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COMPUTER AUGMENTATION of SOIL SURVEY

INTERPRETATION for REGIONAL PLANNING APPLICATIONS

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ABSTRACT

Interpreted soil data are a needed ingredient in all levels of the planning process; however, with (1) the time delay between soil scientists' field work and published soil maps and (2) the changing variety of soil interpretations needed by planners, much of the potential usefulness is lost. A joint working agreement between the Oak Ridge National Laboratory Regional Environmental Systems Analysis Program, the Computer Sciences Division, and the State of Tennessee Soil Conservation Service has resulted in the development of a computer information system which accepts raw field data, thereby allowing soil interpretations to be made and mapped quickly. Steps to implement the system include: (1) generation of computer-drawn field sheet grid overlays, (2) delineation of gridded soil boundaries by soil scientists, (3) digitization of these soil boundaries, (4) production and editing of quick-look soil maps, (5) computer generation of various scale soil maps, and (6) soil interpretation and mapping. Utilizing such a system has allowed decisions to be made easily concerning definition of soil boundaries, soil interpretations, etc. These interpretation maps may then be integrated into the planning process by the regional planner. Implementation of this system has produced solutions to many problems of both soil scientists and planners, thus closing the gap between the two sciences.

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INTRODUCTION

For many years one of the primary variables in the management of agricultural lands has been soil survey data. More recently, the growing needs for environmental data in the field of planning and the broad context of land management have resulted in an increasing need for additional soil data and expanded interpretation information. Due to the urgency of planning decisions and the time frame in which they are made, it becomes imperative that data on field sheets be developed into a preliminary usable form and immediately incorporated into the planning process. This paper describes a procedure designed to overcome these two problems by (1) putting soil scientists' field sheet data directly into a computer information system that maps the soil boundaries at various scales and (2) allowing soil interpretations to be made and mapped quickly and easily, as overlays to be used on the planners' pertinent maps (i.e., comprehensive plans, zoning, and tax maps).

The Oak Ridge National Laboratory/Regional Environmental Systems Analysis Program is developing planning tools to evaluate the consequences of various planning alternatives and growth policies. Inherent in such an endeavor is the need for many diverse types of data (e.g., soils, existing land-use configuration, land-ownership characteristics). In parallel, soil scientists are gathering basic field data but are unable to distribute the information quickly in a final form that can

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be applied by a diverse range of users. A unique working arrangement between the State of Tennessee Soil Conservation Service (SCS) and the Regional Environmental Systems Analysis (RESA) Program was developed from these needs. The SCS provides the scientific understanding of soil mapping and interpretations; the RESA Program contributes the technical knowledge and impetus to link the science and technology into tools that advance the state of the art within the planning process. Besides solving problems pertinent to soil scientists and planners, the interdisciplinary working arrangement has the added benefit of closing the gap between the two sciences and advancing them in unison.

The computer software system described in this paper represents one part of a comprehensive geographical information system, ORRMIS,[1] which is being developed to meet the information processing needs of the RESA program. The ORRMIS system (Oak Ridge Regional Modeling Information System) consists of a series of subsystems with each subsystem having several components. The subsystem which involves processing of geographical data, primarily in a gridded form, is known as the ORRMIS Geographical Data Subsystem. The software component of this subsystem which deals with the manual digitization of data and the creation of two-dimensional computer maps is known as MAPGEN.[2] Thus, this report describes the application of MAPGEN to the problem of digitizing, displaying, and interpreting soil survey data. For a very detailed description of MAPGEN, the reader is referred to the report, "MAPGEN - A Computer-Aided Digitization, Analysis, and Display System for Geographical Information."[2]

DESCRIPTION AND USE OF THE SYSTEM

Selection of Data Sources

Soil data exist primarily in two different forms: (1) field sheets (black and white aerial photographs at a scale of 1:15,840) where the soil boundaries identify both soil types and phases, and (2) published soil maps and county soil surveys (photomosaic soil maps). Both types of information have increased potential if they can be put into a readily usable form that allows for new interpretations (i.e., planning needs ranging from a regional land management scale through regulation and control of subdivisions). In Tennessee several counties were mapped many years ago and published maps exist; however, much of the terminology has changed, and there is a need to update the data. Also, many counties have current soil surveys that could be enhanced with additional updated soil interpretations. The most significant value comes from the system's potential ability to take field data through the mapping and interpretation stage in a very short period of time. A soil scientist could literally delineate soil boundaries on the field sheets in the morning, digitize the maps, and make interpretations for the planner that afternoon.

For the initial phase of the joint RESA/SCS project, two counties were selected for entry into this system, and work is being done on both counties in parallel. Hamilton County, Tennessee, is currently in the process of being mapped. Only a small number of the field sheets (Figure 1) already exist; therefore, they are being digitized as the field work proceeds. Henry County, Tennessee, was mapped in 1940 and the published survey consisting of 1:15,840 scale maps (Figure 2) has

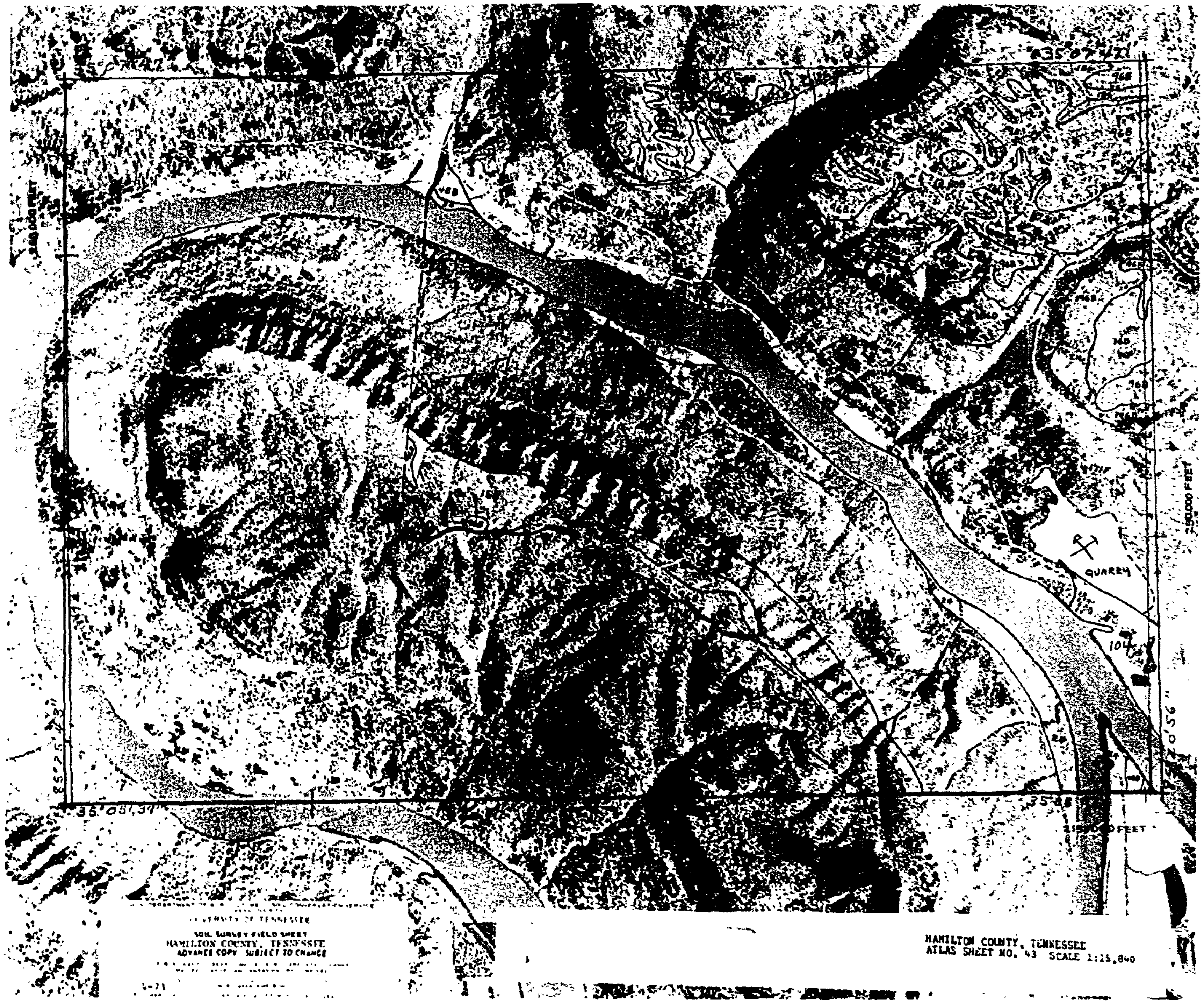

Figure 1. Hamilton County, Tennessee, Soil Survey Field Sheet

Figure 2. Henry County, Tennessee, Published Soil Survey Map

the soils grouped by type and agricultural management units. This county was selected because the survey was in need of update both in interpretation and in redefining soil boundaries.

Choice of Grid Size

The selection of the grid size should be responsive both to the requirements of the data (the use to which it will be put and the questions which will be asked of it) and the original resolution of the soil boundaries (the smallest mapping unit used at the original 1:15,840 scale). To establish the grid size to be used in this Tennessee project, the RESA/SCS work group held a series of workshop sessions. Participants included people from the disciplines of soil science, regional planning, and computer science. A study was conducted that required soil scientists to redefine the soil boundaries by grid assignment. This consisted of using three grids of approximately 1, 5, and 20 acres. Each soil scientist assigned a dominant soil body (phase data) to each cell on the grid overlays. It soon became apparent that use of the smallest (1-acre) grid was superior for the following reasons: (a) The time spent to assign a soil body to a cell was less if the cells only contained one or two soils; therefore, the larger the cell, the more time it took to make decisions regarding each cell assignment. It took less time to assign twenty 1-acre cells than one 20-acre cell. (b) The original resolution of the 1:15,840 data has a unit of slightly less than one acre as its smallest soil body, and, by using the small grids, those areas were not excluded from the data base.

A series of interpretations were made at the workshops that are usable in a variety of planning applications. The dialogue that developed between the soil scientists and planners was very useful because it further identified the appropriate cell size that should be used when extracting source digital data. An example of this is the planner's need to aggregate soil data to a higher level (i.e., regional, county and subdivision scales). Once soil boundaries have been assigned to a grid, aggregation can only go to a higher grid level. Thus, it was decided that the finer grid was most functional from the user's viewpoint and also responded to the quality and resolution of the source information delineated by the soil scientist. The cell size used in this Tennessee project is 2.5"* or 1.18 acres.

Generation of Grid Lattices

Once the grid size had been chosen on which the soil data was to be digitized, it was necessary to generate a grid lattice which may be overlaid on top of the field sheet or existing soil map. This lattice is drawn by the computer on a sheet of transparent Mylar and consists of a series of points representing the four corners of each cell on the grid as shown in Figure 3. This lattice is drawn to the scale and map projection of the specific field sheet or the existing soil map. In order for the computer to draw a lattice for an existing soil map, the boundary of the study area must be specified by its northern and southern latitudes and its eastern and western longitudes.

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*A 2.5-second (") cell is defined as the area bounded by latitude and longitude lines which are integral multiples of 2.5 seconds of arc.

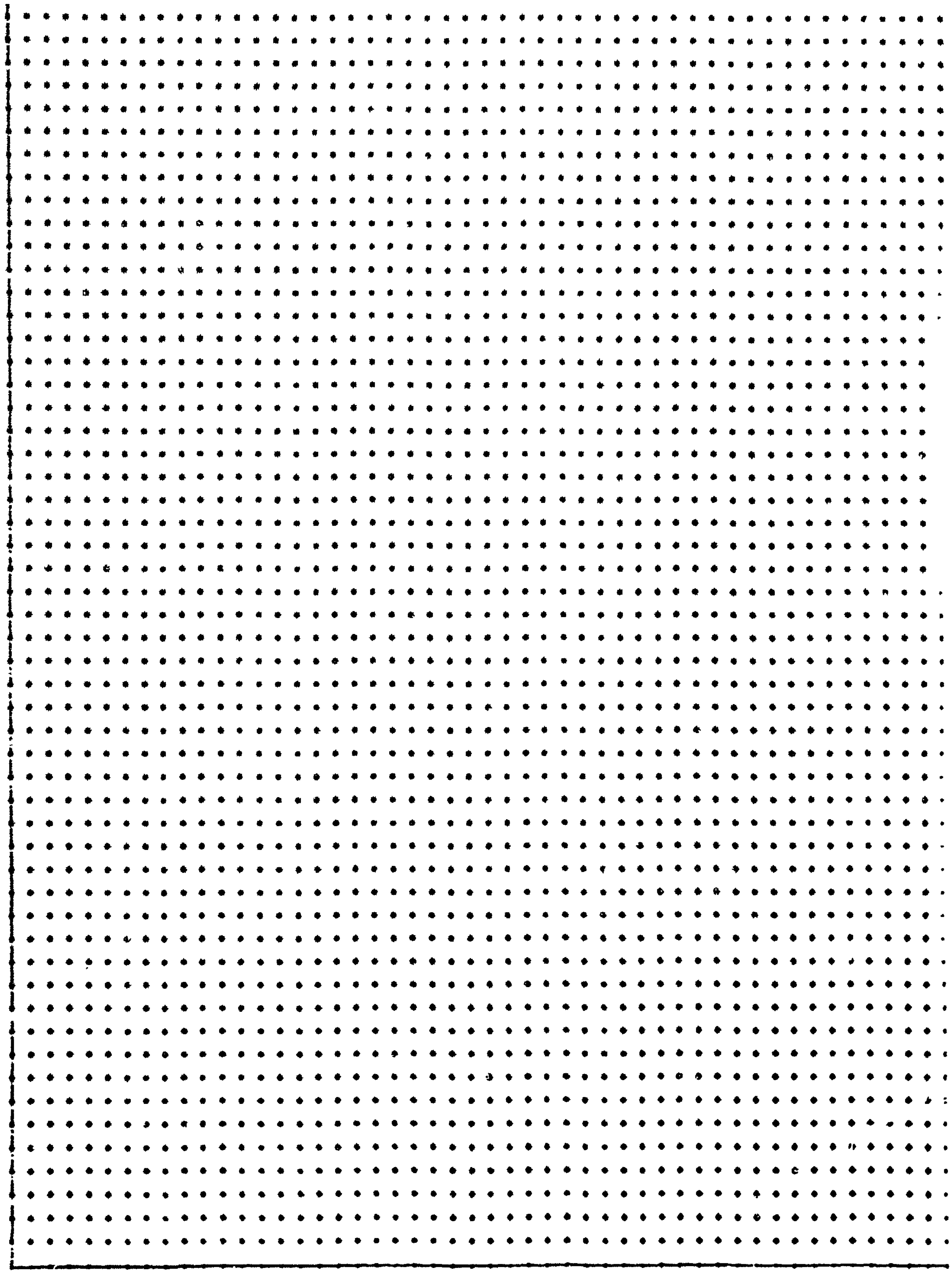

Figure 3. Computer Drawn Grid Lattice for Published Soil Maps

The procedure for creating a lattice for a soil survey field sheet is more difficult since (1) the borders drawn on the photograph may be arbitrary lines which may not correspond to any coordinate system, and (2) the photo reproduction may not be exactly to scale (1:15,840). The only information relating the field sheet to a coordinate system consists of two Tennessee state-plane tick marks drawn on each one of the four borders. The tick marks are designated, of course, in feet. In order to draw a geodetic lattice which may be overlaid on top of the field sheet with the correct orientation and scale, it was necessary to develop a special grid transformation computer program. This program accepts, as input, a series of measurements giving the distance of each tick mark from one of the corners of the photo plus the diagonal distance across the photo. With this input information the program is able to perform the necessary scaling and transformation from state-plane coordinates to geodetic coordinates and thereby draw the lattice of grid points as shown in Figure 4. Notice that four corners have been drawn on the lattice to correspond to the four arbitrarily drawn corners on the field sheet. By aligning these corner marks correctly, the lattice and the field sheet are then properly registered. The row and column numbers and the sheet number have also been drawn for easy identification and digitization. It may be necessary, in the digitization process, to use a small portion of neighboring field sheets to correctly identify those geodetic cells which lie partially outside the field sheet border. These border cells do not usually terminate directly on the border because the borders do not correspond to latitude-longitude lines. Notice, also,

