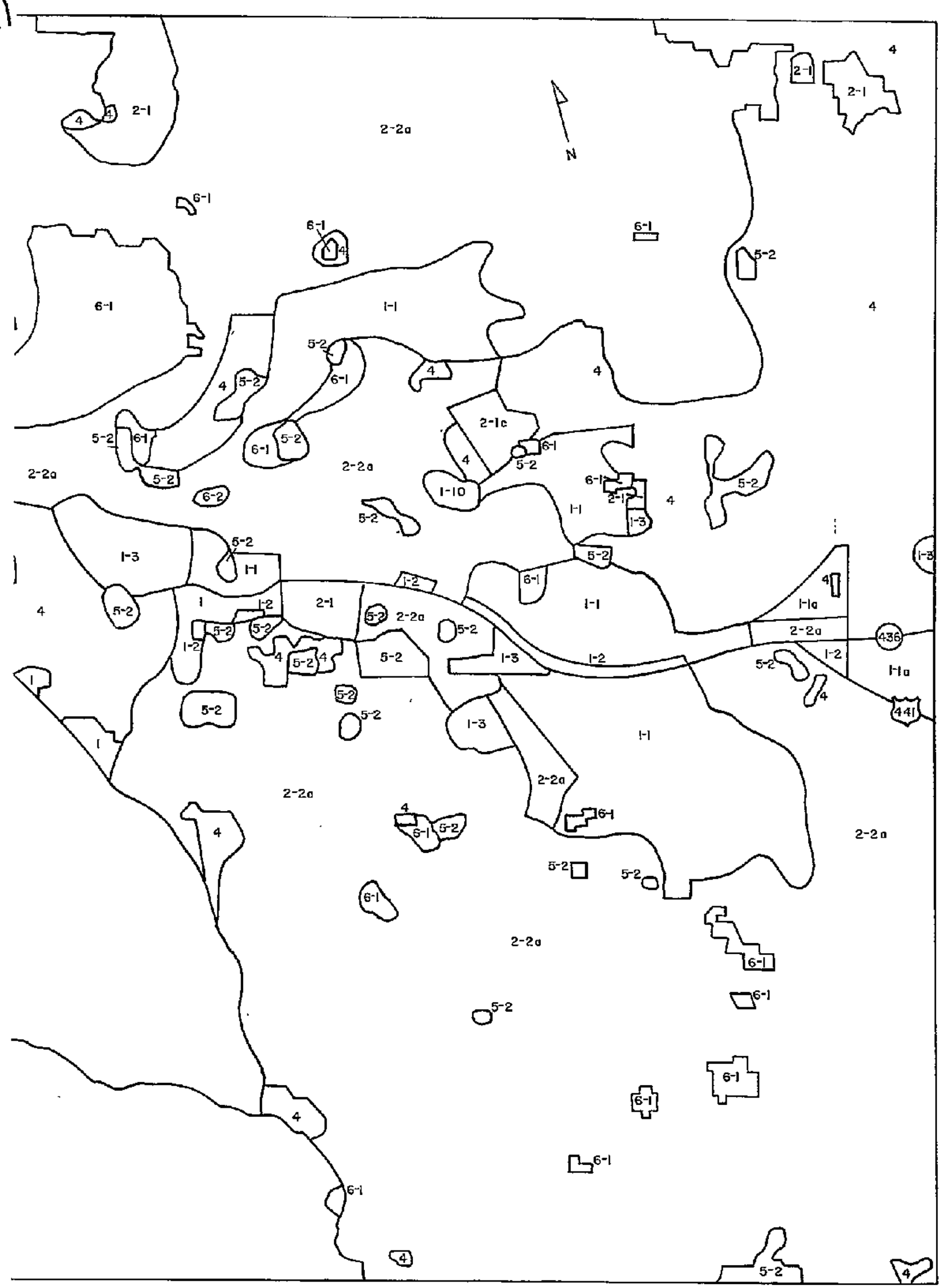
FOLDOUT FRAME

FOLDOUT FRAME 2

FIGURE 66
CORRECTED MAP
SECTOR F, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1



FOLDOUT FRAME 2

FIGURE 67
CORRECTED MAP
SECTOR G, ORANGE COUNTY

SCALE ~ 1/48,000

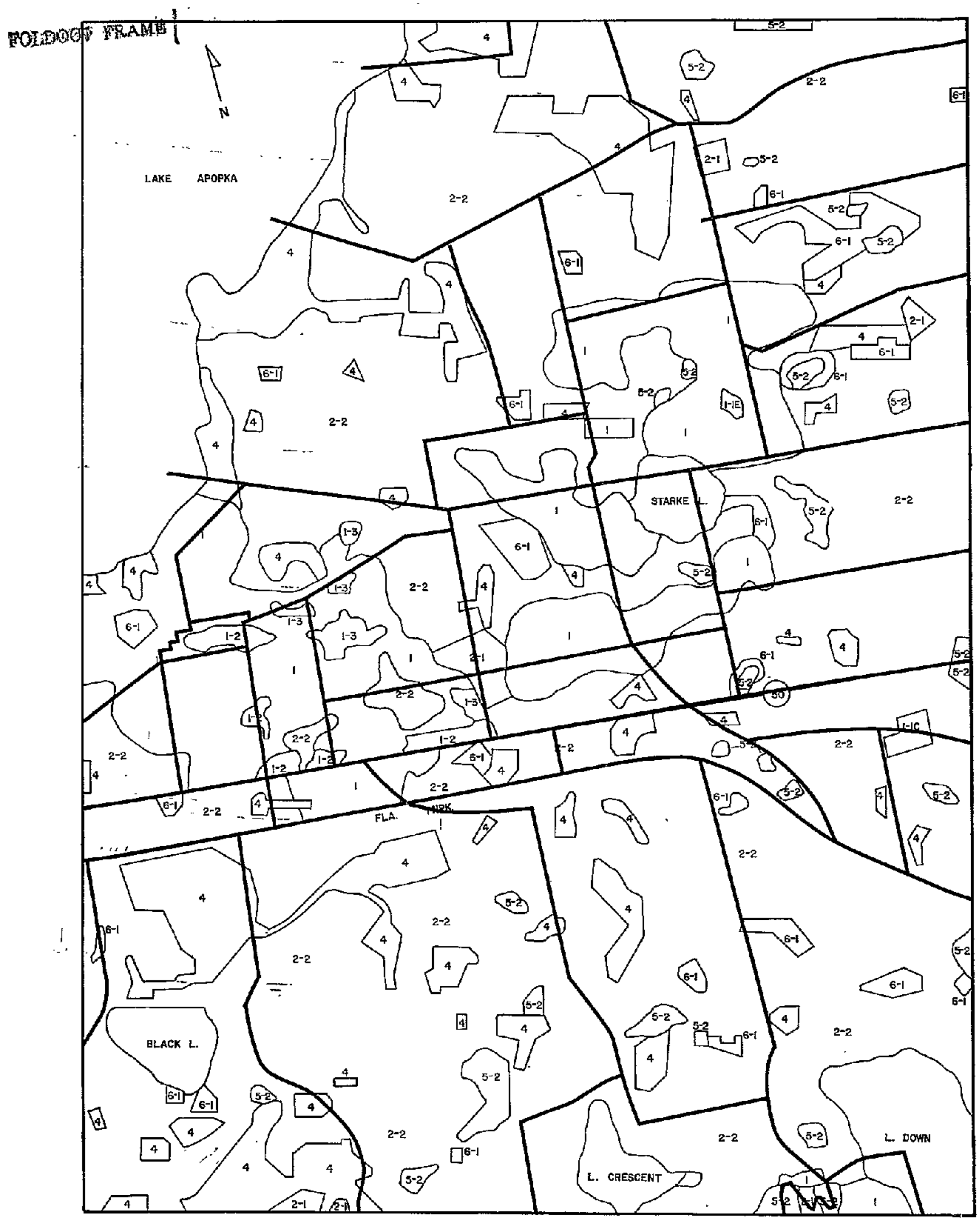
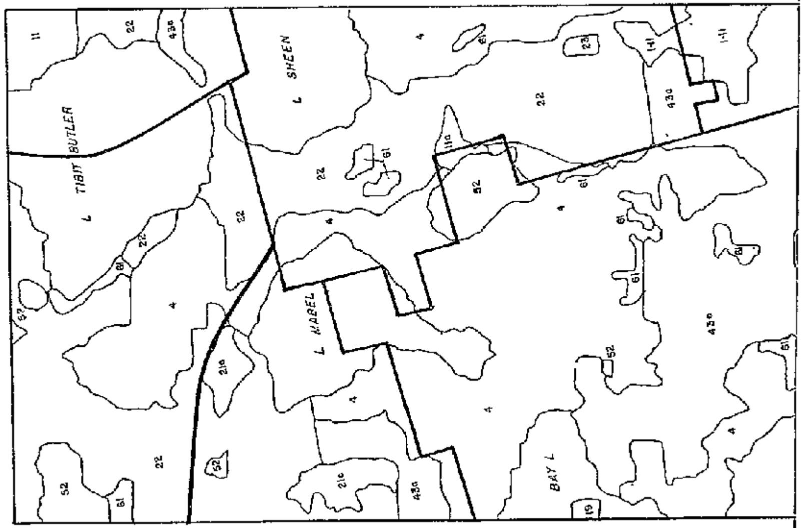
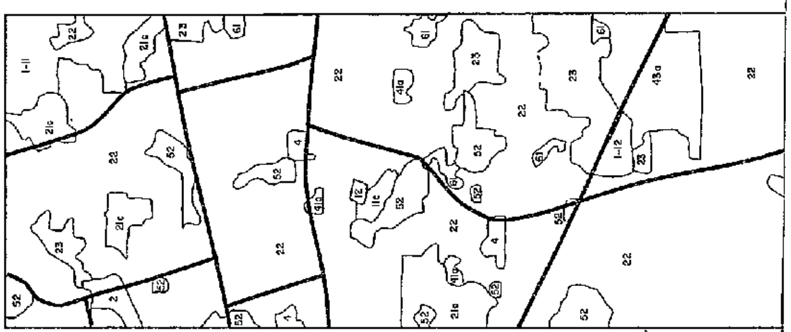


FIGURE 68
CORRECTED MAP
SECTOR H, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME





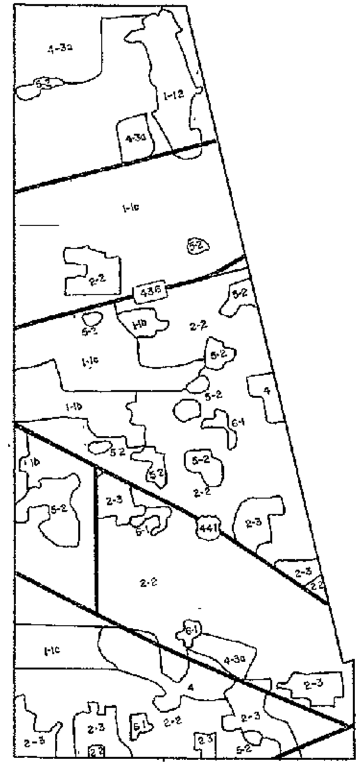


FIGURE 69
SECTOR I, ORANGE COUNTY

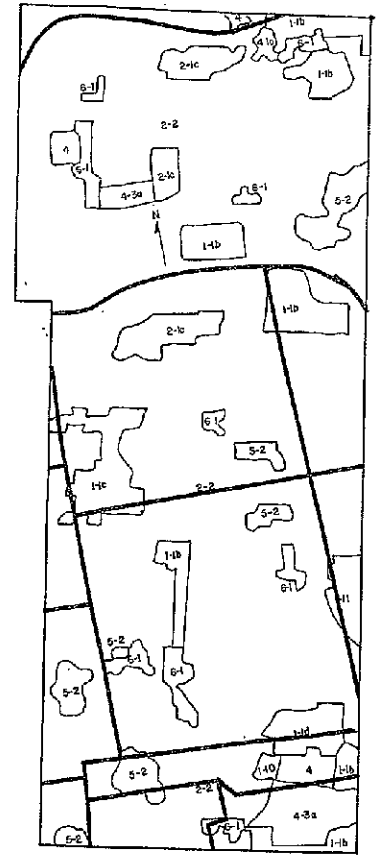


FIGURE 70
SECTOR J, ORANGE COUNTY

CORRECTED MAP
SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

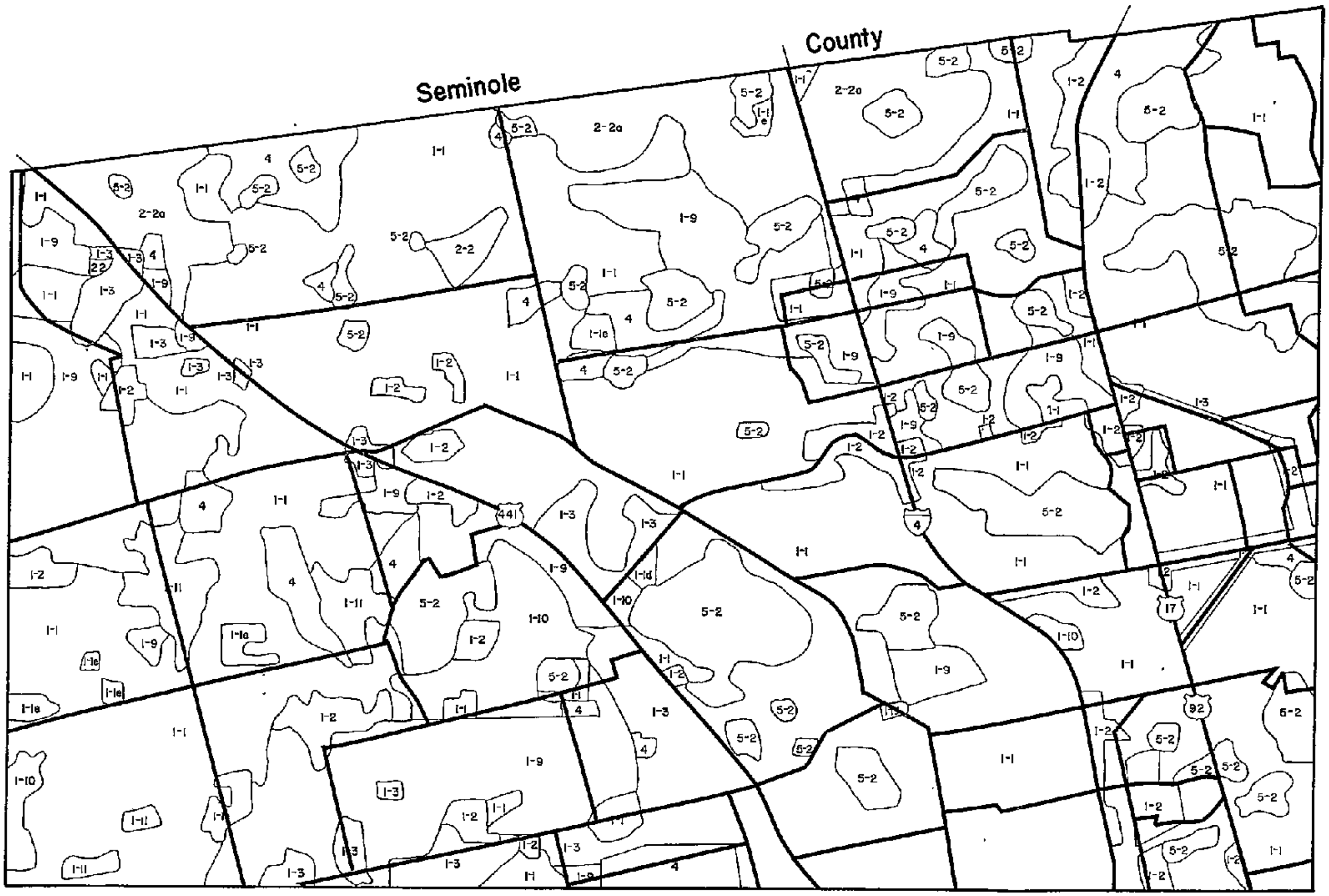


FIGURE 73
CORRECTED MAP
SECTOR M, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 74
CORRECTED MAP
SECTOR N, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 75
CORRECTED MAP
SECTOR O, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

