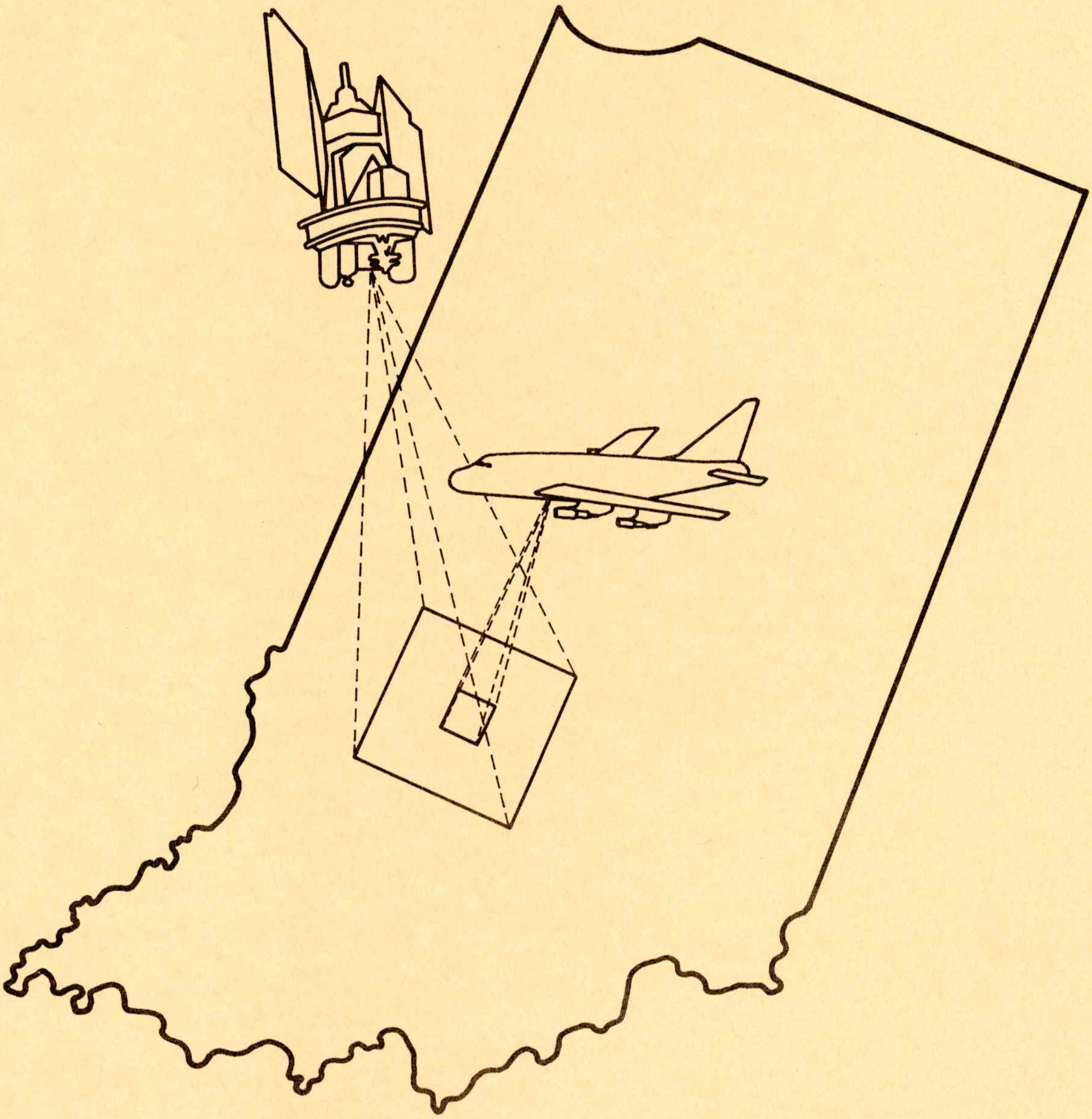
LARS Contract Report 042178

Semi-Annual Status Report

Application of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana



Laboratory for Applications of Remote Sensing
Purdue University W. Lafayette, Indiana

June 1, 1977 - November 30, 1977 NGL 15-005-186

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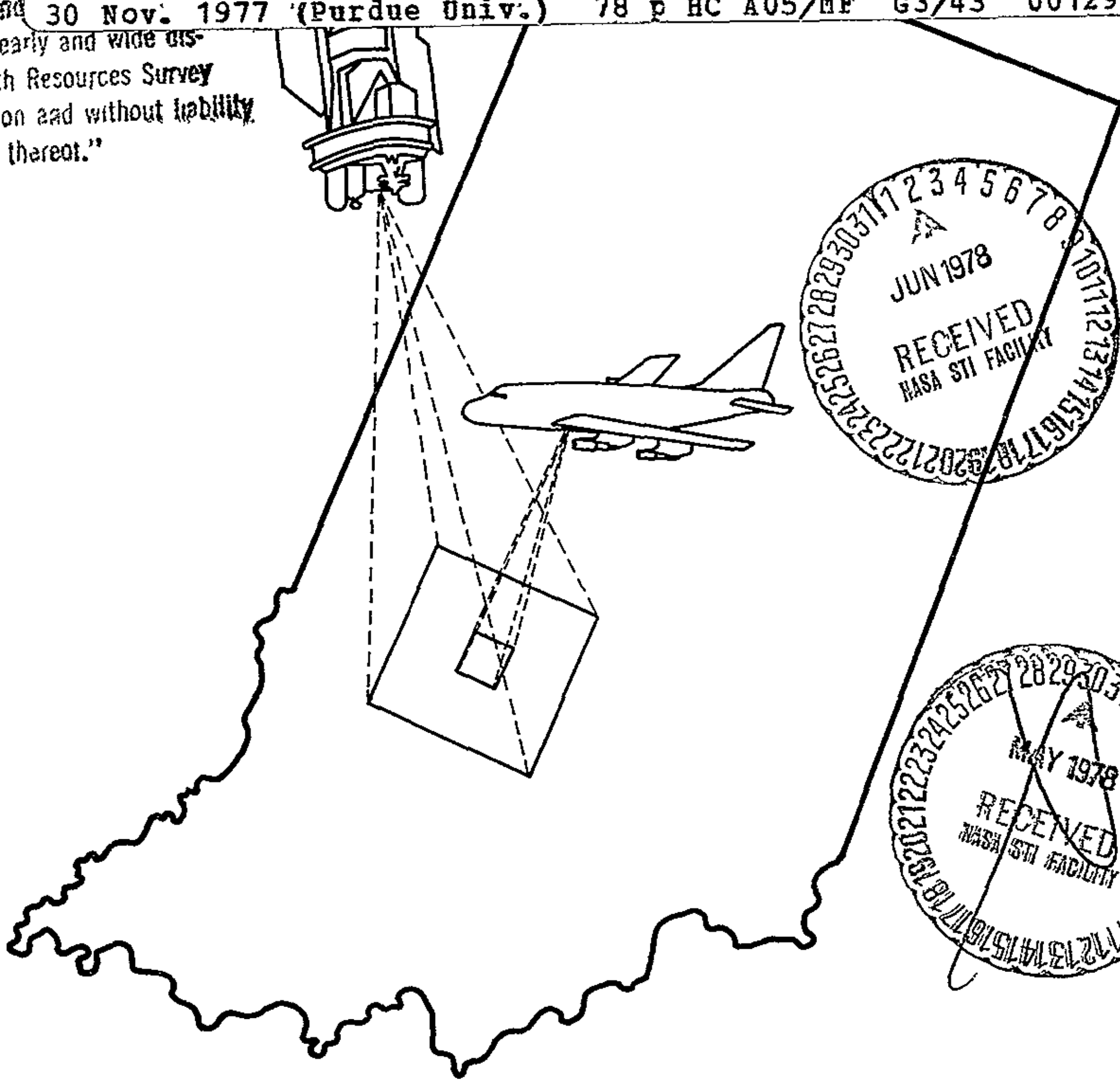

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SEMI-ANNUAL REPORT

Reporting Period: June 1, 1977 - November 30, 1977

Grant No. NGL 15-005-186

Title of Inventigation:

The Application of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana

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The Office of University Affairs
Code P
National Aeronautics and Space Administration
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INTRODUCTION

This semi-annual status report covers the period from June 1, 1977 to November 30, 1977 and contains a review of the research and applications, completed or in progress, as funded by the Office of University Affairs, NASA and conducted by Purdue University, Laboratory for Applications of Remote Sensing.

This reporting period marks the first half of the fifth year of funding for a proposal entitled "The Applications of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana." As indicated in this title, the purpose of this work is to introduce remote sensing into the user community within the state of Indiana. The user community includes those local, regional and state agencies involved in the decision monitoring and/or managing processes of the state's resources.

In order to carry out this work it is not only necessary to initiate projects with these agencies but also it is necessary to meet with and provide information to as many people and groups as well as agencies as possible. During the past six months numerous meetings are held with many different groups.

Among the groups that were contracted and received information about this program were:

Area Planning Commission, Tippecanoe County

Area Planning Commission, Boone County

St. Joseph County Area Plan Commission

Michiana Council of Governments

Indiana Geological Survey

U.S. Forest Service

Tipton County Commissioners and Engineers

Indiana Department of Natural Resources

a) Division of Reclamation

b) Division of Forestry

c) Division of Properties, Fish and Wildlife

d) Soil and Water Conservation Committee

Soil Conservation Service.

Listed below are the projects that are reported in this document:

Soils Inventory

Forestry Demonstration Project

Coastal Zone Management

Tippecanoe County, Land Use Project

SOIL INVENTORY PROJECT

INTRODUCTION

The acceleration of the National Soil Survey Program and the production of useful, high quality soil surveys in Indiana are among the prime goals of the USDA/Soil Conservation Service and the Indiana Department of Natural Resources Soil and Water Conservation Committee. The wide use of soil surveys for engineering and planning purposes in addition to agricultural uses has resulted in many specific questions concerning the physical nature of the different soil units depicted on soil maps. In order to provide the details necessary to understand the landscape composition and to provide interpretation of soil maps for specific uses, information of a quantitative nature is needed. To accomplish this task all avenues are being considered, including remote sensing technology which can provide quantitative measurements through computer analysis of Landsat multispectral scanner (MSS) data.

OBJECTIVE

The overall objective of this task is to determine the applicability of using computer analysis of Landsat multispectral scanner data in accelerating and improving the quality of the soil survey program in Indiana.

To evaluate the usefulness of the data the following specific studies were initiated:

1. Evaluate the usefulness of spectral soil maps produced from

multispectral scanner data using pattern recognition techniques as quality control in soil surveys and as a means to evaluate quantitatively the soil mapping unit composition.

2. Investigate the possibility of producing high quality general soil maps using false color Landsat imagery as the base map.
3. Develop a soil parent material map using multispectral resource data.
4. Determine the feasibility of producing a spectral soil map on a county-wide basis with its accompanying manuscript and evaluate the utility of this type of soil survey report to user groups.
5. Evaluate the usefulness of superimposing computer classification results upon aerial photobase maps in order to gain the benefit of the landscape prospective.

STATUS

Research in this area is now being conducted solely in Jasper County, Indiana. As stated in past reports a data set consisting of Landsat MSS data geometrically corrected and precision registered to ground center points at a scale of 1:15840 has been prepared. This data has been overlaid with a set of boundaries delineating the four types of parent materials found within the county:

1. Glacial till

2. Outwash
3. Outwash over glacial till
4. Lacustrine

These boundaries were developed by visual interpretations of simulated false color imagery and single band grey scale images representations of the Landsat data.

Twelve quarter sections were randomly selected in three different parent materials, namely outwash, lacustrine and glacial till. These quarter section plots have been field mapped of a scale of 1:7920. At this scale, contrasting detail, down to one hectare in size has been delineated. These sites have been located on the Landsat data, and they will be used for correlating spectral data with soils of known parent material and drainage characteristics. If necessary, addition quarter section areas will be mapped to assure representation of all the soils in the county.

Four spectral classification of Jasper county have been completed. All four techniques used an unsupervised approach however these classifications differ by the manner in which the training statistics were developed. The four methods of selecting training statistics are listed below:

1. a) Subjective selection of areas representing the spectral variability within each parent material area;
   b) aggregation of statistics into one set of statistics for the entire county;

c) classification of entire county.

2. a) Subjective selection of areas representing the spectral variability within each parent material area;

   b) development of individual training statistics for each parent material area;

   c) classification of each parent material area using its representative statistics.

3. a) Objective sampling of the entire county using every eleventh line and eleventh column of data;

   b) development of training statistics for the entire county;

   c) classification of the entire county.

4. a) Objective sampling of each parent material area using every fifth line and fifth column of data;

   b) development of training statistics for each parent material area;

   c) classification of each parent material area using its representative statistics.

Evaluation of the four classifications are currently being conducted by comparing them to the twelve quarter sections previously mentioned. The two classifications best representing the soils within the county will be taken to the field for further evaluation. Selection of the final classification will be made after the field evaluation and correlation of spectral classes to soil classes has been completed.

The final product for Jasper County will consist of a digitized multispectral soil map produced at a scale of 1:15,840 printed on clear mylar. This will underlay a matte halfone film positive of the aerial photo field sheet. In this manner the multispectral map will be used to guide the soil scientist in determining where to place soil boundaries for the various mapping units and to also point out specific locations, in the landscape, that are different and where additional investigative borings need to be made.

A more detailed report on the results of this effort will be possible at the end of the next reporting period at which time the field correlation phase will have been completed.

TIPPECANOE COUNTY LANDUSE STUDY

INTRODUCTION

Great need exists to inventory landuse on the county level for planning purposes. As urban areas continue to grow and engulf rural settings it becomes imperative to inventory land cover and use all available information in landuse planning of rural lands.

The Tippecanoe County Area Planning Commission (APC) has expressed a growing interest in utilizing remote sensing data as a planning tool along with its standard maps and black and white aerial photography. As a consequence a demonstration project was devised to see what aid digitally derived landuse maps might benefit the APC.

STUDY SITE

Tippecanoe County is located in the west-central part of Indiana (see figure 1). It is a rectangle 501 square miles, or 320,640 acres, in area. The county is approximately 70% agriculture, 6% urban and 24% other land uses.

Numerous housing developments are scattered over the outlying rural areas and strip development along major highways abound.

OBJECTIVE

The major objective of this demonstration project was to utilize multispectral scanner data (MSS) with its .5 hectare (1.1 acre) resolution to catagorize each .5 ha cell as to its land use with particular emphasis in the rural areas. Project personnel who were experienced in previous landuse studies also were aware that rural-urban interface areas were unique problem areas and would need special attention during the study.

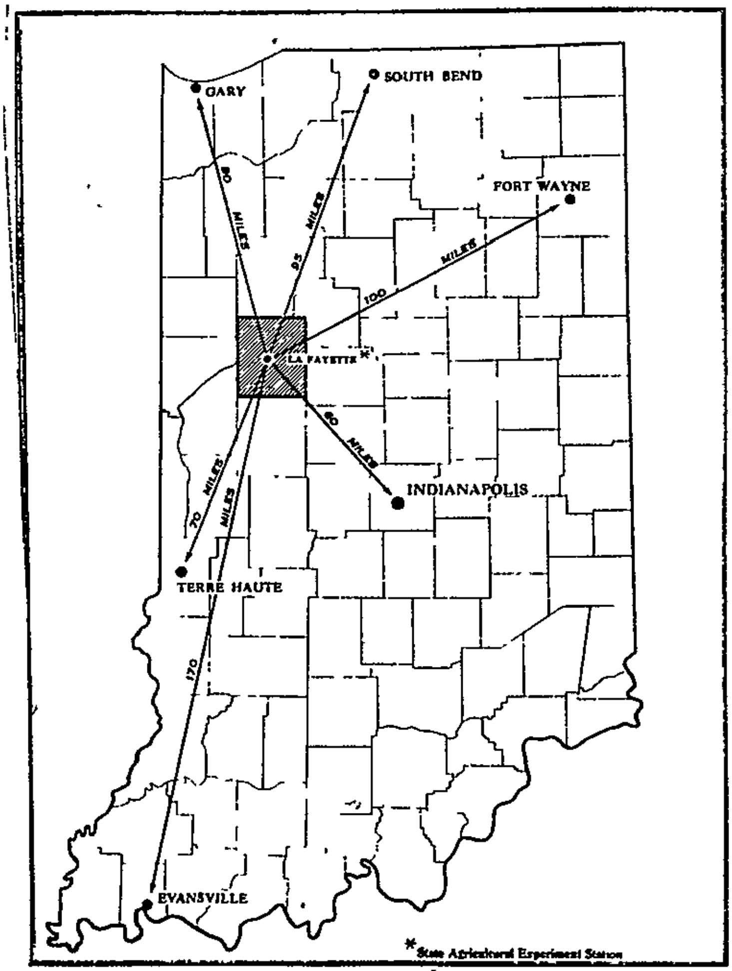


Figure 1. Location of Tippecanoe County, Indiana which was used in this landuse demonstration study.

APPROACH

The overall approach to this study was to produce spectral analysis of Tippecanoe County, Indiana utilizing Landsat MSS data and computer implemented pattern recognition analysis techniques. These results were evaluated for accuracy by means of representative test fields.

In addition, a secondary approach was to delineate urban areas in the county and digitize their boundaries were to be used as an additional channel of data. These urban boundaries were to be utilized along with the spectral data to allow for classification of the urban protions of the county using the urban class statistics and the rural areas using the rural class statistics. These analysis results were to be evaluated by the same test fields used in the earlier evaluation. The two classification results were to be compared and differences noted and interpreted where possible.

ANALYSIS PROCEDURE

A data set over Tippecanoe County for June 1976 (Landsat scene i.d. 2515-15411) was selected because of the in-house availability of the data and the fact that March 1976 1:24,000 scale black and white aerial photographs were available through the Tippecanoe County Area Planning Commission. These MSS data were geometrically corrected and registered to portions of 16 U.S.G.S. 7½ minute topographic maps of the county at a 1:24,000 scale.