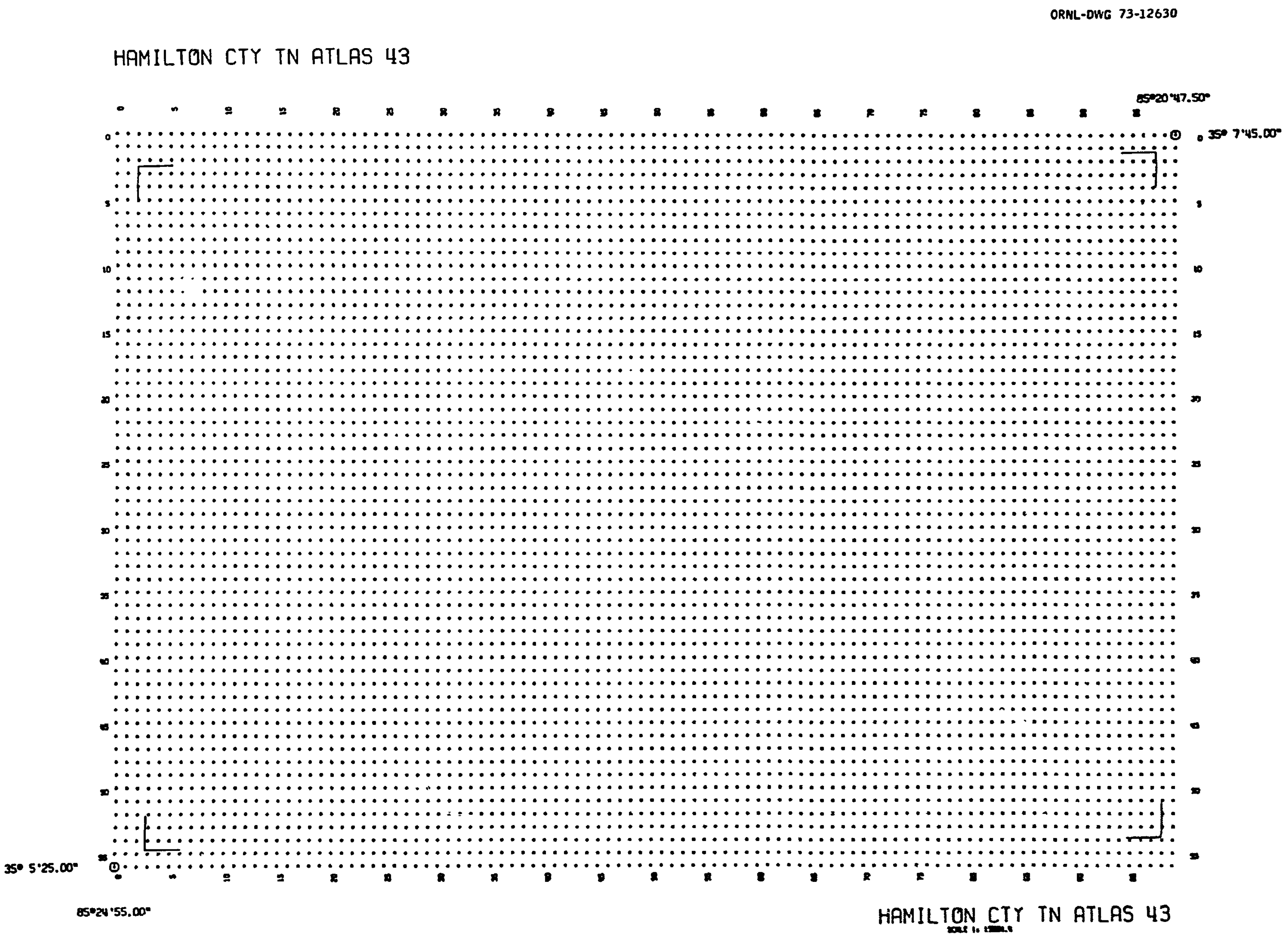

Figure 4. Computer Drawn Grid Lattice for Soil Survey Field Sheets

that the actual scale of the field sheet is computed and plotted in the lower right corner of the grid.

Delineation of Soil Boundaries

After overlaying the field sheet or soil map with the proper grid lattice, soil scientists transfer the boundary of each soil from the field sheet onto the lattice. This delineation of soil boundaries on the Mylar is done by connecting the lattice points with their nearest horizontal or vertical neighboring lattice points. By connecting these lattice dots, the soil scientist creates a series of polygons on the Mylar (Figure 5) which represent the soil boundaries on the original field sheet. After a given polygon is finished, the soil scientist writes the soil number within the polygon as shown in Figure 6. Notice that every soil number must be written directly above a horizontal line delineating the bottom of the polygon. During this process of drawing soil polygons, the soil scientist must make decisions concerning where the boundary line is to be drawn. These decisions are most difficult when a soil boundary passes through the middle rather than the side of a cell. It is most important that this decision be made by the soil scientist himself rather than someone unfamiliar with soil surveying techniques and morphological characteristics of soil boundaries in the area. This will ensure retention of information on those soils which are scarce yet significant.

Digitization of Soil Polygons

This section describes the procedure for transferring the location of soil polygons from the Mylar sheet to the computer. Due to the

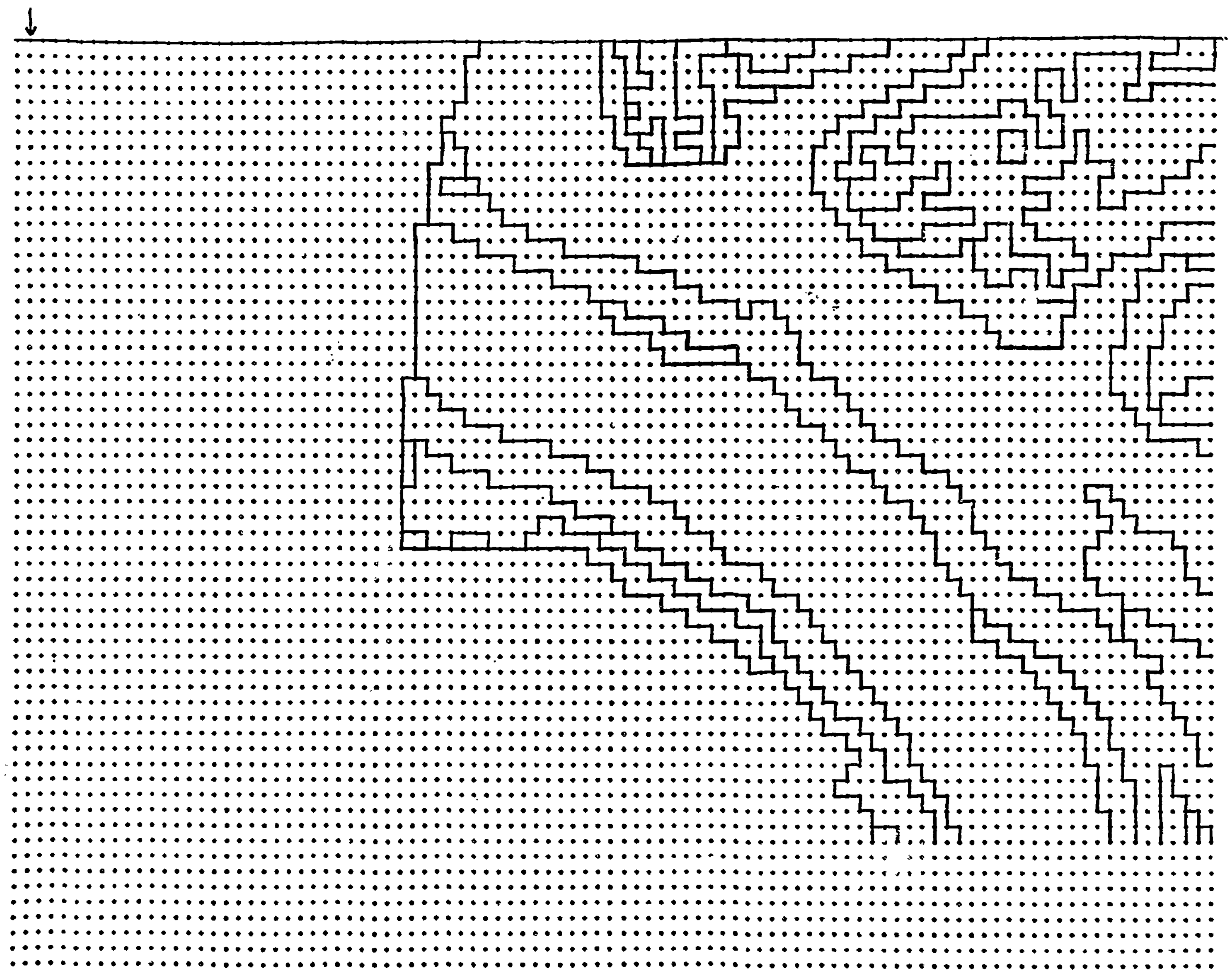

Figure 5. Soil Boundaries Defined by Polygons of Connected Lattice Points

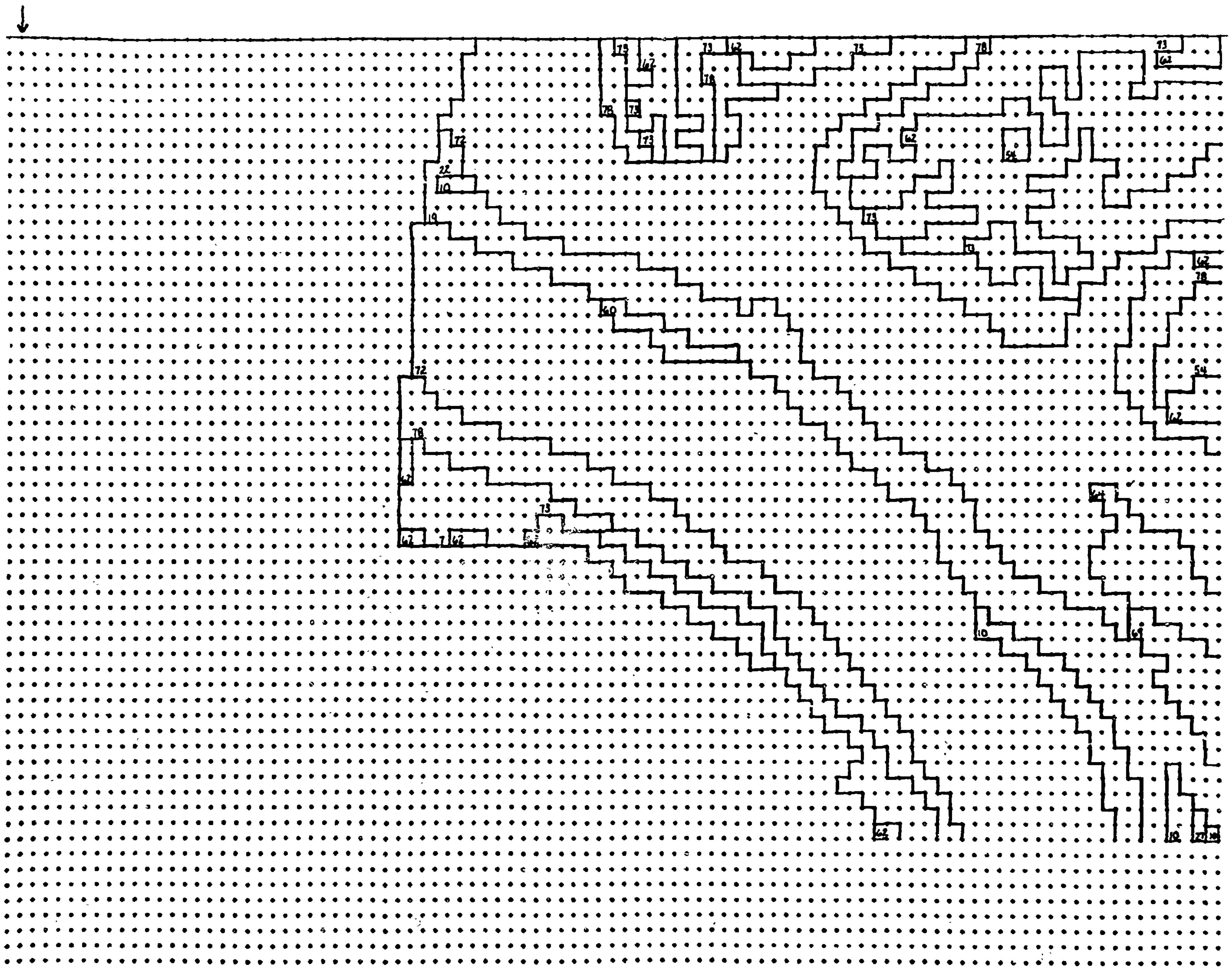

Figure 6. Complete Gridded and Labelled Lattice Overlay Sheet

complexity of the description, this section may be skipped unless the reader is interested in understanding the digitizing process.

