COMPOSITE COMPUTER MAPPING OF ECOLOGICAL DETERMINANTS
FOR IDENTIFYING LAND USE SUITABILITY

by

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B.S., *University of Utah*, 1977

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF REGIONAL AND COMMUNITY PLANNING

Department of Regional and Community Planning

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

Approved by:

Major Professor

ACKNOWLEDGMENTS

It has become very apparent to me, through my graduate studies, that research and the gaining of knowledge is a continuing process. The spirit of this process, not only lives, but, thrives within the Faculty and Staff at Kansas State University. Never, in my life, have I encountered such progressive, responsible people who are constantly looking to the future.

The help given me by my Master's Report committee: Bernd Foerster, Professor/Dean; Dr. Robert Ealy, Professor; and Claude Keithley, Associate Professor; deserve special recognition. My Major Professor and Advisor, Claude Keithley, gave me help which far exceeded any teaching load allowance. To him, I am especially grateful.

I want to express my appreciation to David Brooks, consultant at the Kansas State University Computing Center, who provided extra help, and was strategic in the success of this study.

A special thanks is given to Patricia Weisenburger and Dorothy Barnett, Librarians at the Paul Weigle Library, whose research consultation proved invaluable.

And finally, I wish to thank Vernon Deines, Professor/Head, who was extremely helpful, and supportive to my entire graduate education in the Department of Regional and Community Planning.

Thank you all very much!

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INTRODUCTION

The Planning Process and Purpose of the Study

To facilitate the incorporation of ecological determinants of land use suitability into the planning process, data should be gathered along with the other information on existing physical conditions. These data are usually compiled in the community survey or inventory stage of the planning process. (See Figure 1.) Data on all aspects of natural resources are important to a study of this type.

What purpose does a study of the physiographic differentiation of the natural landscape with computers serve in planning? Aside from helping to establish a comprehensive data base from which to make planning decisions, the prospective results of the inventory and composite mapping could be used in establishing policy and legal regulations. Belknap and Furtodo (1968) recommend that after a comprehensive natural resource study is completed,

> Policy and legal requirements can then be examined with regard to limitations, prohibitions and suggested uses to be implemented.
>
> One advantage of this proposed natural land-unit concept for guiding and controlling land-use would be that specific use requirements, based upon sound ecological principles, could be established for an area rather than more generalized standard zoning requirements.

Zoning is not the only implementation technique that would be aided by this type of study. Annexation policies and capitol improvements

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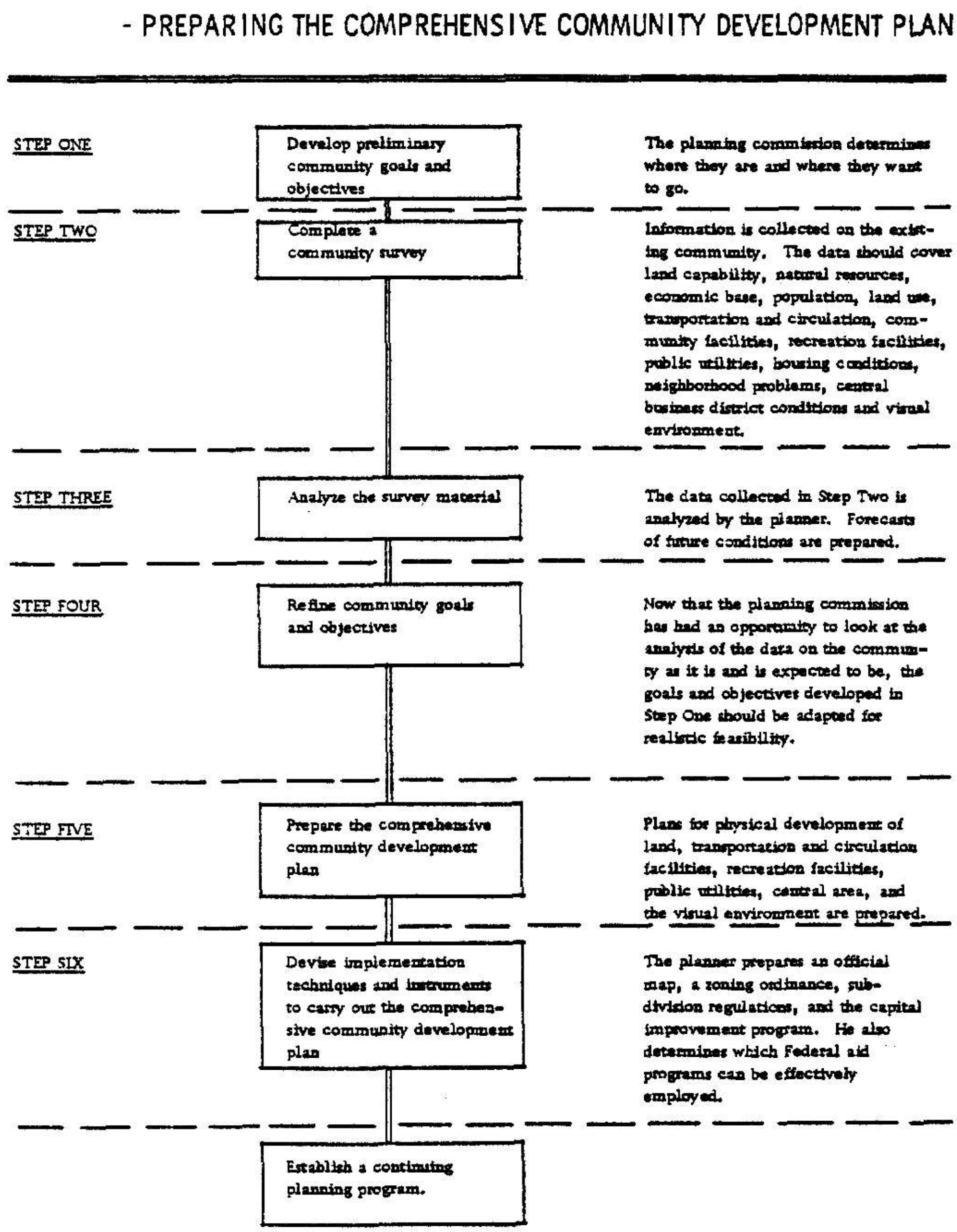

Figure 1. Flow Diagram for Preparing the Comprehensive Plan (Weisenburger, 1967).

programming could benefit as well. This method of analysis would be particularly useful in environmentally sensitive areas.

It is the author's belief that computer mapping techniques may be used to depict ecological determinants of land-use suitability to save time and produce a better analysis of suitability. Considering the speed of computers once the program is set up, they can save valuable office time over doing the overlay mapping procedure by hand. As more planning agencies and offices purchase computers or gain access to computers, this may be one application considered for this type of planning problem. Again, planners as well as others are faced with the dilemma of land-use suitability. In the future, as computers are improved, their costs reduced, and their graphic processes refined, an entire land-use study for an urban area may become feasible through computer graphic applications. The shaded half tone maps produced by this analysis could be used in establishing future growth policies.