Representative areas containing the different covertypes found in the county were handpicked from a digital image displayed on a black and white CRT screen with the aid of the 1:24,000 aerial photographs. Sixteen initial training areas were processed using the LARSYS CLUSTER algorithm to determine the natural spectral structure within each area. Table 1 lists these areas and their line and column coordinate location. Figure 2 illustrates a map showing the location of the training areas.

Table 1. List of the initial 16 training areas with their coordinate location and major landuse group assignment.

Training Area Number	Area Type	Training Area	First Line	Last Line	First Column	Last Column
1	Rural	HERSHEY	213	248	497	545
2	Urban	ORCHARD	288	314	409	437
3	Urban	MALL	327	349	377	401
4	Urban	DWNTWN	285	308	297	330
5	Urban	OLD-RES	304	324	336	357
6	Urban	NEW-RES	339	355	333	361
7	Rural	MCCUTCH	421	468	332	387
8	Rural	WST PT	403	433	113	150
9	Rural	Trailer	351	380	221	258
10	Rural/Urban	LILEY	329	344	238	285
11	Rural	DAYTON E	356	387	540	566
12	Rural	DAYTON	348	379	484	513
13	Rural/Urban	WATER/WD	280	310	126	156
14	Urban	SUBD	256	266	156	171
15	Urban	IND/HWY	223	231	150	160
16	Rural	FLDPLAIN	307	329	189	207

The spectral cluster classes for each training area were related to specific group covertypes with the aid of the black and white aerial photographs and the U.S.G.S. topographic maps. Training areas were then

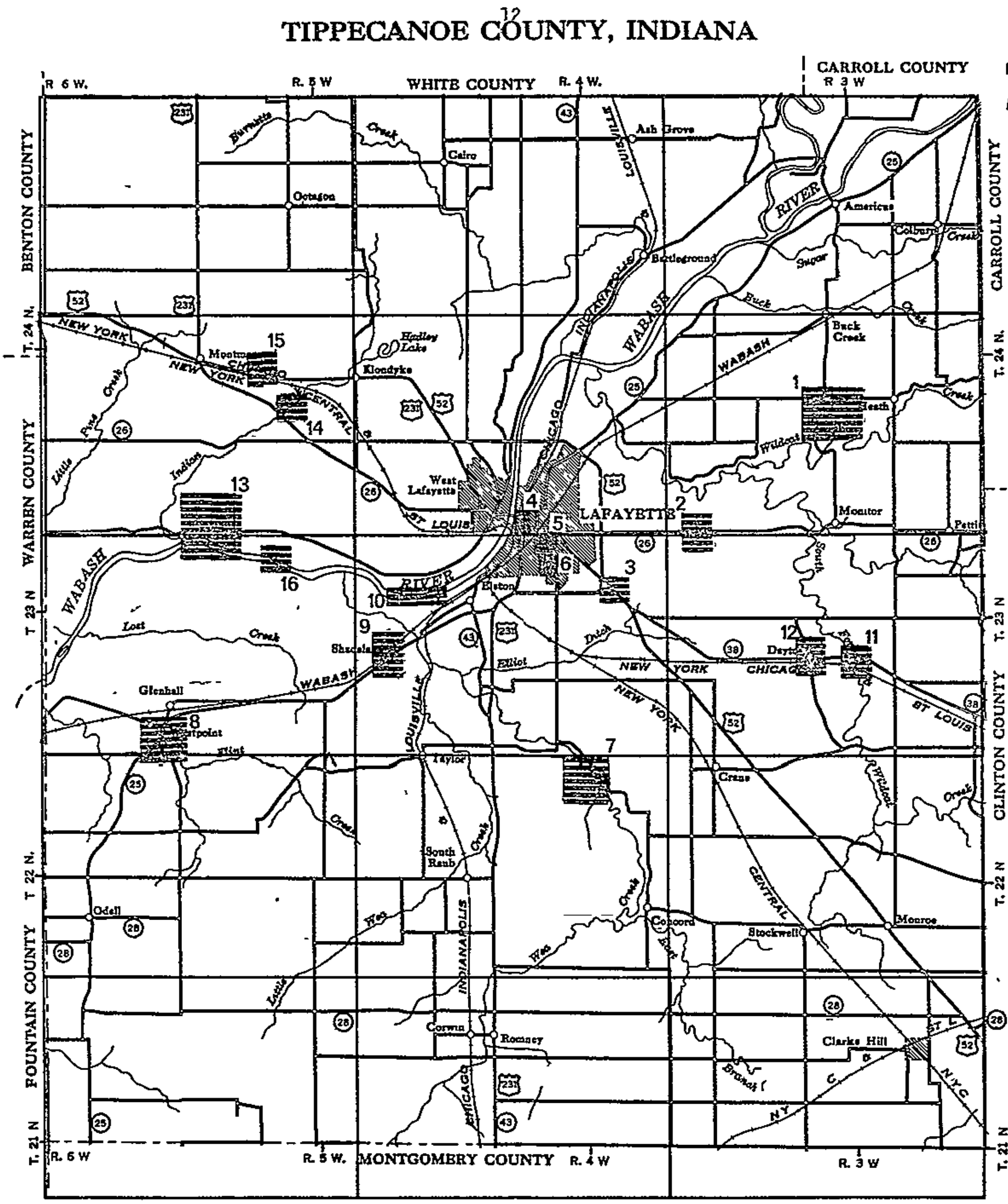


Figure 2 _ Map of Tippecanoe County showing location of the 16 training areas.

assigned to a major landuse group (urban, rural, urban/rural) and their respective cluster classes were grouped together into single sets of urban classes, rural classes, and urban/rural classes.

Each of the resultant set of classes was tested for separability between classes within the set by utilizing the SEPARABILITY processor. The outcome of this step was a recommended set of 20 urban classes, 12 rural classes and 7 urban/rural classes as listed in Table 2.

Table 2. List of the 39 spectral cluster classes for the urban, rural and urban/rural class groups.

Rural Classes	
Agriculture 1	Bare Soil 1
WetSoil 1	Agriculture 4
Agriculture 2	Light Soil
Tree 1	Pasture 1
Agriculture 3	WetSoil 2
Saturated Soil 1	Bare Soil 2
Urban Classes	
Commercial 1	New Residential
Sparse Vegetation	Residential 2
Trees 2	Trees 3
Wet Vegetation	Mall
Wet Soil 3	Wet Agriculture 1
Saturated Soil 2	Commercial 4
Commercial 2	Shallow Water
Commercial 3	Water 2
Residential 1	Wet Soil 4
Street	Water 1
Rural/Urban	
Light Soil 2	Wet Agriculture 2
Sparse Agriculture 2	Water 3
Pasture 2	Trees 4
Bare Soil 3	Industry

These 39 classes were than grouped together to a single statistics set and the separability between these new classes were calculated. Those classes which were similar spectrally were merged together and a final set of classes for the whole county was obtained. This final list of classes is given in Table 3.

The statistics (means and covariances for each class) for these final classes were then used along with the CLASSIFY-POINTS processor to classify every .5 hectare cell (data point) in Tippecanoe County. The results map is shown in figure 3 and acreage tables given in Table 4.

Table 3. List of final 20 classes used to classify Tippecanoe County.

Gravel	Trees 2
Bare Soil	Residential
Light Soil	New Residential
Pasture	Streets
Wet Agriculture 1	Commercial 1
Wet Agriculture 2	Commercial 2
Saturated Dark Soil	Industry
Sparse Vegetation	Shallow Water
Agriculture	Water 1
Trees 1	Water 2

SPECTRAL CLASSIFICATION EVALUATION

Preliminary random test fields were selected from all parts of Tippecanoe County. These fields were photo-interpreted to select those which contained homogenous identifiable covertypes. The selected fields used for testing classification results contained 1138 sample data points which yielded an overall classification performance figure of 86.6%. Table 5 lists the class groupings that were tested (agriculture, forest, urban) and their respective performances.

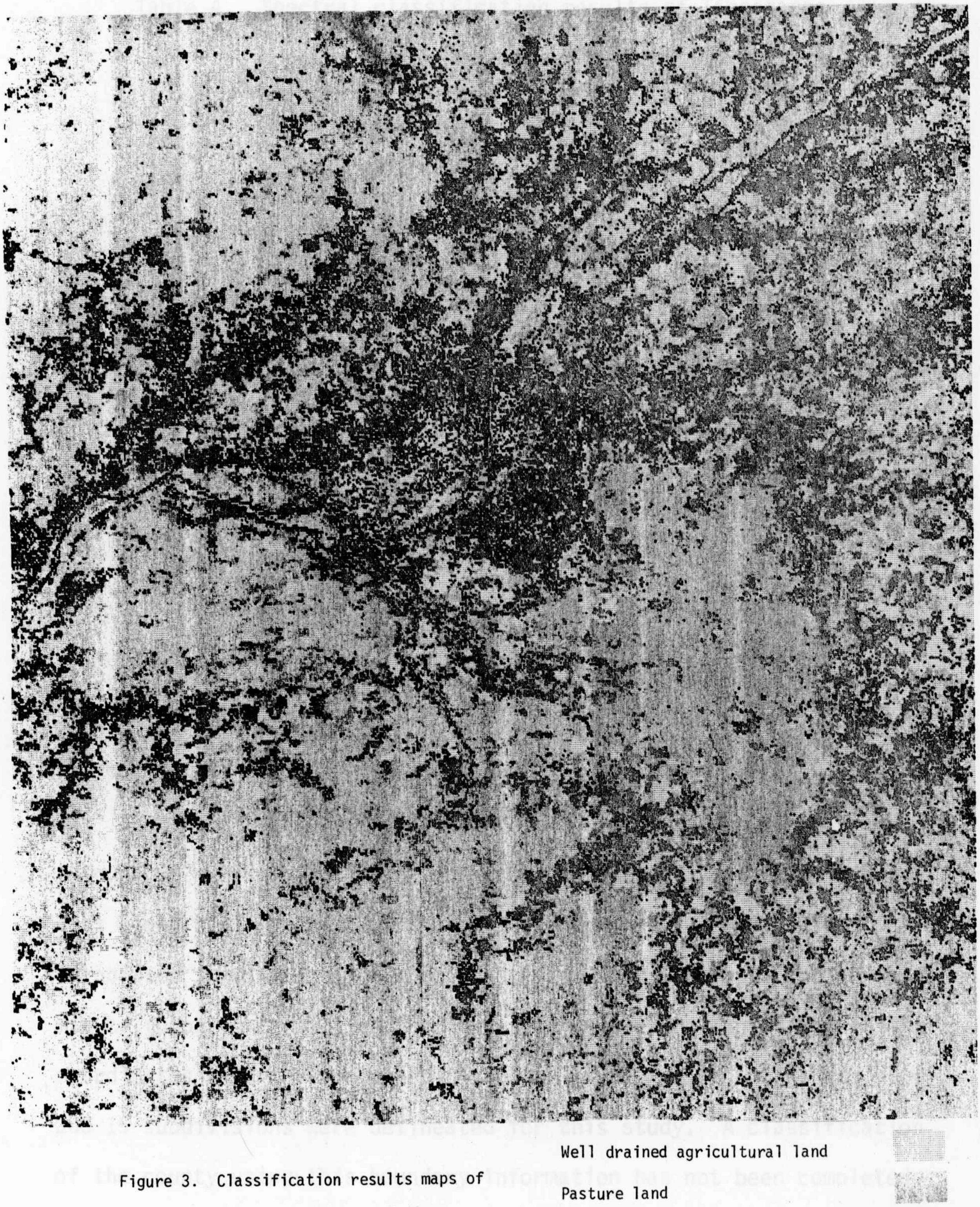


Figure 3. Classification results maps of Tippecanoe County, Indiana.

Well drained agricultural land

Pasture land

Tree covered areas

Poorly drained agricultural land

Residential areas

Industry/Commercial areas

Water

Table 4. Spectral classification results of Tippecanoe County, Indiana, in tabular format.

Class	Total Acres Classified	Percent of County
Gravel	4572.15	1.4
BSOIL	36900.3	11.1
LTSOIL	1484.04	0.4
Pasture	27736.39	8.3
WETAG 1	36834.53	11.1
WETAG 2	52862.43	15.8
SATSOIL	44844.44	13.5
SPRSVEG	7932.60	2.4
Ag	43738.91	13.1
Trees 1	32223.14	9.7
Trees 2	19620.31	5.9
Resident	13591.81	4.1
New Res	586.23	0.2
STREET	4292.88	1.3
Comerc 1	2436.09	0.7
Comerc 2	431.60	0.1
Industry	1332.87	0.4
SHWATER	544.69	0.2
Water 1	115.4	0.0
Water 2	963.59	0.3
	333044.4	100.0

DELINEATION OF URBAN AREAS

The second step in this study involved delineating the urban areas throughout the county. This was accomplished by examining APC zoning maps along with black and white aerial photographs. All cities, incorporated towns and major housing subdicirions were outlined on 7½ minute topographic maps so that they might later be digitized and their coordinates recorded on magnetic tape. A total of 13 cities and towns and 15 subdivisions were delineated for this study. A classification of the county using this boundary information has not been completed, but will be presented in the next semi-annual report.

Table 5. Classification Performance.

	GROUP	NO OF SAMPS	PCT. CORCT	TEST CLASS PERFORMANCE NUMBER OF SAMPLES CLASSIFIED INTO AG	FOREST	URBAN	WATER
1	AG	819	93.7	767	31	18	3
2	FOREST	148	86.5	18	128	2	0
3	URBAN	171	52.6	64	14	90	3
	TOTAL	1138		849	173	110	6

OVERALL PERFORMANCE (985/ 1138) = 86.6

AVERAGE PERFORMANCE BY CLASS (232.8/ 3) = 77.6

CONCLUSIONS

The completion of the first part of this landuse study has made possible the following conclusions:

* Classification performance of the spectral analysis was significantly higher than was expected considering the scattered housing and strip developments.

* Numerous spectral classes which exist in both urban and rural environments in reality have different land uses (ex. park grassland - pasture, disturbed soil in housing developments - plowed farm soils, city parks - rural tree lots, etc.).

* Urban-rural interface zones are complex areas needing concentrated attention during analysis procedures.

* The addition of digitized urban boundaries should greatly aid discrimination between spectrally similar urban and rural classes.

The protion of this study involving utilization of digitized urban boundaries appears to be an exciting and promising step toward developing a usable landuse planning tool.

AN EVALUATION OF INDIANA'S COASTAL ZONE FOREST RESOURCES

A Study of the Impact of Remote Sensing to Forest Inventory

INTRODUCTION

This report describes the results from a forest inventory conducted within the boundary of the Indiana Coastal Zone Management Area (fig. 1). The materials documented here are from the second phase of a two-year study which began in 1976. This inventory utilized combined inputs from remote sensing and ground based technologies to characterize the extent and quality of the forest resource. These results represent a quantative frame work upon which to build forest management policy in the Coastal Zone Management Area. Furthermore, this study demonstrates the feasibility of using Landsat collected data in conjunction with on-going survey to provide important and necessary information to direct the development of Indiana's forest resource.

Background

In response to Public Law 92-583 (the Coastal Zone Management Act of 1972) personnel from the Indiana Department of Natural Resources' (IDNR) Division of Forestry, and the Laboratory for Applications of Remote Sensing (LARS) cooperated in a forest inventory of the Coastal Zone Management Area (CZM). LARS provided maps and statistical data for forest cover through machine-assisted analysis of Landsat multispectral

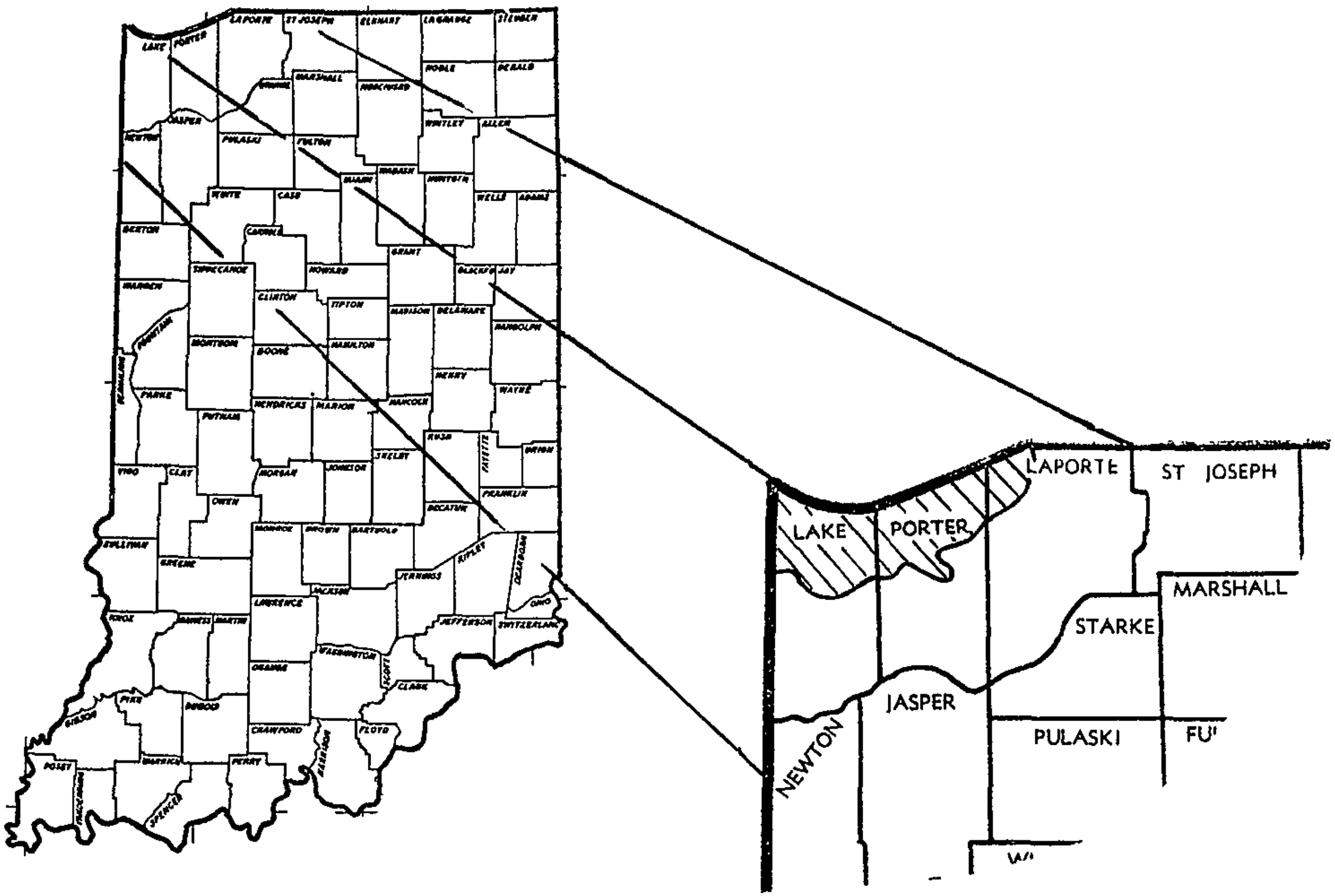


Figure 1. Location of the Coastal Zone Management area in northern Indiana.

scanner data. Using this input IDNR inventory the timber lands for the purpose of categorizing the forest resource. Results from this first phase of the study were published in "Technical Report No. 101."