The standard procedure for transferring the location of these soil polygons to the computer consists of (1) writing the polygon boundaries as a series of row and column numbers on 80-column computer coding sheets and (2) keypunching this information on computer cards. It is possible for two persons who are familiar with the system to omit step (1) and keypunch directly from the sheet of Mylar. This is done by one person reading the row and column numbers from the Mylar sheet while the second person keypunches. It is also possible to read the row and column numbers into a Dictaphone for keypunching at a later time. It is advisable, however, that anyone unfamiliar with the system follow steps (1) and (2).

There are actually two types of coding sheets which must be filled out in order to describe the polygon boundaries. The first coding sheet is used to specify the location of the horizontal boundary lines by scanning the Mylar from top to bottom, one row at a time. The second type of coding sheet is used to specify the location of vertical boundary lines. This is done by rotating the Mylar sheet 90° counter-clockwise so that the column numbers which were at the top are now on the left. The vertical scan is then performed by moving from the top to bottom just as in the horizontal scan.

The process of digitizing a given row when performing a horizontal scan consists of, first, writing the row number of the row being digitized. This is followed by a series of column numbers which represent those cells that have a horizontal line beneath them. It is also necessary during the horizontal scan to specify the location of the soil numbers written on the Mylar sheet. This is done by writing the soil number on the coding sheet just after the column number in which it lies. The soil number must be written as a negative number to distinguish it from the next positive column number which follows.

The digitization of each column of the Mylar sheet during the vertical scan is performed just as during the horizontal scan. Of course, the Mylar sheet will have been rotated 90° counterclockwise for the vertical scan. In this case the first number to be written on a coding line is the number of the column being digitized. It is followed by those row numbers which represent cells that have boundary lines beneath them on the Mylar sheet. Since the soil numbers were specified during a horizontal scan, they are not to be included during the vertical scan. Figures 7 and 8 contain the complete horizontal and vertical digitization of the soil polygons shown in Figure 6.

Other information which must be input consists of soil names corresponding to the digitized soil numbers, a title card, a definition of the map border by latitude and longitude, the map scale, the cell size, the type of computer map to be plotted, the aggregation level, etc. Examples of the computer printout of header information and the digitized data are shown in Figures 9 and 10.

Generation of "Quick-Look" Soil Maps

For the soil scientists to find and correct errors quickly both in the delineation of soil boundaries and the digitization of the soil polygons, it is necessary that the computer (in one run) read the input cards, check for errors, and output an initial soil map which may be

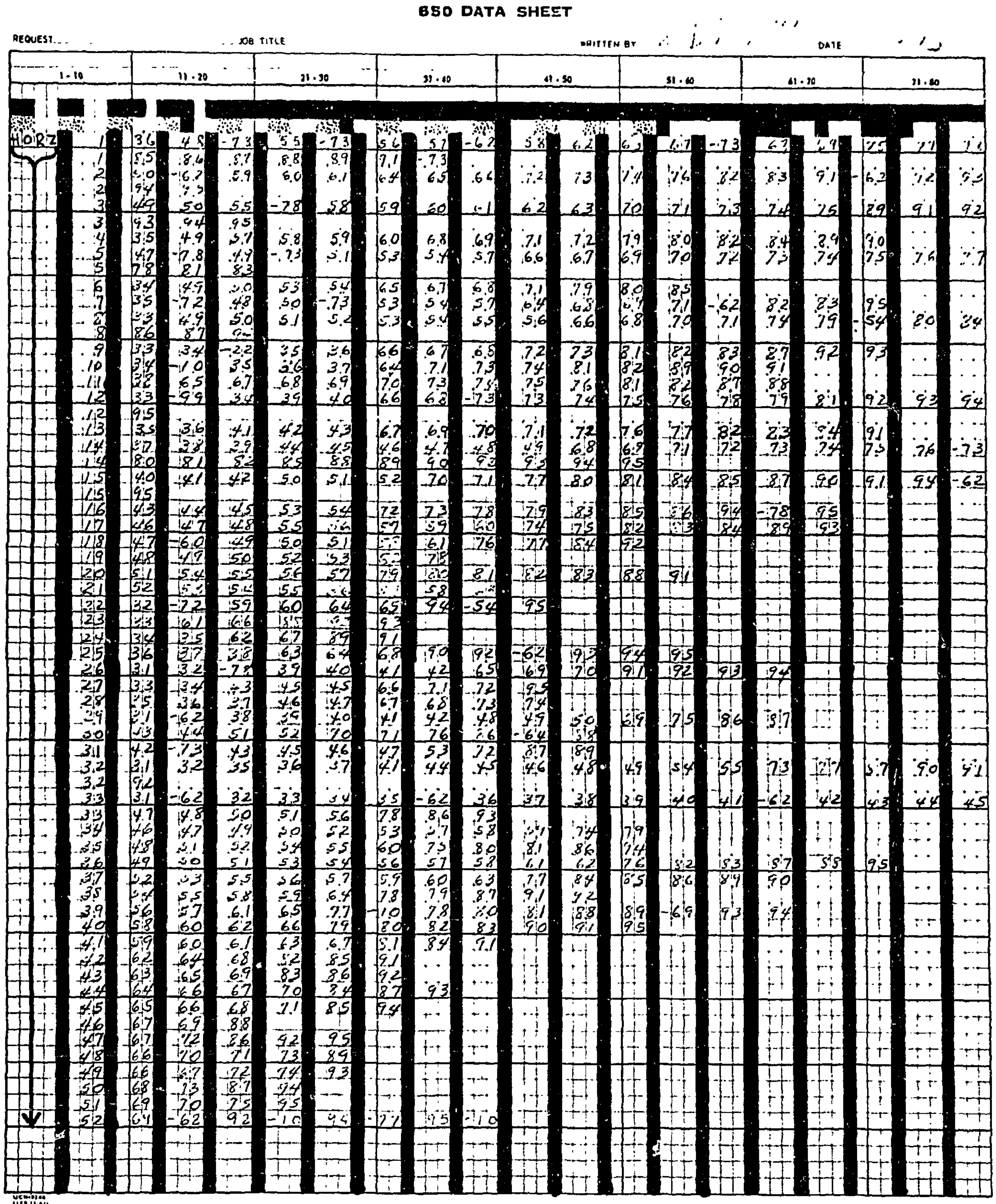

Figure 7. Completed Horizontal Coding Sheet (Fig. 5)

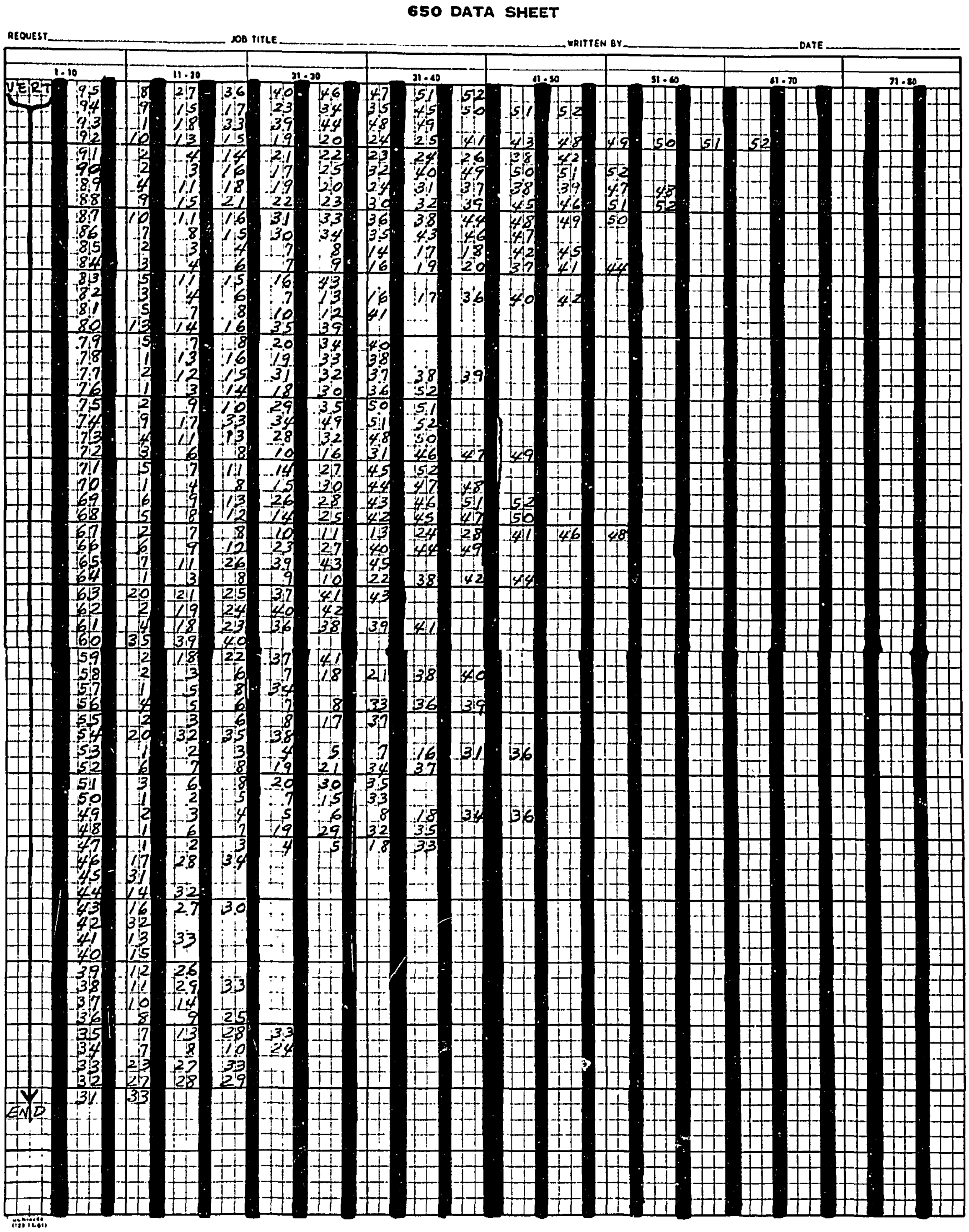

Figure 8. Completed Vertical Coding Sheet (Fig. 5)

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****************************************************************************************************************************
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                        AGGREGATED SOIL MAP = (3 X 3) = 7.5 SECOND GRID - HAMILTON COUNTY

****************************************************************************************************************************
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        NO. OF ROWS     =  52
        NO. OF COLUMNS  =  95
        IPLOT (0=N,1=Y) =   1
        ROW AGGREGATION=    3
        COL AGGREGATION=    3
        PSYMBOL CONTROL=    0