Objectives of the Study

This study is an investigation into a method of analysis. The method is computer mapping of ecological determinants for identifying land-use suitability. The purpose of this study is to examine this method, assess its accuracy and efficiency with respect to time and cost.

In general terms this study utilized a site outside of Manhattan, Kansas (See Figure 2.) and mapped the information that pertains to land-use suitability (soils, slope, hydrology, vegetation, and cultural features). The mapping was all done by computer. Then, a weighting system was applied to establish overall composite maps. These too were mapped by computer with the aid of SWAP (SYMAP Weighting Analysis

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Figure 2. Selected Site for Study.
Source: U.S. Geological Survey, Manhattan and Keats Quadrangles.

Program). The technique used a grid coordinate system for defining the location of data or information cells. This information is used to create the shaded half tone maps. The results of this procedure are recorded and compared to McHarg's overlay approach to ecological mapping. A library search was performed to aid in applying the technique.

The final product is the computer maps of the selected site, the weighting computer program (SWAP), the composite suitability maps and the evaluation and comparison of this method to the overlay approach.

Chapter 2

DESCRIPTION OF METHODOLOGY

Computer Mapping Vs. Overlay Mapping; Advantages and Disadvantages

Most land resource mapping techniques use the methodology of Ian McHarg (Simonds, 1978). This process involves the delineation, with shaded values, of the resource characteristics of a study area. The maps are then used in a series of "overlays" to define the land use suitability. Kiefer and Robbins (1973) explain the drawbacks to this method:

> The overlay technique has several serious limitations: (1) The number of factors that can be considered simultaneously is severely limited by problems in physically seeing through multiple layers of mylar or acetate; (2) it is difficult to give unequal weight to the importance of various factors without compounding the problem of seeing through multiple layers of factor maps; and (3) it is a time-consuming process to make changes to the overlay maps each time it is desired to change the rating criteria.

There are, however, several advantages to overlay mapping when compared to computer mapping: (1) you do not have to understand computer languages or computer programs in order to do it; (2) it is a quick procedure if not impeded by the limitations of the overlay method; (3) the costs are relatively low when compared to computer mapping. These are important considerations. If the objectives of the study are to use a small number of resources, not use a weighting system and produce only one solution which will use only a single set of rating criteria, then the overlay system will meet the requirements of the study. But, for more complex areas, where a high number of weighted resources need to be considered, a computer technique would be more appropriate.

It will be shown in this study that the computer is a useful planning tool which provides a flexibility of analysis which is not easily achieved through the use of hand drawn overlay maps. This statement is supported, also, by Kiefer and Robbins (1973) who conclude in their study that;

> The use of a digital computer to assist in such analysis, rather than the use of more traditional mylar overlay methods, provides a great deal of speed and flexibility of analysis. The users of this land use suitability evaluation system may select the physical characteristics of land they wish to consider in their analysis, may assign the weights they wish applied to these characteristics, and may also set constraints on data characteristics. By these means, the system provides the ability to look at land use suitability from a variety of viewpoints or development policies.

In the application of the procedure it is desirable to find the limitations, possibilities and flexibility of composite computer mapping of ecological determinants for identifying land use suitability.

This study will use computer hardware and software available at Kansas State University and a site selected for experimentation. This study will then be compared to the overlay hand-drawn mapping technique performed in the "Manhattan West Resources Analysis" study with the same site. It is assumed that this will serve as a fair comparison.

Types and Selection of Programs for Problem Application

There are two basic types of computer mapping devices: (1) "character printing" equipment and; (2) "line drawing" (plotting) equipment (U. S. Bureau of the Census, 1969). There are many programs available for each type of equipment. But, it is the character printing method and equipment that is used for the grid cell procedure of resource analysis investigation. A detailed description of this mapping type is offered by the U. S. Bureau of the Census (1969):

> Character printed maps are produced by a standard high-speed computer printer which prints typewriter-like characters, on standard computer printout paper. Where the desired width of the map exceeds the width of the paper, the printing is done in linear sections or "strips" which are joined together to form the final map. Since lines cannot be drawn on this type of map, boundaries of areas can be only roughly approximated and often are inadequately delineated. On the other hand, shading that represents aggregated data values--the number of housing units per block, for instance--can be shown by an overprint of characters. It is also possible to show the actual data values for certain points or areas on the map instead of using shading to represent those values. The data used in generating maps by this technique must be sorted on a line-by-line basis before they can be displayed by character printing devices.

This is best suited to the grid cell system.

The grid cell procedure of resource investigation is an analysis which "allows the planner to quantify variables in a way that will reveal where impacts would be most or least severe" (Catanese, 1979). Catanese (1979) suggests that:

> In order to create a computer analysis and computer-drawn map it is necessary to cover the study area with a grid. The grid provides spatial coordinates that can be programmed for computer analysis. Each cell in the grid can be given a number that reflects the characteristic of the environment of the cell. The cell might be assigned a number reflecting a dominant characteristic (such as a steep slope or water), or the number could be produced from a matrix calculation of a number of variables.

Figure 3 depicts the application of a grid to the topography.

If an institution, agency, or planning office has the financial resources it would be best to use a computer program which is specifically designed for the application of land-use suitability mapping. Some graphic programs were developed for the definite purpose of summing different resources with the grid cell format. The programs and where they

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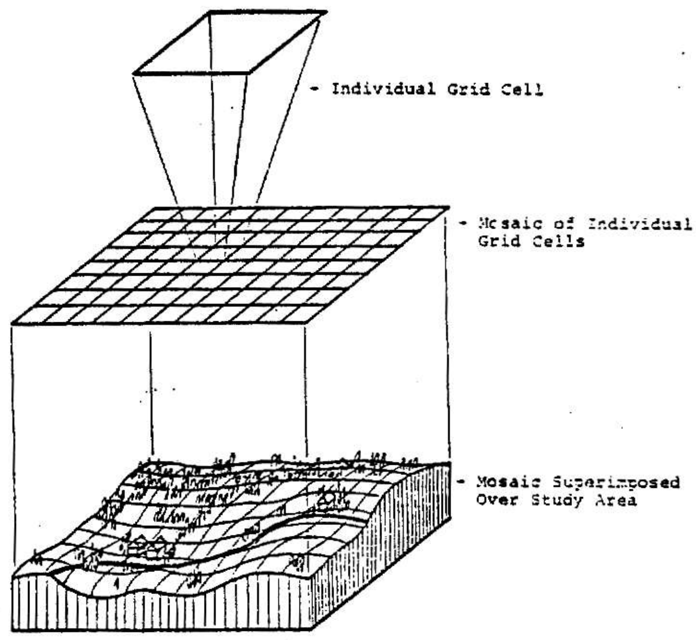


Figure 3. Grid Application Diagram (Cross, 1979).

were developed are listed in Table 1. The programs with an asterisk (*) incorporate the capability of using a weighting system.