The second phase of the CZM forest inventory was initiated in the spring of 1977. The intent of this new phase was to provide a more detailed quantification of the forest resource base. Specifically, information on the potential and present productivity of forest lands, and a measure of their susceptibility to erosion was to be provided. Given these inputs, broad management objective have been defined, along with unique areas which require special management consideration.

Objectives

The objective of Phase II was:

> To further amplify, and quantify forest resource information collected during the 1976 inventory.

In order to accomplish this objective, we needed to:

- Identify the potential productivity, of forests in terms of board foot growth/ acre/year, based on soil productivity.
- Determine the potential erodability, of forest soils.
- Classify the existing resource in terms of annual production, emphasizing areas of high commercial volume productivity, recreation potential or other unique attributes.

These objectives address specific requirements which were necessary to formulate management directions for the CZM. The scope of this inventory did not allow for the intensive collection of data necessary to develop management plans for a small ownership. Therefore, any inferences made from these data to individual forests tracts would be subject to excessive sampling error. Individual forest owners who desire management plans for their land should consult with the INDR - Division of Forestry.

APPROACH

The 1977 survey utilized the previously classified Landsat data, and current soil maps. The forest soils were identified from the Landsat data and were digitized in 2.5 acre cells by section and township. Soil Conservation Service information on woodland suitability and land capability forms the bulk of a data base created at LARS. Field data to supplement the 1976 survey was also collected. IDNR processed the field inventory data and LARS manipulated the data base. Both organizations worked together to complete the inventory and develop recommendation.

Methods and Materials

Landsat data classified by LARS Staff early during 1976 (fig. 2) was the basis for the forest inventory. Fundamentally, the Landsat classifications were used to locate forest land. Four classes, based on distinct spectral response characteristics were identified. Forest inventory data were sampled based on a proportional allocation of acreage by spectral class. These survey data were reduced by IDNR, and the

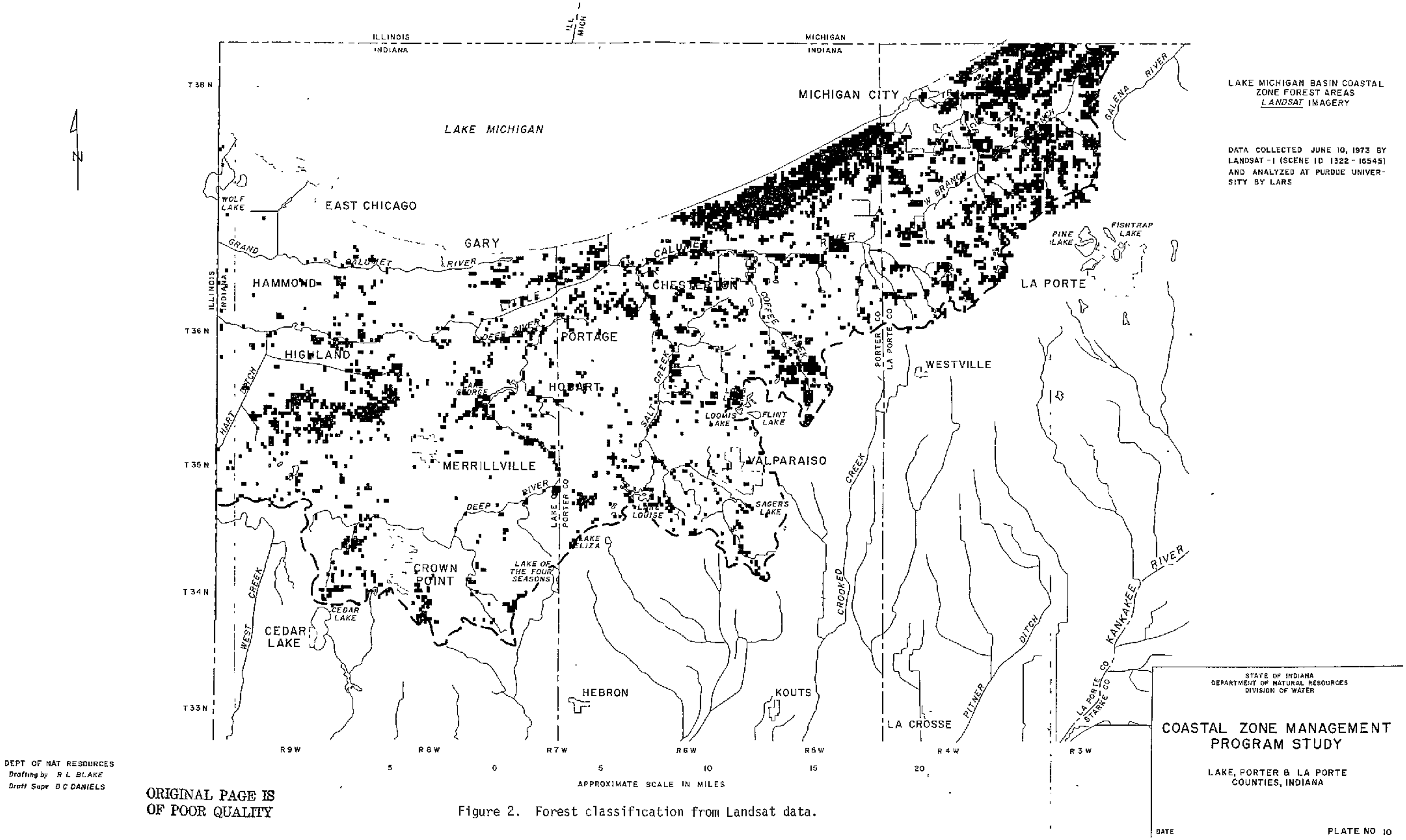


Figure 2. Forest classification from Landsat data.

results analyzed to provide a profile of the CZM forest resource.

An important facet of this study involved combining the results of the Landsat classification with soils data. The soil data was derived from current soil maps for townships within the CZM. The soils information from the map can be related to indicies of potential woodland productivity, and potential erodibility. The Landsat and soils data were combined in a grid-cell data base, which conceptually illustrated in figure 3.

The data base was created by encoding the following information about a 2.5 acre cell into a digital computer record:

County Name

Township

Range

Section

Row Number (1-16)

Column Number (1-16)

Spectral Class of Forest

Soil Symbol

Slop Class

Erosion Class.

A grid, figure 4, at two scales, 1:15840 and 1:24,000 was used to compensate for the difference in scales between the Landsat and soils maps.

Line printer classification maps for the forest classes only (fig. 5a) were manually annotated to show township, range, and section lines. The 1:24,000 grid was used to locate the coordinates of forest tracts

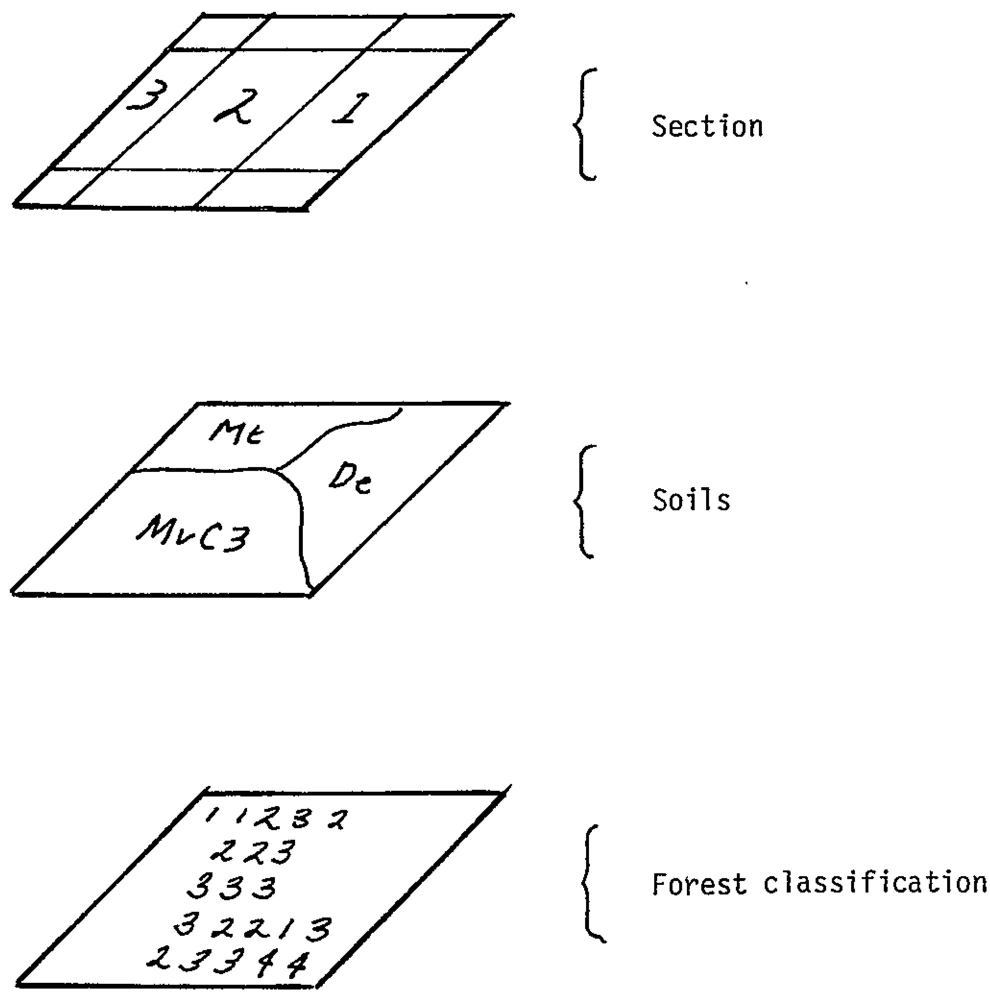


Figure 3. Conceptual data base showing political, soils and vegetation layers.

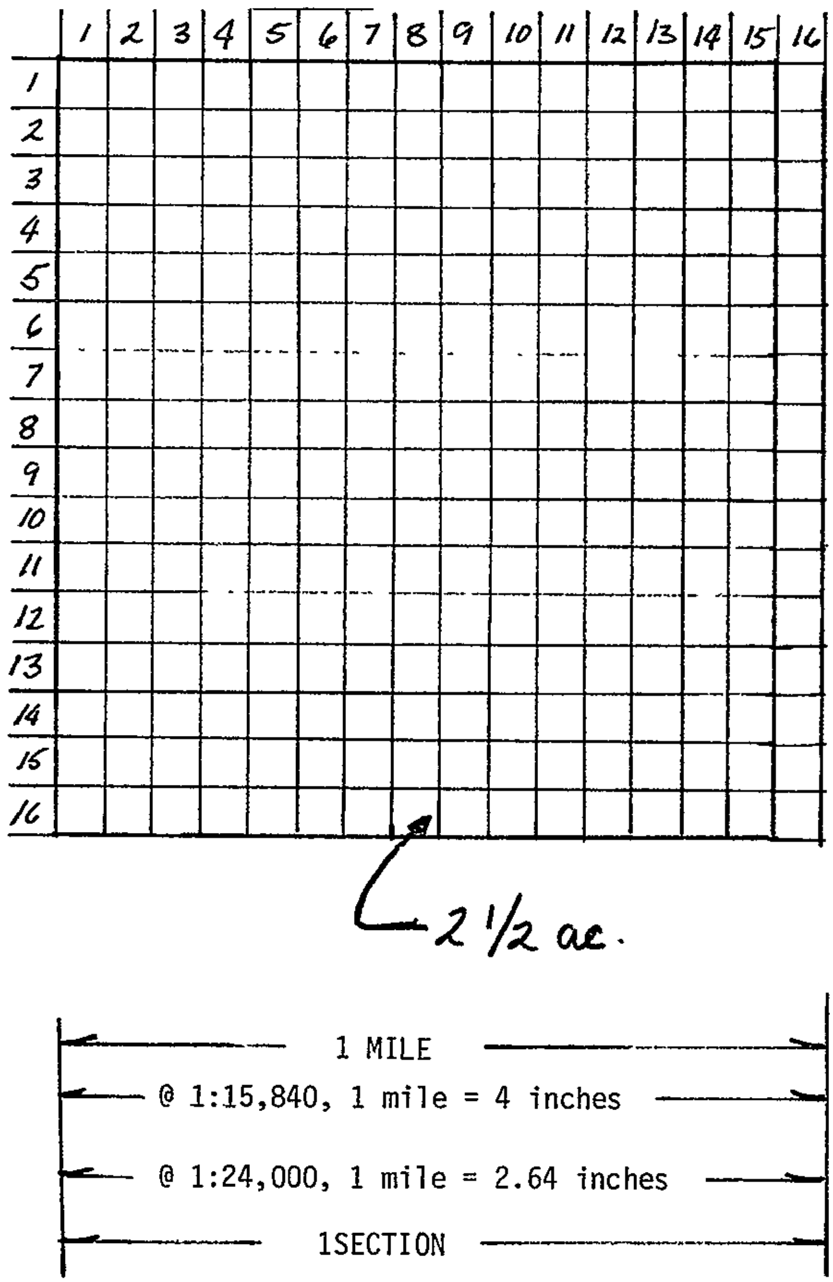


Figure 4. Example of grid use to digitize information about soil and vegetative cover for each section of land with the CZM.

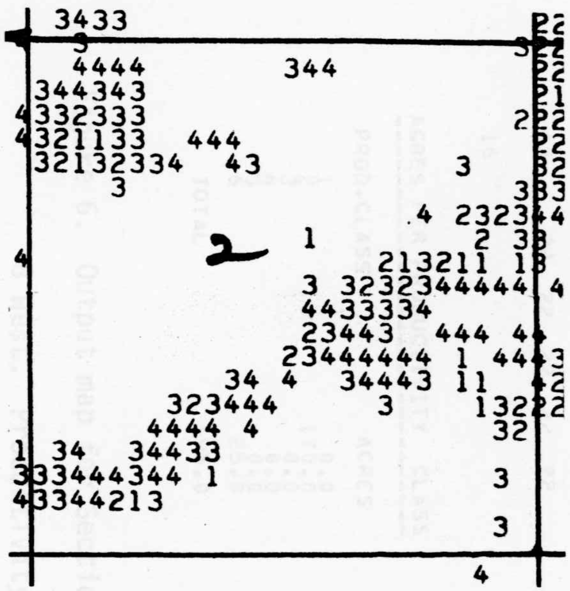
consisting of a minimum of 2 pixels (about 2.3 acres). Soils information for these coordinates were than read from the soils map (fig. 5b) and encoded to a computer file, (fig. 5c and Appendix V-1) and example below.

```
FILE. . .       TWNSHP    373       P1

LAPORTE 37N03W030101          3          MX
LAPORTE 37N03W030201          2          BTA
LAPORTE 37N03W030505          3          MRB2
LAPORTE 37N03W030605          3          MRB2
LAPORTE 37N03W030701          4          CHB
LAPORTE 37N03W030705          3          WT
LAPORTE 37N03W030901          3          BTA
LAPORTE 37N03W030903          3          RR
LAPORTE 37N03W031001          4          FH
LAPORTE 37N03W031002          3          MX
LAPORTE 37N03W031003          3          BR
LAPORTE 37N03W031004          4          RR
LAPORTE 37N03W031101          3          FH
LAPORTE 37N03W031102          2          FH
LAPORTE 37N03W031103          3          WT
LAPORTE 37N03W031104          3          WT
LAPORTE 37N03W031201          1          MX
LAPORTE 37N03W031202          2          FH
LAPORTE 37N03W031203          3          WT
LAPORTE 37N03W031204          4          BR
LAPORTE 37N03W031301          4          MX
LAPORTE 37N03W031302          2          FH
LAPORTE 37N03W031303          2          BAA
LAPORTE 37N03W031304          3          RR
LAPORTE 37N03W031401          3          MX
LAPORTE 37N03W031402          3          FH
```

The procedure use to encode the raw data was described by Yahner, in "Using the Soil Survey for Land Assessment. A Computer Method". Minor modifications were made to Yahner's source deck, in order to encode and manipulate the data necessary for the CZM inventory. Figure 6 shows an example of the output map and summary tables showing the acreage by potential productivity and potential erodibility.