        LATITUDE  BOUNDARY NORTH =  35.0 DEG   7.0 MIN  47.0 SEC
        LATTITUDE  BOUNDARY SOUTH =  35.0 DEG   5.0 MIN  37.0 SEC
        LONGITUDE BOUNDARY WEST  =  85.0 DEG  24.0 MIN  48.5 SEC
        LONGITUDE BOUNDARY EAST  =  85.0 DEG  20.0 MIN  51.0 SEC
        MAP SCALE = (1 /126720.0)
        NORTH-SOUTH CELL HEIGHT  =             0.0 MIN   2.5 SEC
        EAST -WEST  CELL WIDTH   =             0.0 MIN   2.5 SEC
```

Figure 9. Computer Printout of Header Information

HORZ	1	36	44	-71	55	-71	56	57	-62	58	62	61	67	-71	44	61	75	77	-78
HORZ	1	85	86	87	88	89	91	-71	92	0	0	0	0	0	0	0	0	0	0
HORZ	2	50	-62	59	60	61	64	65	66	72	73	74	76	82	81	91	-62	92	93
HORZ	2	94	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	3	49	50	55	-78	58	59	60	61	62	63	70	71	73	74	75	89	91	92
HORZ	3	41	94	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	4	35	49	57	58	59	60	68	69	71	72	79	80	82	84	89	90	0	0
HORZ	5	34	47	-78	49	-73	51	51	54	57	66	67	69	70	72	73	74	75	76
HORZ	5	77	78	41	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	6	34	49	50	53	54	65	67	68	71	79	80	85	0	0	0	0	0	0
HORZ	7	35	-72	48	50	-73	51	54	57	64	68	69	71	-62	82	83	95	0	0
HORZ	8	33	49	50	51	52	53	54	55	56	66	68	70	71	74	79	-54	80	88
HORZ	8	86	87	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	9	33	14	-22	35	36	66	67	68	72	73	81	82	83	87	92	93	0	0
HORZ	10	34	-10	35	36	37	64	71	73	74	81	82	89	90	91	0	0	0	0
HORZ	11	38	65	67	68	69	70	73	74	75	76	83	82	87	88	0	0	0	0
HORZ	12	32	33	-99	34	39	40	66	68	-73	71	74	75	76	78	79	81	92	93
HORZ	12	94	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	13	35	16	41	42	43	67	69	70	71	72	76	77	82	83	84	91	0	0
HORZ	14	37	38	39	44	45	46	47	48	49	68	69	71	72	73	74	75	76	-73
HORZ	14	80	81	82	85	88	89	90	92	93	94	95	0	0	0	0	0	0	0
HORZ	15	40	41	42	50	51	52	70	71	77	80	81	84	85	87	90	91	94	-62
HORZ	15	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	16	43	44	45	51	54	72	73	78	79	83	85	86	94	-78	95	0	0	0
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HORZ	19	48	49	50	52	53	62	78	0	0	0	0	0	0	0	0	0	0	0
HORZ	20	51	54	55	56	57	79	80	81	82	83	88	91	0	0	0	0	0	0
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HORZ	24	14	35	62	67	89	91	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	25	36	37	38	63	64	68	90	92	-62	93	94	95	0	0	0	0	0	0
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HORZ	32	92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	33	31	-62	32	33	34	35	-62	36	37	38	39	40	41	-62	42	43	44	45
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HORZ	40	58	60	62	66	79	80	82	83	90	91	95	0	0	0	0	0	0	0
HORZ	41	59	60	61	63	67	81	84	91	0	0	0	0	0	0	0	0	0	0
HORZ	42	62	64	68	82	85	91	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	43	63	65	69	83	86	92	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	44	64	66	67	70	84	87	93	0	0	0	0	0	0	0	0	0	0	0
HORZ	45	65	66	68	71	85	94	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	46	67	69	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	47	67	72	86	92	95	0	0	0	0	0	0	0	0	0	0	0	0	0
HORZ	48	66	70	71	73	89	0	0	0	0	0	0	0	0	0	0	0	0	0
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HORZ	52	1	-99	69	-62	92	-10	94	-27	95	-10	0	0	0	0	0	0	0	0
VERT	95	8	27	36	40	46	47	51	52	0	0	0	0	0	0	0	0	0	0
VERT	94	9	15	17	23	34	35	45	50	51	52	0	0	0	0	0	0	0	0
VERT	93	1	18	33	39	44	48	49	0	0	0	0	0	0	0	0	0	0	0
VERT	92	10	13	15	19	20	24	25	41	43	48	49	50	51	52	0	0	0	0
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VERT	90	2	3	16	17	25	32	40	49	50	51	52	0	0	0	0	0	0	0
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VERT	88	9	15	21	22	23	30	32	39	45	46	51	52	0	0	0	0	0	0
VERT	87	10	11	16	31	33	36	38	44	48	49	50	0	0	0	0	0	0	0
VERT	86	7	8	15	30	34	35	43	46	47	0	0	0	0	0	0	0	0	0
VERT	85	2	3	4	7	8	14	17	18	42	45	0	0	0	0	0	0	0	0
VERT	84	3	4	6	7	9	16	19	20	37	41	44	0	0	0	0	0	0	0
VERT	83	5	11	15	16	43	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	82	3	4	6	7	13	16	17	36	40	42	0	0	0	0	0	0	0	0
VERT	81	5	7	8	10	12	41	0	0	0	0	0	0	0	0	0	0	0	0
VERT	80	13	14	16	35	39	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	79	5	7	8	20	34	40	0	0	0	0	0	0	0	0	0	0	0	0
VERT	78	1	12	16	19	33	38	0	0	0	0	0	0	0	0	0	0	0	0
VERT	77	2	12	15	31	32	37	38	39	0	0	0	0	0	0	0	0	0	0
VERT	76	1	3	14	18	30	36	52	0	0	0	0	0	0	0	0	0	0	0
VERT	75	2	9	10	29	35	50	51	0	0	0	0	0	0	0	0	0	0	0
VERT	74	9	17	33	34	49	51	52	0	0	0	0	0	0	0	0	0	0	0
VERT	73	4	11	13	28	32	48	50	0	0	0	0	0	0	0	0	0	0	0
VERT	72	3	6	8	10	16	31	46	47	49	0	0	0	0	0	0	0	0	0
VERT	71	5	7	11	14	27	45	52	0	0	0	0	0	0	0	0	0	0	0
VERT	70	1	4	8	15	30	44	47	48	0	0	0	0	0	0	0	0	0	0
VERT	69	6	9	13	26	29	43	46	51	52	0	0	0	0	0	0	0	0	0
VERT	68	5	8	12	14	25	42	45	47	50	0	0	0	0	0	0	0	0	0
VERT	67	2	7	8	10	11	13	24	28	41	46	48	0	0	0	0	0	0	0
VERT	66	6	9	12	21	27	40	44	49	0	0	0	0	0	0	0	0	0	0
VERT	65	7	11	26	39	43	45	0	0	0	0	0	0	0	0	0	0	0	0
VERT	64	1	3	8	9	10	22	38	42	44	0	0	0	0	0	0	0	0	0
VERT	63	20	21	25	17	41	43	0	0	0	0	0	0	0	0	0	0	0	0
VERT	62	2	19	24	40	42	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	61	4	18	23	36	38	39	41	0	0	0	0	0	0	0	0	0	0	0
VERT	60	35	39	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	59	2	18	22	37	41	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	58	2	3	6	7	18	21	38	40	0	0	0	0	0	0	0	0	0	0
VERT	57	1	5	8	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	56	4	5	6	7	8	33	36	39	0	0	0	0	0	0	0	0	0	0
VERT	55	2	3	6	8	17	37	0	0	0	0	0	0	0	0	0	0	0	0
VERT	54	20	32	35	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	53	1	2	3	4	5	7	16	31	36	0	0	0	0	0	0	0	0	0
VERT	52	6	7	8	19	21	34	37	0	0	0	0	0	0	0	0	0	0	0
VERT	51	3	6	8	20	30	35	0	0	0	0	0	0	0	0	0	0	0	0
VERT	50	1	2	5	7	15	33	0	0	0	0	0	0	0	0	0	0	0	0
VERT	49	2	3	4	5	6	8	18	34	36	0	0	0	0	0	0	0	0	0
VERT	48	1	6	7	19	29	32	35	0	0	0	0	0	0	0	0	0	0	0
VERT	47	1	2	3	4	5	18	33	0	0	0	0	0	0	0	0	0	0	0
VERT	46	17	28	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	45	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	44	14	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	43	16	27	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	42	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	41	13	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	40	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	39	12	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	38	11	29	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	37	1	10	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	36	2	3	4	8	9	25	0	0	0	0	0	0	0	0	0	0	0	0
VERT	35	5	7	13	28	33	0	0	0	0	0	0	0	0	0	0	0	0	0
VERT	34	6	7	8	10	24	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 10. Computer Printout of Digitized Data

checked by eye. Thus, the computer line printer has been used to generate a quick-look soil map which is not to scale but does contain the necessary information so that most of the errors may be corrected. Figure 11 shows a quick-look printer map for the digitized soils shown in Figures 1 and 6. Notice that the printer has drawn a boundary around each area containing the same soil type. If an error (such as leaving a polygon open) had been made, the printer map would show the soil numbers from that polygon spilling out of the open hole into nearby polygons. Those areas which are blank on the printer map represent undigitized areas such as bodies of water or areas outside the county being mapped.

It is also possible to categorize soil types so that the printer boundaries may be drawn around areas containing more than one soil type. For example, soil numbers 2, 4, and 5 may be very similar and can be placed in the same category for the purpose of generating a printer map. Such a printer map would consider soil numbers 2, 4, and 5 to be equivalent and therefore draw boundaries around larger areas which include all three soil types.

The generation of quick-look printer maps is invaluable as an error-checking and editing tool since these maps are produced immediately after the computer has read the input data. In this way the soil scientist experiences very little delay in finding and correcting the majority of digitizing errors. The final soil maps are generated to scale on a mechanical plotter external to the computer. The computer creates a magnetic tape containing the information necessary to drive the plotter in creating the final soil map. This magnetic tape is

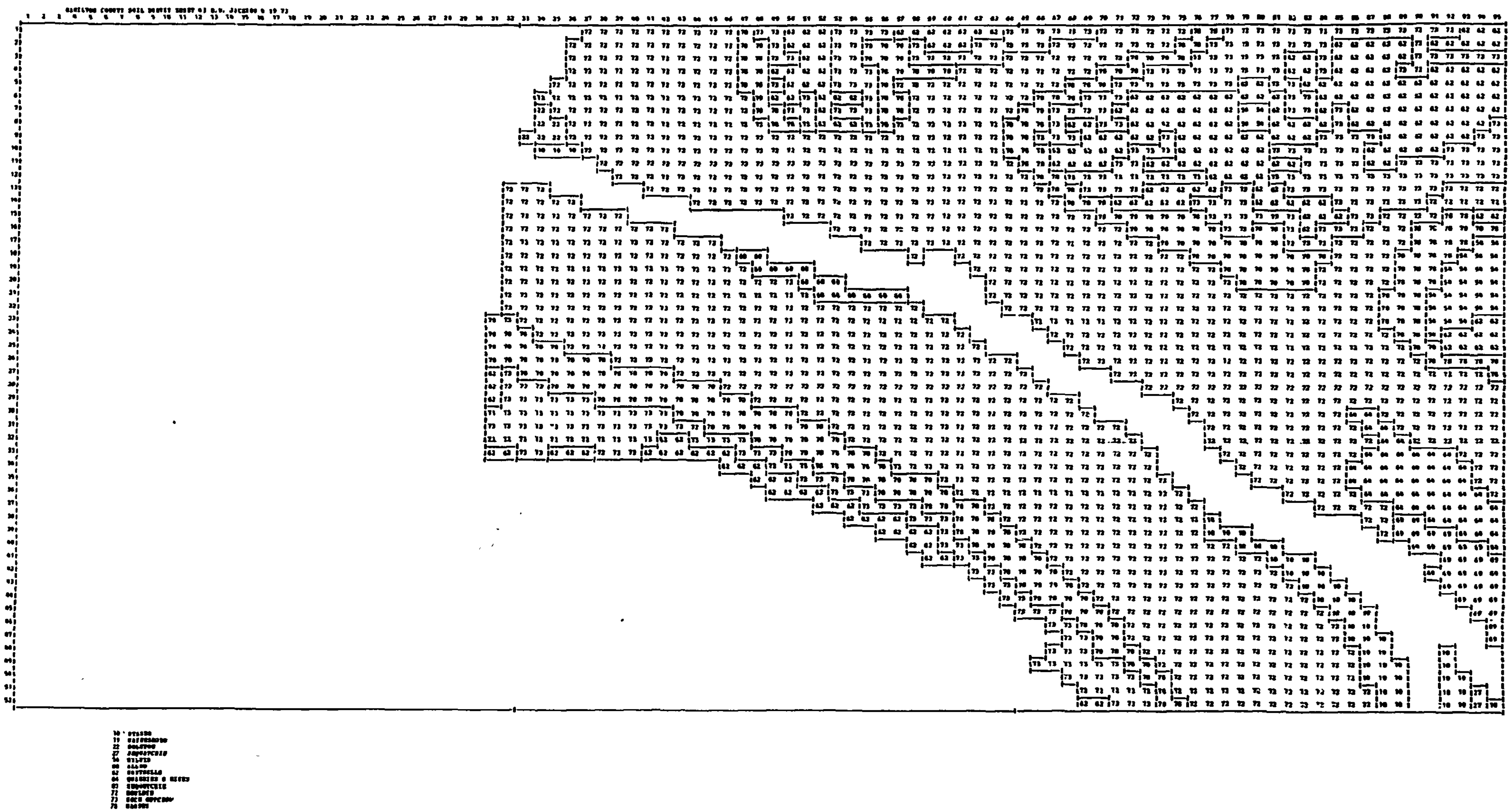

Figure 11. "Quick-Look" Map of Soil Data Shown in Figs. 1 and 6

then taken to the plotter after the computer run and plotted at the specified map scale.

Editing of Soil Maps

The previous section describes the generation of computer soil maps for the purposes of error checking and editing. In addition to searching these maps by eye to spot errors, the computer itself searches for mistakes. For example, the soil scientist may have failed to place a soil number within a polygon, thereby leaving it undefined, or perhaps a particular polygon has not been completely closed by its border. In such cases the computer is able to detect the error and print error messages to the soil scientist so that he may correct these before searching the "quick-look" map. There are a wide variety of errors which the computer can find; for example, placing two different soil numbers within the same polygon, using soil numbers which are out of range or invalid, or scanning down or across the map in an improper order. In each case the computer prints an appropriate message to the soil scientist so that he may correct the computer cards. Some example error messages are shown in Figure 12.

There are other errors which the computer is not able to detect and only the soil scientist can find by comparing the computer-drawn soil maps with the original soil maps. For example, soil type 1 may have been written as soil type 4 on the Mylar sheet, and this can only be detected by comparing the two maps. Or, it may be that a given soil polygon was improperly drawn on the Mylar sheet as compared with the soil boundary on the source map. In correcting these errors on the computer cards, it is not necessary to repunch the erroneous card.

```
SUMMARY OF ERRORS FOR THIS JOB                    NUMBER OF ERRORS
                                                        12