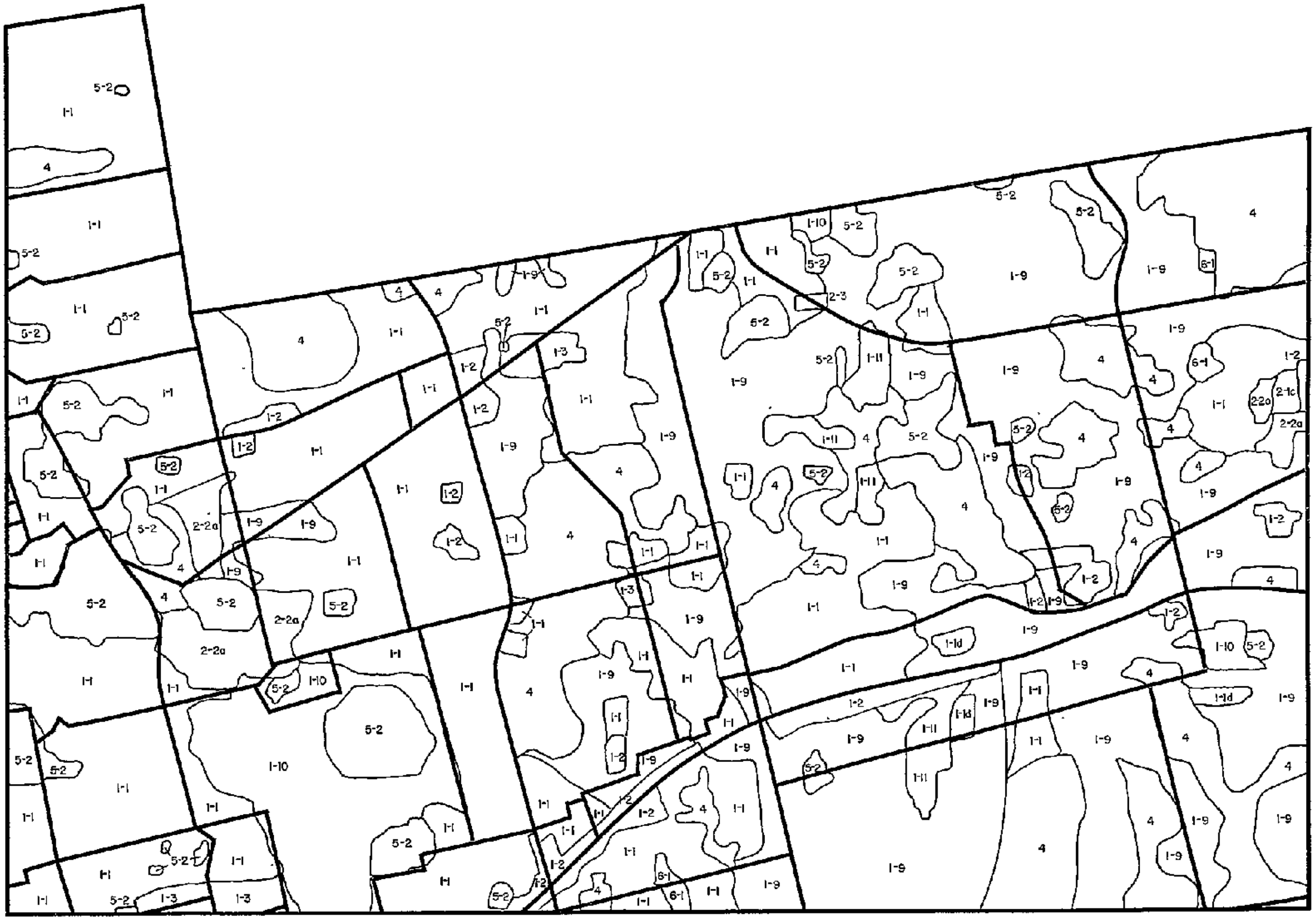


FIGURE 76
CORRECTED MAP
SECTOR P, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 77
CORRECTED MAP
SECTOR Q, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME

FIGURE 78
CORRECTED MAP
SECTOR R, ORANGE COUNTY

SCALE ∿ 1/48,000

FOLDOUT FRAME

FOLDOUT FRAME 1

FOLDOUT FRAME 2

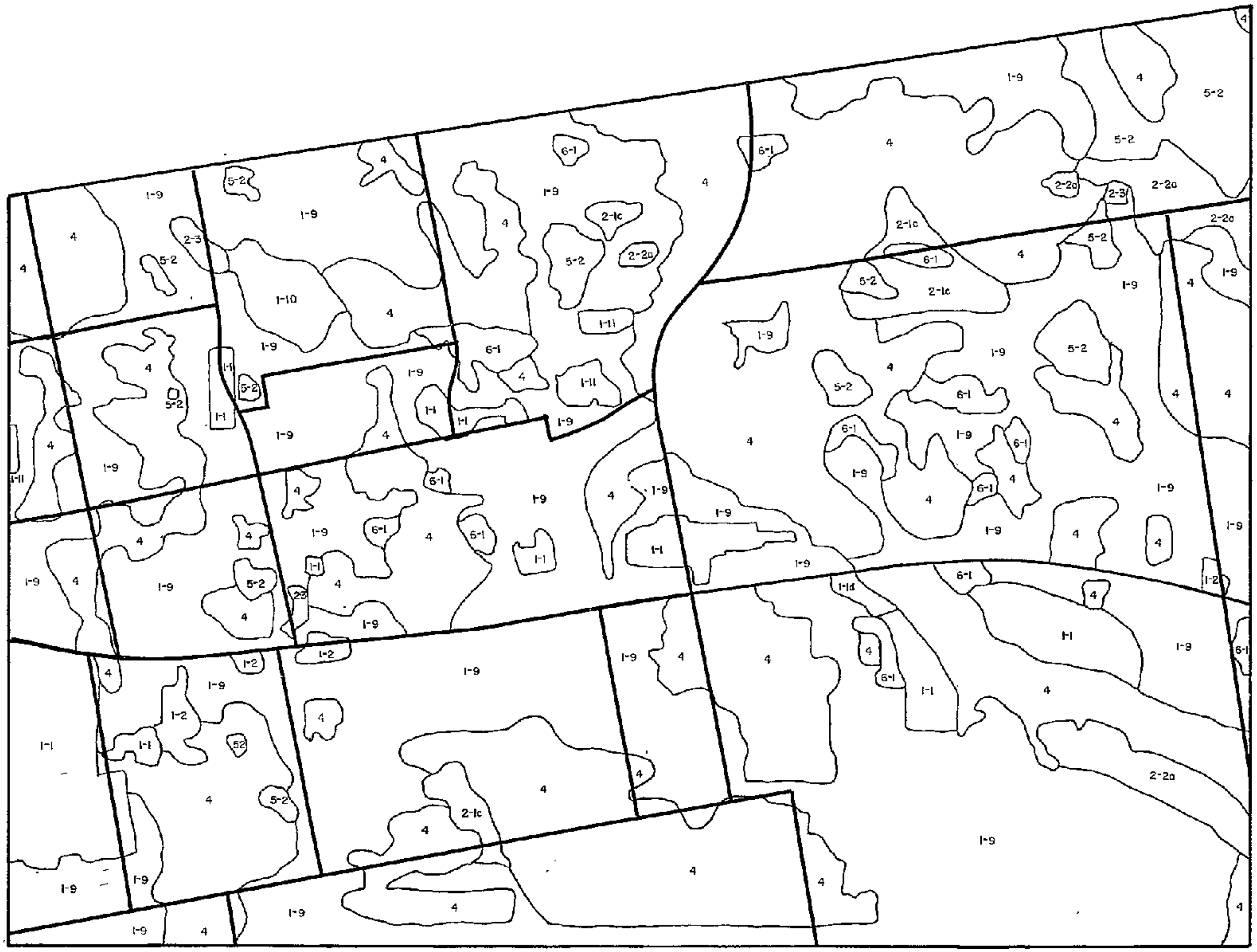


FIGURE 79
CORRECTED MAP
SECTOR S, ORANGE COUNTY

SCALE ∿ 1/48,000

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 80
CORRECTED MAP
SECTOR T, ORANGE COUNTY

SCALE ~ 1/48,000

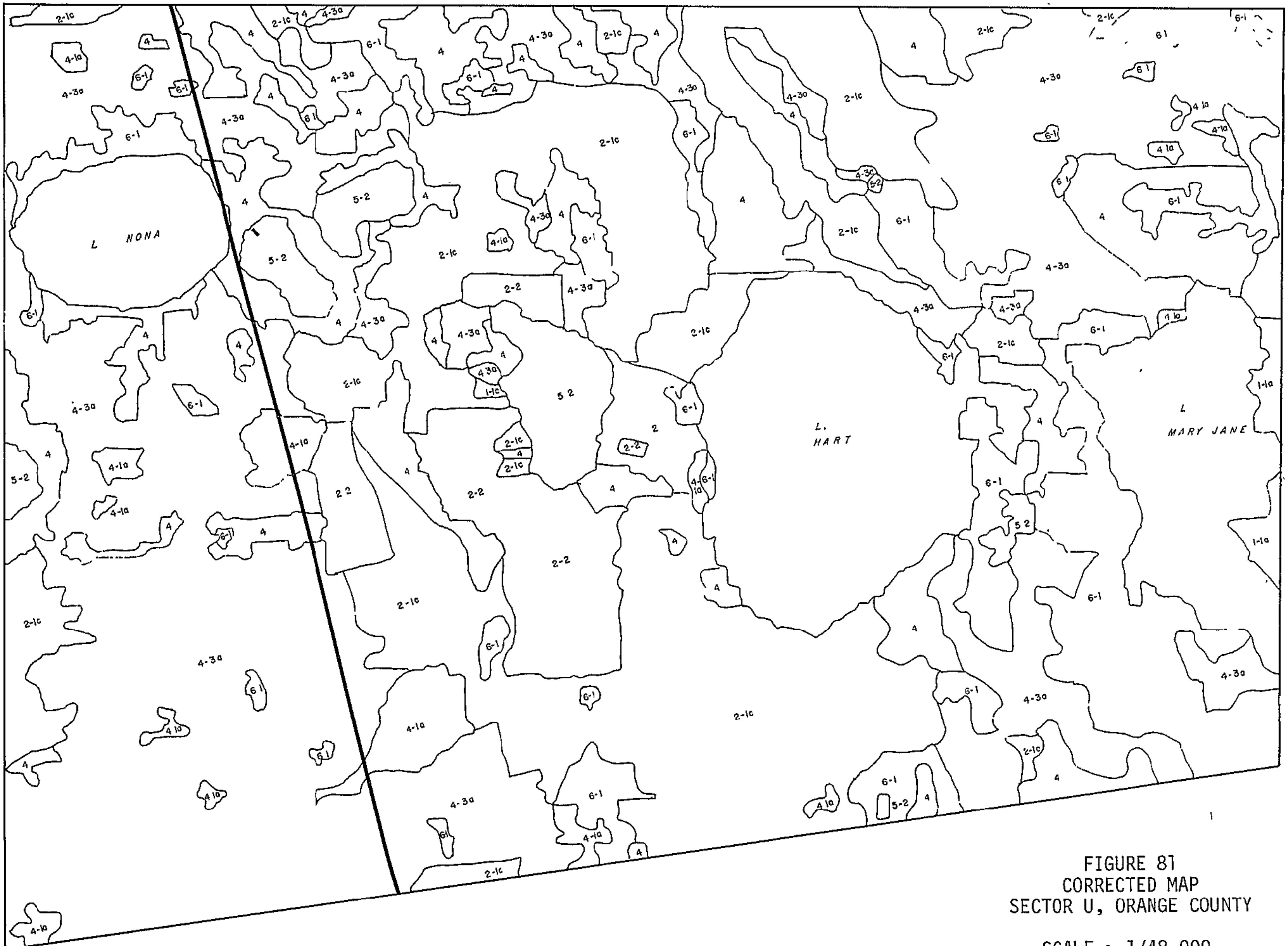


FIGURE 81
CORRECTED MAP
SECTOR U, ORANGE COUNTY

SCALE ∿ 1/48,000

FOLDOUT FRAME 1

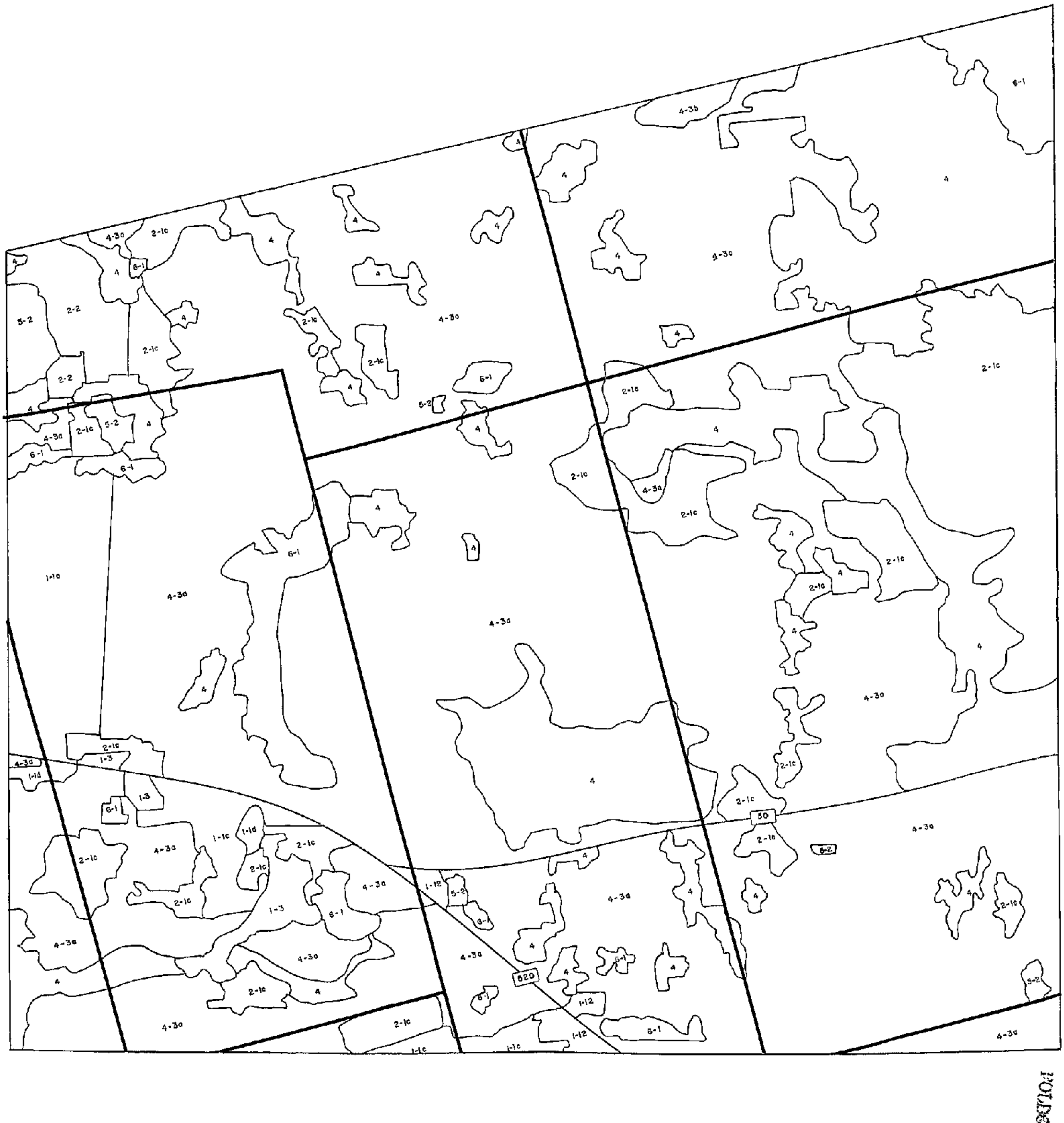


FIGURE 82
CORRECTED MAP
SECTOR V, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME 2