An addition was also made to Yahner's programs that allowed us to select sample points for the field inventory. A discription, flow chard, program listing and tape file examples for program NEWSAMP appears in Appendix I. The output of NEWSAMP, fig 7, is a table showing the random grid locations for points in sections within a township. Points are selected with a probility proportional to the productive acreage. A summary at the top of the table shows the number of points



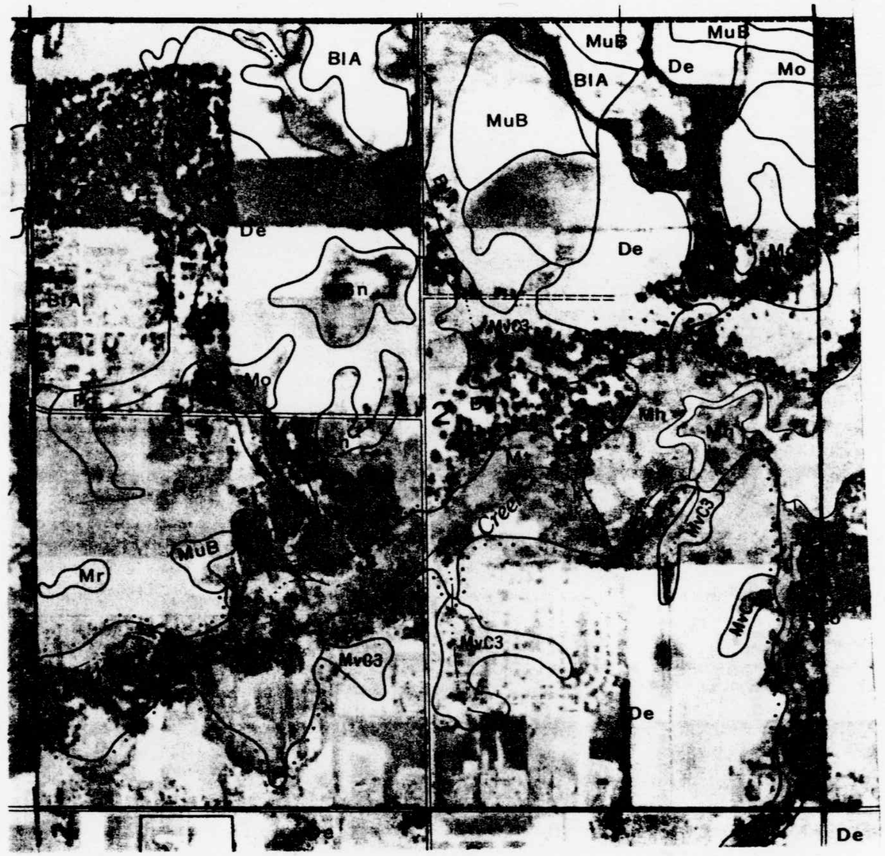
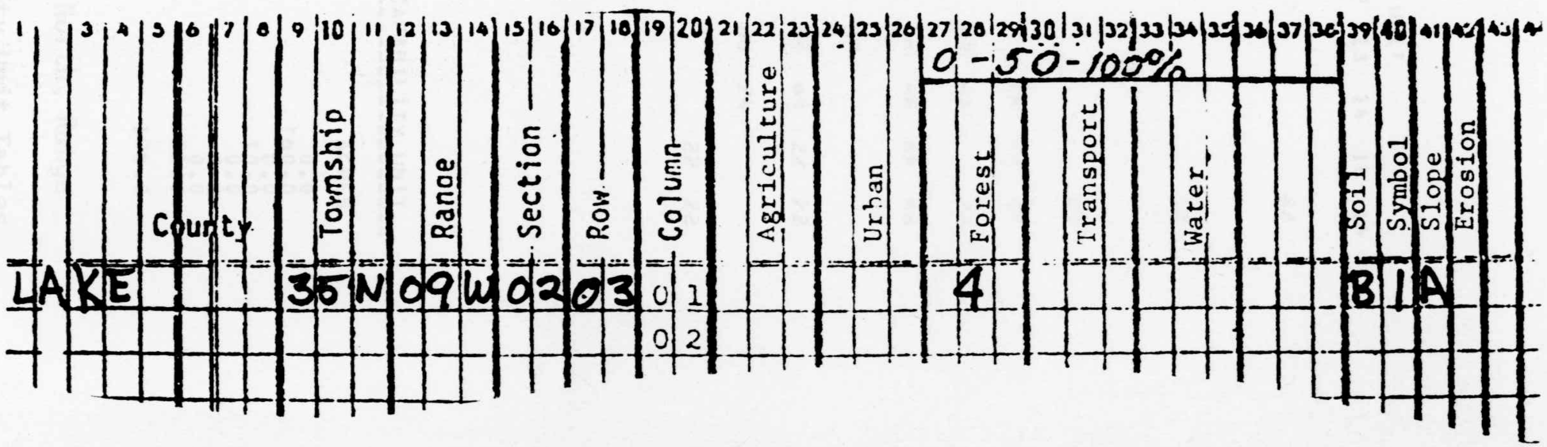


Figure 5. Inputs to Soils data base.

5a. landsat classification

5b. Soil Survey Map

5c. Data input form



TOWNSHIP 35N RANGE 08W SECTION 2

SOIL PRODUCTIVITY VALUE/CAPABILITY UNIT

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		22	22	22					22	22						22
2	22	22	22	22												
3	22	22	22	22												22
4	22	22	22	22	22	22	22									
5			22													22
6														24	24	22
7												24	22	68		22
8									22		22	22	68	68	68	68
9									22	22	22	22	68			
10									22	22	22	68	68	68	22	22
11							22				22	22	68	24		
12					22	22	22	22				22			22	22
13		22		22	22	22										
14	22	22	22	22	22	22										
15	22	22	22	22	22											
16																

ACRES PER PRODUCTIVITY CLASS

PROD.CLASS	ACRES
1	0.0
2	170.0
3	0.0
4	0.0
5	0.0
6	25.0
TOTAL	195.0

ACRES PER CAPABILITY UNIT

CAP. UNIT	ACRES
1	0.0
2	160.0
3	0.0
4	10.0
5	0.0
6	0.0
7	0.0
8	25.0
TOTAL	195.0

Figure 6. Output map for Section 2 of Township 35 North, Range 8 West. Productivity Class and Capability Unit Tables are also part of the output from the data base.

NO. OF SAMPLE CELLS PER PRODUCTIVITY CLASS

PROD.	SAMPLES
1	0
2	6
3	1
4	0
5	0
6	2

SEED = 13

COORDINATE LOCATION OF SAMPLES

COUNTY	TOWNSHIP	RANGE	SECTION	ROW	COLUMN	PROD. CLASS
LAKE	35N	08W	1	1	1	2
LAKE	35N	08W	5	7	8	2
LAKE	35N	08W	6	15	9	3
LAKE	35N	08W	11	3	13	2
LAKE	35N	08W	10	3	7	2
LAKE	35N	08W	10	1	10	2
LAKE	35N	08W	30	10	9	2
LAKE	35N	08W	30	2	4	6
LAKE	35N	08W	6	13	6	6

NUMB = 72

Figure 7. Output from the sample program NEWSAMP. The table shows the sample point location for Township 35 North, Range 8 West.

selected by productivity class. With this information, a topographic map, and a 1:24,000 grid the field crew could locate specific plot centers.

Normal IDNR forest inventory procedures were followed for the field data collection. Five variable radius plots were measured for each sample point. The plots were arranged as a cluster sample, figure 8. Tally trees were selected by a pps (probability proportional to size) method with a 10 factor basal area angle prism. Information recorded on field sheets, figure 9, included: species, diameter at breast heighth (dbh), merchantable height (as number of logs), cull (percent of defect) and log grade. Ten year growth data for one dominant or co-dominant tree per points was measured. Also site index was measured for one dominant tree per sample plot. These data were sent to the IDNR offices in Indianapolis for card punching and analysis.

The IDNR forest data processing service computer programs reduced the raw data to:

- Stand and Stock tables, figure 10
- Table of board foot volume by species and log grade, figure 11
- Pulpwood production, figure 11
- Statistical sample summary, figure 12
- Ten year predicted stock and stand tables, figure 12 and
- Average board foot growth per acre, figure 12.

These results were produced for each sample point. Results for sample points were combined by Landsat classes to yield summary data

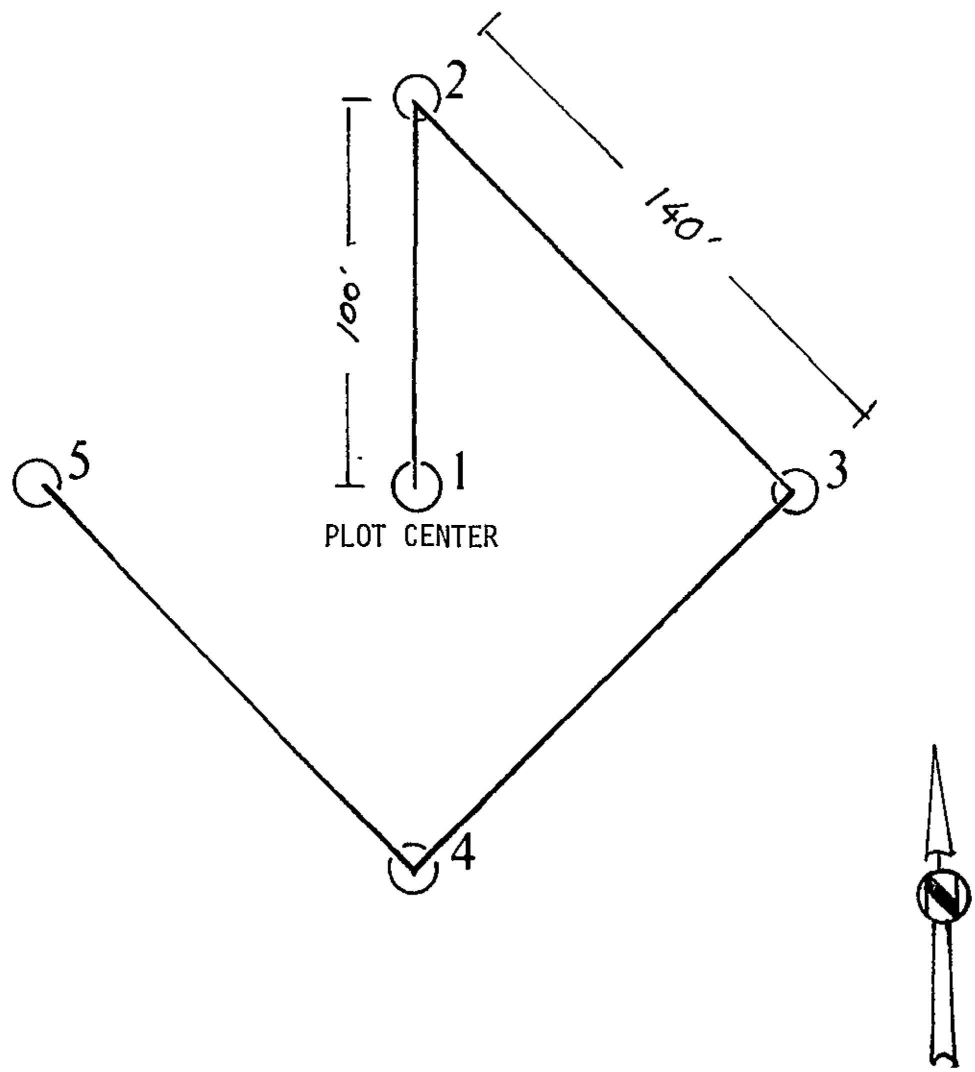


Figure 8. 5-point cluster design.

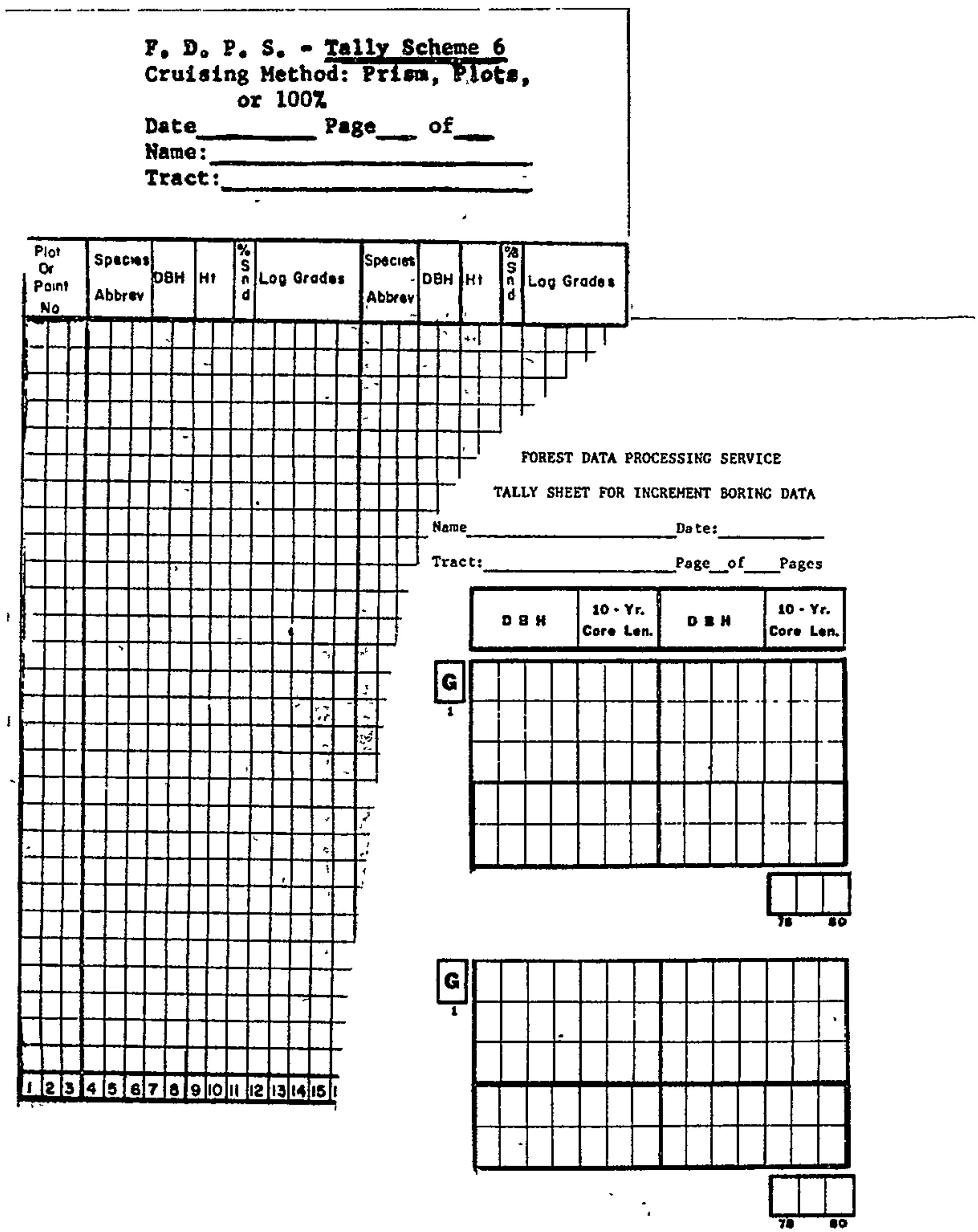


Figure 9. Field tally sheets used to record forest data for the selected sample points.

CZM-PORTER CO., T37N,R5W,SEC.2, ROW 13, COL. 1
DOYLE BOARD FOOT VOLUME BY SPECIES AND DIAMETER CLASS
(PER ACRE VALUES)
1 OF 2

SPECIES LISTING	BASAL AREA/A.	NO. TREES	TWO INCH DIAMETER CLASSES 10	12	14	16	18	20	22
WHITE ASH	4.0	2.8	0.0	0.0	76.7	0.0	0.0	182.4	0.0
SUGAR MAPLE	8.0	7.7	0.0	58.6	183.4	157.6	0.0	0.0	0.0
RED OAK	8.0	5.7	0.0	25.5	0.0	0.0	190.1	101.8	0.0
T O T A L S	20.0	16.2	0.0	84.0	260.1	157.6	190.1	284.2	0.0
NUMBER TREES BY DBH CLASS			0.0	5.1	5.6	1.4	2.3	1.8	0.0

34

CZM-PORTER CO., T37N,R5W,SEC.2, ROW 13, COL. 1
DOYLE BOARD FOOT VOLUME BY SPECIES AND DIAMETER CLASS (CON'T.)
(PER ACRE VALUES)
2 OF 2

SPECIES LISTING	TWO INCH DIAMETER CLASSES 24	26	28	30	32	34	36	38	40	TOTAL VOLUME
WHITE ASH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	259.1
SUGAR MAPLE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	399.5
RED OAK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	317.4
T O T A L S	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	976.0
NO. TREES BY DBH CLASS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Figure 10. Example of Stand and Stock table output from field inventory data.

CZM-PORTER CO., T37N,R5W,SEC.2, ROW 13, COL. 1
DOYLE BOARD FOOT VOLUME BY SPECIES AND PURDUE LOG GRADES
(PER ACRE VALUES)

SPECIES LISTING	BASAL AREA/A.	NO. TREES	PURDUE LOG GRADES PRIME	ONE	TWO	THREE	TOTAL VOLUME
WHITE ASH	4.0	2.8	0.0	0.0	105.8	153.3	259.1
SUGAR MAPLE	8.0	7.7	0.0	0.0	0.0	399.5	399.5
RED OAK	8.0	5.7	0.0	0.0	101.8	215.6	317.4
T O T A L S	20.0	16.2	0.0	0.0	207.6	768.4	976.0

CZM-PORTER CO., T37N,R5W,SEC.2, ROW 13, COL. 1
TONS OF PULPWOOD, BASAL AREA AND NO. OF TREES BY SPECIES AND DIAMETER CLASS
(PER ACRE VALUES)

SPECIES LISTING	BASAL AREA/A.	NO. TREES	TWO INCH DIAMETER CLASSES 2	4	6	8	10+	TOTAL VOLUME
RED OAK	2.0	3.7	0.0	0.0	0.0	0.0	0.6	0.6
T O T A L S	2.0	3.7	0.0	0.0	0.0	0.0	0.6	0.6
NUMBER OF TREES BY DBH CLASSES			0.0	0.0	0.0	0.0	3.7	

Figure 11. Table of board foot volume by species and log grade, and summary pulpwood production table.