Kansas State University does not at this time have any of the programs listed in Table 1. However, the program SYMAP (Harvard Laboratory for computer graphics and spatial analysis, 1975) is available here and used regularly. The users manual for SYMAP suggests that it could be applied to a resource analysis situation.

SYMAP is a well known program and it has a number of users options that make it applicable to a variety of thematic mapping uses (U. S. Bureau of Census, 1969). SYMAP is written in FORTRAN IV and can produce conformant, contour, trend surface, residual and proximal maps. These map types are described by the Harvard Laboratory (1978):

1. Conformant -- Maps that display data by predefined zones, e.g., counties or census tracts. Input required consists of a set of x-y coordinates defining the outline of each zone and a data value for each zone.

2. Proximal (or Thiessen polygon) -- Maps that depict zones which are created from data points by the nearest neighbor method, i.e., the value of any point on the surface is the same as the data value of the closest data point. Input required is the same as for contour maps.

3. Contour -- Maps that graphically represent a continuous surface which has been computed by interpolation from data values at specified data points. The value computed for each point on the surface is influenced by the values at the nearest data points and the weights assigned to these points. These weights are based on $1/d^2$ where d is the distance from a data point to the point for which a value is being interpolated. The weights are modified as a function of the spatial distribution of the data points around the interpolation point. Input required consists of a x-y coordinate and a data value for each data point. Papers describing the contouring algorithm in greater detail are available from the Laboratory.

4. Trend Surface -- Maps that graphically depict a polynomial surface of a specified order fitted to a set of data points and their data values. A surface is constructed by minimizing the sum of the squares of the differences between the known data values and the computed value of the surface at each data point. Surfaces from a first order ($z=ax+by+c$) to a sixth order

Table 1

A List of Computer Programs Developed
for Land-Use Suitability

	Program Name	Developed at	Source
1.	COMPUTER BASED LAND USE SUITABILITY*	University of Wisconsin at Madison	Kiefer and Robbins (1973)
2.	GRID OR GRIDS*	Harvard University	Harvard Laboratory for Computer Graphics and Spatial Analysis (1978)
3.	DOT MAP	Harvard University	Harvard Laboratory for Computer Graphics and Spatial Analysis (1978)
4.	MAP 01	New York State Department of Public Works	U. S. Bureau of Census (1969)
5.	LAND DMS*	Southeastern Wisconsin Regional Planning Commission	Walesh et al. (1977)
6.	ORRIMIS	Oak Ridge National Laboratory in Oak Ridge, Tennessee	Phillips (1974)
7.	MSDAMP*	Iowa State University	Van Driel (1977)

*Include weighting capabilities

($z=ax^6+bx^5y+cx^4y^2+...+fy^2+gx+hy+i$) polynomial can be calculated. Input required is the same as for contour maps.

5. Residual -- Maps that describe a surface created by subtracting a trend surface from an interpolated contour surface where both surfaces were derived from the same set of data values. Input required is the same as for contour maps.

The types of mapping which are most applicable to resource analysis are conformant, and proximal mapping. Conformant mapping is very cumbersome to use for areas which have small zones and are many in number; like a grid cell area. This is because conformant mapping requires each data zone to be defined by the coordinants of its outline. For example, with a study area with 500 cells it would take 2,500 sets of x-y coordinates or data cards to define the conformant zones of the study area. This is not very practical.

For this study it was determined that proximal mapping would be used. This enables the programmer to describe the study area by encoding the centroids of the grid cells into x-y coordinants. This requires that there be only as many cards or x-y coordinants as there are cells. This is much more easier to code and faster to program into SYMAP.

Selection of Cell Size for Computer Mapping

In computer mapping of natural resources the grid cell size must be decided before any encoding or mapping is performed. It is important that this be given careful consideration. There are many different factors that need to be considered before selecting a cell size: (1) scale and resolution of the base map; (2) size of study area; (3) political jurisdiction and; (4) purpose or intended use of the study are a few principal ones. This is substantiated by Cross (1979).

> The definition of the grid cell should be prefaced by a clear definition of the ultimate purposes of the project, of the budgetary and time constraints on the project, and the nature and accuracy of anticipated data sources.

For this case study the grid cell considerations include:

1. Variations in the existing physiography;
2. The necessity to locate ecologically sensitive areas;
3. Coding and mapping to be performed by one person;
4. The scale and resolution of a USGS 1:24000 Quadrangle map and HUD 1:24000 Flood Hazard Maps.

The grid is overlayed the study area in Figure 4.

<u>Weighting Systems: Bias Based on Objectives</u>

The application of a weighting system is what sets computer mapping apart from the hand overlay technique. The computer is very efficient at handling mathematical manipulation of numbers; the hand overlay method is not. In most cases the weight is a multiplier--often called an "importance weight" (Hopkins, 1977). Each group of rated resources are multiplied by the weight for each cell. This is best explained by Hopkins (1977):

> The suitability rating for a particular region is then the sum of the multiplied ratings, or in mathematical terms, the linear combination. The effect of multiplication by the weights is merely to change the unit of measure of the ratings on each factor by the ratio of the multipliers so that all of the ratings are on the same interval scale (e.g., if one factor is in dollars and another in cents, then the first would be multiplied by 1 and the second by 0.01 to put both in dollars). The ratings can then be added. Thus, the units of measure for suitability with respect to each factor can be made equivalent after rating the types for each factor individually on interval scales with different measurement units.

Does a weighting system bias an analysis? This question is difficult to answer. Based on the prospective types of land use and the