FIGURE 83
CORRECTED MAP
SECTOR W, ORANGE COUNTY

SCALE ~ 1/48,000

FOLDOUT FRAME
FOLDOUT FRAME 2

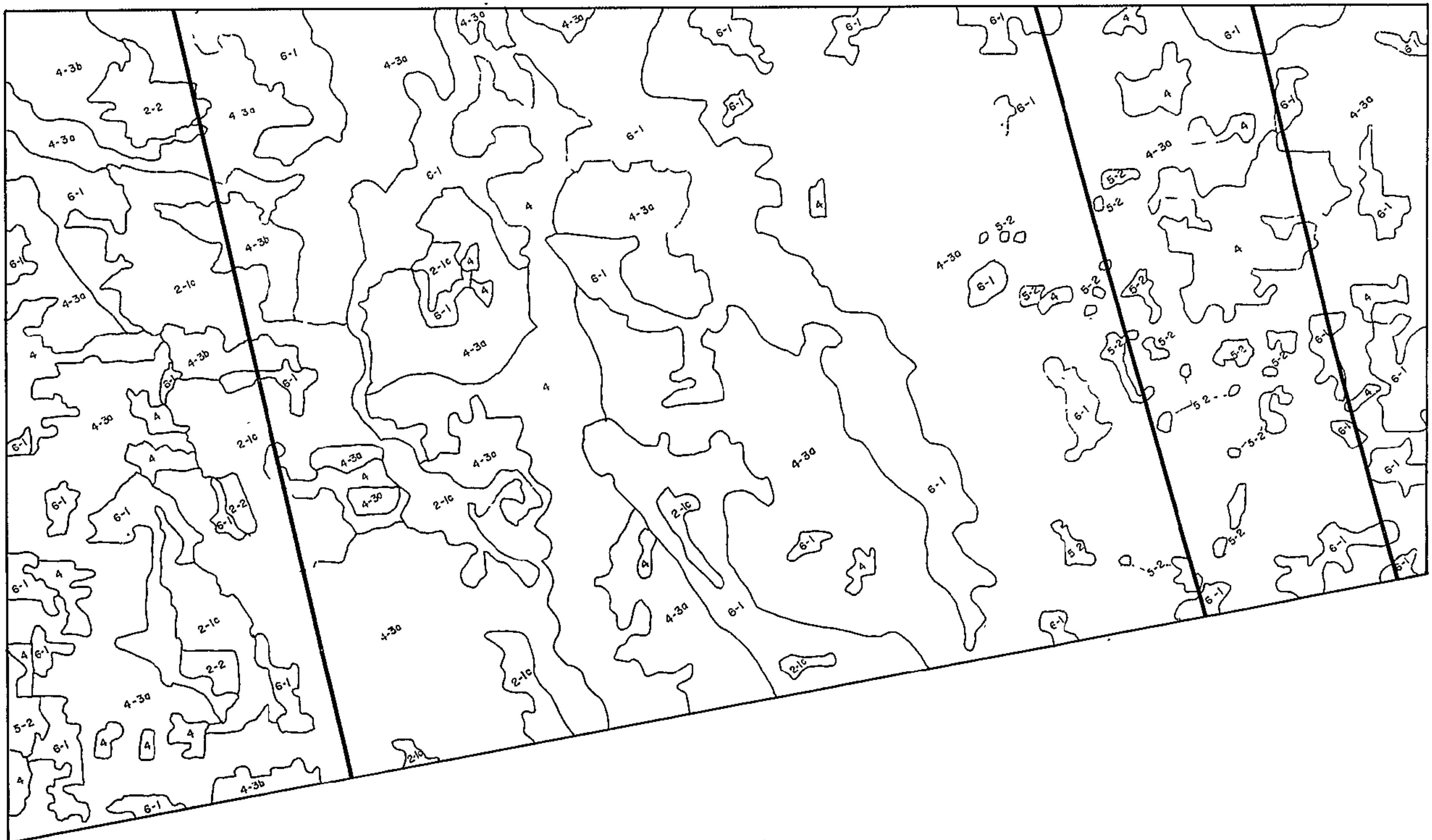


FIGURE 84
CORRECTED MAP
SECTOR X, ORANGE COUNTY

SCALE ~ 1/48,000

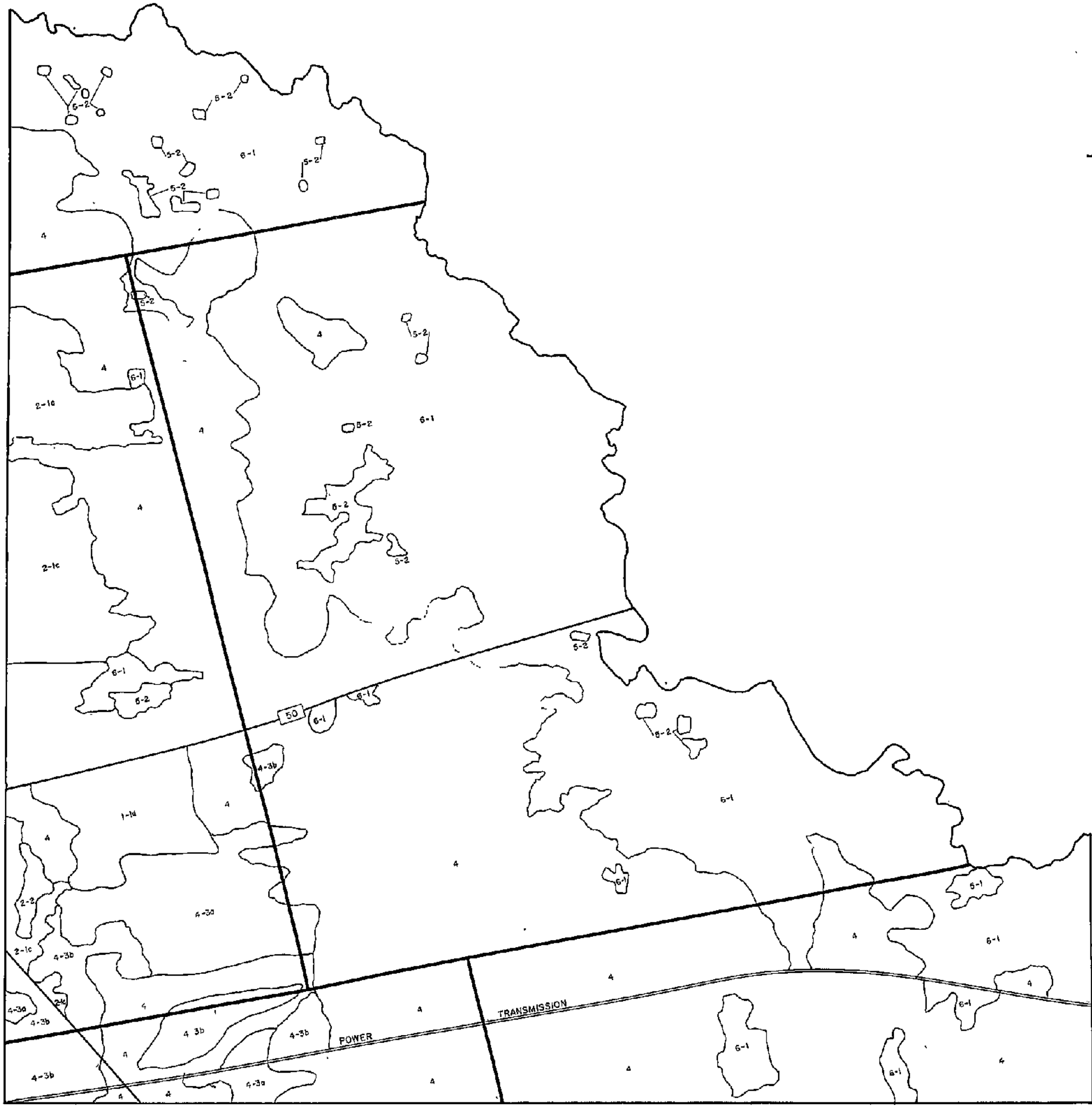


FIGURE 85
CORRECTED MAP
SECTOR Y, ORANGE COUNTY

SCALE ∿ 1/48,000

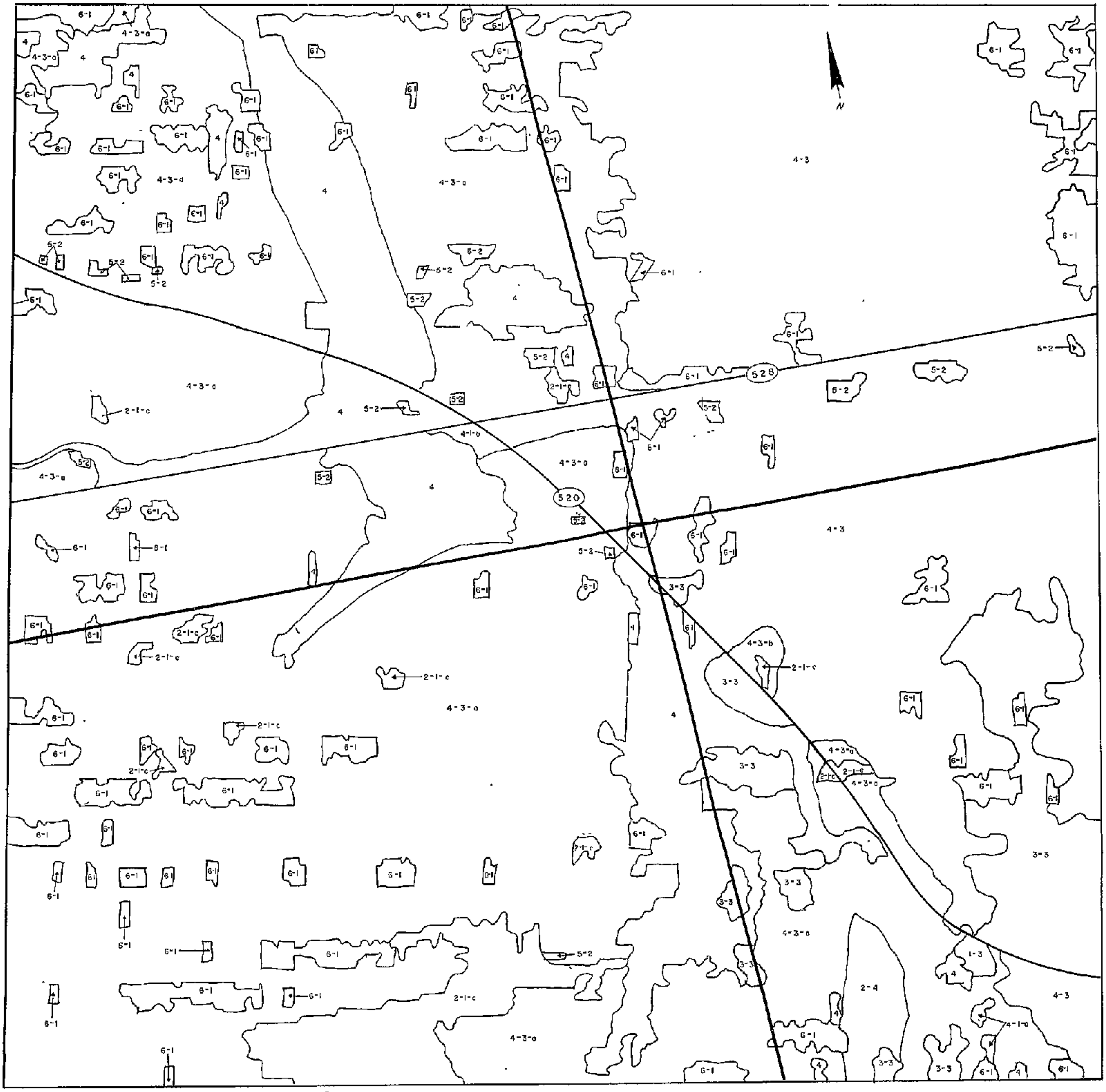


FIGURE 86
CORRECTED MAP
SECTOR Z, ORANGE COUNTY

SCALE ~ 1/48,000

FIGURE 87
CORRECTED MAP
SECTOR AA, ORANGE COUNTY

SCALE ~ 1/48,000

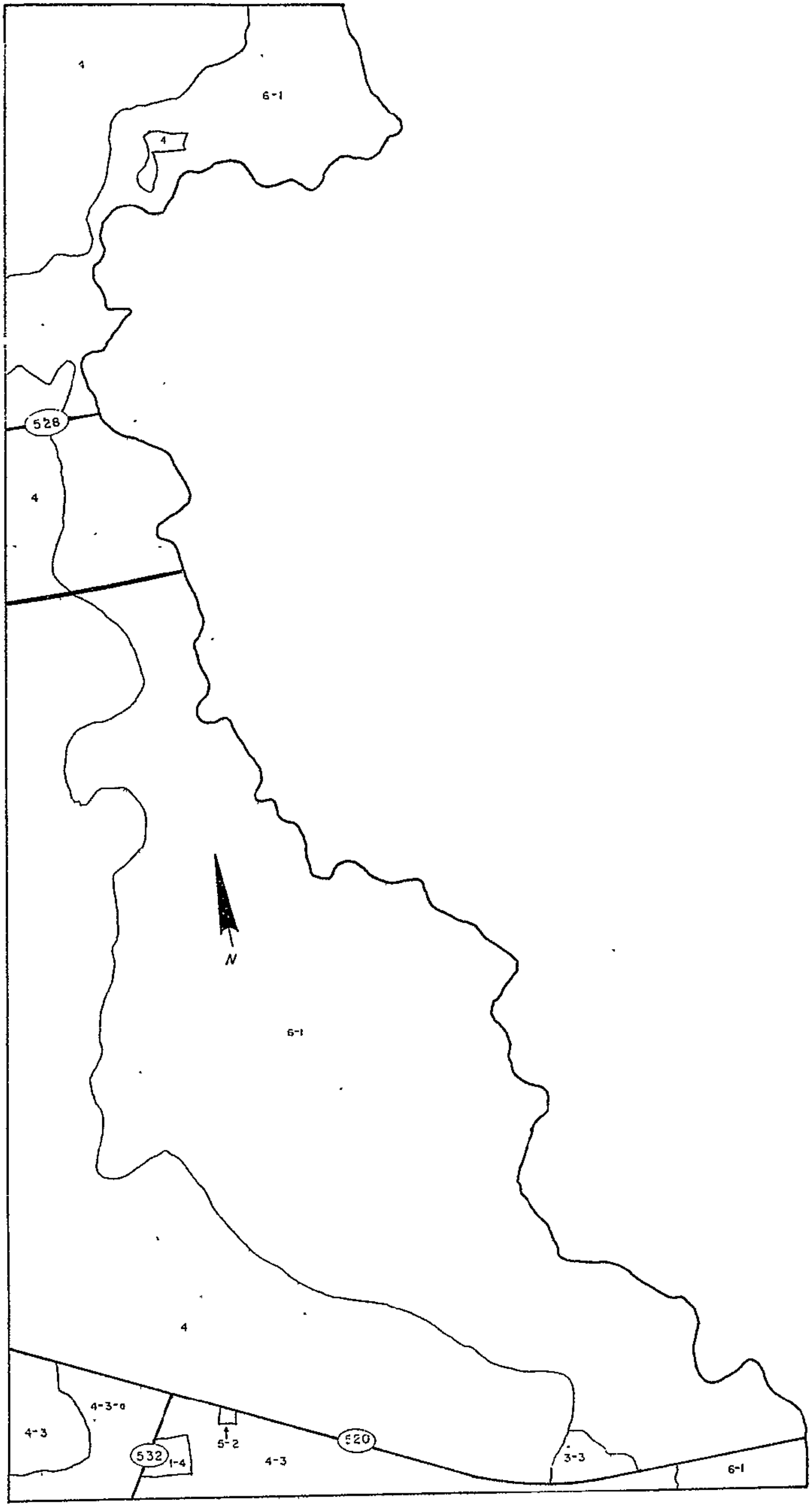


FIGURE 88
CORRECTED MAP
SECTOR AC, ORANGE COUNTY

SCALE ∿ 1/48,000

distinction between wooded and non-wooded residential. That information, however, is still available to the Orlando city planners from another corrected version which does make that distinction. Similarly, the original map (Figures 5-34) distinguished between forest types where the distinction was clear from the Landsat data; but the corrected map does not make that distinction.

This requirement of less detail for the planners' classification would increase the accuracy figure for a map prepared for the planners, but lack of classification beyond Level 1 for certain smaller urban areas on the Landsat map reduces the figure. The result is given in Table 7. This table, then, corresponds to a map prepared for the county planners' purpose prior to checking against photography.

In this low, flat region, the extent of standing water varies significantly with the season, being large during the wet, summer months and small during the dry, winter months. Results to be discussed later in this report, however, indicate that marsh identification is strongly influenced by vegetation types in the absence of standing water. The date of the pass mapped was March 18, 1974, during the dry season.

A useful type of thematic map on a county basis is a forest map, an example of which is shown in Figure 89, for Sector H. This map does not distinguish forest types, but some success in that regard has been obtained through collaboration with Michael Sweeting, Orange County Urban Forester, in obtaining training data. Pines, cypress, and mixed hardwoods are distinguished with sufficient reliability to be useful.

TABLE 7

ACCURACY FOR PLANNERS' NEEDS

Class	Area Prior to Correction		Incorrect (Hectares)	Accuracy (Percent)
	Hectares	Acres		
1 Urban	1,363	3,368	1,363	0
11 Residential	24,285	60,010	3,343	86
12 Commercial/Industrial	5,956	14,718	283	95
19 Urban Undeveloped	1,277	3,156	216	83
2 Agriculture	22,071	54,539	22,071	0
21c Pasture	14,509	35,853	2,269	84
22 Citrus	37,584	92,872	6,706	82
23 Bare Sand in Agricultural Sector	227	561	38	83
33 Brush	529	1,307	0	
4 Forest	48,570	120,019	2,195	95
43a Pine and Palmetto	45,914	113,456	5,793	87
43b Palmetto and Scrub Oak	5,218	12,894	2,417	54
51 Streams	13	32	0	
52 Lakes	23,329	57,647	0	100
61 Marsh	18,791	46,434	2,084	89
TOTALS	249,636	616,856	48,778	80

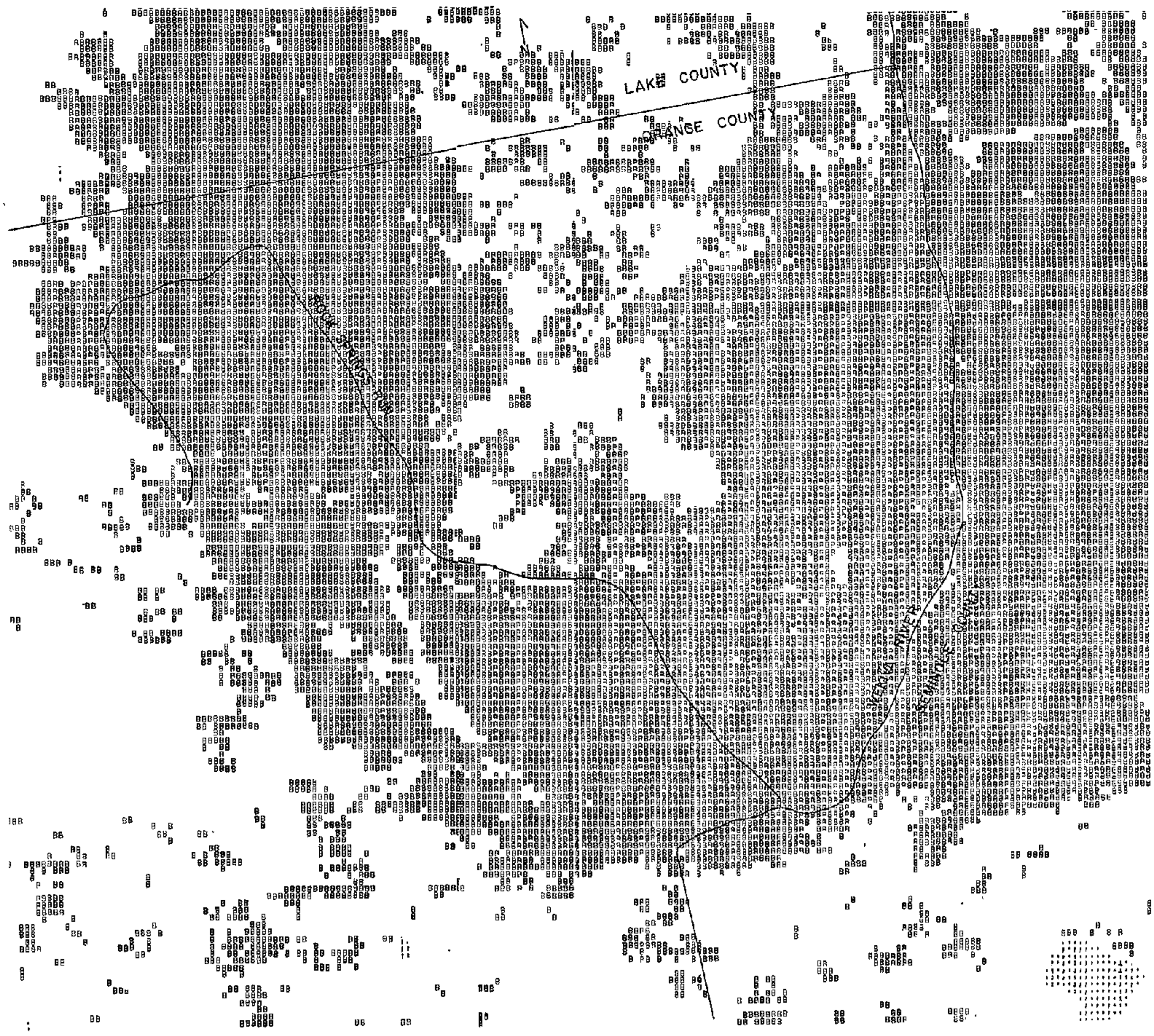


FIGURE 89
WEKIVA FOREST
SECTOR H, ORANGE COUNTY

A map or a portion of Brevard County, shown later in the report, has useful separation of forest types. Mid-spring passes seem to be most effective for this purpose.

Change Monitoring:

Probably the application which has created the most interest among planners to date is change-monitoring. Pending development of operational automatic methods, we find that a simple technique can be used, with results which appear useful. The geometric precision and high degree of classification accuracy required for successful application of automated methods can be obviated by inserting a human observer in the process to detect changes by looking at the two maps overlaid on a light table. Figure 84 shows the results of comparing Orlando classification maps for two dates: September 6, 1972 and April 23, 1973, an interval of almost eight months. In this case, an 8-class map for the later date was compared to an industrial-commercial thematic map for the earlier date. We find that some human judgment is needed in comparing patterns. We do not feel that, at this state of development, the results should be accepted without verification, which, however, is usually not difficult. All of the changes noted have been checked by photography followed by ground observation where needed. We feel fairly confident of nearly all of the interpretations and have found five definite errors, three of which are due to bad scan lines, a problem which is less serious with more recent data. In addition, cases were found where the change apparently was a change in the cultivation state of a citrus grove, an illustration of the need for checking the computer results. When appropriate photography is available,

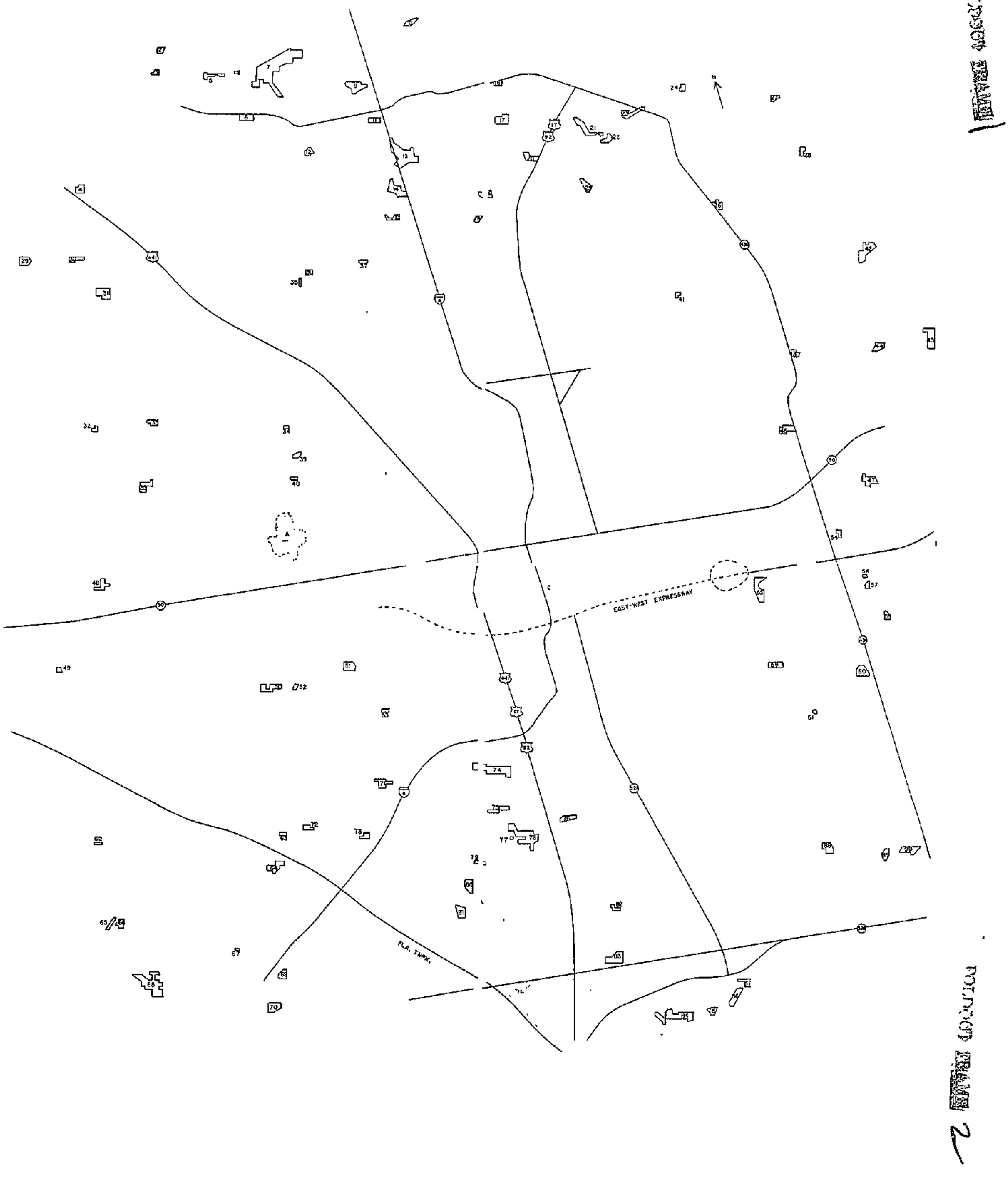


FIGURE 90
ORLANDO CHANGES
Sept. 6, 1972 to April 28, 1973

its use can greatly reduce the amount of ground checking needed.

This appears to be an effective and relatively inexpensive method of up-dating land use maps--perhaps even detailed maps of urban areas, although certain changes which do not involve appreciable land-clearing or addition of concrete surface or roof tops might be missed.

The period in this case was one of rapid development in the Orlando area, so the changes are more numerous than normal.

In addition to the up-dating of land use maps, this kind of map provides other benefits for the planner, such as showing him the state of development of specific large projects (such as large residential developments) and giving him an overview which indicates the areas of highest development activity. This map, for example, shows major activity in three areas: (1) in the southwest quadrant, toward Disney World; (2) along the north-south portion of Highway 436, where many new condominiums were being built, and (3) in Altamonte Springs (north of the city), where much commercial and residential development was occurring.

In addition to new developments, two other interesting changes are shown on the map: Two lakes were filled with silt at the second date and, therefore, do not appear as lakes: Lake Lawn, north of Highway 50 was being dredged to fill in land for a park and its level was lowered in a rejuvenation procedure, and it appears as commercial use. Lake Underhill appears as industrial use, as it was filled with silt due to the East-West Expressway under construction through it at the time.

One portion of the East-West Expressway was under construction on the first date, and shows on the first map; another portion was under construction on the second date, and both portions show on that map.

The changes shown in Figure 82 are listed in Table 8.