STATISTICAL SUMMARY FOR
CZM-PORTER CO., T37N,R5W,SEC.2, ROW 13, COL. 1

SAMPLE SIZE = 5

VARIABLE OF INTEREST	MEAN (PER ACRE)	STD. ERROR OF MEAN ABS. VALUE	STD. ERROR OF MEAN PERCENT
SAWTIMBER			
DOYLE BOARD FOOT VOLUME	976.0	366.25	37.53
SQ. FT. BASAL AREA	20.0	4.47	22.36
NUMBER OF TREES	16.2	3.55	21.85
PULPWOOD			
TONS OF PULPWOOD	0.6	0.62	100.00
SQ. FT. BASAL AREA	2.0	2.00	100.00
NUMBER OF TREES	3.7	3.67	100.00

TEN YEAR PREDICTED STAND AND STOCK TABLE FOR
CZM-PORTER CO., T37N,R5W,SEC.2, ROW 13, COL. 1

DIAMETER CLASS	NO. TREES PER ACRE	VOLUME PER ACRE
14	5.0	231.5
16	5.5	607.0
18	1.6	130.5
20	2.2	339.2
22	1.8	459.3
24	0.1	52.0
T O T A L S	16.2	1819.5

AVERAGE ANNUAL DOYLE BOARD FOOT VOLUME GROWTH PER ACRE = 84.3

Figure 12. Statistical summary table, and ten year predicted stock and stand table.

by spectral class. These data, supplemented by results from the previous years inventory form the basis for the recommendation of the study.

RESULTS

Evaluation of the inventory results indicate that forest lands in the Coastal Zone Management area:

- Predominantly belong to the Oak-hickory association
- Are producing less average board foot volume per acre than their potential
- Have been subjected to less than desirable management, and as a result
- Have a majority of their growing fiber volume to low quality logs.
- Are frequently growing on soils which are susceptible to erosion and, therefore, must be carefully managed.

Table 1 summarizes the composition of the four forest classes which occur in the CZM. Typically the coastal zone's forests belong to the broad classification of forest ecosystem known as the central hardwoods. This association is composed of a mixture of hardwood species, which are predominated by the species oak. Rarely, do homogenous stands of timber exist in this region. Usually, hardwood species intermix forming a large continua rather than a small uniform type. Certainly, the forest resources in the CZM reflect this intergration, as shown in figure 13. These diagrams represent the distribution, by volume (sawtimber trees), for the four classes of forest.

Table 1. Description of Forest Classes in the CZM

Class	Symbol	Sawtimber	Pulpwood	Bd.ft. growth/ ac./year
1 Oak-hickory-maple	OHM	3851 bd.ft.*/ac.vol. 50 trees/ac. 54 sq.ft. basal area 61% Oaks by vol.	5 tons/ac.vol. 79 trees/ac. 22 sq.ft. basal area	243
2 Oak-hickory-lowlands	OH-1	6019 bd.ft./ac.vol. 55 trees/ac. 70 sq.ft. basal area 68% Oaks by vol.	4 tons/ac.vol. 64 trees/ac. 16 sq.ft. basal area	363
3 Oak-Hickory-uplands	OH	5292 bd.ft./ac.vol. 55 trees/ac. 67 sw.ft. basal area 78% Oaks by vol.	3 tons/ac. vol. 59 trees/ac 15 sq.ft. basal area	258
4 Transition type	T	3823 bd.ft./ac.vol. 43 trees/ac. 51 sq.ft. basal area 75% Oaks by vol.	5 tons/ac.vol. 72 trees/ac. 20 sq.ft. basal area	129

* bd. ft. vol. by Doyle Scale.

The four types (fig. 13) belong predominantely to the oak-hickory association. The major differences occur in type one and four. The first type contains the greatest proportion of maple volume per acre. The fourth type has no maple volume but contains more red oak and cottonwood, so therefore, is considered a pioneering or transition type. Types two and three are more typical of the oak-hickory association, each containing approximately equal amounts of the white and black oak groups and the walnut groups. The major difference between these types is that type two will more likely be found on moister lower sites than type three.

For each type, the average annual productivity, measured by board foot growth per year, was calculated from the inventory data. These results are shown in the last column of Table 1. These productivity figures were compared to the potential board foot/acre productivity published by the Soil Conservation Service.

Figure 14 shows the distribution of forest productivity classes in the CZM mapped according to potential board foot growth per acre per year. This data were summarized from Soil Conservation Service County Soils maps for Lake, Porter and La Porte counties. The forest acreage ranked by potential productivity from soil survey data is shown in Table 2. A summary of Table 2 indicates:

- 45% or 25,758 acres of forest land in the CZM is composed of pioneering species occupying sites capable of producing more volume and better quality timber than at present.
- 39% or 23,191 acres of forest land in the CZM consist

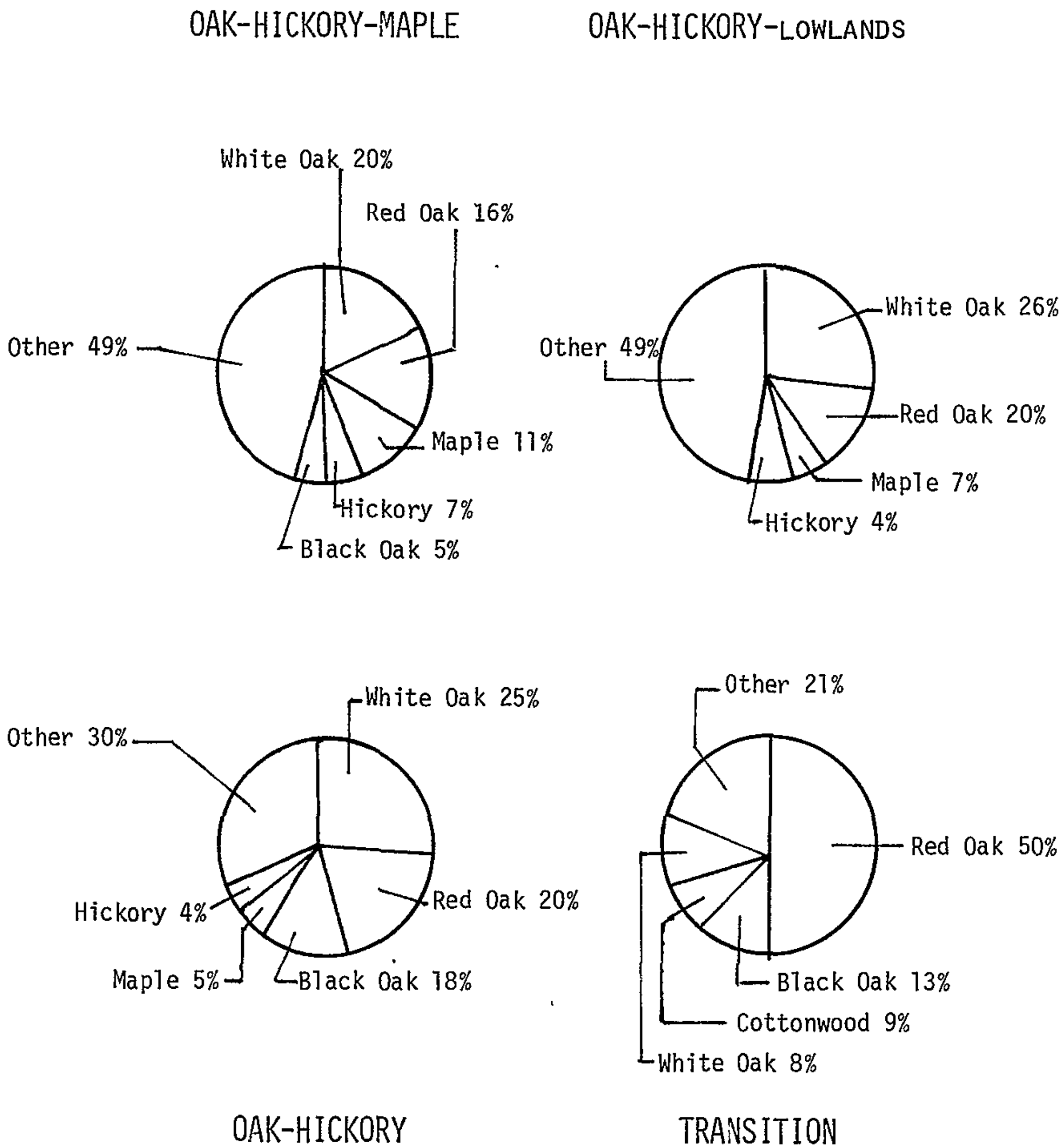


FIGURE 13. DISTRIBUTION BY PERCENT STOCKING FOR MAJOR SPECIES FOR CZM FOREST TYPES.

TABLE 2. DISTRIBUTION OF FOREST ACREAGE BY CLASS FOR POTENTIAL PRODUCTIVITY GROUPS BASED ON ACCEPTED SOIL CONSERVATION SERVICE WOODLAND SUITABILITY RANKINGS.

FOREST TYPE		Potential Productivity			
		High	Medium-High	Medium	Low
	bd.ft./ac/yr growth (Doyle Scale)	300-375	220-300	155-260	115-155
			(Acres)		
1 Oak-hickory-Maple	243	1233	2030	1015	145
2 Oak-hickory-lowlands	363	1668	3626	2321	290
3 Oak-hickory-uplands	258	3843	5656	6671	2103
4 Transition hardwood	129	2683	4714	11530	3553

of white, black and red oaks, of small sawtimber dimensions growing on soils that have optimum site conditions for these species, and therefore are producing within acceptable productivity limits.

- 15% or 8,919 acres of forest land in the CZM is composed of red oak, cottonwood and willow, which occupy sites that pose extreme management limitations, but are producing above average growth.

Productivity, as used in Table 2, is a measure of a stands capability to utilize the site (soil resource). The annual board foot growth does not suggest anything about stand quality or stocking. In order to determine occupancy (stocking) the average stocking per acre of Acceptable Growing Stock Trees (AGS) was calculated. These results are presented in Table 3. AGS trees, Table 4, are those species for which a timber market exists. Acceptable stocking for well managed oak-hickory stands is 60 to 100% in AGS trees. As Table 3 indicates, average stocking for forest types in the CZM is less than desirable.

An evaluation of product quality further supports the contention that timber stands in the CZM are poorly managed. Table 5 shows the distribution of board foot volume by Purdue log grade. Greater than half the stand fiber volume is the study area is in poor quality logs. The high proportion of poor log grades indicates suboptimal stand management. This assumption is supported by comments from the field crews, which indicated that a large portion of the sample plots had been grazed, burned or high graded in the past.

The data base created from the soil survey maps was manipulated

TABLE 3. Growing Stock Distribution, in basal area and percent stocking.

Species Class	Acceptable GS		Unacceptable GS		
	Saw Timber	Pulpwood	Saw Timber	Pulpwood	Total
OHM					
BA	44.1	16.8	10.2	4.9	76.6
%	58	22	14	6	
OHu					
BA	61.5	12.6	8.6	3.5	86.6
%	71	15	10	4	
OH					
BA	59.3	11.4	7.7	3.7	82.6
%	72	14	9	5	
T					
BA	47.9	14.0	3.2	6.2	73.3
%	65	19	7	9	

Acceptable Growing Stock are all merchantable tree species, Table 4.

Unacceptable Growing Stock trees are those species for which presently no market exists.

Saw timber are trees which d.b.h. is greater than 10 inches.

Pulpwood trees are those between 6 and 10-inch d.b.h.

BA - basal area is a measure of stem occupancy, expressed in square feet/acre.

TABLE 4. Acceptable Growing Stock trees for types in the CZM.

White Ash	Sugar Maple
Basswood	Soft Maple
Beech	White Oak
Cottonwood	Red Oak
Cherry	Black Oak
White Elm	Tulip Poplar
Shagbark Hickory	Sycamore
	Black Walnut

TABLE 5. Distribution of board foot volume by log grade for forest types in the CZM.

Type	Purdue Log Grade			
	Prime	1	2	3
	(percent of board foot vol/ac)			
Oak Hickory Maple	8	9	33	50
Oak Hickory lowlands	13	13	31	43
Oak Hickory uplands	10	11	30	49
Transition	5	6	23	66

to give generalized maps for; 1) potential board foot/year productivity (fig. 14), and 2) soil capability (fig. 15). The soil capability map, figure 15, indicates generalized zones where soils possess similar characteristics, related to their susceptibility to erosion. Zone I is the least susceptible, Zone III the most susceptible and, therefore, will require the most caution when planning for any human activity on these soils.

Table 6 gives the distribution of forest area by soil capability zones.

RECOMMENDATIONS

The recommendations in this section are based on the preceeding results and accepted management practices for the oak-hickory cover type, guidelines are given for water, wildlife, recreation and timber uses of the forest resource.

Water

Since the majority of forest land in the coastal zone occurs on erodible soils, these areas should be a carefully managed to prevent excessive erosion. Human activities, including the development of housing sites, should be regulated in order to minimize soil loss and stream sedmentation.

Intensive silvicultural activities should be limited in Zone III (figure 15) forest lands. Only those activities that perpetuate good watershed management should be utilized. The management of these forest lands for a commercial timber crop should be carefully monitored. In no instance should indiscriminate timber clearing be condoned.