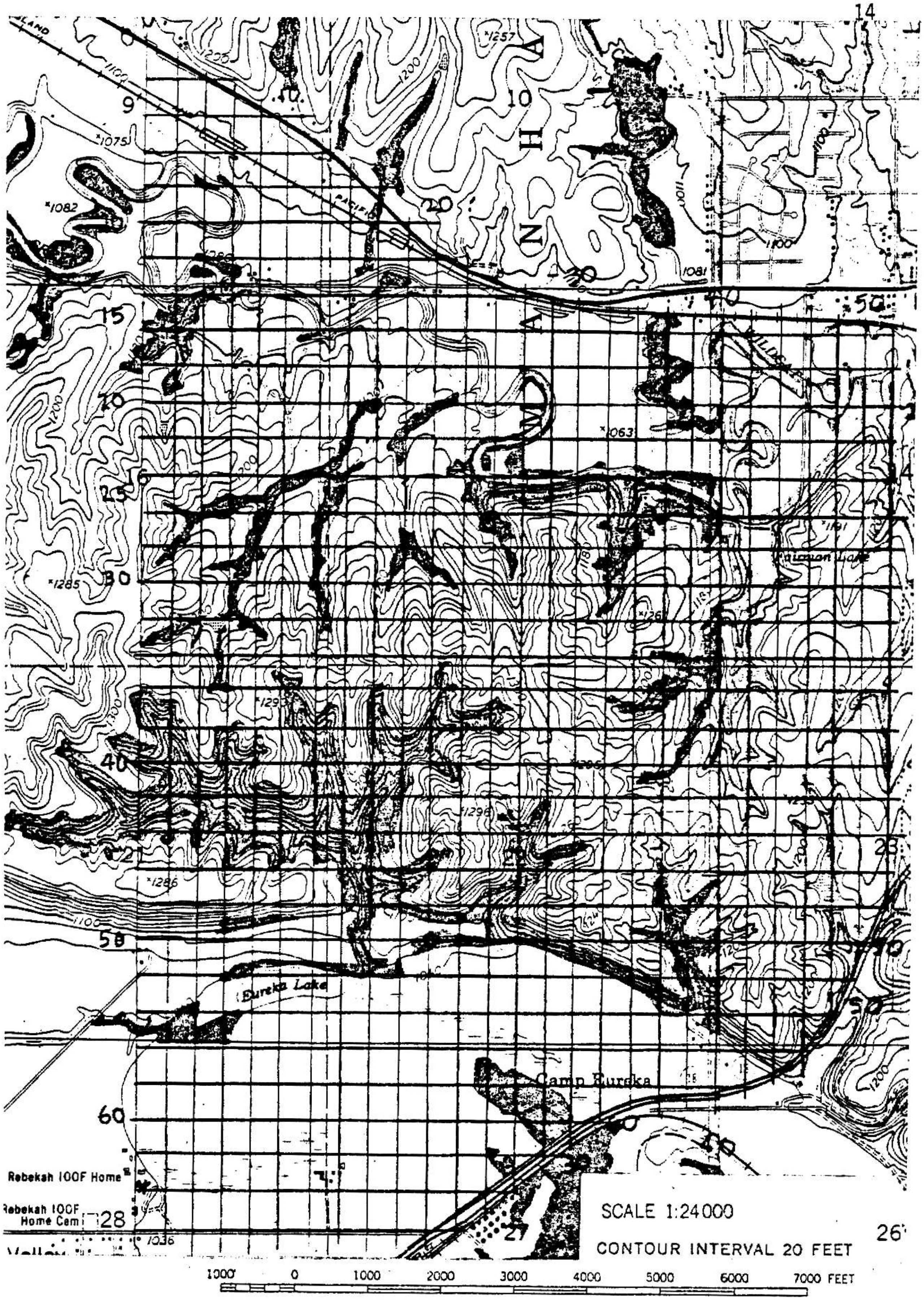


Figure 4. Study Area with Grid Applied. Source: U.S. Geological Survey, Manhattan and Keats Quadrangles.

significance of the resources, weighting supports the objectives of the study. A good system is one where honest attempts at fair judgment have been made. As long as the bias reflects the overall goals and objectives of the study, it makes a great deal of sense.

As with the grid cell size the weighting factors should be thought out very carefully. Figure 5 is an example of how a weighting system is applied to composite mapping.

<u>The Flexibility of SYMAP</u>

SYMAP was first written and developed in 1963 by Howard Fisher at Northwestern University. The program is currently maintained and researched by the Harvard Laboratory for Computer Graphics and Spatial Analysis.

A standard high speed printer is used to print typewriter like characters on a standard 11x15 inch computer printout sheet. Areas can be shaded like a half-tone newspaper photograph with up to 10 progressively darker shades. The darker shades are produced by overprinting two or more type printer characters (U. S. Bureau of the Census, 1969).

By 1968 SYMAP was being applied to natural land units as a planning base (Steimitz, 1968). A variation of the proximal option using a grid was also being investigated in New Haven, Connecticut showing hours spent by a visiting nurses association (U. S. Bureau of Census, 1969). To date, SYMAP has been used in a variety of applications including:

1. Market Research -- To delineate patterns of ethnicity and socio-economic characteristics in determining the most cost-effective approach for product testing and potential market penetration.
2. City Planning -- To highlight urban social and economic problems.
3. Commerce -- To identify a state's tourism and its potential for growth.

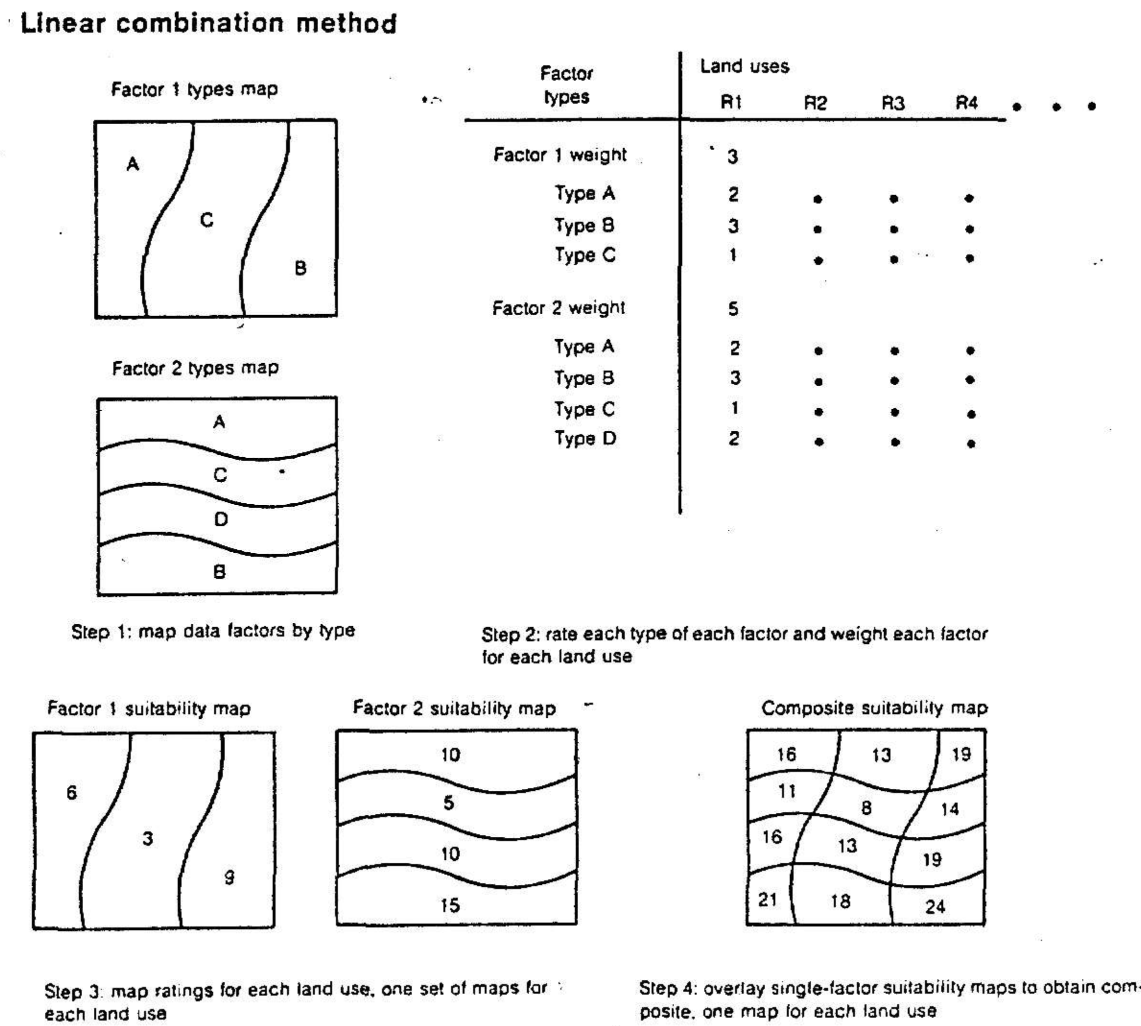


Figure 5. Linear Combination Method of Weighting Resources for Composite Suitability (Hopkins, 1977).