***** ERROR - TWO CELLS IN SAME POLYGON HAVE DIFFERENT POLYGON NO.S - CELL(  8, 12) = 26 .NE. CELL(  9, 12) = 10

***** ERROR - TWO CELLS IN SAME POLYGON HAVE DIFFERENT POLYGON NO.S - CELL( 14,  6) = 30 .NE. CELL( 14,  7) = 25

***** ERROR - TWO CELLS IN SAME POLYGON HAVE DIFFERENT POLYGON NO.S - CELL( 14,  7) = 25 .NE. CELL( 14,  6) = 30

***** ERROR - TWO CELLS IN SAME POLYGON HAVE DIFFERENT POLYGON NO.S - CELL(  9, 12) = 10 .NE. CELL(  8, 12) = 26

HORZ  27  33  34  43  45  45  66  71  72  95   0   0   0   0   0   0   0   0   0

 ***** ERROR - A CONNECTOR NO. IS LESS THAN OR EQUAL TO THE ONE BEFORE IT IN THE CARD ABOVE
***** ERROR - POLYGON NUMBER IS ZERO - CELL(  7,  4) =  0
***** ERROR - POLYGON NUMBER IS ZERO - CELL(  8,  4) =  0
***** ERROR - POLYGON NUMBER IS ZERO - CELL( 14,  5) =  0
***** ERROR - POLYGON NUMBER IS ZERO - CELL( 15,  3) =  0
***** ERROR - POLYGON NUMBER IS ZERO - CELL( 15,  4) =  0
***** ERROR - POLYGON NUMBER IS ZERO - CELL( 15,  5) =  0
***** ERROR - POLYGON NUMBER IS ZERO - CELL( 16,  5) =  0
```

Figure 12. Example Error Messages

Special "add-delete" cards have been provided on which only that information to be corrected is punched. Thus if a column number was left out in the middle of a card, an "add" card is punched containing only that column number. The old card is still kept in the input deck with the new "add" card being placed at the end of the deck.

Once all of these errors have been corrected and the computer has generated a second or, if necessary, a third printer map containing no errors, the final plotted soil map can be generated. A few errors may still remain undetected until the final soil map plotted to scale is laid over the original source map. This is the easiest way to see if the soil boundaries on the source map coincide with the computer-drawn boundaries on the plot.

Generation of Final Soil Maps

Inherent in the planning process is the need to extract data and make decisions utilizing information from many different maps. In most cases, these maps are of different scales and projections. One of the required features of the computer data system is the ability to map the information at virtually any scale or projection in several different ways. In addition, as the scale changes, the data stored in the cells can be aggregated in terms of both spatial delineation and classification of soil boundaries (phase, type, family, etc.). The user specifies the manner in which the aggregation is to be performed.