The Orange County Planning Department has established a computer-stored land use inventory of the county, with the information obtained by direct observation of individual parcels. That tabulation is more detailed than Landsat-obtained information and also contains economic and political information which Landsat cannot provide. In July, 1976, there was an immediate need for a land use inventory to meet transportation planning requirements; and, since the direct-observation tabulation was not yet complete, Landsat-obtained information was called upon to fill in the incompleted sectors. This turned out to be the metropolitan Orlando region. This region amounted to 14% of the area of the county but approximately half of the traffic zones, as the traffic zones are smaller in urban regions. The region for which Landsat results were used is shown in Figure 91, which is taken from the planners' report.[3]

Coloring Process:

Sidney L. Whitley of the Manned Space Flight Center has reported on two relatively low cost commercial methods of producing colored maps from processed Landsat data[4], "Kwik-Proof" and "Cromalin". Through the courtesy

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[3]Land use date for OUATS Sketch Planning Process, Orange County Planning Department, July 1976.

[4]Sidney L. Whitley, A Low Cost Data Analysis System for Processing Multispectral Scanner Data, NASA TR R-467.

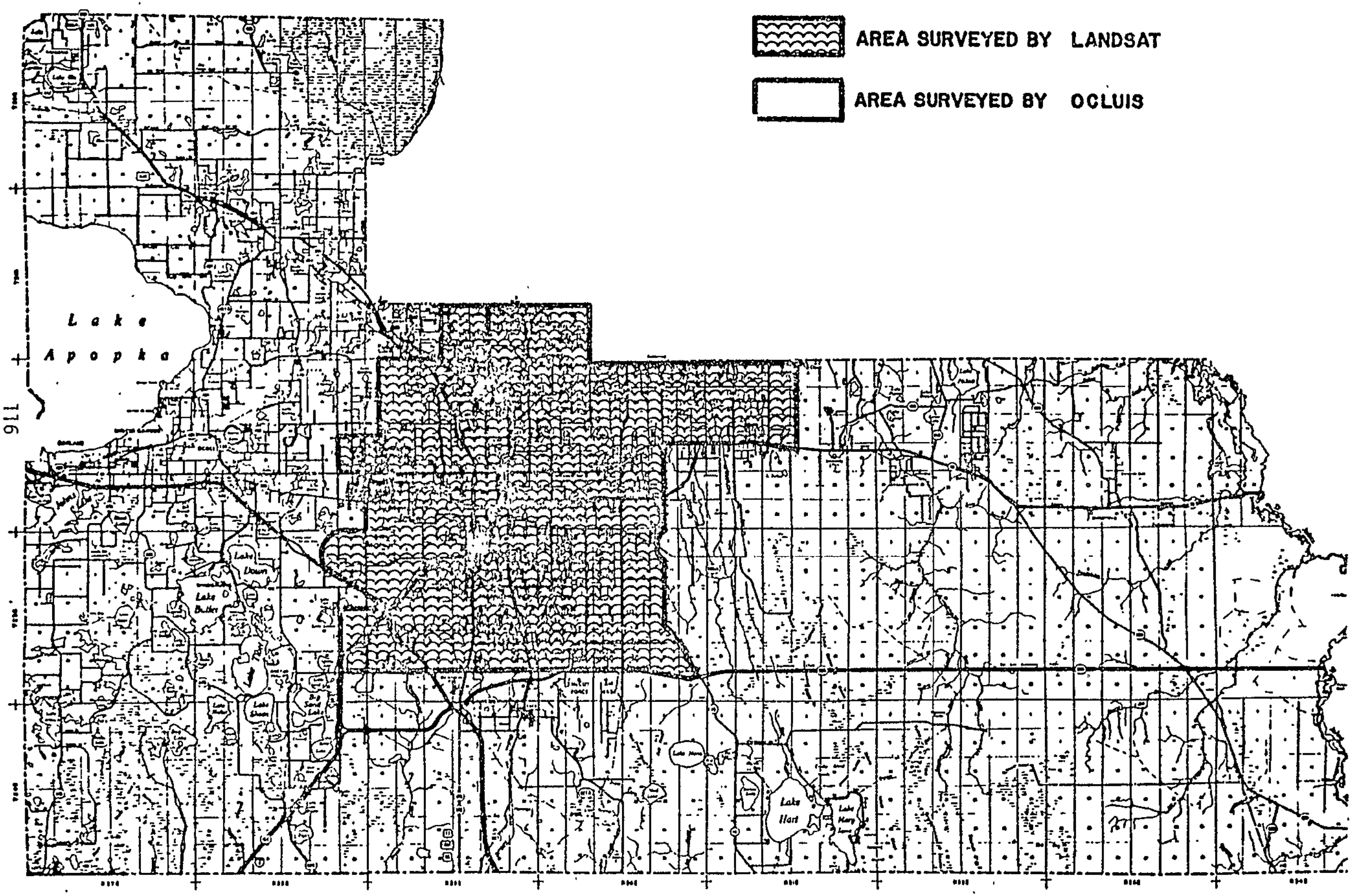
TABLE 8

ORLANDO CHANGES

Sept. 6, 1972 - April 28, 1973

1. Cultivated citrus
2. Residential development
3. School
4. Cultivated citrus
5. Single-family residential
6. Single-family residential
7. Residential development
8. Commercial
9. Industrial
10. School
11. Apartments
12. Single-family residential
13. Apartments
14. Apartments
15. Land grading
16. Industrial
17. Apartments
18. Condominium
19. Single-family residential
20. Industrial
21. Condominium
22. Condominium
23. Commercial & residential
24. Single-family residential
25. Single-family residential
26. Shopping Center
27. School
28. Single-family residential
29. Cultivated citrus
30. Land Clearing - industrial
31. Cultivated citrus
32. Single-family residential
33. Condominiums
34. Unidentified
35. Single-family residential
36. Condominiums
37. Grove cultivation
38. Industrial
39. Industrial
40. School playground
41. Apartments
42. Condominiums
43. Apartments
44. Single-family residential
45. Condominiums
46. Construction of lake
47. Single-family residential
48. Industrial
49. Grading for single-family residential
50. Condominiums
51. Industrial
52. Omission due to bad scan line
53. Apparently error due to bad scan line
54. Present but missed on first pass
55. Condominium
56. Grading
57. Condominiums
58. Condominiums
59. Condominiums
60. Graded streets
61. Unidentified
62. Commercial
63. Condominium
64. Unidentified
65. Unidentified
66. Missed on first pass due to bad scan line
67. Single-family residential
68. Commercial
69. Grading
70. Unidentified
71. Unidentified
72. Graded land
73. Condominium
74. Graded land
75. Condominium
76. Graded land
77. Graded land
78. Canal spoil
79. Canal spoil
80. New Road
81. Residential development
82. Apartments
83. Industrial
84. Industrial
85. Industrial
86. Industrial
87. Single-family residential
88. Mobile home park
89. Single-family residential

FIGURE 91
LANDSAT MAPPING USED IN OUATS PROCESS



of Claude Wolf, NASA, Kennedy Space Center, and T. M. King, of the DuPont Company, a five-class map of central Orlando has been produced by the Cromalin method. Five thematic line-printer maps were made and photographed (at KSC); positive transparencies then being used by the DuPont Photo Products Department to produce the map. Planners who have looked at the product are pleased with it.

BREVARD COUNTY

The northwest portion of Brevard County has been mapped, as indicated by Figure 92. Since the Brevard County mapping was begun after the Orange County mapping was nearly completed, no attempt was made to repeat the accuracy-checking process. Instead, the map was corrected by comparison with photography, producing the highest accuracy practicable. This map is scale- and skew- corrected and, in its original 1/24,000 scale, can be overlaid on 1/24,000 scale photography or USGS 7½' topographic maps. The revised USGS classification system[5], Table 9, was used. Since there are few urban features in most of sectors A, B, and C, Figures 93-95 are indicators of the vegetation mapping capability of the system.

Areas of the various classes as measured by planimeter are given in Table 10 for sectors A and C. Sector B is not included in the tabulation because the mapping of its southeast corner is incomplete.

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[5] J. R. Anderson, E. E. Hardy, J. T. Roach, and R. E. Witmer, A Land Use and Land Cover Classification System for Use with Remote Sensing Data, Geological Survey Professional Paper 964 (1976).

FIGURE 92

BREVARD COUNTY SECTORS

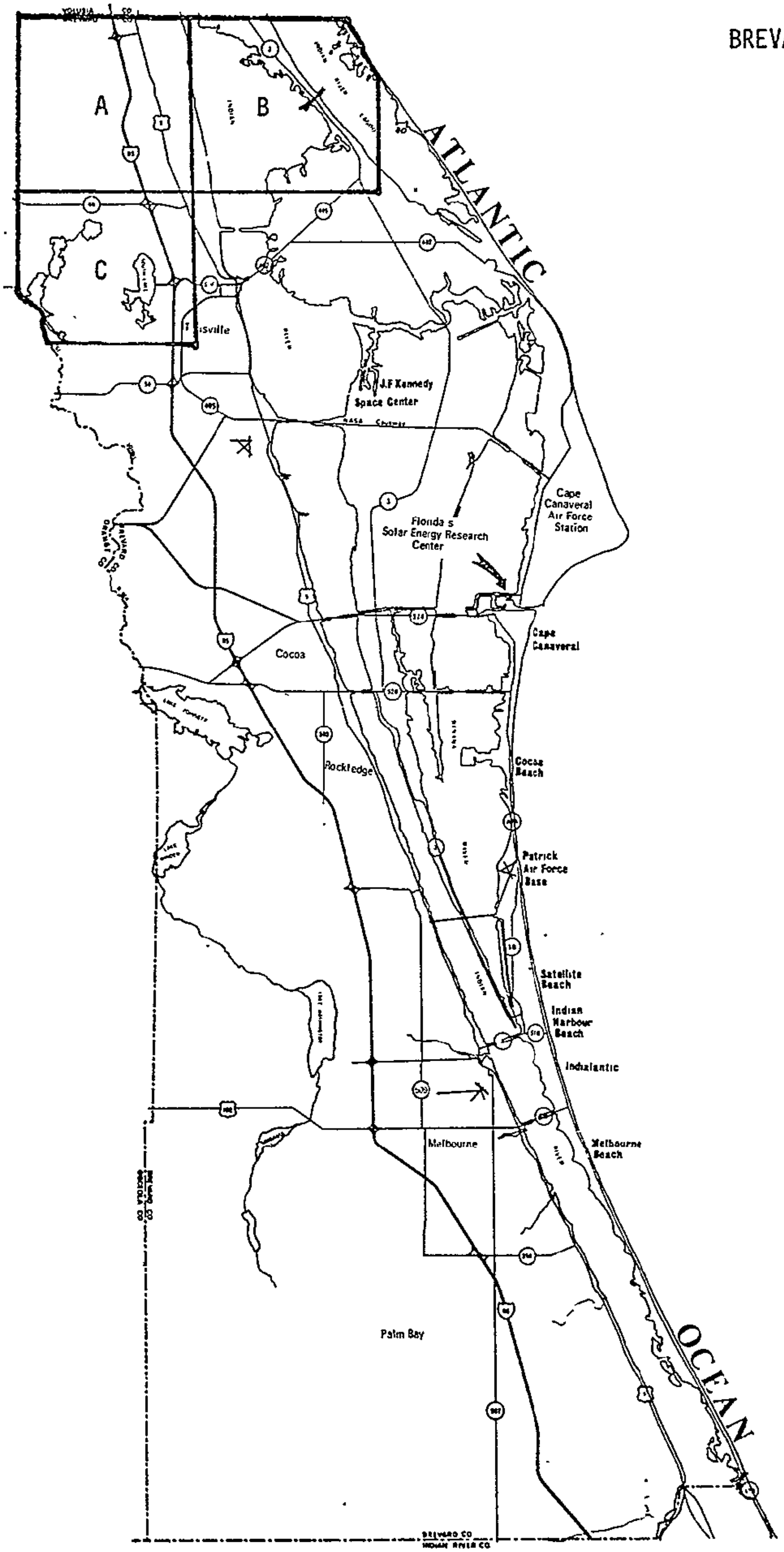

TABLE 9

CLASSIFICATION SYSTEM USED FOR BREVARD COUNTY

Level 1	Level 2
01. Urban and built-up land	01. Residential
	a. Wooded residential
	b. Non-wooded residential
	c. Rural residential
	d. Mobile-home parks
	e. Bare sand (non-landscaped)
	02. Commercial and services
	03. Industrial
	04. Transportation
	08. Institutional & recreational
	09. Undeveloped
	10. Grass
	11. New Construction
02. Agricultural land	01. Cropland and pasture
	a. Vegetable
	b. Pasture
	02. Groves
	03. Bare sand in agricultural sector
04. Forest lanc	01. Deciduous
	a. Cypress
	b. Hardwoods
	02. Pine
	03. Mixed
	a. Pine and palmetto
	b. Palmetto and scrub oak
05. Water	01. Streams and waterways
	02. Lakes
	03. Other
06. Wetland	01. Forested
	02. Nonforested
07. Barren land	02. Beaches
	03. Sand other than beaches
	05. Strip mines, quarries, and gravel pits

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 93
SECTOR A, BREVARD COUNTY