4. Site selection -- To display patterns related to such factors as land cost, slope, depth of water table, and transportation access in order to identify sites suitable for development.
5. Energy Resource Studies -- To map areas of retrievable, low-sulfur bituminous coal deposits.
6. Air and Water Quality Analysis -- To identify spatial and temporal patterns related to various concentrations of suspended particulates.
7. Demography -- To define patterns of past, present, or projected future population characteristics (Sheehan, 1979).

One of the reasons for the wide variety of applications is because of some statistical support options which permit calculations of means, standard deviations, histograms, and percentile groups (U. S. Bureau of Census, 1969). For those who are familiar with computer programming:

> . . . the program is capable of being more effectively tailored to their specific needs. Commensurate with one's programming ability, highly sophisticated models can be integrated with SYMAP by using a special subroutine (FLEXIN) without altering the program's internal structure (Sheehan, 1979).

The flexibility, good documentation and the proven performance of SYMAP were significant criteria for its selection in this study.

Chapter 3

TYPES OF ECOLOGICAL DATA

Sources of Information

There are two kinds of data sources: primary and secondary data (Krueckenberg and Silvers, 1974).

> Primary data are first-hand information, gathered from original sources, for instance, through interviews, or going out and directly observing the phenomena that is being studied. Secondary data are second-hand data, data that someone else has gathered but that are available and may fit one's needs. Data collected by the United States Bureau of the Census, published and stored in the library, become a secondary source for everyone's use (Krueckenberg and Silvers, 1974).

In a resource analysis it is secondary data which are used most often. Only for a very small site would it be possible to survey and collect data for all the resources first hand.

Various types of ecological information are available from secondary sources. In land use planning, however, the appropriate ones for a particular study may be difficult to find. Ideally, in a resource analysis one should decide which resources are to be inventoried before looking for data sources. This can be difficult. The solution is to look at published information that already exists and gather any missing information through primary sources.

Certain kinds of data exist for almost every location in the United States. This information is compiled as part of the U. S. government or various state government's data base systems. The following is a list of common sources of principal information:

1. Topographic slope -- Most all slope information can be extracted from a 1:24,000 scale United States Geological Survey (USGS) topographic map. Categories of slope class can be developed from the relief shown on these maps.

2. Soil -- Soil types are classified and mapped by the United States Department of Agriculture-Soil Conservation Service (USDA-SCS). These can be interpreted into suitability ratings by characteristics, i.e., depth to bedrock, shrink-swell potential, drainage and depth to ground water.

3. Hydrology -- The United States Department of Housing and Urban Development (HUD) Federal Insurance Administration will publish data about Flood Hazard areas. This information is mapped at the same scale as the USGS 1:24,000 maps. For some areas, the United States Army Corps of Engineers will have flood area maps. In most cases these, also, are at 1:24,000 scale.

4. Vegetation -- General categories of vegetation are included on the USGS topographic maps. These denote: marsh, wooded marsh, woods, brushwood, mangroves and scrub. A list of plant species should be available from most states Cooperative Extension Service in conjunction with the U. S. Department of Agriculture. This information is valuable when identifying what could exist in a certain area. A detailed vegetation map of an area is difficult, if not impossible in some cases, to find. The situation is aided by the possibility of low altitude aerial photography and interpretation. Many advancements have been made in recent years in remote sensing with the use of infrared photos and interpretation of vegetation (Ford, 1979). To find out if any aerial photos exist for a particular area, the United States Department of

Agriculture-Agricultural Stabilization and Conservation service should be contacted. Oftentimes these aerial photos are not up to date, and should be verified by on-site inspection.

5. Wildlife -- Wildlife is the most difficult to map. Again, the state Cooperative Extension office or state office of Wildlife, Fish and Game or Biology will have a list of what habitats probably exists in the area. Maps of wildlife habitats are very scarce. Some information could exist if there had been a special study of the area, though.

6. Climate -- Most general information about climate is available with the United States Weather Bureau. Climate is a very important element of the resource analysis. The on-site climatic changes are closely related to such on-site factors such as topographic relief, vegetation and water (U. S. Department of the Interior, 1974). Mapping of the micro-climate is often only an interpretation of the Weather Bureau information. This might include severe run off areas, high wind areas or drifting snow areas.

7. Historic and Cultural Features -- This category includes significant historical landmarks, utility easements, publicly owned land and existing physical development, i.e., structures, roads, railroads, utility sub-stations. This information will have to come from a variety of sources. The historical resources could be located with the aid of the state Historical Preservation Society office or literature regarding local history. Utility easements have to be located through contacting the county planning office, recorder's office or the utility itself. Publicly owned land and existing physical development information should be available from the county or regional planning office. Also, existing

physical development will be mapped on the USGS 1:24,000 topographical maps.

8. Sub-Surface Geology -- The geology should be checked along with soils or as a separate inventory. Depth of layers of limestone and impermeable clay need to be mapped, especially if septic systems are being considered for sewage disposal. The best source for information on geology is the U. S. Geological Survey or the state Geological Survey.

All data sources for the various types of resources should be verified by spot checking or an on-site inspection.

Scale and Detail of Information

For most areas the base map will be the same scale as the USGS 1:24,000 scale. However, this is not a restriction. With the overlay method, if a base map has to be reduced or enlarged to match the scale of another map, it may take much time to redraw the map or increase expenses to do it photographically. With computer mapping, all that is required is to change the grid size proportionally and draw a new grid on an acetate overlay. So, with computer mapping the problem of different scales of information is solved much easier. There is a trade-off, however. The detail of the hand overlay system is slightly more accurate. This is because of the fact that computer mapping makes an approximation with the utilization of the grid cell system. Figure 6 shows the interpolation of data into the grid cell system and how a weighted composite is formed.