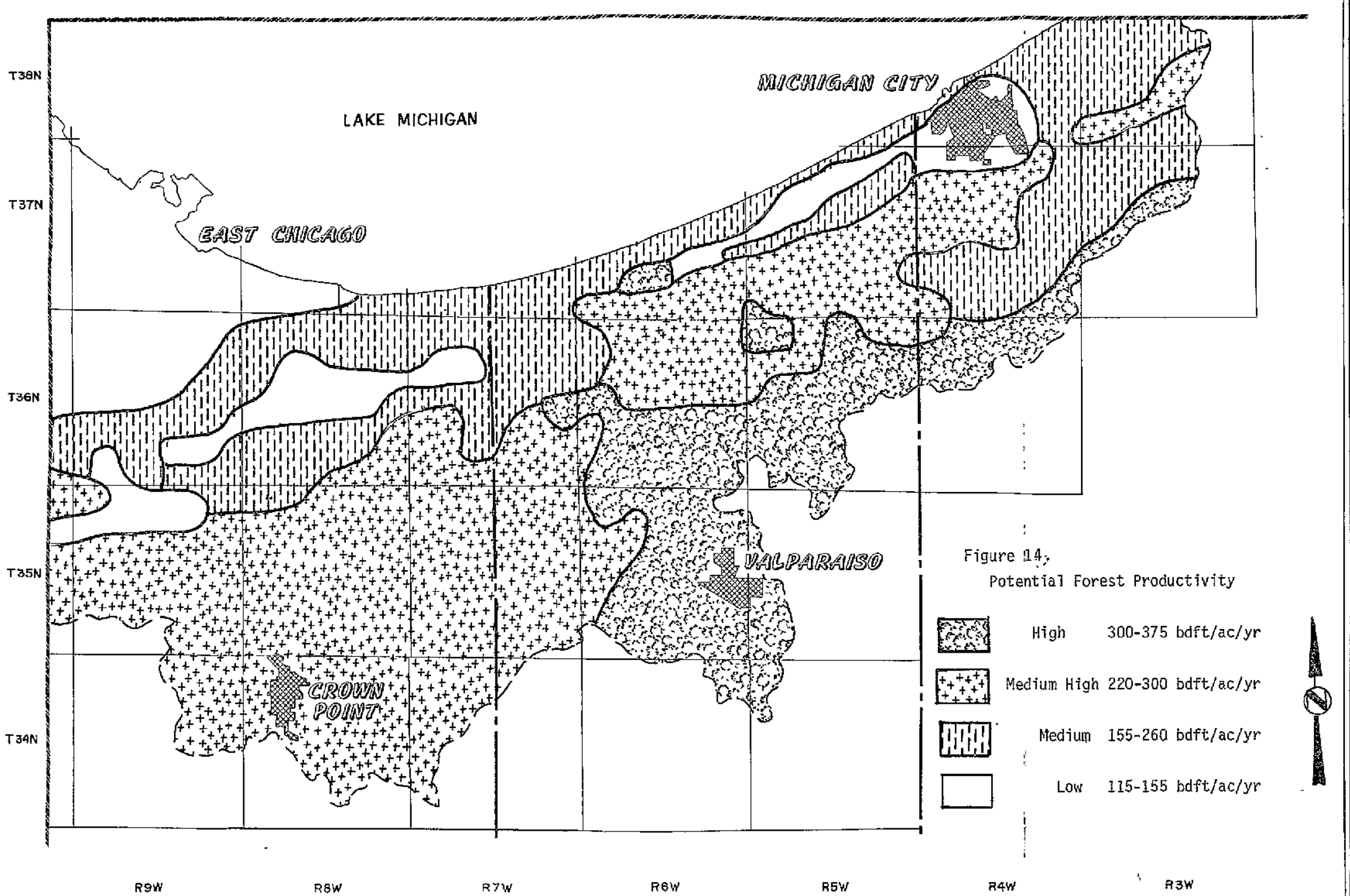


Figure 14. Potential Forest Productivity

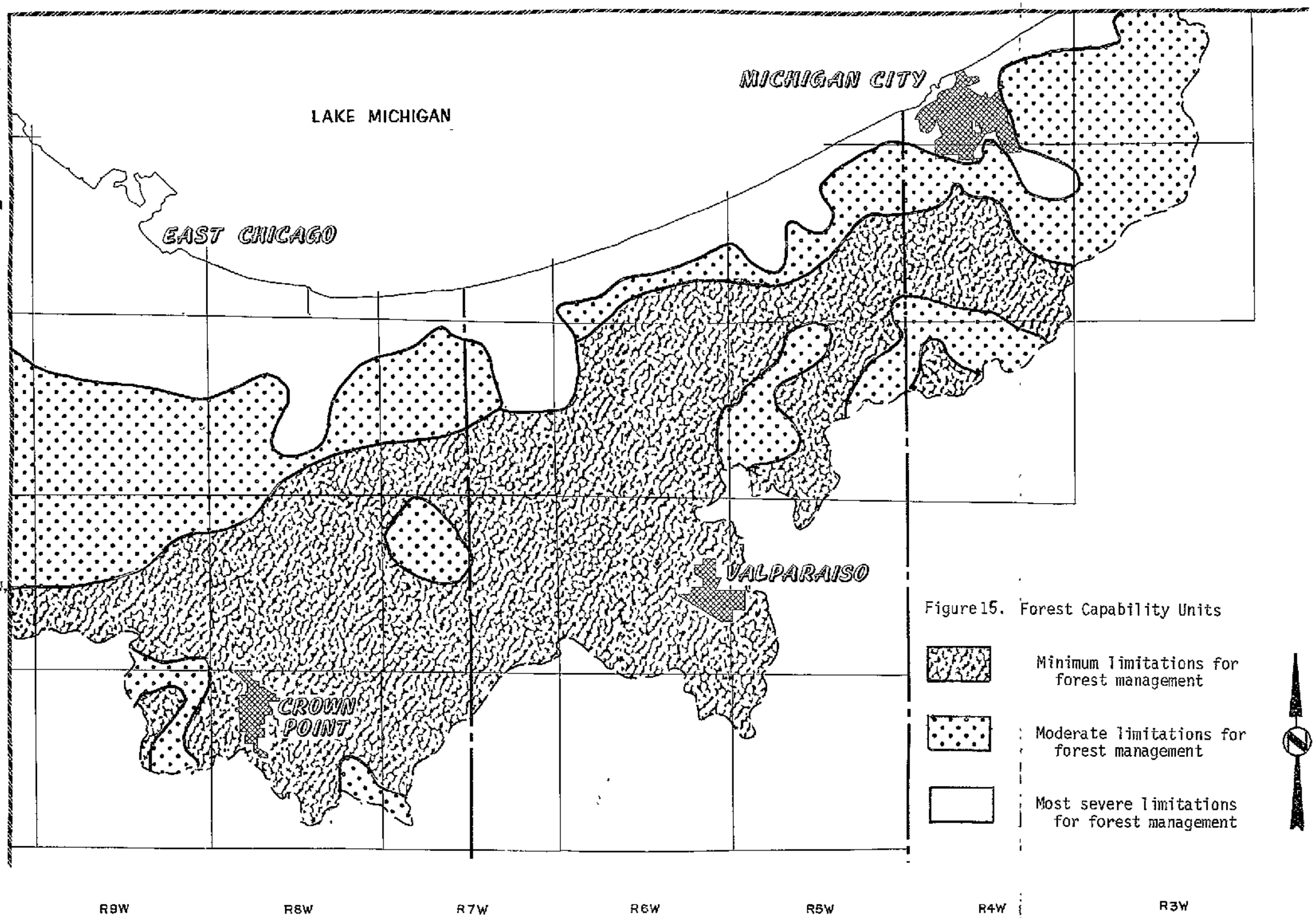


Figure 15. Forest Capability Units

Wildlife

Wildlife management in the oak-hickory forests is compatible with other management practices. These forests provide habitat, for numerous species. The enhancement of wildlife habitat usually occurs in conjunction with selective cutting or timber stand improvement practices. These practices produce small openings in the forest stand that encourage wildlife.

If wildlife is a highly desired element in a management scheme, specific activities should be pursued. Ideally, a manager should strive for a stand having a good distribution of size classes from saplings to mature sawtimber. Currently, forests of the coastal zone lack the ideal with regard to diameter distribution. However, through controlled thinnings and timber stand improvement methods stand structures could be modified. In order to make these activities economically feasible, these practices should be concentrated to forest areas growing on highly productive soils (figure 14).

Recreation

The coastal zone management area is located within easy reach of millions of people living around the fringe of Lake Michigan. Recreational opportunities are currently at a premium for such a large populace. The coastal zone forests along the lake and major water courses offer the potential for recreational development.

Figure 16 delineates areas where recreation is best suited for development. However, care should be taken when developing these areas to prevent misuse of the soils. The forests along the coast grow on

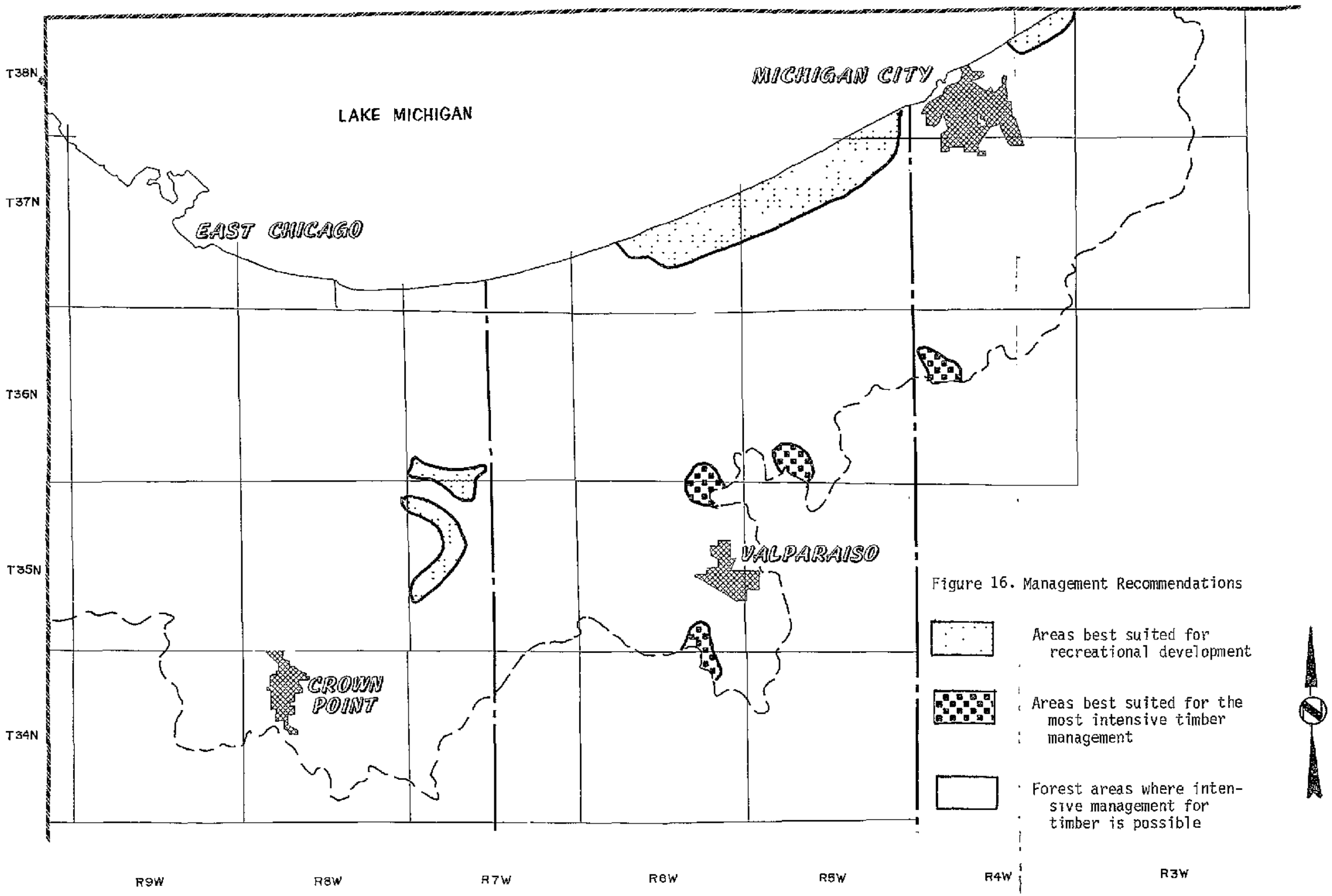


Figure 16. Management Recommendations

TABLE 6. DISTRIBUTION OF FOREST LAND BY SOIL CAPABILITY IN THE CZM.

ZONE	OCCUPANCY (PERCENT FOREST)	DESCRIPTION
I	40.5	No limitations due to excessive soil erosion or slope. Usually well drained soils.
II	4.0	Limitation because of slope or wetness and/or erosion hazards are more serious, and require care in management.
III	55.5	These soils have severe limitations, often due to excessive slopes and generally unstable soil profiles. These areas should have use restricted to activities which do not promote removal of the vegetation.

unstable soils prone to excessive wind and soil erosion. In these areas summer residences and large camping complexes should be kept to a minimum. The area is best suited to smaller recreational sites of a dispersed nature.

The area along Deep River should be managed for maximum protection of the stream course. Heavy development should not be permitted along the stream. Walking trails or camping/picnic facilities should be located with great care.

Timber

The potential for developing the timber resources of the coastal zone is best for areas growing on highly productive and least erodible site. These sites should be managed for forest production (fig. 16). Currently these areas are not optimally managed. Practices which would increase productivity in these stands should be encouraged.

Basically, silvicultural practices, primarily thinnings with some selective cuttings should be undertaken on these sites. These activities should be pursued with the objective of perpetuating oak regeneration and increasing stocking of the acceptable growing stock trees. If intensive management activities were pursued over a 40-or 50-year planning horizon an estimated 56 percent increase in timber value (using current timber price information) could be anticipated.

Currently, limited opportunities exist in the coastal zone to fully exploit the timber potential. Figure 17 shows the number of sawmills in the counties adjoining the study area. This lack of primary wood using industry in the CZM creates difficulty in marketing timber for top prices.

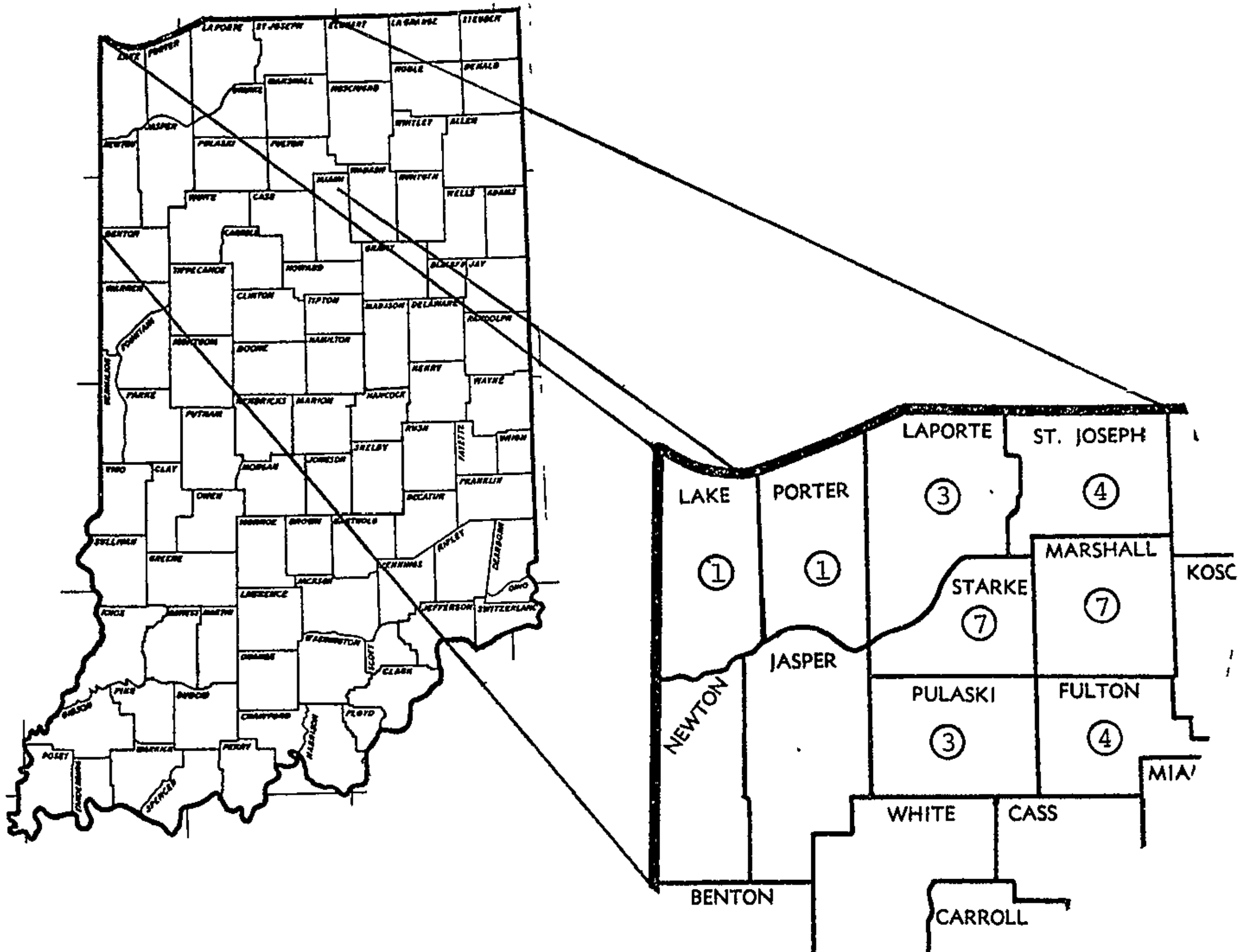


FIGURE 17. NUMBER OF SAWMILLS IN COUNTIES ADJOINING THE CZM.

CONCLUSIONS

This report culminates one phase of a cooperative program between LARS and the IDNR- Division of Forestry. The results of this two year effort, documented here and in previous semi-annual reports, can be summarized as follows:

- Computer-aided analysis of Landsat digital data can be effectively used to help characterize the central hardwood forest resource.
- Landsat classification provide timely information about the forest resource base which is not available elsewhere
- Spectral differencies of forest classes classified on Landsat data can be used as a basis to allocate field sample plots, and therefore, reduce costs associated with collecting the field data
- Landsat classifications in combination with ancillary information, such as soils maps provide a powerful tool to help the IDNR set priorities for forest management opportunities.

Empodied in the recommendations is the knowledge that use of remote sensing (i.e.: computer-assisted Landsat classifications) can benefit man. These benefits accure to the populace indirectly through legislative actions that protect and improve Indiana's forest resources. The

CZM study results and recommendations have identified the potential for various management alternatives. These recommendations will be translated into land use policies. Empowered by federal mandate, the State of Indiana will enforce these policies through zoning regulations designed to protect the coastal zone management area resources.

Landsat inputs, although minimal, form a critical base upon which the forest resource policies will develop. Without this remote sensing input the quantative data upon which to base this studies recommendations would not have been available. Remote Sensing has definately played an important role in shaping Coastal Zone Management policies for the forest resources in northern Indiana.

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Indiana Coastal Zone Management Project
Summarization and Sampling Program Documentation

PURPOSE OF THE PROGRAM

The name of this program is "SAMPLE". Its purpose is to summarize and sample from data collected on a township basis. Given the soil type of a cell with forest cover, the program assigns that cell a value for the soil's productivity, and a value for its capability. It then counts the total number of acres per productivity class and per capability unit on a section basis and a township basis. The number of cells per productivity class which need to be field-checked are calculated, and then are randomly selected from the township. See the following pages for more details.

THE EXEC ROUTINE

This program is written for a IBM 370 computer in fortran IV, G level, in conjunction with a CMS 360 exec routine. This exec routine has a file name of SAMPLE and a file type of EXEC. This means that whenever "SAMPLE" is typed on CMS mode, statements are defined and commands are carried out which are found in the file SAMPLE EXEC.
Contents of the exec file:

```
GLOBAL TXTLIB SSPLIB SKSLIB
FILEDEF 1 DSK LAKE SOIL
FILEDEF 2 DSK PORTER SOIL
FILEDEF 3 DSK LAPORTE SOIL
FILEDEF 4 DSK TWNSHP &1
FILEDEF 5 DSK SEED &2
FILEDEF 6 PRT
FILEDEF 8 DSK-T1 LRECL 10240 ETENT 36
GETDISK TEMP 5CYL CLEAR
LOAD SAMPLE
START SAMPLE
RELEASE 192 T (DET
```


The statement which begins the exec routine enables the program to have access to the scientific sub-program library, which is used to generate random numbers in this case. Access to the system library is also obtained.

Next follow seven statements which define program files:

Program file 1 is defined as the file which is on disc with the file name and file type of LAKE SOIL. Program file 2 is defined as the disc file PORTER SOIL, and program file 3 is defined as the disc file LAPORTE SOIL.

For the program files 4 and 5, another note of explanation needs to be made. In exec routines, an ampresand (&) may be used which will be exchanged for a value later on. This exchange is made when you are in CMS, and "SAMPLE", followed by a space and a number, is typed on the terminal. For example, with the exec statement:

FILEDEF 4 DSK TWNSHP &1

and when "SAMPLE 369" is typed in the CMS mode, the exec routine will be performed and the program file 4 will be defined as the disc file TWNSHP 369.

More than one value may be exchanged. The "1" placed after the ampersand in the FILEDEF 4 statement indicates that, in CMS, the first value typed after "SAMPLE" is typed will be exchanged for the &1, and the second value typed after "SAMPLE" will be exchanged for the & with the 2 placed after it, as in the FILEDEF 5 statement. The first and second values are separated by a space. When "SAMPLE 369 5" is typed in CMS, the exec routine will run with the program file 5 defined as the disc file SEED 5.

Program file 6 is defined as the printer, which means that when the program says to write things on file 6, the information will be printed as output.

Program file 8 is defined as a temporary disc with a specified format. This file also must be defined within the program with a fortran statement.

The exec routine also gets a temporary disc of five cylinders, clears all previous information and logs it into your system.