The final soil maps created for the initial phase of this project include a variety of different types and scales. For example, boundary maps may be drawn with only soil boundaries shown, numbered maps may be plotted with each polygon numbered inside, or shaded maps may be produced so that each soil is shaded with a different texture. The 1:15,840 scale maps (Figures 13-16) can be overlaid directly onto the field sheet photographs. The 1:24,000 scale map (Figure 17) uses the 7-1/2 minute U.S. Geological Survey topographic quadrangles. The Tennessee State Highway Commission has created excellent county land-use and road maps at a scale of 1 inch to 2 miles. To illustrate the potential application at this degree of aggregation and scale, the field sheet was mapped to overlay on these county maps (Figure 18). By combining a large number of field sheets, a composite map may be created which covers a large area, such as a county, at this 1 inch to 2 mile scale.

Soil Interpretation and Mapping

The true worth of a soil survey emerges when the basic data have been interpreted for application and problem solving. In this study two types of interpretations have been made: (1) enhancement of the base data (for example, converting soil types to a map of physical soil characteristics) and (2) management/limitations and intrinsic soil suitability maps (for example, limitations to industrial development and suitability for septic systems). To implement the interpretation mapping sector of the system, the user fills out a matrix that groups or signifies categories of suitability or different combinations of soil phase data. To run an interpretation map a user simply adds this categorization matrix to the soil data he has already digitized and mapped. The inherent flexibility this gives the user is extremely valuable in that any time new problems arise, additional interpretations

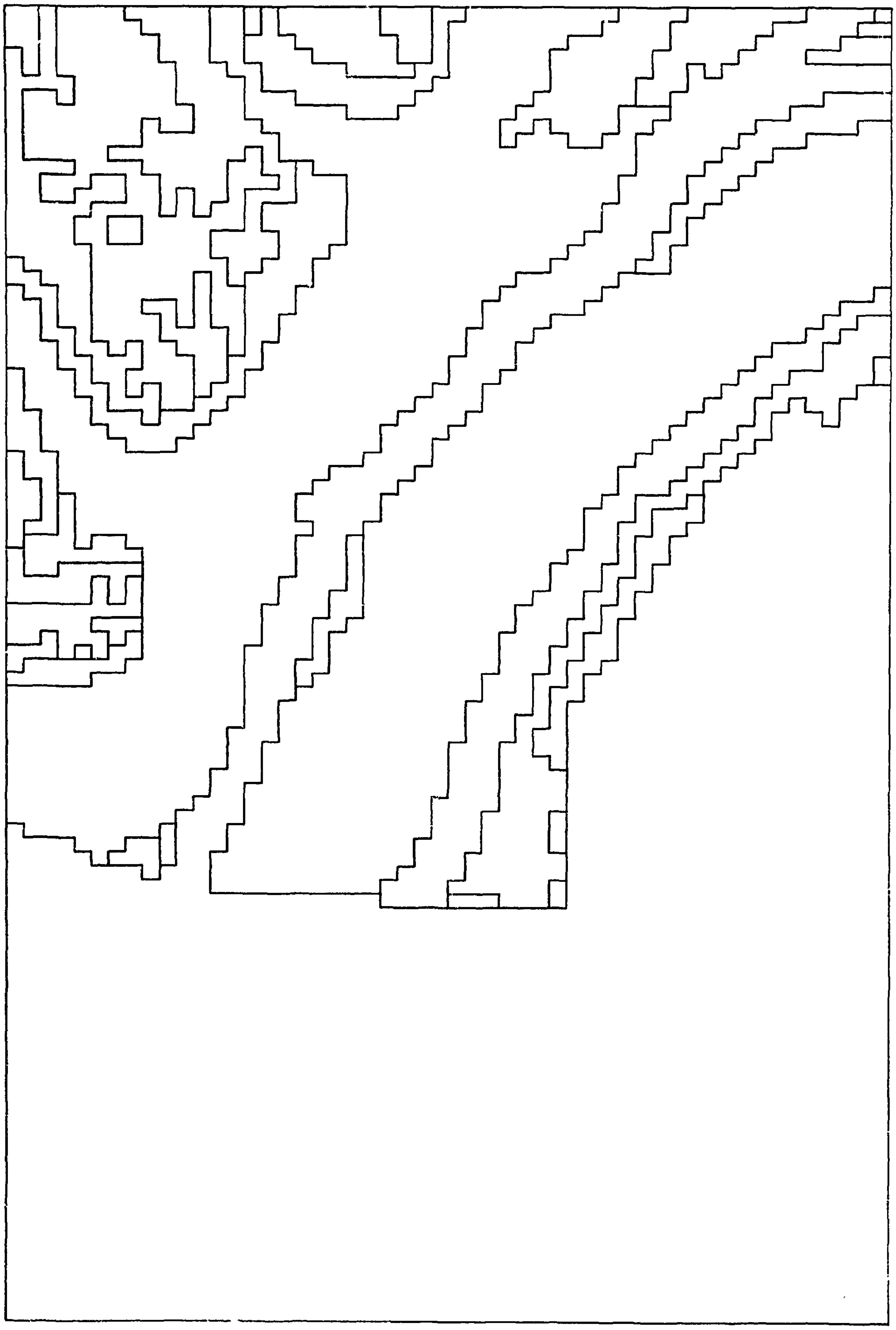

Figure 13. Computer Generated Soil Boundary Overlay, 1:15,840 Scale, 2.5 Second (1.18 acre) Grid