SCALE ~ 1/48,000

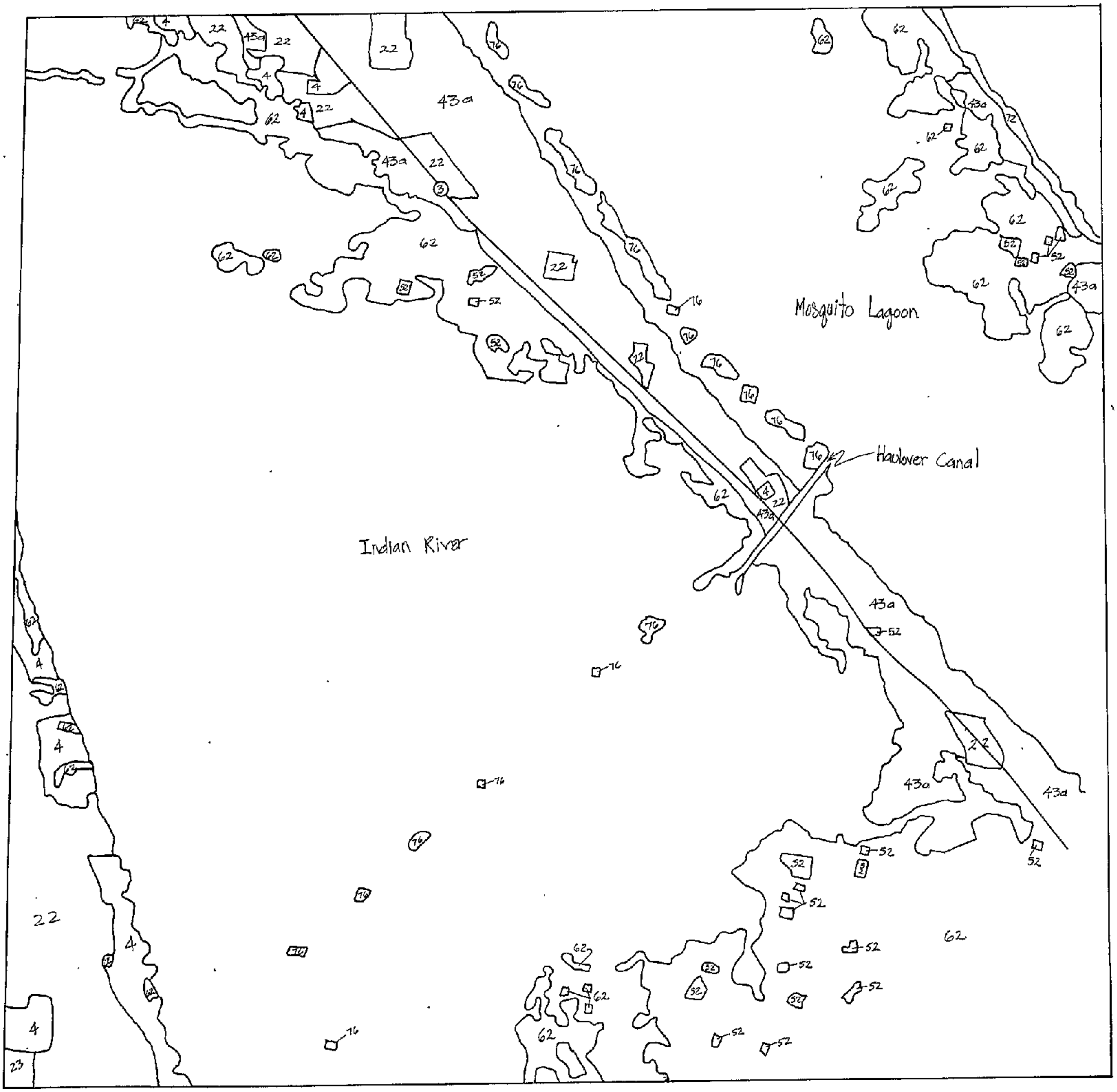

FIGURE 94
SECTOR B, BREVARD COUNTY

SCALE ~ 1/48,000

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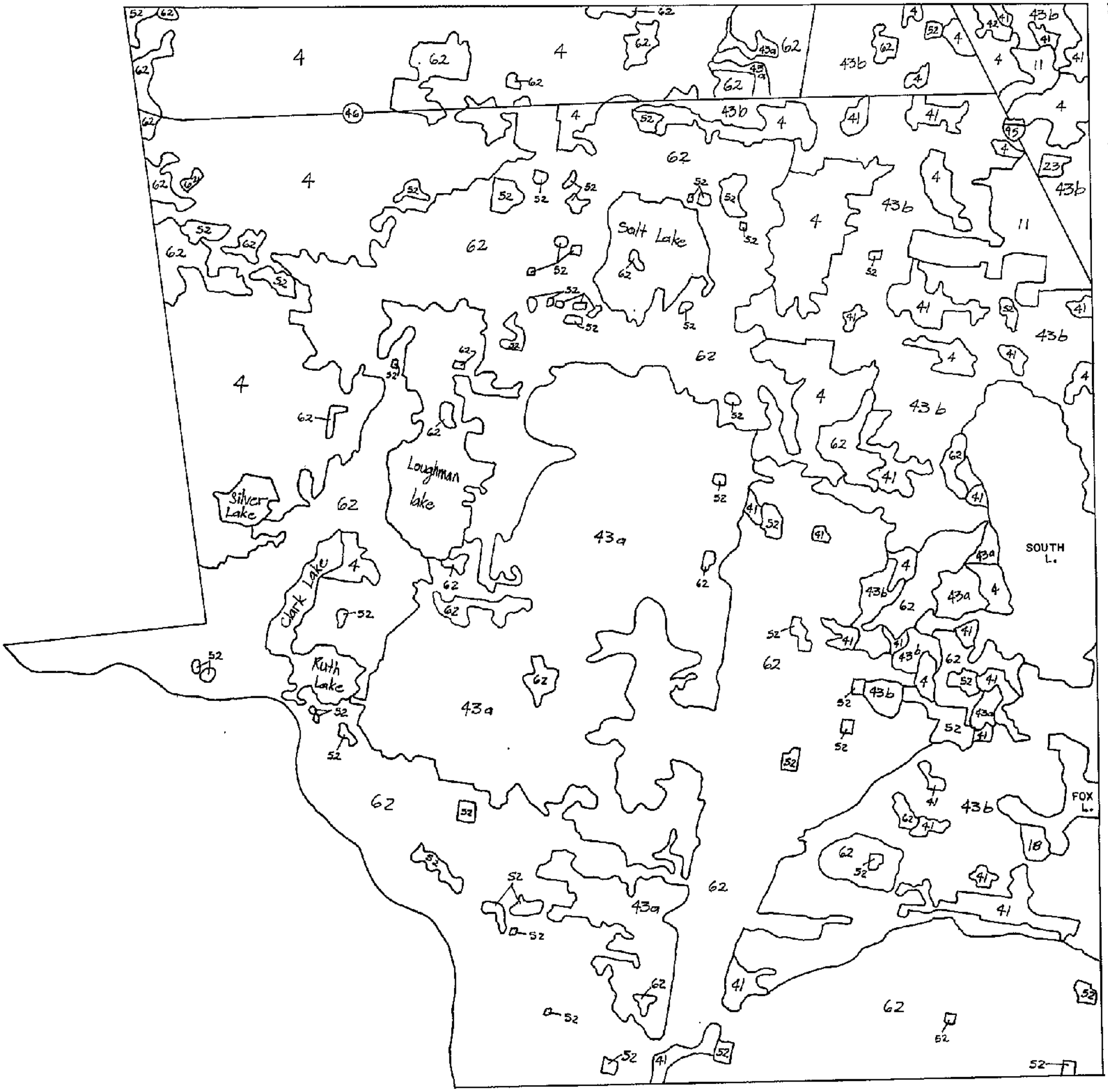

FIGURE 95
SECTOR C; BREVARD COUNTY

SCALE ~ 1/48,000

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TABLE 10

AREAS BY CLASS

NORTHWEST BREVARD COUNTY

SECTORS A, C

Class	Area Hectares	Area Acres
11 Residential	154	381
11a Wooded Residential	8	20
11b Non-wooded Residential	88	217
11c Rural Residential	138	341
11d Mobile-home Parks	59	146
TOTAL Residential	447	1,105
12 Commercial	19	47
13 Industrial	6	15
18 Recreational	10	25
TOTAL Urban	482	1,191
21b Pasture	291	719
22 Citrus	2,465	6,091
23 Bare Sand in Agricultural Sector	59	146
TOTAL Agricultural	2,815	6,956

Class	Area Hectares	Area Acres
4 Forest	2,278	5,629
41 Deciduous	276	682
41a Cypress	577	1,426
41b Mixed Hardwoods	1,815	4,485
42 Pine	2,334	5,767
43 Mixed Forest	2,987	7,381
TOTAL Forest (exclusive of 43a & 43b)	10,267	25,370
43a Pine and Palmetto	3,393	8,384
43b Palmetto and Scrub Oak	1,860	4,596
TOTAL Forest (including 43a & 43b)	15,520	38,351
51 Rivers	360	890
52 Lakes	1,267	3,131
TOTAL Water	1,627	4,020
62 Marsh	5,667	14,003
73 Barren Sand	6	15

St. Johns River Marshes:

The flat terrain of east central Florida is conducive to an extensive marsh area associated with the St. Johns River. Both Landsat images (particularly band 7) and computer mapping effectively display the marsh region. Networks of drainage ditches and associated dikes have converted significant areas of former marsh to pasture. In a few instances, however, drainage efforts have been less effective than intended; and the marsh pattern overrides the pattern of drainage ditches. One such region has been particularly prominent, which has led to landsat mapping of the region and several ground studies by the co-author and Kenneth Sylvester, hydrologist, and Marvin Miller, biologist, with Brevard County's '208' Water Resources Study. The Deseret Ranch, owner of the property on which the region is located, has been cooperative in allowing access for the study. The characteristic pattern shown by Figure 96 can be seen in wet and dry seasons. During the wet season this sector is mostly covered by standing water; but during the dry season there is standing water only in a few ponds. Looking down from above during the dry season, one sees marsh vegetation, mostly spartina and sawgrass, with a ground cover of dead vegetation so that virtually no bare ground is seen. Ground study of the vegetation, in collaboration with Richard Van Epp, Brevard County Beautification Supervisor, shows a correspondence between sawgrass density and the marsh pattern, leading to the conclusion that sawgrass (assisted by dead vegetation) is the primary contributor to the reflectance characteristic of the marsh pattern in the dry season.

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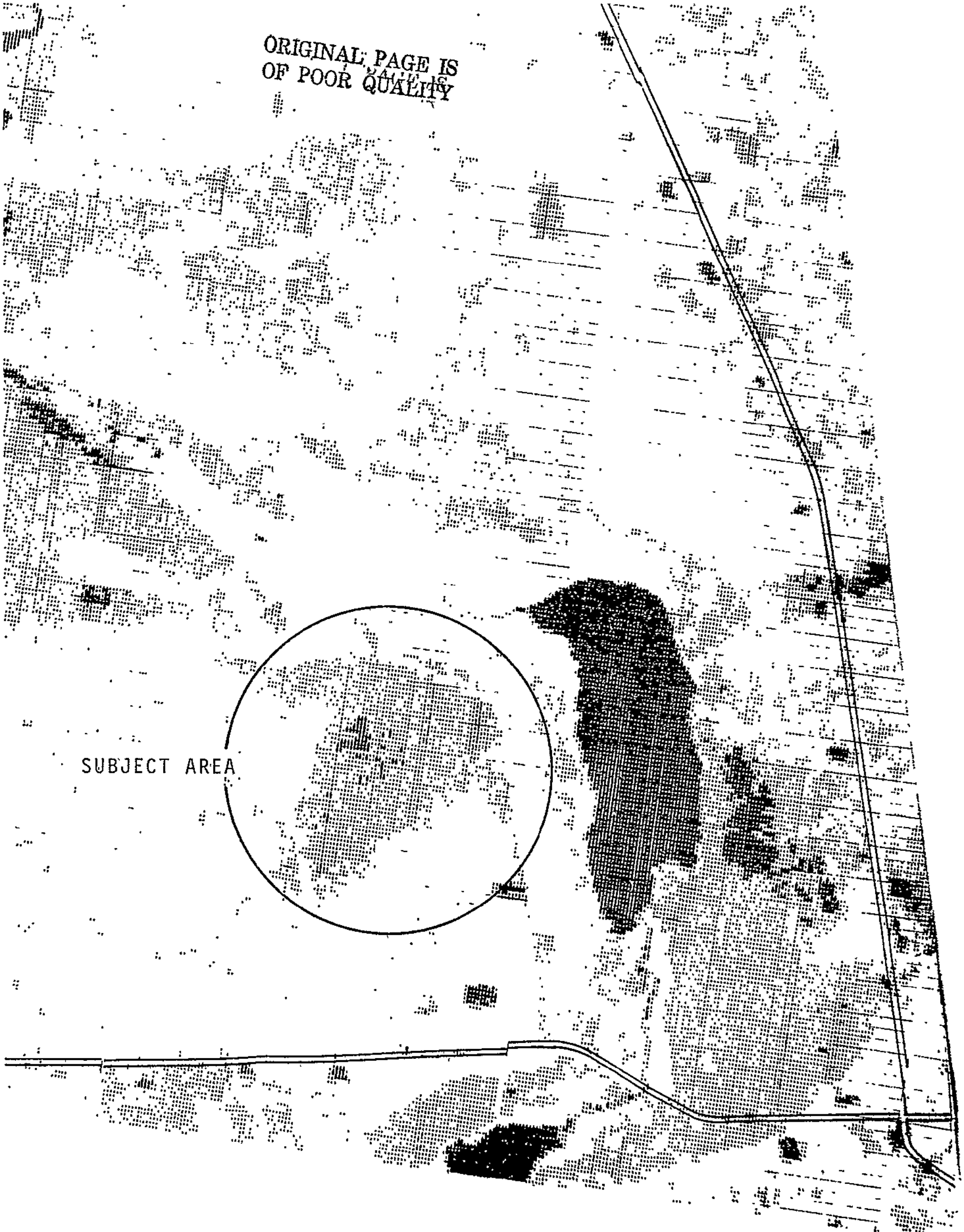

FIGURE 96
ST. JOHNS RIVER MARSHES

(Band 7 density-slicing)

The vegetation changes gradually from marsh to improved pasture as one moves outward from the central portion of the pattern.

Color infrared photography (taken between dry and wet seasons) shows a vegetation pattern which corresponds to the Landsat band 7 pattern.

The persistence of the particular marsh pattern and its overriding of drainage ditches suggested to Kenneth Sylvester that the effect might be due to discharge from the Floridan Aquifer, the top of which is 120 to 140 feet below the land surface. A depression in the potentiometric surface at this location (Figure 89) suggests that significant quantities of water are being discharged from the aquifer. A fault is known to exist in the region, and this can also serve as a route for ground-water discharge. The question of discharge can be checked, as the Floridan water has higher salt content, therefore, higher conductivity than surface water. Conductivity checks in the drainage ditches and ponds showed the conductivity to increase as one moves outward from the central portion of the pattern until it reaches a level equivalent to that in the Floridan aquifer. Water levels observed in the drainage ditches and ponds indicate that the subject region is a topographic depression. The pattern for conductivity measurements and that for topographic observations appear roughly to match the band 7 Landsat pattern. The above combination of circumstances has led to a suggestion by Marvin Miller that water from the aquifer is coming to the surface over an area larger than the subject pattern and then is collecting in the subject pattern by surface flow, maintaining the marsh characteristics. It is to be emphasized that the measurements taken to date are scattered and not at all definitive and that the above hypothesis

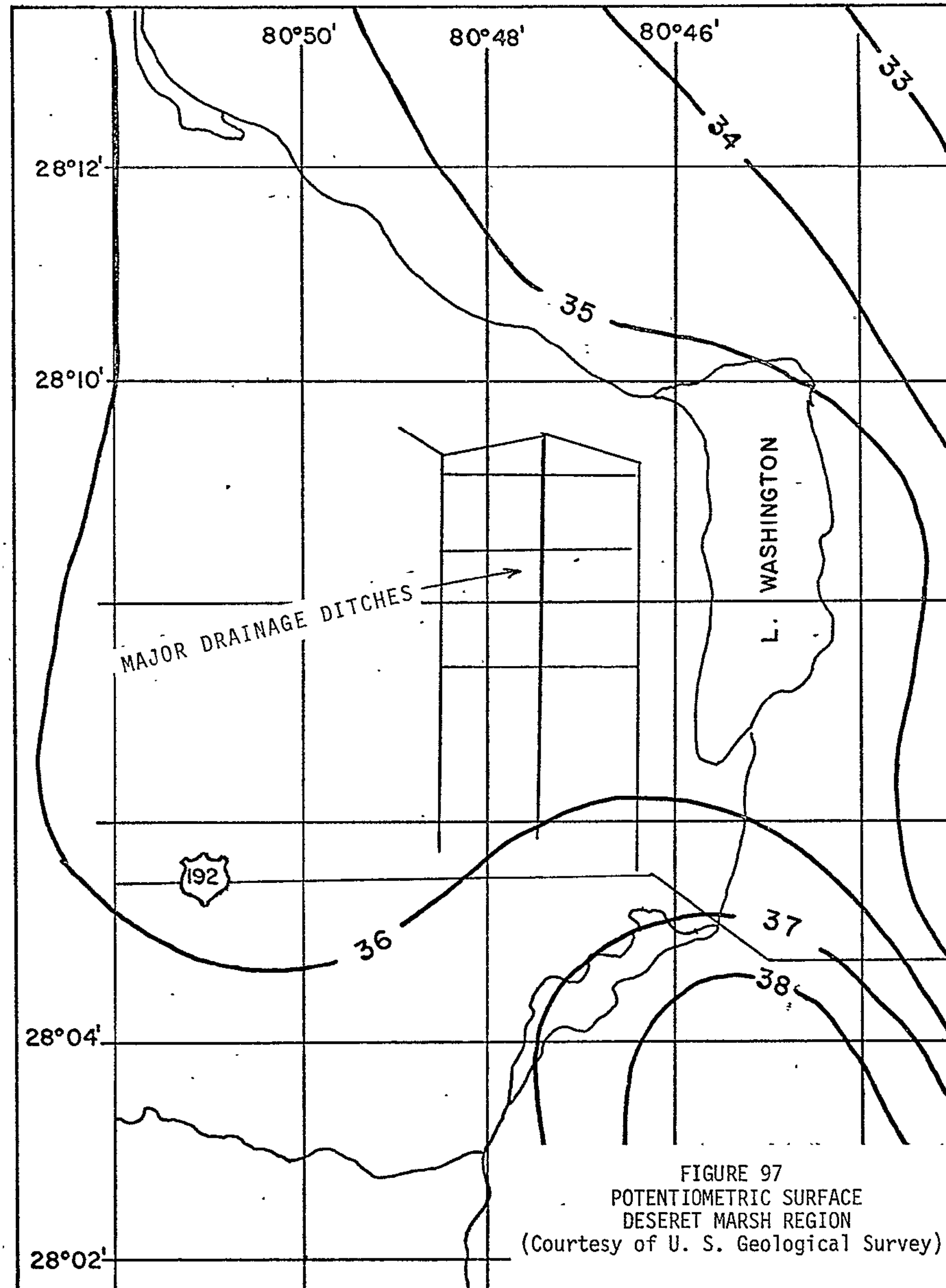

FIGURE 97
POTENTIOMETRIC SURFACE
DESERET MARSH REGION
(Courtesy of U. S. Geological Survey)

is speculative. Whatever the cause, Landsat data show two other sectors along that portion of the St. Johns River where the same sort of situation exists: drainage ditches overridden by a marsh pattern.