The next commands load for fortran program with the filename of SAMPLE, and begin its execution. Once the execution of the program is completed, device 192, which is the tempory disc, is detached from your system.

Therefore, to execute the program while CMS, simply type in SAMPLE followed by the TWNSHP file type you want, and with the SEED file type you want.

FORMAT OF INPUT

1). TWNSHP

There are five sources of input to this program. All are located on disc. The major data which the program works on is contained in the file with the name TWNSHP and of the type which is a series of three integers, depending on the particular TWNSHP for which you want the output. For example, a file called TWNSHP 369 means that the program will work on the data from township 36 N, range 9W. The other TWNSHP files follow a similar pattern.

The TWNSHP file contains the following information in the following format, all on one line. Each coordinate row and column combination which has data is on a separate line. The number in parenthesis is the number of spaces which the data may take, or the number of spaces between pieces of data.

County name (8), Township (3), Range (3), Section (2), Coordinate row (2), Coordinate column (2), Forest spectral class (2), (6), An end of section marker (3), Soil Symbol and slope (3), Erosion value of soil (1).

The end of section marker is either the letters ALL or HAF. When data for an entire section is available, use ALL. When data for less than an entire section is available, use HAF.

See page 5 for an example of the data in a TWNSHP file.

How data for a TWNSHP file was collected:

The data for a township was encoded on a section basis. Coded LANDSAT data for the section was used. Each section was divided into 256 2½-acre cells. A particular cell's location was defined by a coordinate system consisting of 16 rows and 16 columns, which also totals 256 cells. Information for the section was collected on each cell which had a forest spectral class in it, which included the spectral class, and the soil type found at that location. The soil type was found by using a soil map.

2. Soil file

For reasons of convenience, much of the information having to do with the soil type was not put into the TWNSHP file, but was put into different soil files, depending on the county in which the soil was located. The program matches this information with the soil types in TWNSHP.

The soil files have the name of either LAKE SOIL, PORTER SOIL, or LAPORTE SOIL. The following information is contained in these files, in the following format. The number in parenthesis is the number of spaces which the data may take on a line, or the number of spaces between pieces of data.

Soil symbol and slope (3), soil name (6), soil texture (6), erosion number (1), soil productivity class (1), soil capability unit (1).

See pages 6-9 for a copy of the information which is in the soil files.

3). SEED

The last file which is used as input is the file named SEED. The sub-program which calculates the random numbers calls for a seed with which to begin its calculations. This number should be a prime number. To avoid using the same random numbers for each TWNSHP file which is run through the program, a different seed is used for each TWNSHP file that is run. These each are simply contained within files with the name SEED and of type designated by a number. The file type simply differentiates one seed's file from another. Each file contains one seed.

HOW THE PROGRAM SAMPLES

The program gives the location of a particular number of 2½-acre cells which should be field-checked to find out what is actually growing in that cell.

When the data for each section is read and complied, it is stored on a temporary disc. The entire section's data takes up one line on the disc. Since there may be up to 36 sections included in a township, there may be up to 36 lines on the temporary disc. The section's data within the line where it is stored is made up of the following information for each 2½-acre cell:

The row coordinate of the cell
The column coordinate of the cell
The forest spectral class form the Landsat data
Whether data for the entire section was available or not,
(i.e. only entered for the last 2½ acre cell of the section.)
The soil symbol and slope
The soil's erosion value
The soil name
The soil texture
The soil's productivity class
The soil's capability unit
The section number.

Next, the number of 2½-acre sample cells required per productivity class is calculated. This is done by taking 1% of the number of 2½-acre cells which are in each productivity class. This number is rounded off to the nearest integer.

400 groups of random numbers are then called. The first two random numbers of the group are between 1 and 16, inclusive, and the third is between 1 and 36, inclusive. When a group of 3 random numbers is called, the third number points to a row on the temporary disc which contains the township information. That is, it points to a particular section's data. The first two random numbers then pick out a row and column coordinate location

of a 2½-acre cell in the section. If the soil productivity class of that cell is one from which a sample is required, that cell location, etc. is printed. If it is not, another group of 3 random numbers is tried. This is repeated until all the samples which are required have been found. Since there are many cells in a section with no forest spectral class and hence no productivity class, this procedure for finding the sample cells required may be repeated frequently. Since there are only 400 groups of random numbers, this procedure may not be repeated more than 400 times, however. Hopefully by then all the samples will have been found.

PROGRAM OUTPUT

The following is printed in the output:

For each section - County, Township, Range, Section number

An indication for whether all the data for section was available or not. (If all not available, an asterisk is beside the section no.)

No. acres per productivity class
No. acres per capability unit
Total no. of acres in all productivity classes
Total no. of acres in all capabilities units

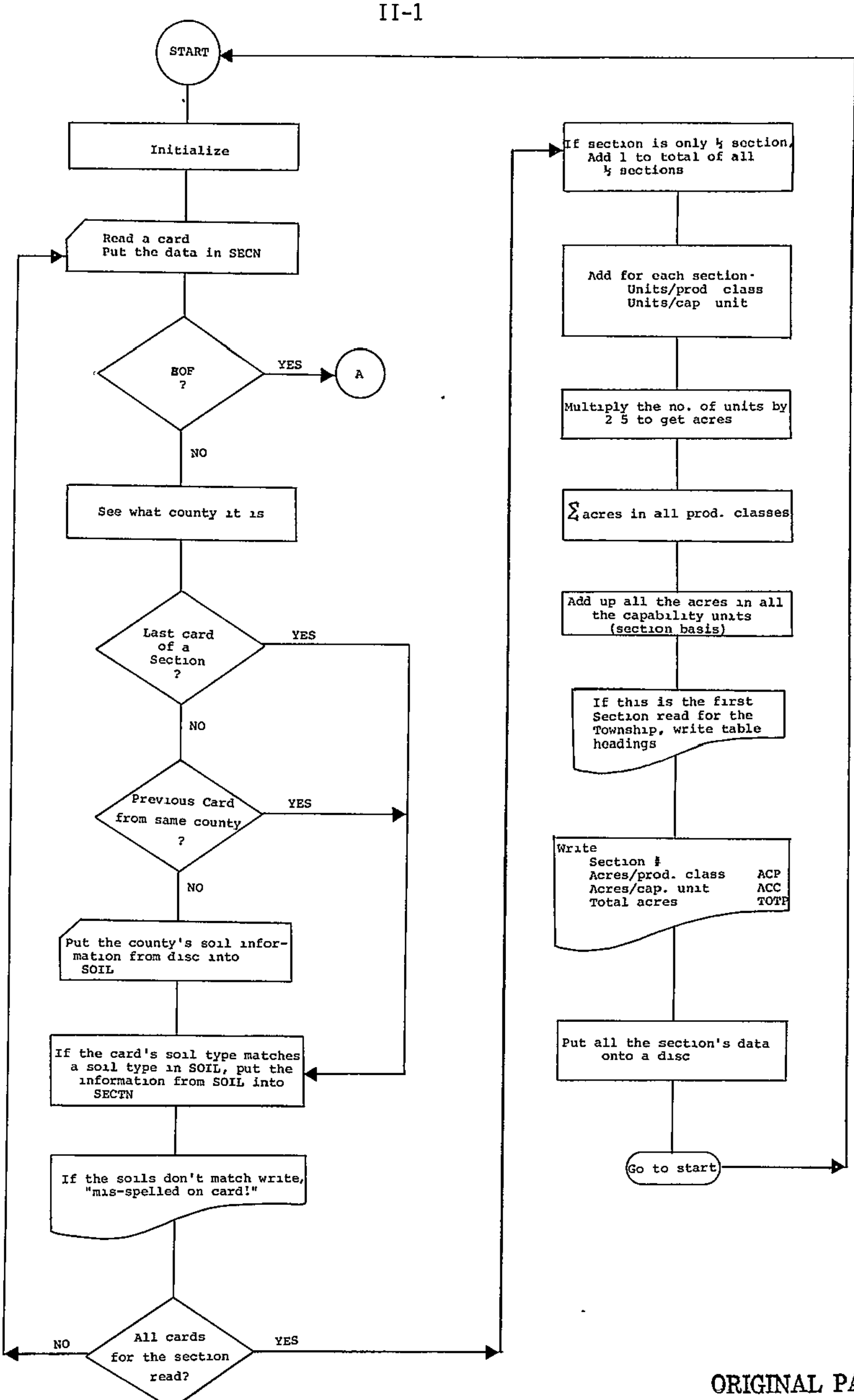
For the township - No. acres in each prod. class for all sections.
Total no. acres in all prod. classes for all sections.
No. acres in each cap. unit for all sections.
Total no. acres in all cap. units for all sections.

The no. of sections for which all the data was available minus the no. of sections for which not all the data was available (called a half-section).
Total no. of sections for which data was taken.
The no. of samples required per productivity class.
Total no. of samples required.
The seed which was used for the random number calculations.

For the sample cells - County
Township
Range
Section
Row Coordinate
Column Coordinate
Soil symbol and slope
Soil erosion value

Any "misspellings" of soil symbols in the TWNSHP file, with the section, row, and column of the misspelling.

The number of soil names (NUMB) in a county's soil file if there are more than 99.



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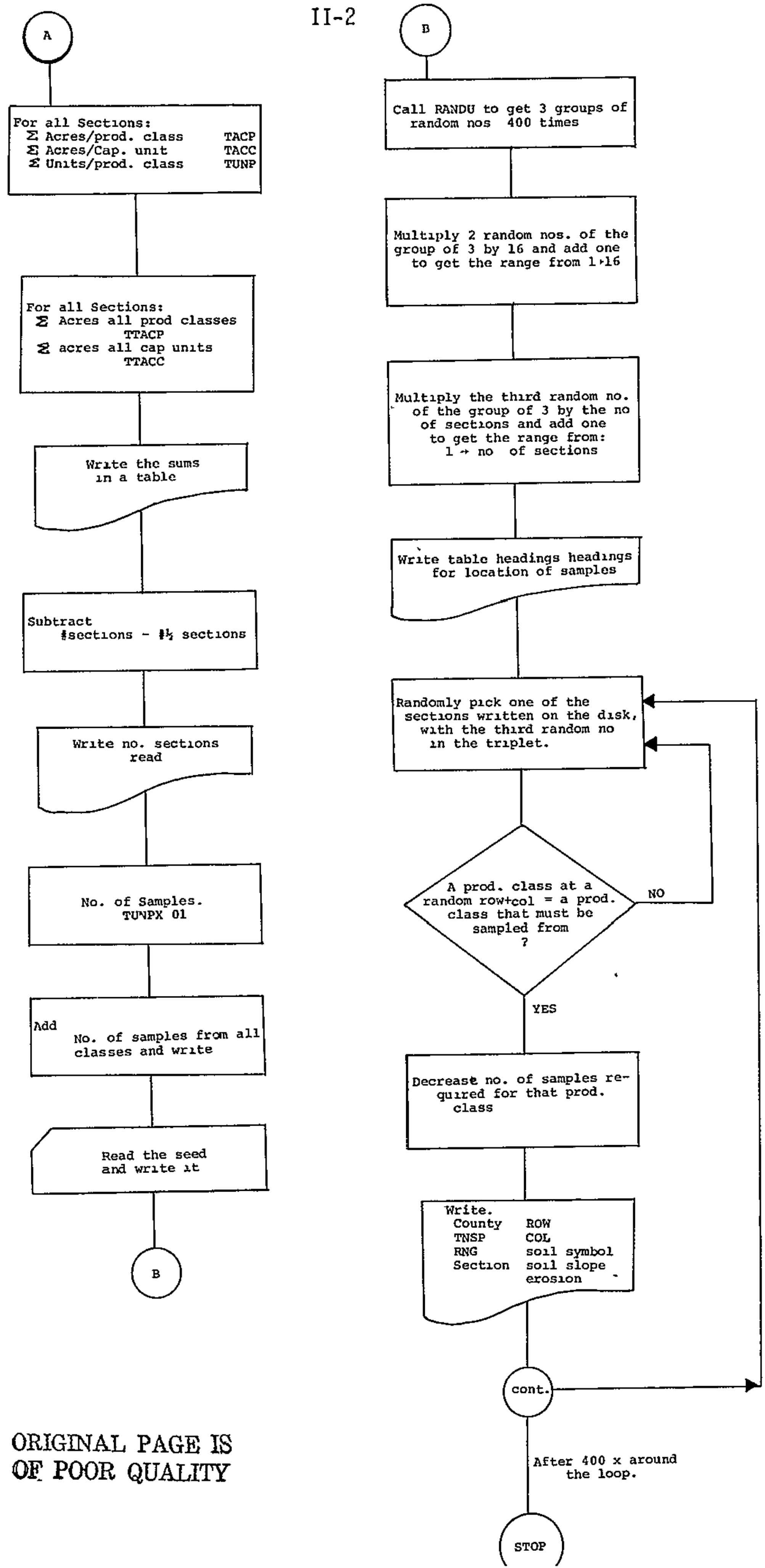

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```
FILE. . .      NEWSAMP  FORTRAN  P1
C              *****SUMMARIZATION AND SAMPLING PROGRAM*****
C
C    WRITTEN BY MARK BEAN
C    JUNE 28, 1977
C    INDIANA COASTAL ZONE MANAGEMENT PROJECT
C
C
C    GLOBAL TXTLIB SSPLIB SYSLIB
C    FILEDEF 1 DSK LAKE SOIL
C    FILEDEF 2 DSK PORTER SOIL
C    FILEDEF 3 DSK LAPORTE SOIL
C    FILEDEF 4 DSK TWNSHP A1
C    FILEDEF 5 DSK SEED A2
C    FILEDEF 6 PRT
C    FILEDEF 8 DSK-T1 LRECL 10240 BLKSIZE 10240 XTENT 36
C    GETDISK TEMP 5CYL CLEAR
C    LOAD SAMPLE
C    START SAMPLE
C    RELEASE 192 T (DET
C
C    ENTER 'ALL' IN COLUMNS 30-32 WHEN DATA FOR AN ENTIRE SECTION
C                HAS BEEN ENCODED.
C    ENTER 'HAF' IN COLUMNS 30-32 WHEN HALF OF THE DATA FOR A SECTION
C                HAS BEEN ENCODED, AND NO MORE DATA FOR THIS SECTION
C                IS AVAILABLE.
C
C
      INTEGER SOIL(100,6),SECTN(16,16,10),NSAMP(6),SEC,ROW,COL,ALL,HAF,
     1        BLANK,HOLD,PORT
      DIMENSION ACC(36,9),ACP(36,9),UNC(36,9),UNP(36,9),SAMP(6),
     1          NX(400),NY(400),NZ(400),TUNP(9),TACP(9),TACC(9)
      DATA ALL, BLANK, HAF,LAKE,PORT,LAPO  /'ALL ', '    ' , 'HAF',
     1     'LAKE','PORT','LAPO'/
      REAL *8 CNTY
      INTEGER *4 KEY
      EQUIVALENCE (CNTY,KEY)
      DEFINE FILE 8(36,2560,U,IPTR)
      IPTR=1
      HNO=0.
      TNO=0.
      NN1=1
      NN2=1
      NN3=1
      NO=1
C
C*****************************************************************************
C
C                    INITIALIZE AND READ A CARD
C
C*****************************************************************************
C
    5 CONTINUE
      DO 20 I=1,16
      DO 25 J=1,16
      DO 30 K=1,10
      SECTN(I,J,K)=0
   30 CONTINUE
   25 CONTINUE
   20 CONTINUE
      DO 21 I=1,100
      DO 22 J=1,6
      SOIL(I,J)=0
   22 CONTINUE
   21 CONTINUE
   12 HOLD = BLANK
      READ(4,300,END=140)CNTY,TNSP,RNG,SEC,ROW,COL,SECTN(ROW,COL,1),
     1   HOLD,(SECTN(ROW,COL,N),N=3,4)
  300 FORMAT(A8,2A3,3I2,6X,I3,A3,6X,A3,I1)
      SECTN(ROW,COL,2) = HOLD
      IF(KEY.EQ.LAKE)GO TO 6
      IF(KEY.EQ.PORT)GO TO 7
      IF(KEY.EQ.LAPO)GO TO 8
C
C*****************************************************************************
C
C          READ THE NO. OF SOIL TYPES, COUNTY NAME, AND SOIL DATA
C
C*****************************************************************************
```