ORNL-DWG 73-12356

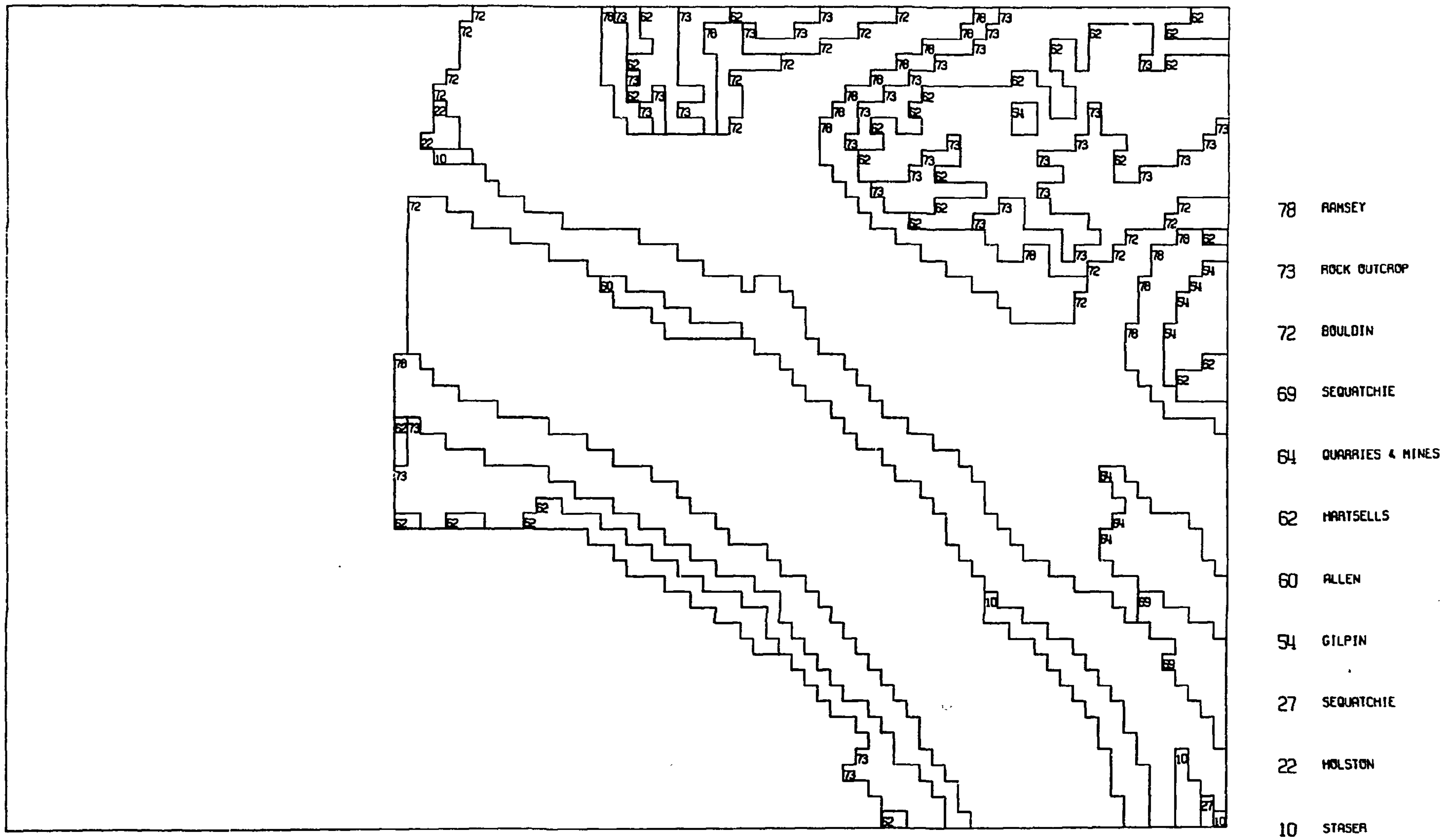

Figure 14. Computer Generated Numbered Soil Map, 1:15,840 Scale, 2.5 Second (1.18 acre) Grid

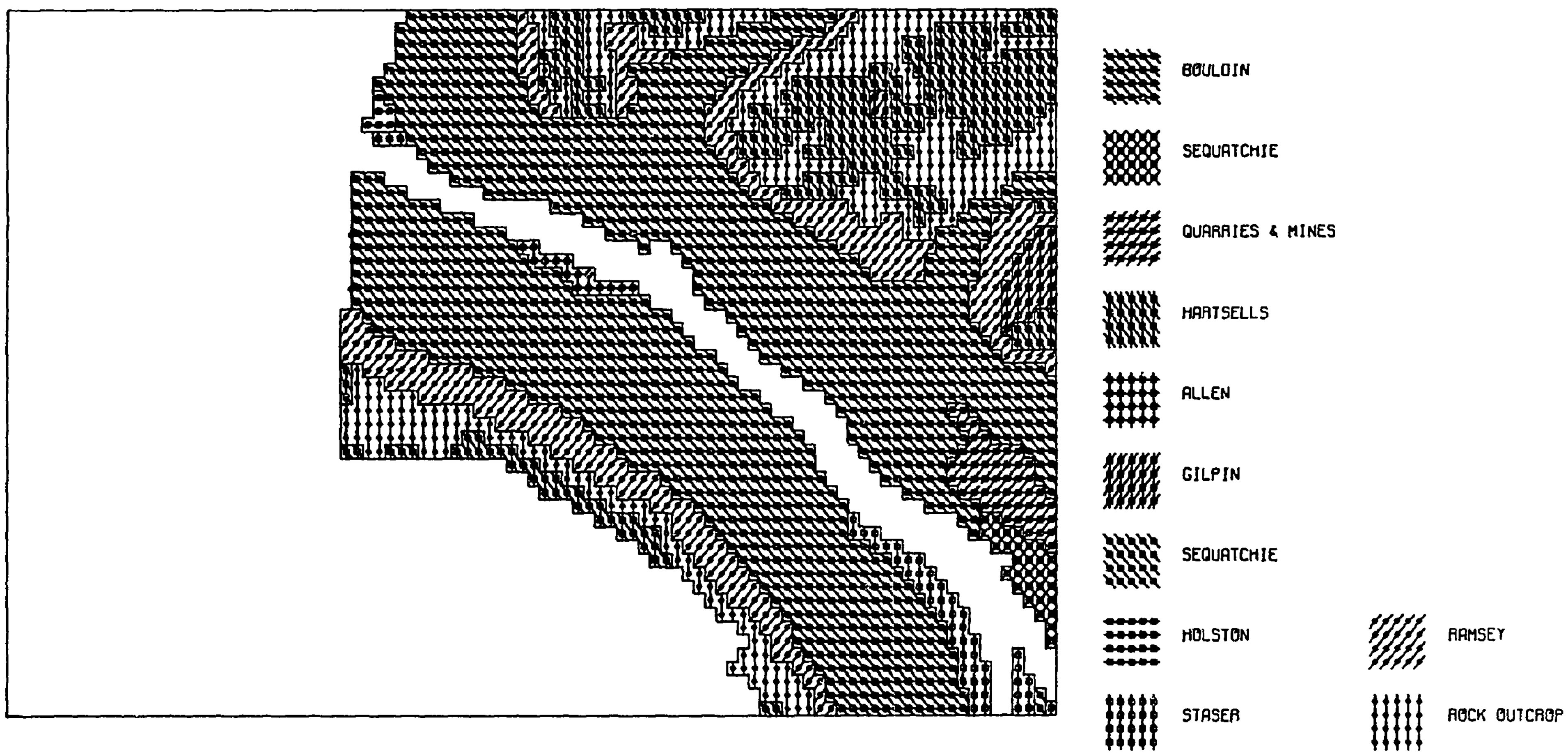

Figure 15. Computer Generated Shaded Soil Map,
1:15,840 Scale, 2.5 Second (1.18 acre) Grid

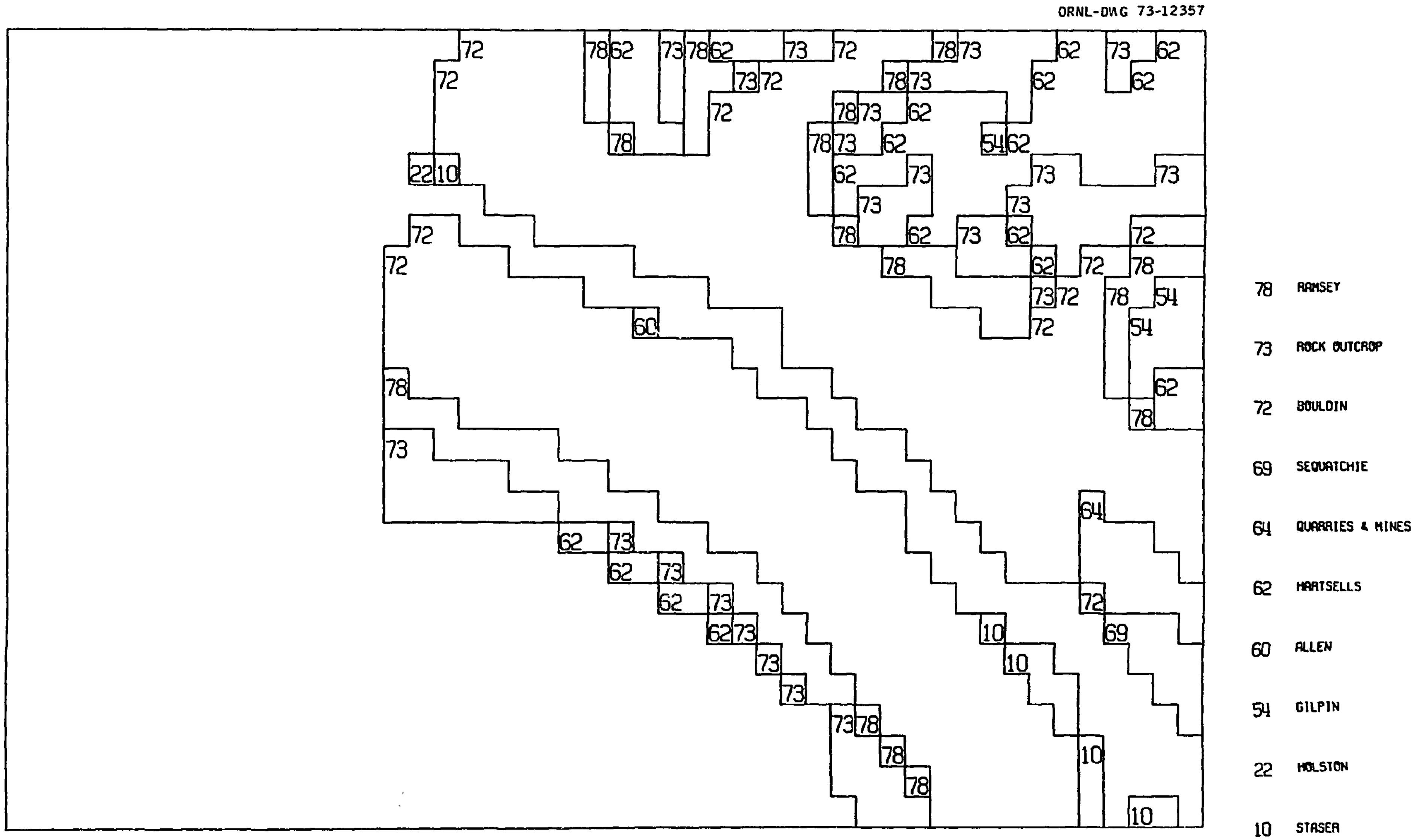

Figure 16. Computer Generated Aggregated Soil Map, 1:15,840 Scale, 5 Second (4.72 acre) Grid

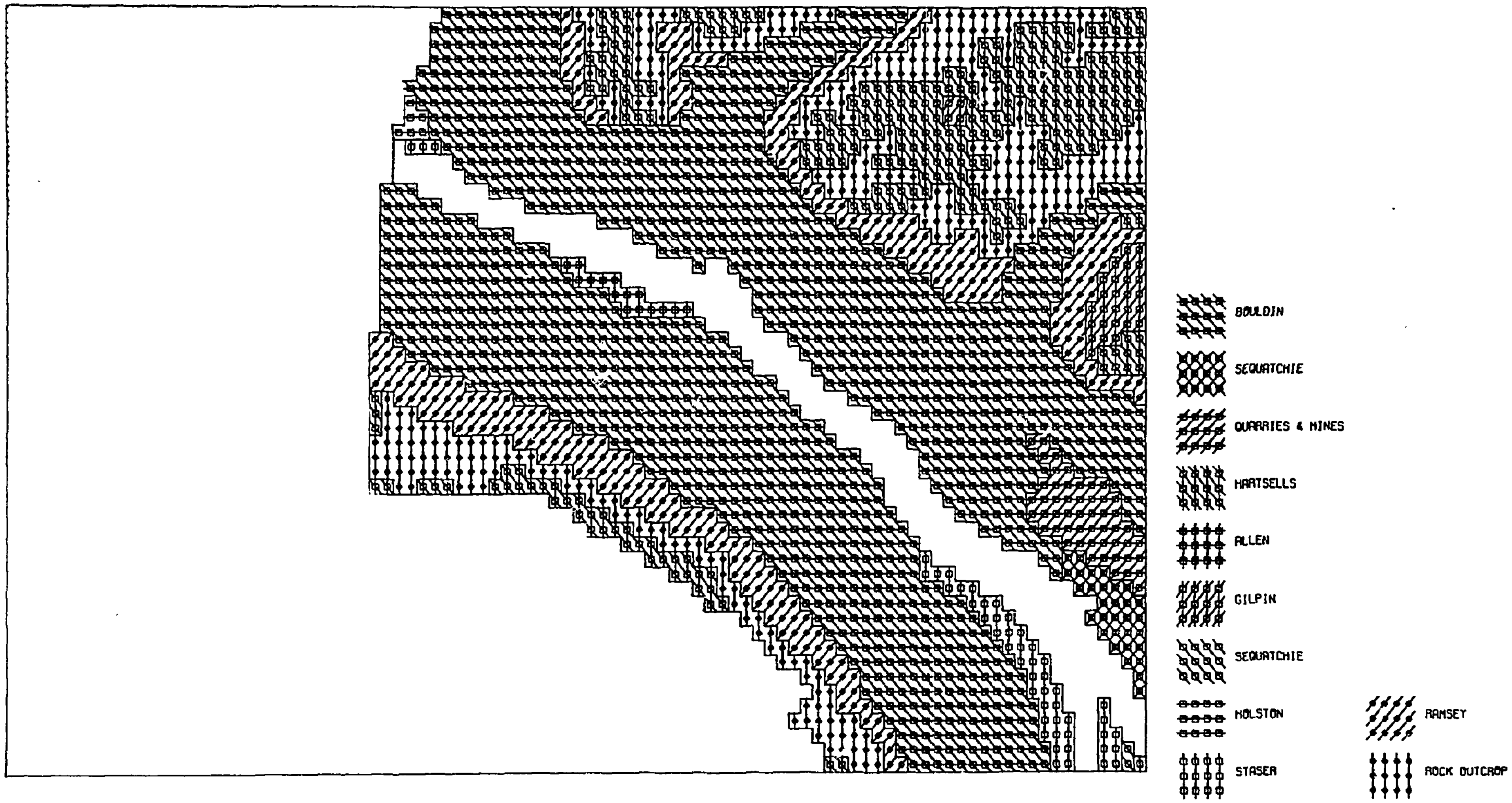

Figure 17. Computer Generated Soil Map, 1:24,000 Scale, 2.5 Second (1.18 acre) Grid

ORNL-DWG 73-12355

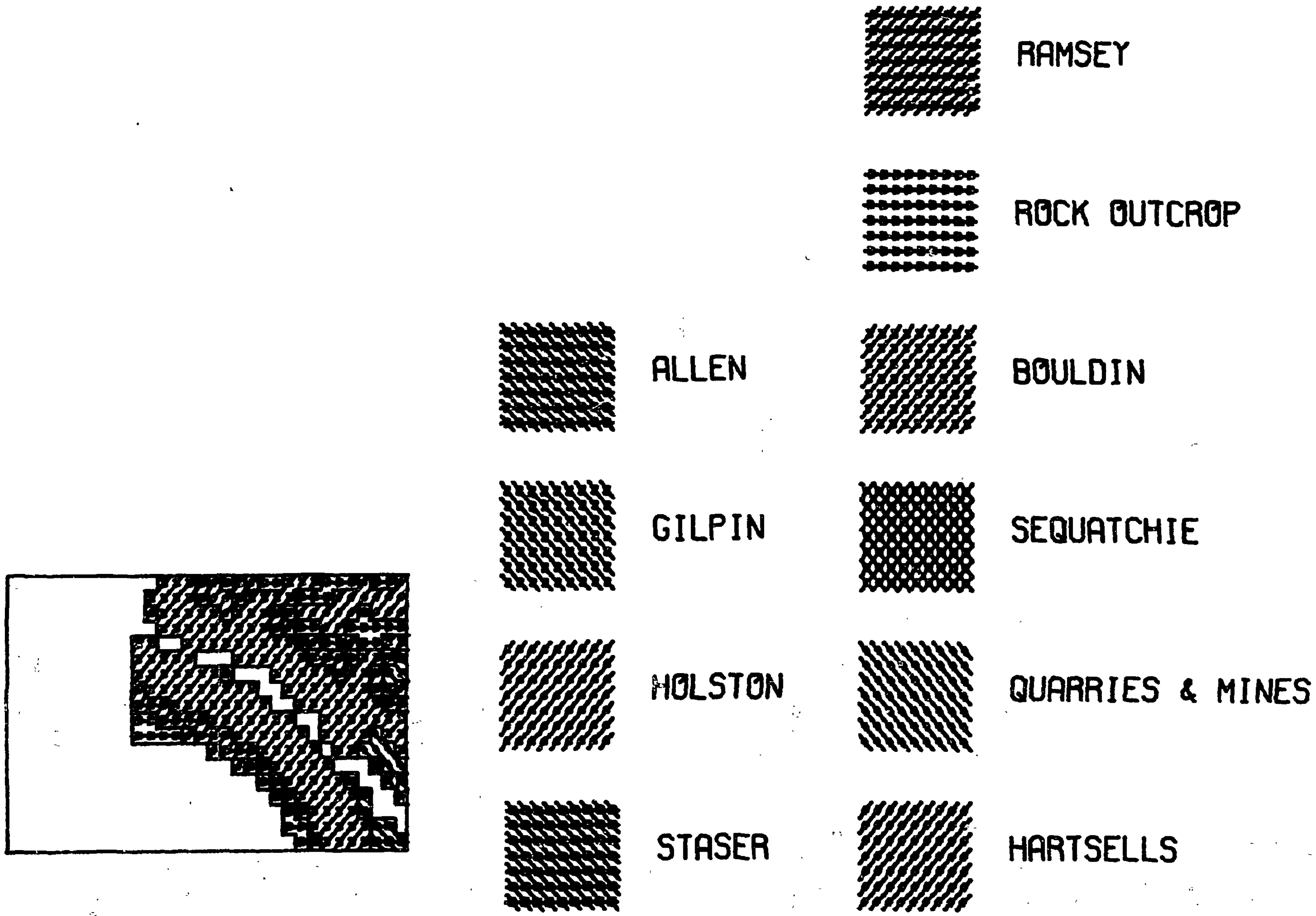

Figure 18. Computer Generated Aggregated Soil Map, 1 inch = 2 miles Scale, 7.5 Second (10.62) Grid

can easily be made. The feature of mapping at any scale is also included in the interpretation maps. If planning work is being done using specific scale maps, the interpretation maps are printed at this scale. The initial set of interpretations that were mapped using the Hamilton County field sheet data include (1) subsoil textures, (2) slope categories, (3) depth to hard rock, (4) soil capability units, (5) potential erodibility, (6) residential limitations with septic systems, (7) light industrial limitations, and (8) tax assessment values. These are illustrated on a scale of 1:15,840 in Figures 19-26.

Conclusions

The work and results described in this report represent only the initial phase of a new step forward in soil survey and the introduction of soil information into a form highly usable for all phases of the planning and decision-making processes. The manual digitization technique described in this report represents just one of many different ways in which soil information may be presented to the computer. Sophisticated spatial information systems are being developed, not only by RESA, but all over the county utilizing such hardware devices as automatic x-y digitizers, optical scanners, CRT displays, and mechanical plotters. With the advent of national and state land-use legislation and policy implementation, there is an accelerated demand for soil data that can be analyzed with other variables. In addition, utilizing techniques wherein planners and soil scientists are able to combine efforts and develop interpretations that can be quickly mapped and used continues to create a strong rationale for environmental land planning.