Non-Ecological Data

Non-ecological data could be adopted to composite computer mapping. Socio-economic information such as age, sex, income, housing

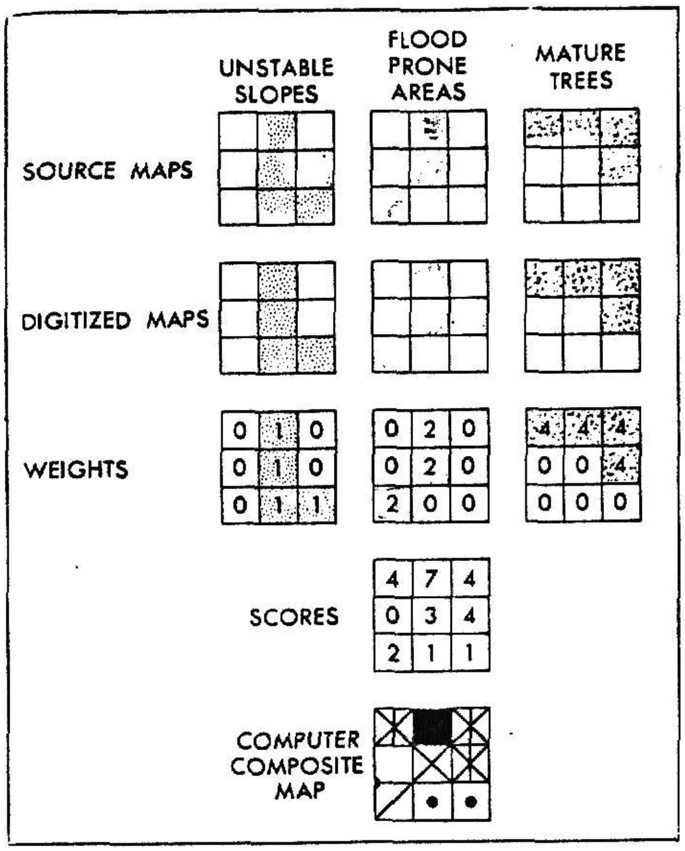


Figure 6. Grid Interpolation of Natural Resource Information for Composite Mapping (Van Driel, 1977).

conditions, land use, and ethnicity could be mapped and some general land use plans produced. Computer mapping could also be used in capital improvements programming. Areas of urban blight might be identified for redevelopment or rehabilitation proposals too. Other social data could be mapped as well. It would be possible to show areas of physical disease, mental disease, crime, unemployment and illiteracy (McHarg, 1969). Computer mapping of this information could be done on a block by block basis. The different scales of information would be a relatively small problem because of the capability to change scales by drawing an appropriately sized grid.

While it is beyond the scope of this study composite computer mapping could be valuable to urban planners as well.

Chapter 4

ANALYSIS OF STUDY AREA

Ecological Determinants Used for Study Area

The general physical character of the study area is that of the Kansas Flint Hills region with rolling hills and limestone bluffs. In areas of little slope there exist some agricultural uses. The entire area exhibits the population characteristics of a rural area with a sparse distribution of residences.

The resources that were analyzed in the "Manhattan West Resources Analysis," and for this computer study too, include: (1) slope (physiography); (2) hydrology; (3) soils and subsurface geology; (4) vegetation and; (5) cultural features. It was determined in that study that these were the most important resources to consider for land use suitability analysis. The "Manhattan West Resources Analysis" evaluated the climate and wildlife as well, but these could not be mapped and used with the overlay technique because of a lack of appropriate detail. For this report it will suffice to say that general information on climate and wildlife is contained in the "Manhattan West Resources Analysis" report.

The sources for the resource inventories used and mapped in this analysis include:

1. Soil -- Riley County Soil Survey by the Kansas Soil Conservation Service

2. Slope -- USGS Topographic 1:24,000 scale Keats and Manhattan quadrangles

3. Hydrology -- U. S. Army Corps of Engineers, Flood Plain Information: Wildcat Creek, Manhattan: 1974

4. Cultural Features -- USGS Topographic 1:24,000 Keats and Manhattan quadrangle, and the Pottawatomie-Riley Counties Water and Sewer Plan (utility location).

Each of these resources has its own significance as explained in the "Manhattan West Resources Analysis" (Shearer et al., 1979).

Slope

The analysis of slope in determining appropriate uses for a particular land area requires the evaluation and interpretation of several interrelated factors. The degree of steepness--or lack of it--must be studied in relation with subsurface geology, subsurface hydrology, soil type, local climate, and vegetation cover to determine risk of surface slippage, flooding, potential erosion problems, etc.

A slope of five to one may present only limited problems to urban development in an area of low rainfall with good subsurface structure; the same slope may prove disastrous if it is located over clay substructure in a more wet climate (such as the mud slides in parts of California for an example). In the area covered by this study, slopes range from zero percent in the areas along the river valleys to ninety percent on rock outcroppings where the subsurface limestone layers emerge. In general, however, slopes range from zero to about fifty percent over most of the area.

On the low side, slopes in the zero to two percent range generally coincide with poorly-drained alluvial breaks soil types and therefore are poor risks for any active type of development except agriculture (but could also have passive recreation and conservation). These areas also contain most of the vegetative overstory and therefore provide maximum wildlife habitats.

The cutoff for slopes too steep for most development is fifteen percent. Above this point, soils classed as stony steep, sometimes overlaid with thin layers of loess, present major construction problems and are highly susceptible to erosion. The remaining area--the two percent to fifteen percent range--lends itself to most types of development. This does not of course eliminate other slope categories for specific uses; it would be quite appropriate to construct a hiking trail on the level areas by the river or on the steep side of fifteen percent. These categories simply lend themselves most easily to further analysis within this study area.

Hydrology

The type and quality of on-site water is a critical resource. Even more important is the overall consideration of the entire interlocking hydrological system. Surface water and drainage patterns greatly affect vegetation, wildlife, and even climatic systems. The capability of the surface and subsurface systems must be considered to utilize it as a significant resource. The following represent the hydrological features that were analyzed as part of the hydrology survey:

- A. Surface water
    1. Streams
    2. Rivers
    3. Ponds
    4. Lakes
    5. Reservoirs
- B. Drainage Ways (watersheds)
    1. Major
    2. Minor

Groundwater is generally less than twenty feet below the surface in major stream valleys. The depth will range from twenty to fifty feet in the upland regions except in some localized areas where it may exceed a hundred feet (Oblinger and Smith, 1971). Wells in the alluvial deposits along Wildcat Creek show water-table depths of approximately fifteen feet. Flooding has occurred along Wildcat Creek. The U.S. Army Corps of Engineers made a study of Wildcat Creek and outlined an area that would be covered by water should a rain having a 100-year frequency (sometimes referred to as the 100-year flood) occur. Flooding on the tributaries of Wildcat Creek may be a hazard to increasing the intensity of use of this area.

Soils

Soil is the end product of five factors. These factors are topography, climate, parent material, biota, and time and can act concurrently or separately to form specific soil for a given area. A soil found in a given area can be either residual, evolved in place, or transported. If transported into an area, the soil can be glacial till, loess (wind carried), or lacustrian (deposited by fresh water). In the case of the study area, the predominate soil is loess. This loess was carried from bluffs, near the Missouri River that formed from glacial runoff. The most important soil forming factor for this area is topography. If not for differences in topography this area would be covered almost entirely by a cap of loess varying in thickness but not in basic texture.