```
FILE. . .     NEWSAMP  FORTRAN  P1
C
    6 REWIND 1
      IF(SECTN(ROW,COL,2).NE.ALL.AND.NN1.GE.2)GO TO 13
      IF(SECTN(ROW,COL,2).NE.HAF.AND.NN1.GE.2)GO TO 13
      READ(1,100)NUMB
  100 FORMAT (I3)
      IF(NUMB.GT.99)GO TO 980
      READ(1,200)((SOIL(I,J),J=1,6),I=1,NUMB)
  200 FORMAT(A3,2A6,3I1)
      NN1=NN1+1
      GO TO 13
    7 REWIND 2
      IF(SECTN(ROW,COL,2).NE.ALL.AND.NN2.GE.2)GO TO 13
      IF(SECTN(ROW,COL,2).NE.HAF.AND.NN2.GE.2)GO TO 13
      READ(2,100)NUMB
      IF(NUMB.GT.99)GO TO 980
      READ(2,200)((SOIL(I,J),J=1,6),I=1,NUMB)
      NN2=NN2+1
      GO TO 13
    8 REWIND 3
      IF(SECTN(ROW,COL,2).NE.ALL.AND.NN3.GE.2)GO TO 13
      IF(SECTN(ROW,COL,2).NE.HAF.AND.NN3.GE.2)GO TO 13
      READ(3,100)NUMB
      IF(NUMB.GT.99)GO TO 980
      READ(3,200)((SOIL(I,J),J=1,6),I=1,NUMB)
      NN3=NN3+1
      GO TO 13
C
C*********************************************************************
C
C                    SET THE SOIL DATA INTO THE SECTION ARRAY
C
C*********************************************************************
C
   13 IF(ROW.EQ.0)GO TO 80
      INUMB=NUMB+1
      DO 50 M=1,INUMB
      IF(SECTN(ROW,COL,3).NE.SOIL(M,1))GO TO 60
      SECTN(ROW,COL,5)=SOIL(M,2)
      SECTN(ROW,COL,6)=SOIL(M,3)
      SECTN(ROW,COL,8)=SOIL(M,5)
      SECTN(ROW,COL,9)=SOIL(M,6)
      GO TO 52
   60 IF(M.EQ.INUMB)GO TO 55
   51 CONTINUE
   50 CONTINUE
   52 INUMB=INUMB-1
      SECTN(ROW,COL,10) = SEC
      IF(SECTN(ROW,COL,2).EQ.ALL)  GO TO 80
      IF(SECTN(ROW,COL,2).EQ.HAF)  GO TO 80
      GO TO 12
C
C*********************************************************************
C
C                       INITIALIZE AND ACCUMULATE
C                            (SECTION BASIS)
C
C*********************************************************************
C
   80 CONTINUE
      NN1=1
      NN2=1
      NN3=1
      IF(SECTN(ROW,COL,2).EQ.HAF) HNO = HNO + 0.5
      DO 90 J=1,9
      ACC(NO,J)=0.
      ACP(NO,J)=0.
      UNC(NO,J)=0.
      UNP(NO,J)=0.
   90 CONTINUE
      DO 110 I=1,16
      DO 115 J=1,16
      DO 120 K=1,9
      IF(SECTN(I,J,8).EQ.K)UNP(NO,K)=UNP(NO,K)+1.
      IF(SECTN(I,J,9).EQ.K)UNC(NO,K)=UNC(NO,K)+1.
  120 CONTINUE
  115 CONTINUE
  110 CONTINUE
```

FILE. . .   NEWSAMP   FORTRAN   P1

```
C
C*******************************************************************
C
C            CALCULATE ACRES, TOTAL, AND WRITE
C
C*******************************************************************
C
      TOTC=0.
      TOTP=0.
      DO 130 J=1,9
      ACP(NO,J)=UNP(NO,J)*2.5
      ACC(NO,J)=UNC(NO,J)*2.5
      TOTP=ACP(NO,J)+TOTP
      TOTC=ACC(NO,J)+TOTC
  130 CONTINUE
      IF(NO.EQ.1)GO TO 106
      IF(SECTN(ROW,COL,2).EQ.HAF) GO TO 107
      GO TO 108
  106 WRITE(6,640)CNTY,TNSP,RNG
  640 FORMAT(1H1//15X,'COUNTY ',A8,3X,'TOWNSHIP ',A3,5X,'RANGE ',A3,
     1////17X,'ACRES PER PRODUCTIVITY CLASS', 24X,'ACRES PER ',
     2'CAPABILITY UNIT',/1X,'SECTION',4X,'1',6X,'2',6X,'3',
     36X,'4',6X,'5',6X,'6',9X,'1',6X,'2',6X,'3',6X,'4',6X,'5',6X,'6',6X,
     4'7',6X,'8',6X,'9')
      GO TO 108
  107 WRITE(6,603)SEC,(ACP(NO,I),I=1,6),(ACC(NO,J),J=1,9),TOTP
  603 FORMAT(/3X,I2,'*',4X,F5.1,2X,F5.1,2X,F5.1,2X,F5.1,2X,F5.1,2X,F5.1
     1,4X,9(F5.1,2X),4X,F5.1)
      GO TO 109
  108 WRITE(6,602)SEC,(ACP(NO,I),I=1,6),(ACC(NO,J),J=1,9)
  602 FORMAT(/3X,I2,5X,F5.1,2X,F5.1,2X,F5.1,2X,F5.1,2X,F5.1,2X,F5.1,4X,
     19(F5.1,2X),4X,F5.1)
  109 WRITE(8'IPTR)SECTN
      NO=NO+1
      GO TO 5
C
C*******************************************************************
C
C                  INITIALIZE, ACCUMULATE, AND WRITE
C                         (TOWNSHIP BASIS)
C
C*******************************************************************
C
  140 NO=NO-1
      DO 150 I=1,9
      TACP(I)=0.
      TACC(I)=0.
      TUNP(I)=0.
  150 CONTINUE
      TTACP=0.
      TTACC=0.
      DO 160 J=1,9
      DO 165 I=1,NO
      TACP(J)=ACP(I,J)+TACP(J)
      TACC(J)=ACC(I,J)+TACC(J)
      TUNP(J)=UNP(I,J)+TUNP(J)
  165 CONTINUE
  160 CONTINUE
      DO 166 J=1,9
      TTACP=TACP(J)+TTACP
      TTACC=TACC(J)+TTACC
  166 CONTINUE
      WRITE(6,641)CNTY,TNSP,RNG
  641 FORMAT(1H1//15X,'COUNTY ',A8,3X,'TOWNSHIP ',A3,5X,'RANGE ',A3)
      WRITE(6,650)(K,TACP(K),K=1,6)
  650 FORMAT(//////////20X,'TOTAL ACRES PER PRODUCTIVITY CLASS',/20X,
     1 34(1H=)//25X,'PROD.',14X,'ACRES',/25X,'CLASS',//6(27X,I1,15X,F6.1
     2 /))
      WRITE(6,660)TTACP
  660 FORMAT(25X,'TOTAL',12X,F7.1)
      WRITE(6,670)(K,TACC(K),K=1,9)
  670 FORMAT(/////////21X,'TOTAL ACRES PER CAPABILITY UNIT'/21X,31(1H=)/
     1 /27X,'CAP.',12X,'ACRFS',/27X,'UNIT',//9(28X,I1,13X,F6.1/))
      WRITE(6,680)TTACC
  680 FORMAT(26X,'TOTAL',10X,F7.1)
      TNO = FLOAT(NO) - HNO
      WRITE(6,605)TNO,NO
  605 FORMAT(/////5X,'NO. OF SECTIONS MINUS HALF SECTIONS = ',F4.1//5X,'
```

FILE. . .   NEWSAMP FORTRAN P1

```
     1      TOTAL NO. OF SECTIONS = ',I2)
C
C**********************************************************************
C
C         CALCULATE NO. OF SAMPLES REQUIRED, AND PRINT
C
C**********************************************************************
C
      NSAM=0
      DO 190 I=1,6
      SAMP(I)=TUNP(I)*.01
      NSAMP(I)=SAMP(I)+0.5
      NSAM=NSAM+NSAMP(I)
  190 CONTINUE
      WRITE(6,690)(I,NSAMP(I),I=1,6),NSAM
  690 FORMAT(1H1//22X,'NO. OF SAMPLE CELLS PER PRODUCTIVITY CLASS'//29X,
     1'PROD.',15X,'SAMPLES'//6(31X,I1,20X,I2/)/,30X,'TOTAL',16X,I3)
C
C**********************************************************************
C
C           CALL 400 RANDOM NOS. IN GROUPS OF 3
C
C**********************************************************************
C
      READ (5,400)IX
  400 FORMAT (I5)
      WRITE(6,405)IX
  405 FORMAT(/5X,' SEED = ',I5)
      DO 210 I=1,400
      CALL RANDU(IX,IY,YF)
      IX=IY
      NX(I)=YF*16+1
      CALL RANDU(IX,IY,YF)
      IX=IY
      NY(I)=YF*16+1
      CALL RANDU(IX,IY,YF)
      IX=IY
      NZ(I)=YF*NO+1
  210 CONTINUE
C
C**********************************************************************
C
C           SAMPLE THE TOWNSHIP, DECREASE NO. OF SAMPLES REQUIRED,
C                                AND PRINT
C
C**********************************************************************
C
      WRITE(6,689)
      DO 220 I=1,400
      IPTR=NZ(I)
      READ(8'IPTR)SECTN
      IF(SECTN(NX(I),NY(I),8).EQ.1.AND.NSAMP(1).GT.0)GO TO 222
      IF(SECTN(NX(I),NY(I),8).EQ.2.AND.NSAMP(2).GT.0)GO TO 223
      IF(SECTN(NX(I),NY(I),8).EQ.3.AND.NSAMP(3).GT.0)GO TO 224
      IF(SECTN(NX(I),NY(I),8).EQ.4.AND.NSAMP(4).GT.0)GO TO 225
      IF(SECTN(NX(I),NY(I),8).EQ.5.AND.NSAMP(5).GT.0)GO TO 226
      IF(SECTN(NX(I),NY(I),8).EQ.6.AND.NSAMP(6).GT.0)GO TO 227
      GO TO 219
  222 NSAMP(1)=NSAMP(1)-1
      WRITE(6,691)CNTY,TNSP,RNG,SECTN(NX(I),NY(I),10),NX(I),NY(I)
     1,SECTN(NX(I),NY(I),3),SECTN(NX(I),NY(I),4)
      GO TO 219
  223 NSAMP(2)=NSAMP(2)-1
      WRITE(6,692)CNTY,TNSP,RNG,SECTN(NX(I),NY(I),10),NX(I),NY(I)
     1,SECTN(NX(I),NY(I),3),SECTN(NX(I),NY(I),4)
      GO TO 219
  224 NSAMP(3)=NSAMP(3)-1
      WRITE(6,693)CNTY,TNSP,RNG,SECTN(NX(I),NY(I),10),NX(I),NY(I)
     1,SECTN(NX(I),NY(I),3),SECTN(NX(I),NY(I),4)
      GO TO 219
  225 NSAMP(4)=NSAMP(4)-1
      WRITE(6,694)CNTY,TNSP,RNG,SECTN(NX(I),NY(I),10),NX(I),NY(I)
     1,SECTN(NX(I),NY(I),3),SECTN(NX(I),NY(I),4)
      GO TO 219
  226 NSAMP(5)=NSAMP(5)-1
      WRITE(6,695)CNTY,TNSP,RNG,SECTN(NX(I),NY(I),10),NX(I),NY(I)
     1,SECTN(NX(I),NY(I),3),SECTN(NX(I),NY(I),4)
      GO TO 219
```

FILE. . .   NEWSAMP FORTRAN P1

```
  227 NSAMP(6)=NSAMP(6)-1
      WRITE(6,696)CNTY,TNSP,RNG,SECTN(NX(I),NY(I),10),NX(I),NY(I)
     1,SECTN(NX(I),NY(I),3),SECTN(NX(I),NY(I),4)
      GO TO 219
  689 FORMAT(/////51X,'COORDINATE LOCATION OF SAMPLES'/51X,30(1H=)//
     110X,'COUNTY',8X,'TOWNSHIP',8X,'RANGE',8X,'SECTION',8X,'ROW',
     28X,'COLUMN',8X,'PROD. CLASS',7X,'SOIL SYMB.'//10X,
     3114(1H-)///)
  691 FORMAT(11X,A8,7X,A3,11X,A3,11X,I2,12X,I2,11X,I2,15X,'1',16X,A3,//)
  692 FORMAT(11X,A8,7X,A3,11X,A3,11X,I2,12X,I2,11X,I2,15X,'2',16X,A3,//)
  693 FORMAT(11X,A8,7X,A3,11X,A3,11X,I2,12X,I2,11X,I2,15X,'3',16X,A3,//)
  694 FORMAT(11X,A8,7X,A3,11X,A3,11X,I2,12X,I2,11X,I2,15X,'4',16X,A3,//)
  695 FORMAT(11X,A8,7X,A3,11X,A3,11X,I2,12X,I2,11X,I2,15X,'5',16X,A3,//)
  696 FORMAT(11X,A8,7X,A3,11X,A3,11X,I2,12X,I2,11X,I2,15X,'6',16X,A3,//)
  219 CONTINUE
  220 CONTINUE
      GO TO 900
  980 WRITE(6,695)NUMB
  697 FORMAT(/5X,'NUMB = ',I4)
      GO TO 900
   55 WRITE(6,56) SEC,ROW,COL
   56 FORMAT(/5X,'YOU HAVE MIS-SPELLED A SOIL SYMBOL!  ',/5X,'SECTION',
     1   I3,3X,'ROW',I3,4X,'COL',I3)
      GO TO 51
  900 STOP
      END
```

```
FILE. . .      LAKE      SOIL      P1

072LAKE
AD  ALIDA   FSL 23
AL  ALIDA     L 22
BLABLOUNT   SIL 22
BN   BONO   SIC 23
BP BORROW    XX 68
BR  BRADY   FSL 33
BSB BREMS    FS 34
CA CARLIS     M 63
CP CLAYPI     C 68
DA DARROC     L 62
DE DELREY   SIL 22
DL DELREYSILDCV 22
DOA  DOOR     L 61
DOB  DOOR     L 62
DRB  DOOR SICLS 62
DU DUNELD    XX 68
EL ELLIOT   SIL 62
GD GILFOR   FSL 42
GF GILFOR  MFSL 42
GM GILFOR     L 42
GP GRAVEL    XX 68
LB LAKEBE    XX 68
LM LINWOO     M 63
LYALYDICK     L 61
LYBLYDICK     L 62
MABMARKHA   SIL222
MB MARLBD    XX 66
MH  MARSH    XX 68
MM MAUMEE   LFS 43
MN MAUMEE   SIL 43
MO MILFOR  SILO 22
MR MILFOR  SICL 22
MS MILFORSICLSA 22
MT MILFOR    XX 22
MUBMORLEY   SIL 22
MUCMORLEY   SIL223
MUDMORLEY   SIL224
MUEMORLEY   SIL 26
MVBMORLEY  SICL323
MVCMORLEY  SICL324
MVEMORLEY  SICL327
OAEOAKVIL    FS 38
OKBOAKVIL    XX 38
SP SANDPI    XX 68
OSAOSHTEM   FSL 33
OSBOSHTEM   FSL 33
OSCOSHTEM   FSL 33
PC PEWAMO  SICL 22
PE PEWAMOSICLCV 22
PLBPLAINF    FS 34
PLCPLAINF    FS 34
RE RENSSL     L 22
RN RENSSL   LSS 22
RR RENSSL  MLSS 22
RS RENSSL  LCSV 22
RE RENSSL     L 22
SPBSPARTA    FS 64
SRBSPARTAFSSICL 63
TA  TAWAS     M 63
TCA TRACY     L 11
TCB TRACY     L 12
TCC TRACY     L 13
TRB TRACY LSICL 12
TYB TYNER   LFS 33
UR  URBAN    XX 68
WA WALLKI   SIL 62
WE WARNER    SL 66
WR WARNER   SIL 66
WK WATSEK   LFS 64
WL WATSEK LSMDV 62
WO WASEON   FSL 22
WT WHITAK     L 22
```

FILE. . . TWNSHP 357 P1

PORTER	35N07W010213	4	ELA
PORTER	35N07W010214	4	ELA
PORTER	35N07W010215	3	ELA
PORTER	35N07W010216	4	ELA
PORTER	35N07W010311	4	ELA
PORTER	35N07W010411	4	ELA
PORTER	35N07W011309	4	ELA
PORTER	35N07W011310	4	ELA
PORTER	35N07W011311	4	ELA
PORTER	35N07W011312	4	ELA
PORTER	35N07W011313	4	ELA
PORTER	35N07W011316	4	MRB
PORTER	35N07W011409	4	ELA
PORTER	35N07W011410	4	ELA
PORTER	35N07W011411	4	ELA
PORTER	35N07W011412	4	ELA
PORTER	35N07W011413	4	ELA
PORTER	35N07W011414	4	PE
PORTER	35N07W011415	4	PE
PORTER	35N07W011416	4	PE
PORTER	35N07W011513	4	MRB2
PORTER	35N07W011516	4ALL	PE
PORTER	35N07W020603	4	HK
PORTER	35N07W020701	3	SO
PORTER	35N07W020702	2	SO
PORTER	35N07W020703	3	SO
PORTER	35N07W020704	3	SO
PORTER	35N07W020801	4	WT
PORTER	35N07W020802	3	MRE2
PORTER	35N07W020803	4	HK
PORTER	35N07W020901	4	HK
PORTER	35N07W020902	3	HK
PORTER	35N07W021001	3	HK
PORTER	35N07W021002	2	HK
PORTER	35N07W021010	2	SO
PORTER	35N07W021105	1	SO
PORTER	35N07W021205	1	SO
PORTER	35N07W021206	1	WT
PORTER	35N07W021207	1	WT
PORTER	35N07W021209	1	HK
PORTER	35N07W021211	1	BAA
PORTER	35N07W021305	2	HK
PORTER	35N07W021308	4	HK
PORTER	35N07W021309	4	HK
PORTER	35N07W021310	3	BAA
PORTER	35N07W021312	4	BAA
PORTER	35N07W021315	3	BAA
PORTER	35N07W021405	3	HK
PORTER	35N07W021408	4	HK
PORTER	35N07W021410	4	WT
PORTER	35N07W021505	1	HK
PORTER	35N07W021506	1	WT
PORTER	35N07W021507	3	WT
PORTER	35N07W021605	1	SB
PORTER	35N07W021607	1ALL	SB
PORTER	35N07W030302	1	DE
PORTER	35N07W030303	2	DE
PORTER	35N07W030401	3	MQ
PORTER	35N07W030402	4	MQ
PORTER	35N07W030404	1	WT
PORTER	35N07W030506	2	MRB2
PORTER	35N07W030605	2	MQ
PORTER	35N07W030606	2	MQ
PORTER	35N07W030607	2	WT
PORTER	35N07W030608	2	WT
PORTER	35N07W030705	2	WT
PORTER	35N07W030706	2	WT
PORTER	35N07W030707	2	MQ
PORTER	35N07W030709	3	MQ
PORTER	35N07W030716	2	WT
PORTER	35N07W030806	1	MQ
PORTER	35N07W030807	1	MQ
PORTER	35N07W030809	3	SB
PORTER	35N07W030810	1	SB
PORTER	35N07W030811	1	SB
PORTER	35N07W030812	1	SB
PORTER	35N07W030813	3	SB
PORTER	35N07W030816	4	HK