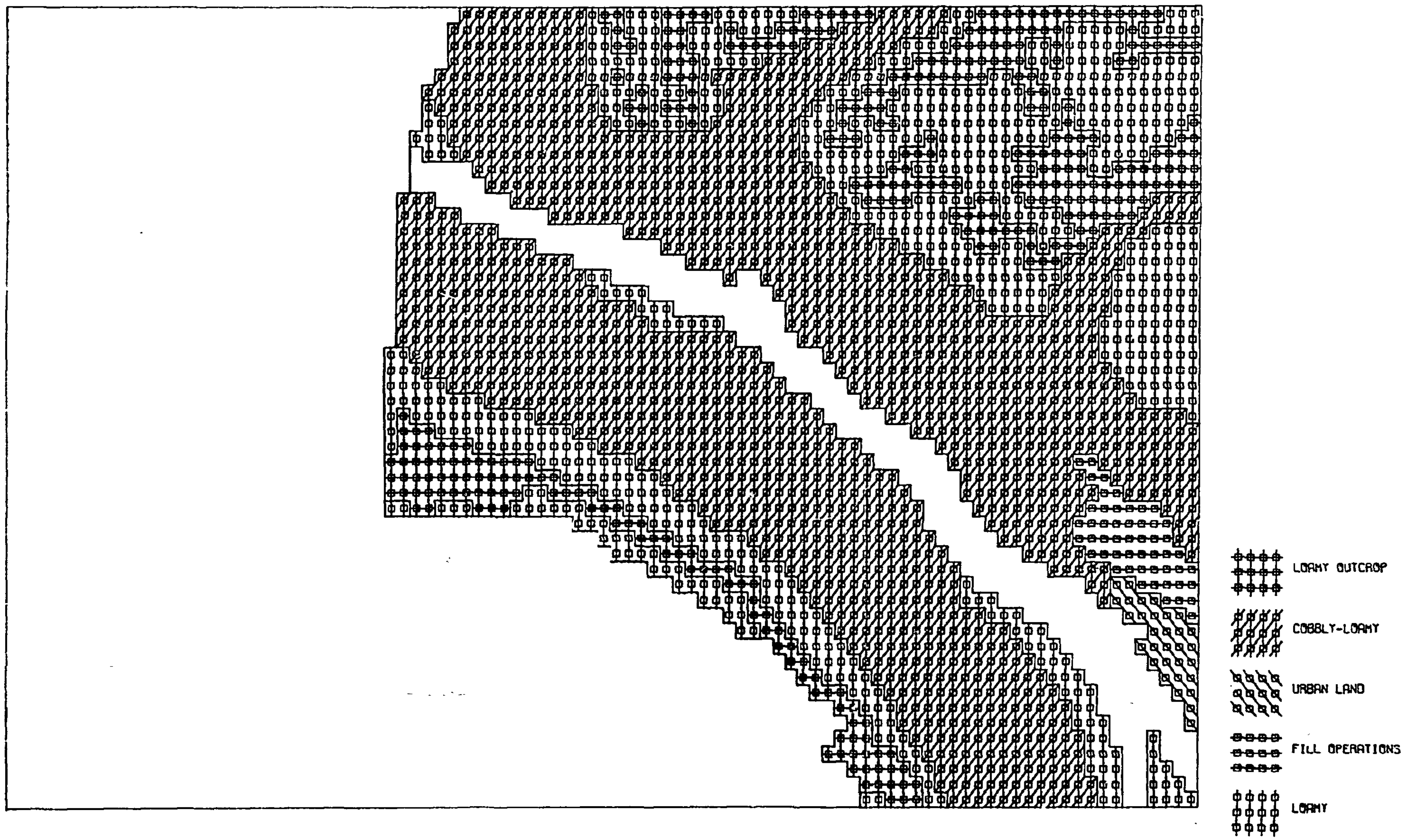

Figure 19. Interpretation Map - Subsoil Textures, 1:15,840 Scale, 2.5 Second (1.18 acre) Grid

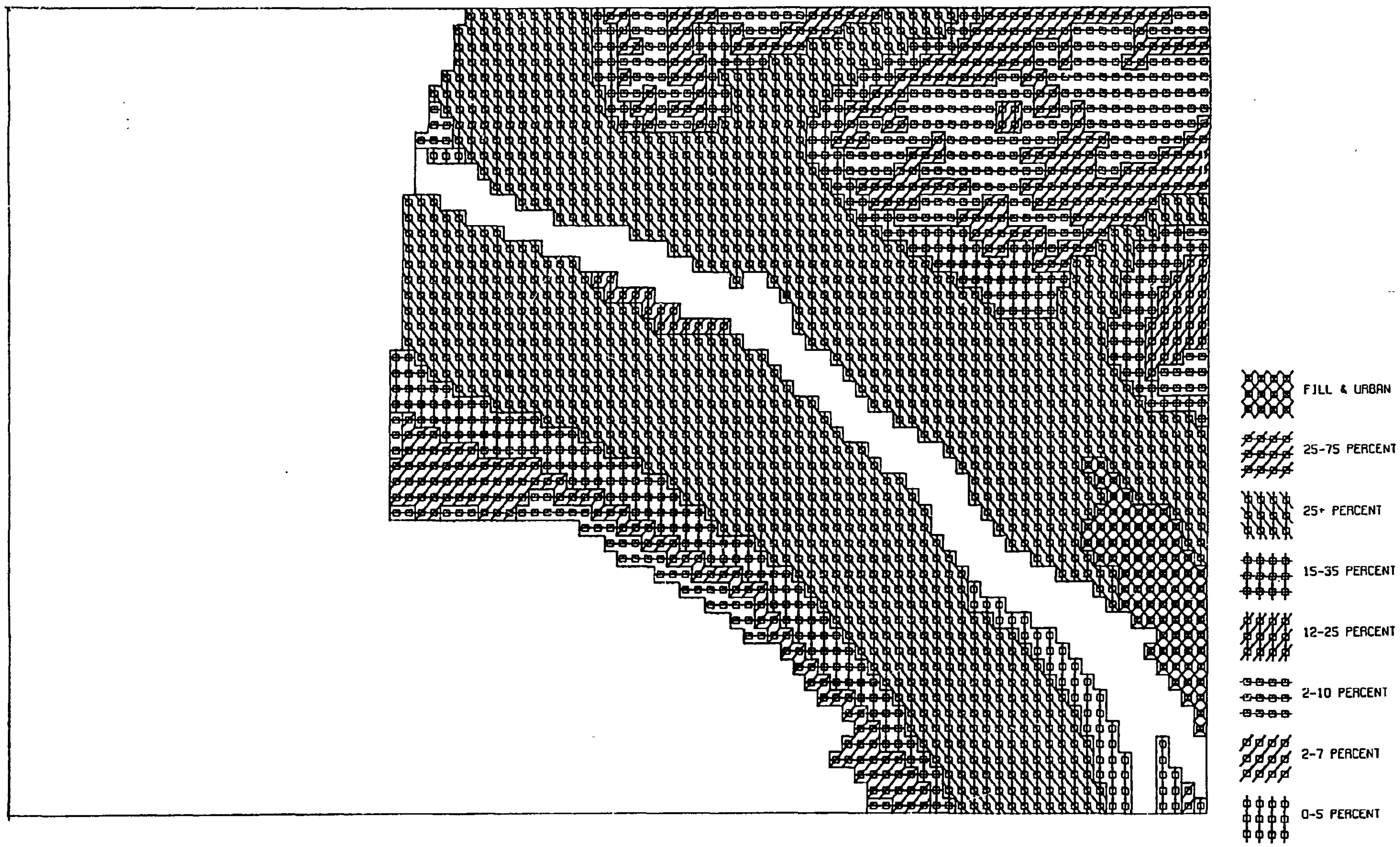

Figure 20. Interpretation Map - Slope Categories, 1:15,840 Scale, 2.5 Second (1.18 acre) Grid

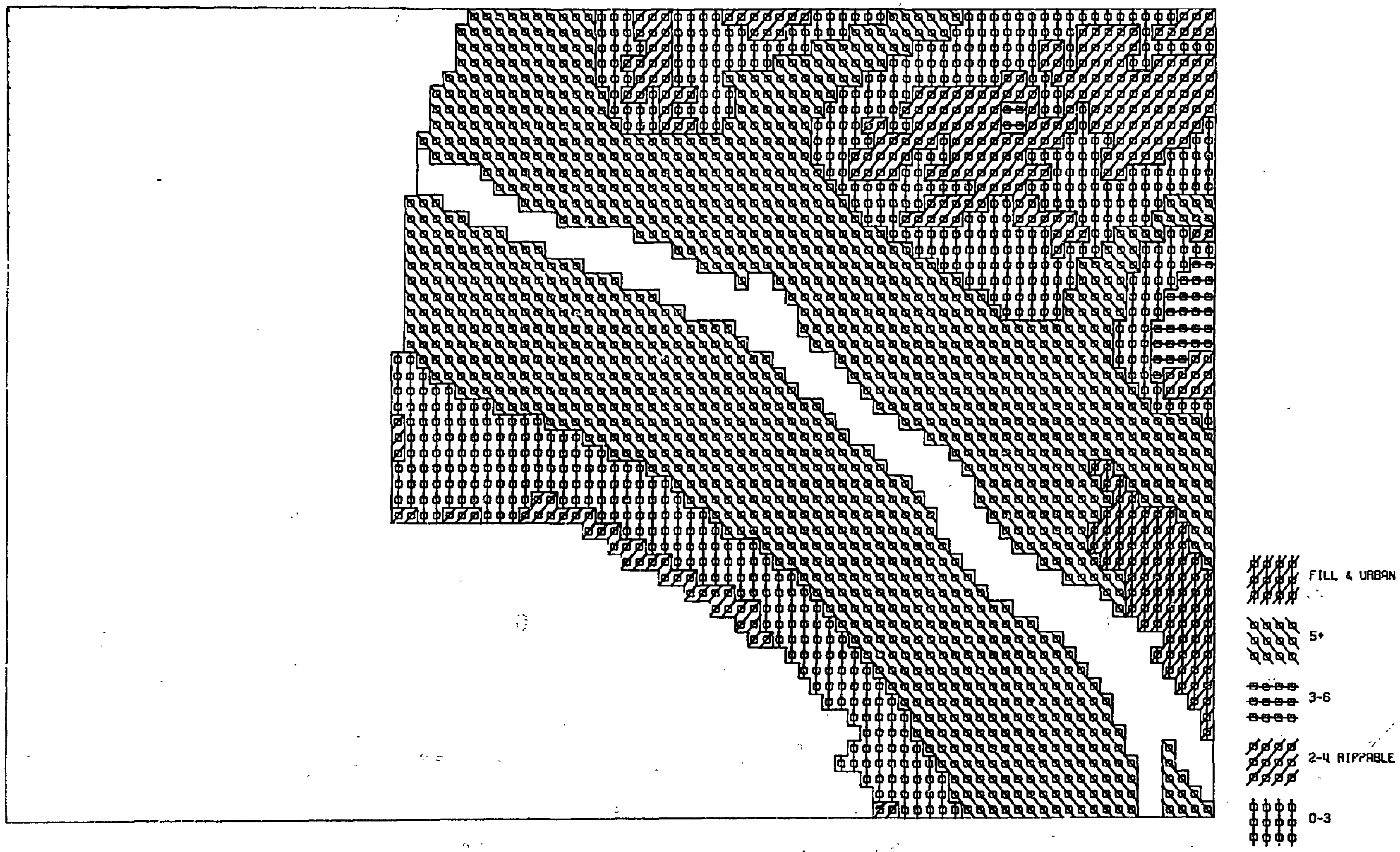

Figure 21. Interpretation Map - Depth in Feet to Hard Rock, 1:15,840 Scale, 2.5 Second (1.18 acre) Grid

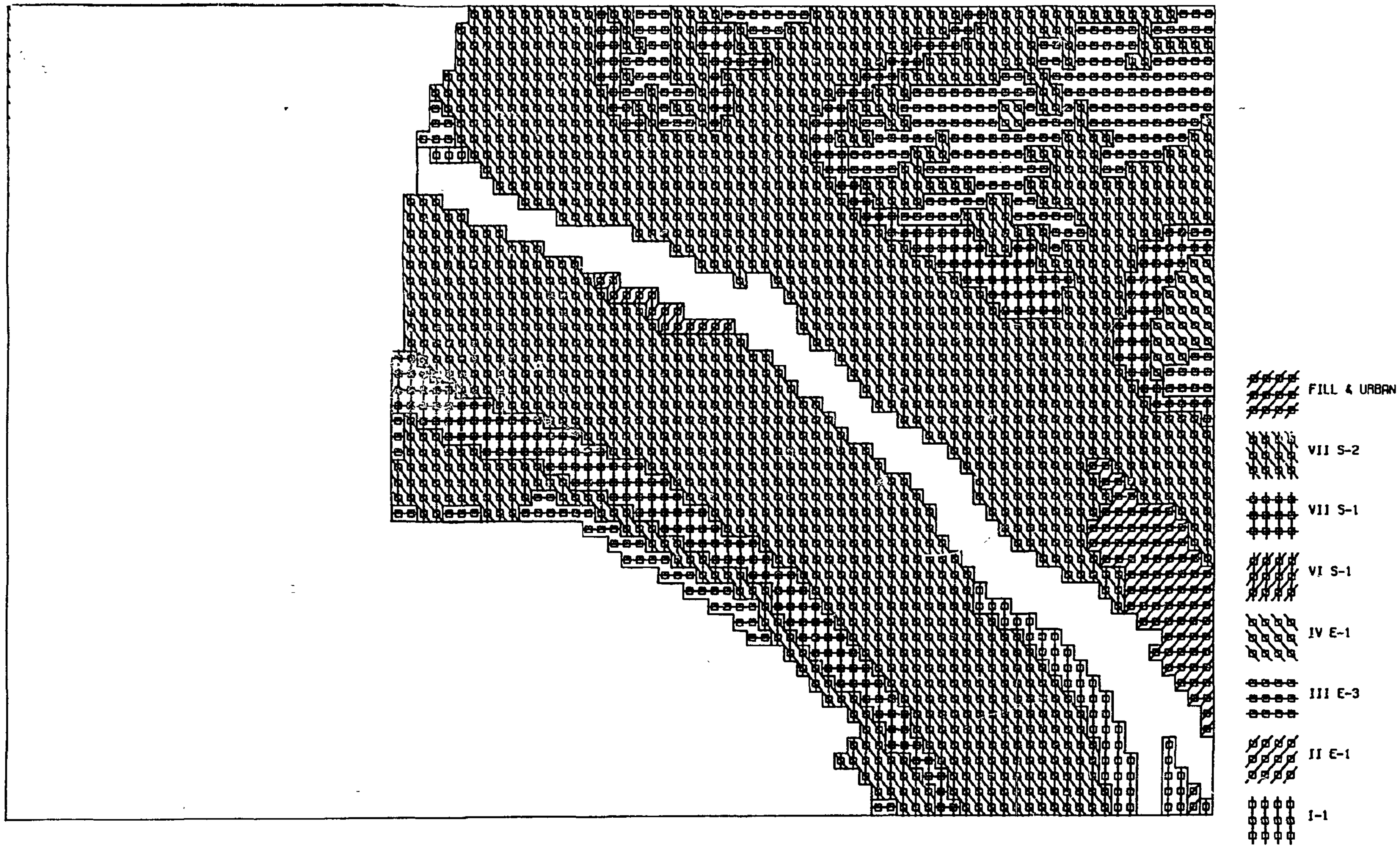

Figure 22. Interpretation Map - Soil Capability Units, 1:15,840 Scale, 2.5 Second (1.18 acre) Grid

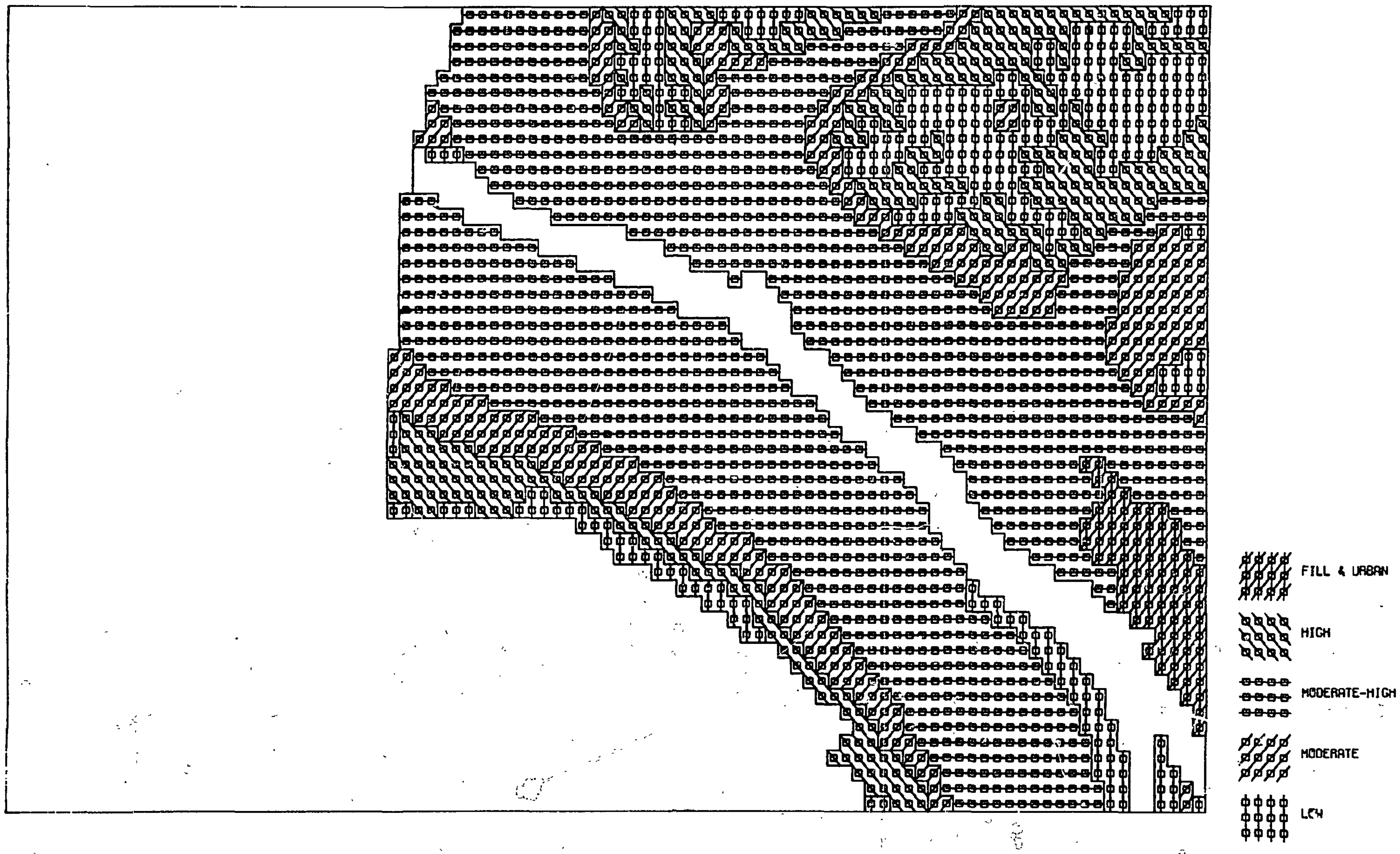

Figure 23. Interpretation Map - Potential Erodibility, 1:15,840 Scale, 2.5 Second (1.18 acre) Grid

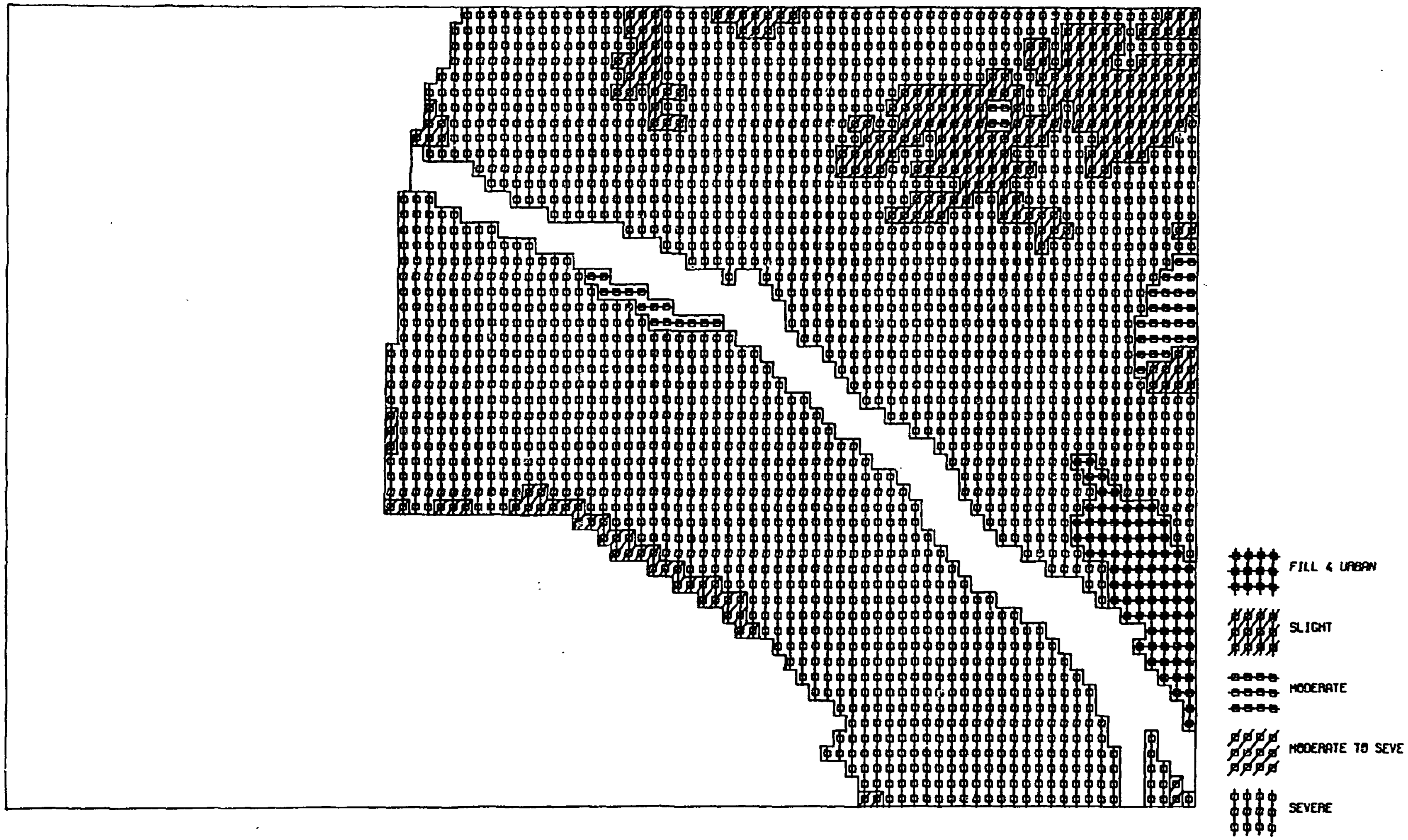

Figure 24. Interpretation Map - Residential Limitations with Septic Systems, 1:15,840 Scale, 2.5 Second (1.18 acre) Grid

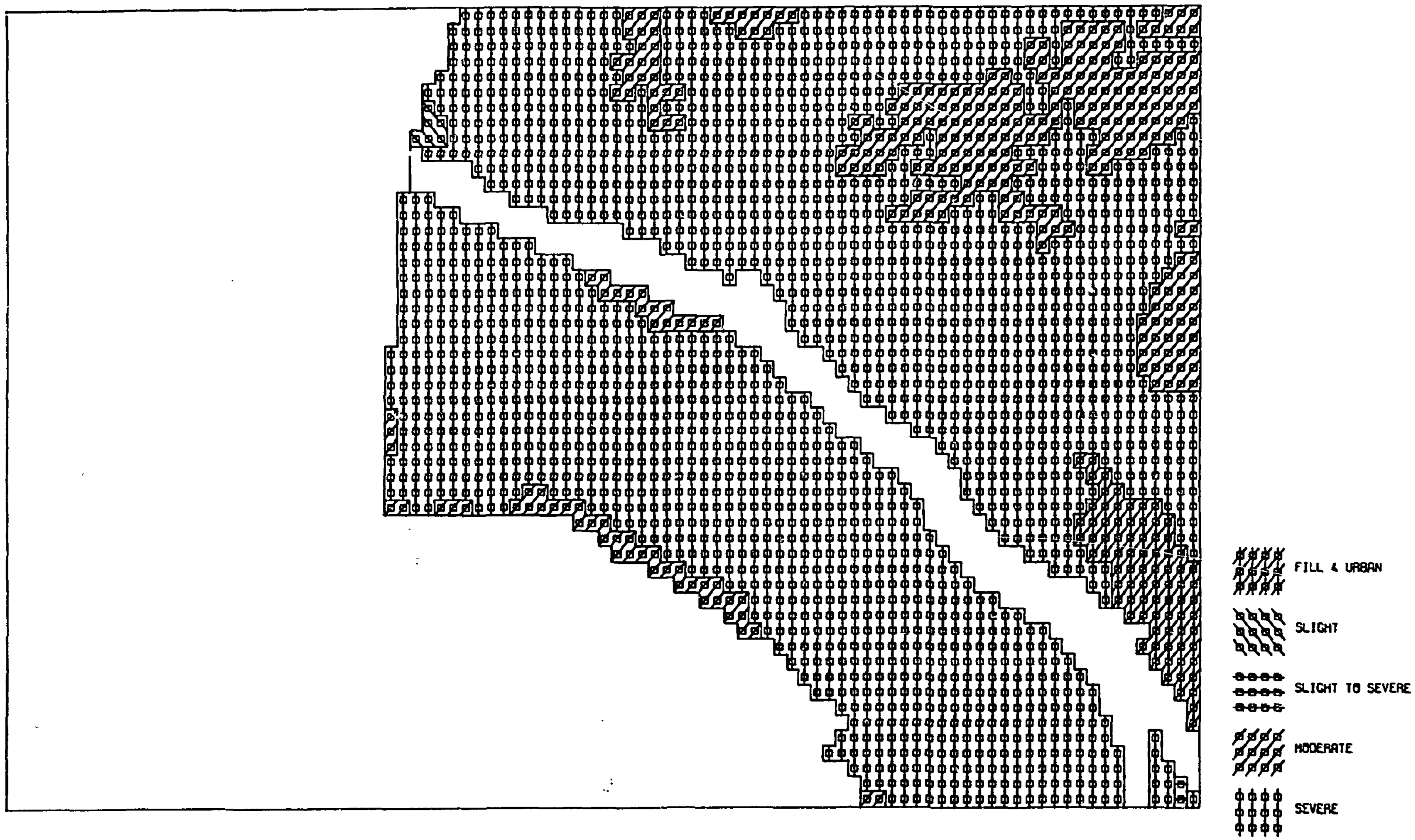

Figure 25. Interpretation Map - Light Industrial Limitations, 1:15,840 Scale, 2.5 Second (1.18 acre) Grid

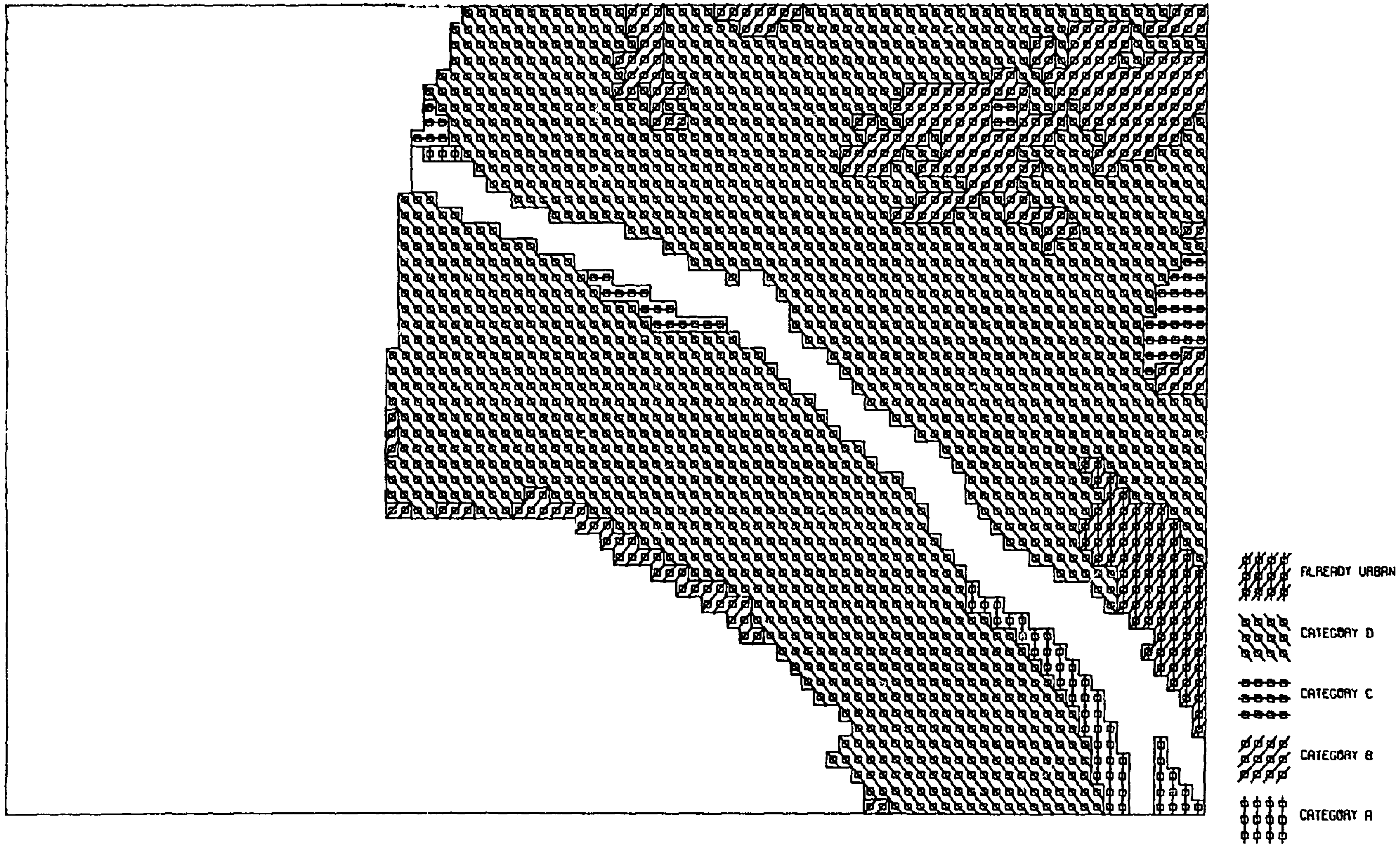

Figure 26. Interpretation Map - Tax Assessment Value, 1:15,840 Scale, 2.5 Second (1.18 acre) Grid

One of the long-term goals of this project is to use the computer-drawn maps as copy for the printer at the final publ hing state of the county soil survey. In this way, work done by the joint RESA/SCS effort becomes an integral phase of the soil survey process (i.e., field sheets are mapped; data is digitized, stored, and mapped; interpretations made and mapped; and computer-prepared final copy is generated for publication).

In summary an overwhelming quantity of data exists today; however, to fully utilize the potential of the data, interdisciplinary groups must work toward integration and development of combined problem-solving abilities. The RESA/SCS effort is but one small beginning to accomplish this end.

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2. R. C. Durfee, MAPGEN - A Computer-Aided Digitization, Analysis, and Display System for Geographical Information, ORNL-NSF-EP report, Oak Ridge National Laboratory, Oak Ridge, Tennessee (in preparation).