Although there are many and varied soils found in the project area they will be grouped into six basic groups. This is done both for convenience and in keeping with the detail required. These six groups are as follows:

1. Alluvial break stony steep--properties that prevent any development.

2. Sandy--(Ha) Haynie: fine sandy loam, level to gently sloping, found mainly in flood plains.

3. Silt loam--Readin-Kennebec-Ivan association: silt loams, nearly level to gently sloping, found on terraces and flood plains.

4. Silty clay loam--Smolan-Wymore-Irwin association: silty clay loam, found on high terraces and uplands.

5. Upland loams--Clime-Sogn association: Silty clay loams, sloping to steep, found on uplands.

6. Highland loams--Benfield-Florence association: silty clay loam and cherty silt loam, sloping to steep, found on uplands.

Vegetation

The vegetative types in Riley county are those found throughout the Flint Hills. This area is a large expanse of nearly level wind-deposited loess cut by several large rivers and numerous small streams. These rivers and streams along with their associated drainageways form the dominate topographical characteristics of the area. This character of deep valleys sloping steeply upward to nearly flat uplands imparts a very unique vegetative stratification to the area. This stratification yields extremely fertile crop lands in the flood plains, dense hardwood forests at the bases of slopes, hardwood-softwood mixtures at midslope, and tall grass prairie on the uplands.

The vegetation found in the analysis area was divided into three broad categories: overstory, understory, and grasses. These categories were selected because of ease of mapping and are believed to be sufficiently comprehensive to meet the needs of the vegetation analysis.

Overstory is composed of hardwoods with a small percentage of softwoods and makes up a total canopy. Understory is composed of a mixture of hardwoods, softwoods, and shrub species and is a broken canopy. Grasses are composed of both short and tall prairie grasses.

Cultural Features

The cultural features inventory map was done primarily to locate existing man-made and man-imposed elements that should be considered when compiling the suitability maps. Such features that were noted were electricity lines and gas pipelines, structures, roads, power stations, railroad tracks, and publicly-owned lands which of course would have limited urban or recreational uses.

Publicly-owned land includes several Kansas State University properties, and power stations. The university-owned property and power stations (along with the land immediately surrounding the power stations) would be unsuitable for urban or recreational development but should be conserved in their present states with the university land remaining in research oriented activities.

Weighting System Used for the Study Area

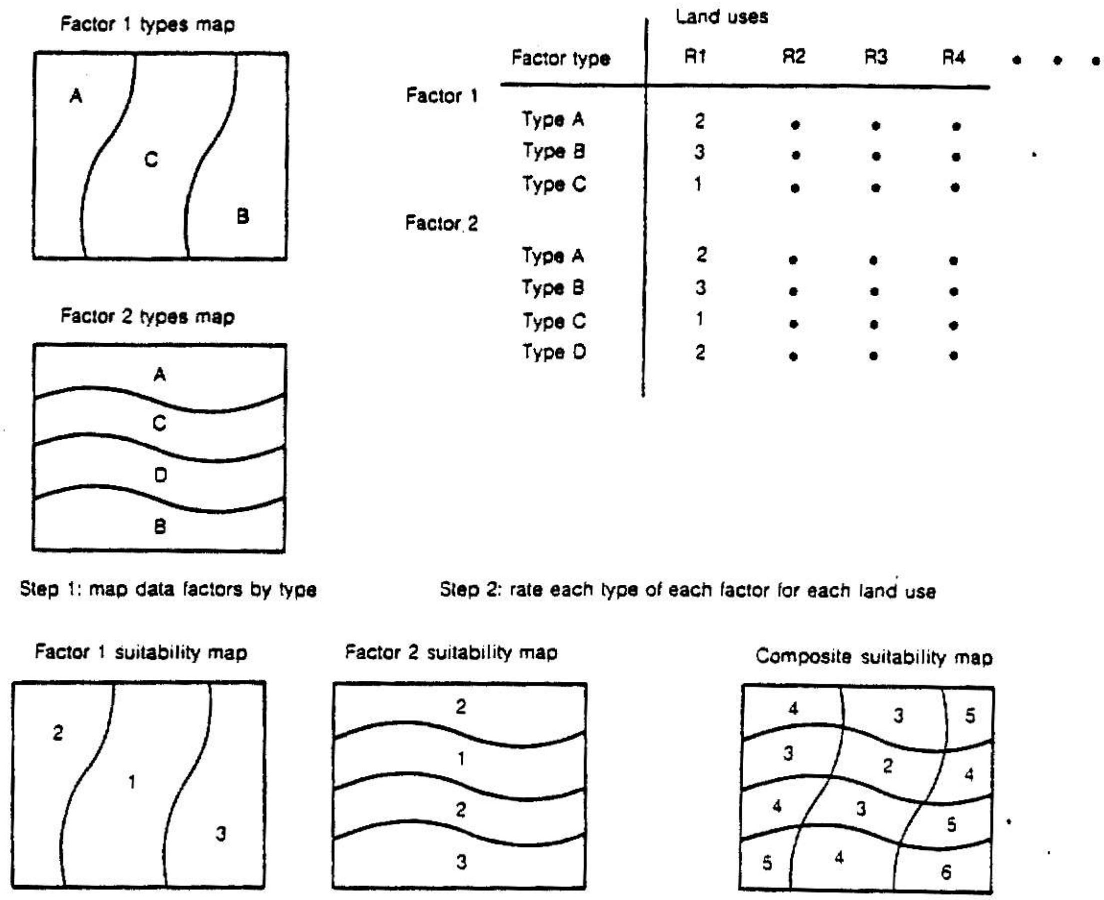
In mathematical terms the production of suitability maps with the McHarg (1969) method is called an ordinal combination (Hopkins, 1977). This means that a series of resource inventories are combined or summed in a particular order with equal weight given to each resource. (See Figure 7.)

> The first step is to map for each of a set of factors (e.g., soils, slope, vegetation, land-use) the distribution of types (soil types, slope classes, vegetation types, land use types). The second step consists of filling in a table that indicates (in this case by levels of gray) the relative suitability rating for each land use of each type (e.g., soil type) of each factor (e.g., soils) (Hopkins, 1977).

Figure 7 and Figure 8 are the same except that gray values have been replaced by an ordinal numbering system. Hopkins (1977) claims that, "This addition is an invalid mathematical operation." This is further explained.

> This method cannot deal with the situation where the relative suitability for a particular use of a given soil type depends on the slope type with which the soil type occurs. A slope of 25 per cent occurring on well-drained soil over clay might be quite disastrous for high cost residential development, as demonstrated in California, and therefore receive a low rating.