During the period that this region was under observation, there was a burn in one sector of the pasture on the edge of the subject marsh region. The burn was clearly seen and well defined in Landsat images.

St. Johns Natural Wildlife Refuge:

A 4,000 acre marsh region bounded on the east by Interstate Highway 95 and on the south by Florida Highway 50 has been established by the U.S. Fish and Wildlife Service as the St. Johns Wildlife Refuge, primarily to protect the Dusky Seaside Sparrow. Dr. James L. Baker, wildlife biologist with that organization, in a study of the Dusky Seaside Sparrow and its preferred habitat, has made a vegetation map of the refuge based on ground observations and color infrared photography. Convenient access to this good quality ground truth and the collaboration of Dr. Baker suggested this refuge as an appropriate site for a vegetation-mapping experiment.

The preferred habitat of this sparrow is high-to-medium density spartina (a marsh grass) with no trees nearby. An increase in spartina density corresponds to an increase in marsh wetness. A version of Dr. Baker's vegetation map which is relevant to the bird's preferences and also suitable for Landsat comparison is shown as Figure 98.

Representative sectors for the classes shown in Figure 98 were chosen by Dr. Baker as training samples for a maximum likelihood classification Landsat data. The results of the classification are given by the map of Figure 99, which is a simplification of the computer map.

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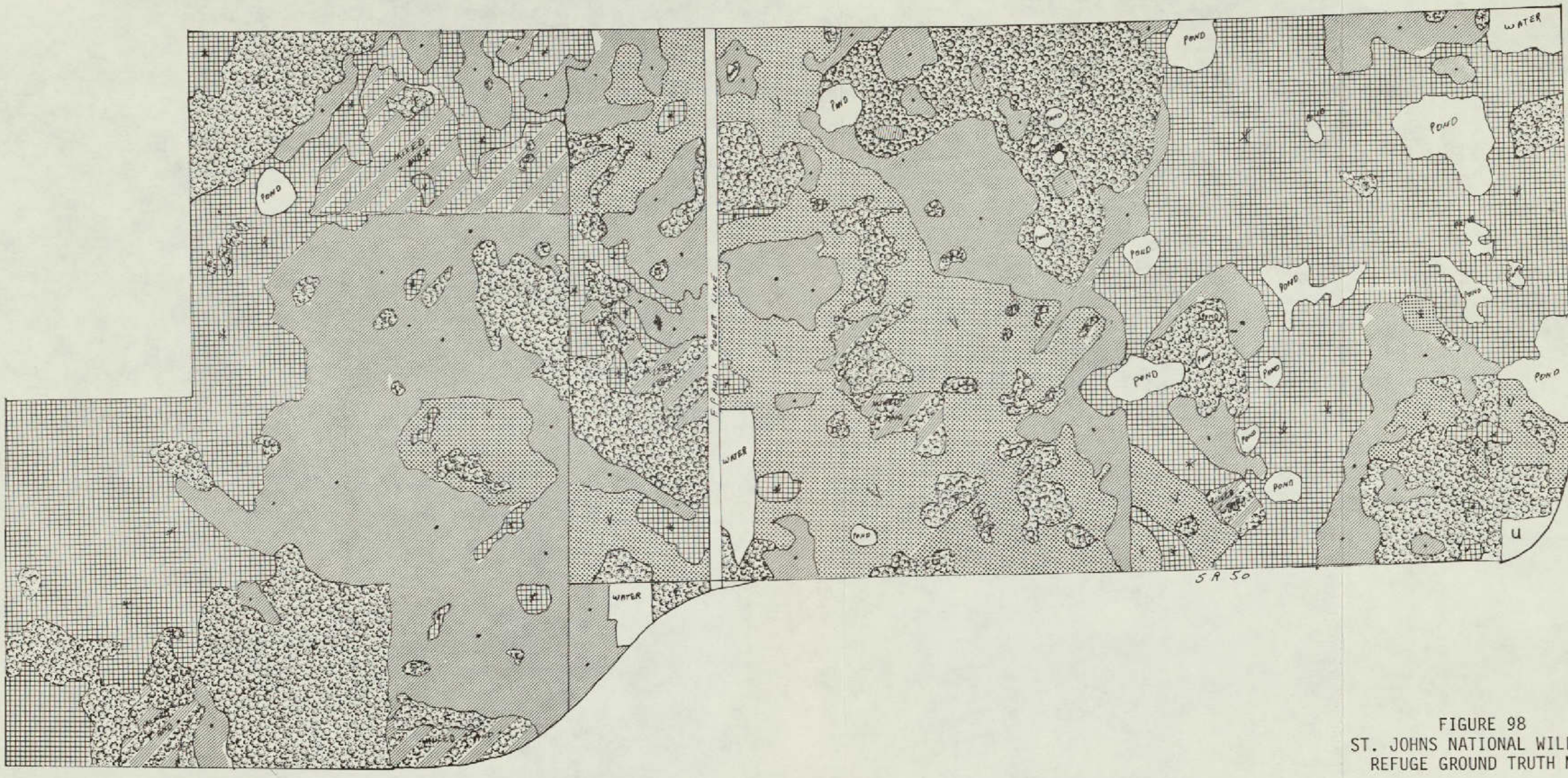

FIGURE 98
ST. JOHNS NATIONAL WILDLIFE
REFUGE GROUND TRUTH MAP

Trees, shrubs

Dense spartina

Medium density spartina

Sparse spartina

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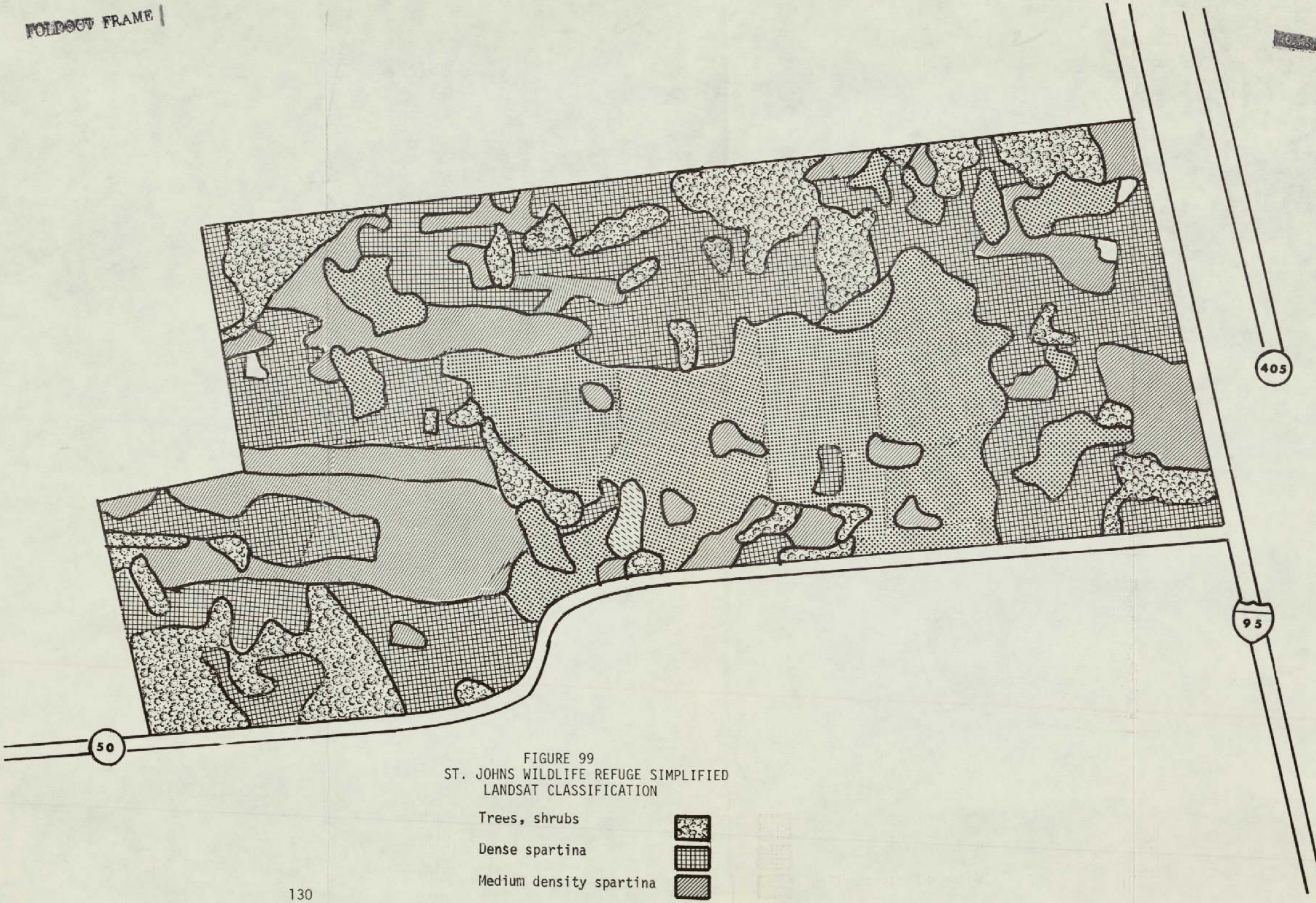

FIGURE 99
ST. JOHNS WILDLIFE REFUGE SIMPLIFIED
LANDSAT CLASSIFICATION

Trees, shrubs
Dense spartina
Medium density spartina
Sparse spartina

The bird prefers to live in medium-to-dense spartina with no trees close by. Figure 100 is a thematic map showing the preferred habitat in terms of asterisk's density; generally, the preferred habitat is the region of higher character density. Proximity of trees can be checked by referring to a Landsat map.

The limited success of the Landsat system in mapping the sparrow's preferred habitat in the above case led to its use in evaluating another region under consideration for purchase as a refuge area for the bird. This region is located at the fork of the Beeline Highway and is outlined in the thematic classification map of Figure 101. It is seen that this map does show a favorable habitat for this bird within the delineated region. It also shows some nearby regions which appear to provide the desired characteristics. Areas associated with the several classes (as obtained by character counting) within the delineated region are given by Table 11.

Another factor to be considered is urban encroachment in the surrounding region. This is shown as a thematic map in Figure 102. Since bare sand appears in this class along with urban features, local knowledge or checking must be used to distinguish the two in a map of this type. On this map, the patches of slashes are identified as follows:

1,3,6,7,9 - bare sand around borrow pits used in the highway construction.

2,8 - bare sand.

4 - electrical power line.

5 - Port St. John - residential development, most of which is presently a network of streets without houses.

FOLDOUT FRAME 1

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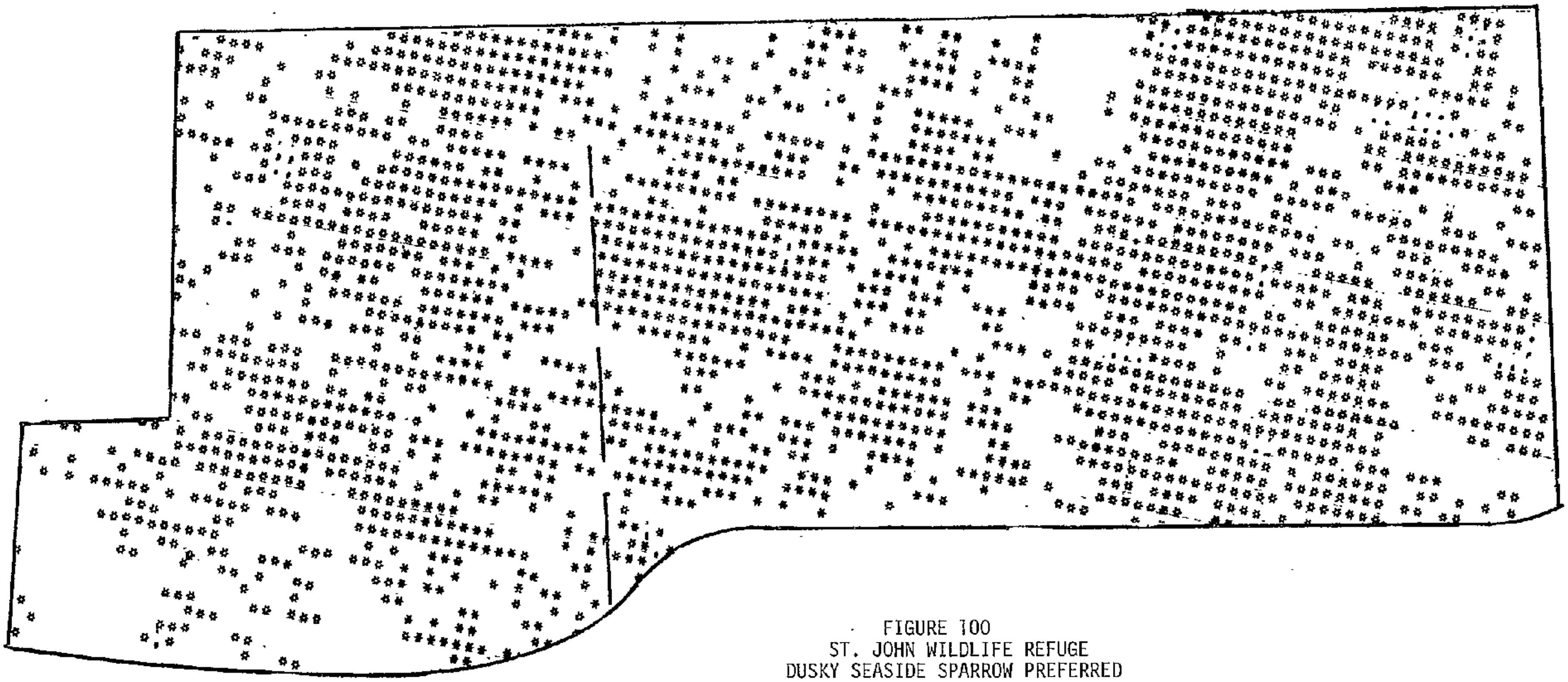

FIGURE 100
ST. JOHN WILDLIFE REFUGE
DUSKY SEASIDE SPARROW PREFERRED
HABITAT

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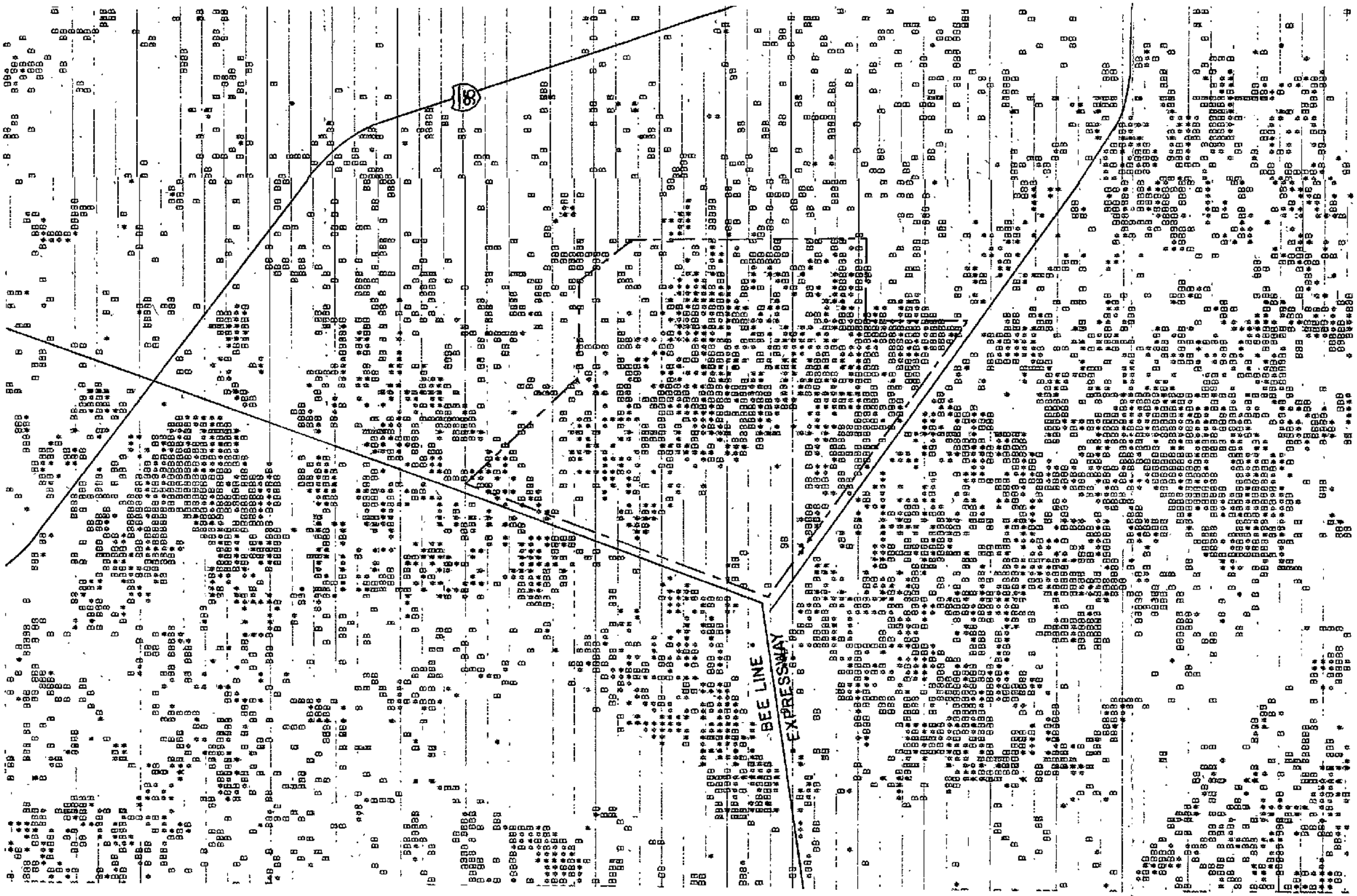

FIGURE 101
BEELINE HIGHWAY REGION

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TABLE 11

AREAS BY CLASS IN BEELINE EXPRESSWAY REGION

CLASS	AREA HECTARES	AREA ACRES	PERCENT OF TOTAL
Water	4	11	1
Dense Spartina	193	476	24
Medium Density Spartina	203	501	25
Sparse Spartina	131	324	16
Trees, Shrubs	145	357	18
Highway Construction, Bare Sand	143	354	18
TOTAL	819	2023	

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FIGURE 102
BEELINE HIGHWAY REGION
HIGHWAYS, BARE SAND, AND
URBAN FEATURES

10 - dump.

11 - residential development.

Jane Green Pool:

The Jane Green Pool is a diked pool west of the St. Johns River, in Osceola County, which has been proposed as a water retention area. William Stimmel, of the Department of Environmental Sciences and Regulation of the St. Johns River Water Management District has been studying the effect on the associated forest of raising the water level in the pool. A Landsat thematic map showing the extent of the forest, primarily mixed hardwoods, has been prepared, Figure 103. The character counting capability of the histogram has been used to determine the acres of forest below the 25' and 30' contour lines, respectively (Table 12).

COST BENEFITS

An attempt has been made to evaluate costs of the Orange County mapping program. Experimental work which normally would not be included in an operational program is not included. Two sets of figures are given: (1) the present mapping program which may be regarded as semi-operational and (2) an operational program, with more of the work done by technicians.

The figures on Table 13 do not include the planimeter measurement of areas, a time-consuming process, but one which would be necessary regardless of how the land use map is made, although the possibility exists of coloring or shading the land uses and using one of the cathode ray tube-electronic measuring systems to measure areas. Theoretically, areas can be determined by computer character-counting; but it is our experience that this is not a sufficiently accurate method at this time.

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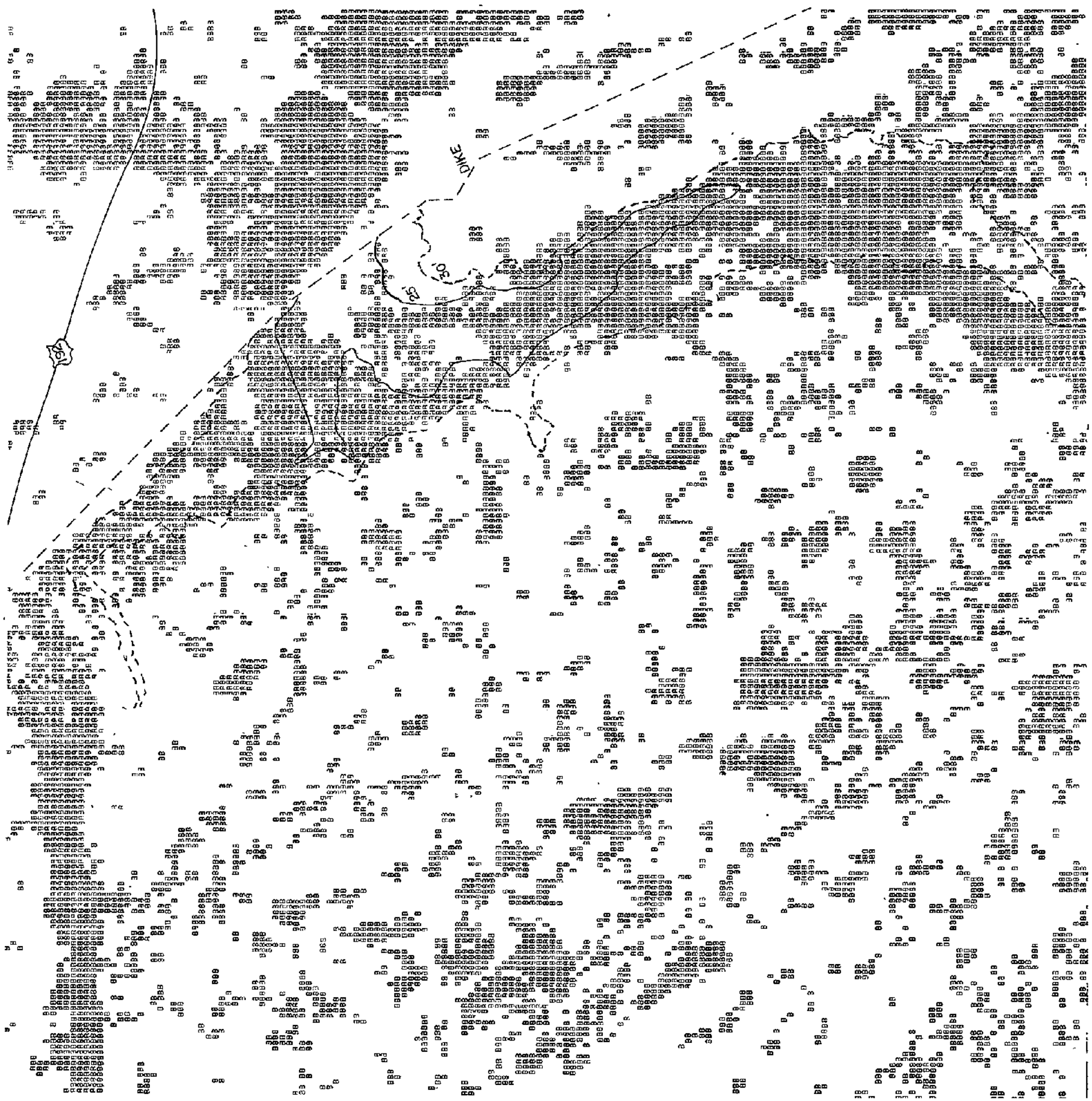

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FIGURE 103
JANE GREEN POOL
FOREST MAP

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TABLE 12

JANE GREEN RESERVOIR

CHARACTER COUNTING

25' CONTOUR

	AREA		FRACTION
	Hectares	Acres	
Bare Sand	22	55	5%
Hardwoods	318	786	69
Palmetto-Grass	21	53	5
Pines-Palmetto	100	248	22
TOTAL	461	1,142	

30' CONTOUR

	AREA		FRACTION
	Hectares	Acres	
Bare Sand	60	149	4%
Hardwoods	1,120	2,768	70
Palmetto-Grass	73	181	5
Pines-Palmetto	340	840	21
TOTAL	1,593	3,938	

TABLE 13

COST ESTIMATES

Operation	Estimated Time	Estimated Cost	
		Present Project	Operational System
A. Data This figure will vary. In this case, one set of data was used for mapping two counties; hence, half the cost of a data set is used. Better results could be obtained by using two data sets taken in different seasons. Only one set was used in this mapping project, however.		$112	$112
B. Ground Truth Determination On-site training sample determination. Estimated time and mileage. (Done operationally by technician)	40 hr. 500 mi.	$280 $ 70	$160 $ 70
C. Training Sample Determination Office determination of training data from photography and local knowledge. Locating training points on preliminary map. Two people for ½ day. (one person operationally)	8 man-hr. (4 operationally)	$ 48	$ 16
D. Training Data Processing Transfer of training data locations from preliminary map to form for key punching.	8 hr.	$ 56	$ 32
E. Key Punching	3 hr.	$ 20	$ 20
F. Preparation of material for computer runs. Estimated at 45 min./run for 35 computer runs. Above figure includes transit time between buildings.	26 hr.	$184	
Operationally, assuming 30 min./run.	17 hr.		$121

TABLE 13
(continued)

Operation	Estimated Time	Estimated Cost	
		Present Project	Operational System
G. Preliminary Computer Processing Band 7/band 5 mapping. Statistical analysis of training data. The KSC computer cost rate of $130/hr is used. Note that this is a federal government cost rate and may not be applicable for other computer facilities. An average computer time for classification and mapping is 2.5 sec/km^2. In order to get the best map, this process normally is done 2 or 3 times with different classes and input parameters. Using 2.5 runs, one gets 6.3 sec/km^2 for computer classification and mapping time, or a computer classification and mapping cost of 23¢/km^2. The area of Orange County is 2496 km^2, giving a total computer classification and mapping cost for the county of $574.	4.5 hr.	$598	$598
H. Tracing of Line Maps from Computer Maps In pencil.	100 hr.	$700	$400
I. Correction of Line Maps			
30 hrs. each for two people (1 person operationally)	72 hr.	$432	$144
J. Addition of Traffic Zone Boundaries	20 hr.	$100	$ 80
K. Drawing Final Maps in Ink	90 hr.	$450	$360
TOTAL		$3,050	$1,941
		$1.22/km^2	$.78/km^2
		$3.18/mi^2	$2.01/mi^2

Richard MacMillan, of the Orange County Planning Department, has estimated the time required to produce a comparable map from photography. He assumed use of 1/24,000 scale photography for Level 1 mapping (375 hr.), followed by use of 1/7,920 scale photography for modification to Level 2 (187 hr.), followed by use of 1/3,600 scale photography for Level 3 mapping (2,030 hr.) where possible, supplemented by ground checking. With 225 hours drafting time, the time comes to 2,817 hours, which at $4.00/ hour runs $11,000 ($4.51/km^2 or $11.69/mi^2). This photography is all available (some at poor quality) to the Planning Department, so no cost is assigned to the photography. There would be some cost for making blueprint copies (not included). Level 3 mapping would be done only where possible from the photography, as was the case for the Landsat maps. Since the same photography was used in correcting the Landsat maps, the final amount of Level 3 mapping should be about the same in the two cases.

VI. CONCLUSIONS AND RECOMMENDATIONS

Our experience leads us to the conclusion that Landsat land use mapping is a practical process on a county or regional scale.

In urban areas, it is useful for change-monitoring and for analysis of general features, as in thematic maps. Its thematic maps point out features not so easily or clearly brought out by other methods. It can tell planners where to investigate for the greater detail they often need.

For non-urban regions, the Landsat system provides much more information than normally is found on land use maps or is otherwise readily available to planners: information such as swamp hardwood patterns, marsh extent, uplands regions, forest patterns - especially environmental information which is useful in environmental planning and in consideration of appropriate future uses of presently undeveloped regions.

Landsat data can be valuable in aiding the solution of specific problems, usually of an environmental nature.

Landsat results are used most effectively when monitored from other data. Except in circumstances where other sources of information are not available, Landsat results should be checked and modified by comparison with photography or ground observations. When used in this way, that is as a primary source supplemented by other sources, Landsat data significantly reduce the requirements for other data.

Computer systems need not be elaborate. Relatively simple, basic programs can be used on small computer systems. Interactive capability is not necessary.

Exposure of planners and other potential users to Landsat capabilities and education in basic principles should continue; but, at the present state of development, a person with training and experience in the use of Landsat data is needed at a data processing and analysis facility. It seems that these considerations lead to state and regional operations as the best response to current needs and capabilities.