Ordinal combination method with numerical index



	Factor type	Land uses R1	R2	R3	R4	• • •
Factor 1						
	Type A	2	•	•	•	
	Type B	3	•	•	•	
	Type C	1	•	•	•	
Factor 2						
	Type A	2	•	•	•	
	Type B	3	•	•	•	
	Type C	1	•	•	•	
	Type D	2	•	•	•	

Step 1: map data factors by type

Step 2: rate each type of each factor for each land use

Step 3: map ratings for each land use, one set of maps for each land use

Step 4: overlay single factor suitability maps to obtain composite, one map for each land use

Figure 7. Ordinal Combination Method of Composite Suitability (Hopkins, 1977).

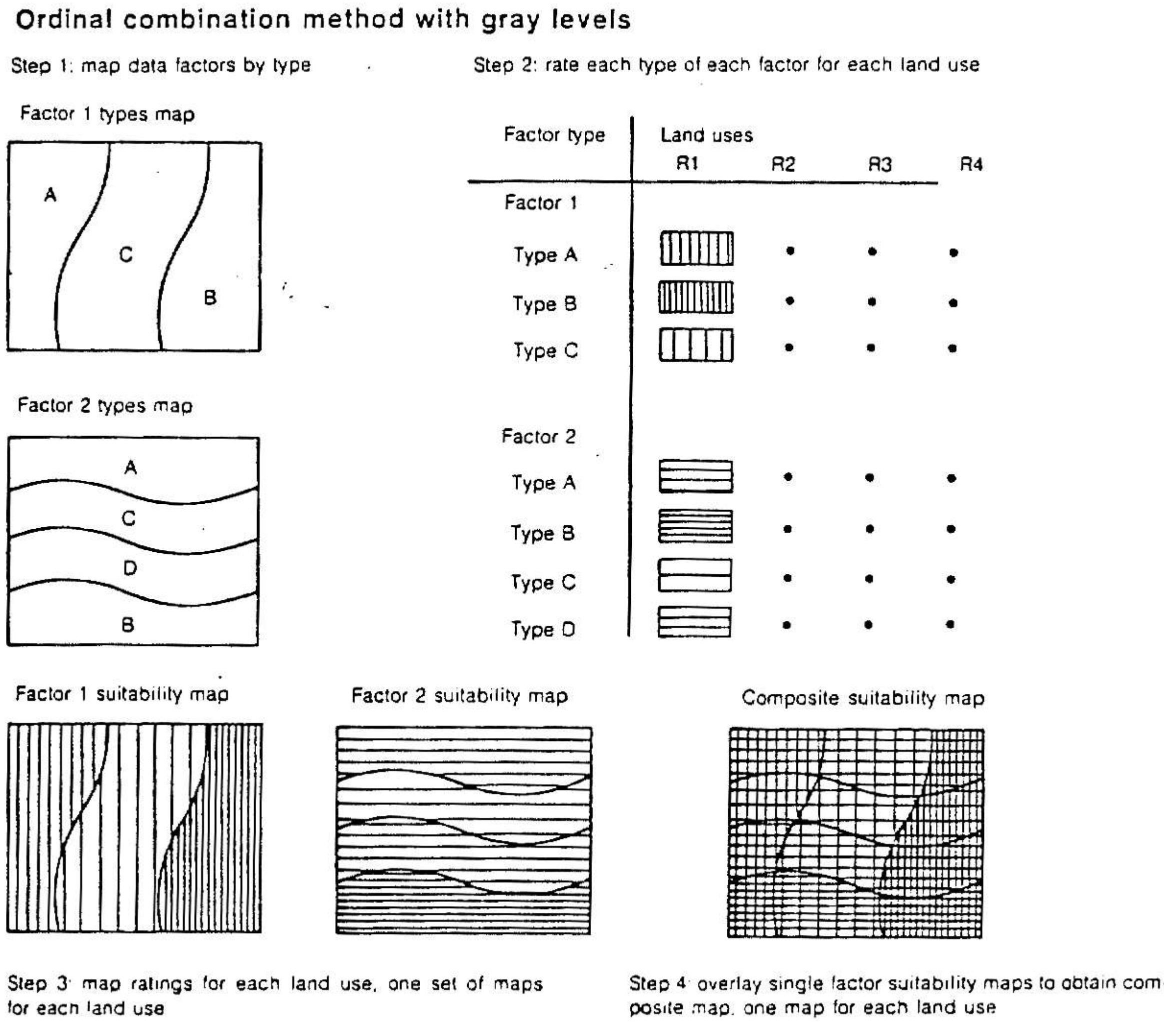


Figure 8. Ordinal Combination Method of Composite Suitability with Gray Levels (Hopkins, 1977).

> At the same time, a slope of 25 percent and well-drained soil on a different subsurface or a slope of 5 percent on well-drained soil over clay might be quite acceptable.
>
> Ordinal combination is not a good method for generating suitability maps because of the implied addition of ordinal scale numbers and because of the implied independence of factors (Hopkins, 1977).

For this study the first step, the mapping of resource types, was performed (like McHarg) with SYMAP. But, for the suitability step an importance weight or, mathematically, a linear combination method was used. The explanation of this is simple. Each type of each resource is assigned an interval rating from one to three or one to six, depending on the resource. Each of the resources is then multiplied by a weight. This information is then combined, or summed. Then by subtracting the lowest score from the highest score a range of scores is established which is then divided into equal rank groupings. The number of these rank groupings is equal to that of the number of resources that were inventoried. This is the standard formula for a weighted average.

For this study a separate program was written and developed to read in all the resource interval ratings, multiply them by the weighting factor and combine or sum them. This program is SWAP which stands for SYMAP Weighting Analysis Program. It was conceived by the author and written by David Brooks at the Kansas State University Computing Center in May 1980. SWAP is written in PL-1 and reads input with the SYMAP format, performs the mathematical calculations and outputs the solution in the SYMAP format. The last step of creating the rank groupings is done with the F-map electives, 3, 4, 5, and 6 within SYMAP. These are: Number of Value Class Intervals, Value Range Minimum, Value Range Maximum and Ranges and Value Class Intervals respectively.

Computer Services Used for Study Area

In the first stage of the computerization process the centroidal points of the grid cells are encoded and punched on cards using an X-Y coordinate format. This is done by drawing a SYMAP grid (Figure 9) over the entire study area (Figure 10) and writing the centroid locations on a numbered piece of paper or listing. The grid cell numbers on the encoding sheet should correspond with the cells of the study area. This is made possible by numbering the cells of the study area. (See Figure 11.) The listing is then punched on computer cards. The card punching is made very efficient if a drum card is set up on the keypunch machine. This enables the keypunch machine to skip all spaces on the computer card and stop only at the data field locations. For the satisfaction of SYMAP field definition there is one cell centroid location per card. When all the cells are punched this group of cards becomes the B-data points package for the SYMAP program. For ease of handling, and knowing that this package could be used over and over, the B-data points package can be stored on a magnetic disk. The disk space is rented from the computing center. (See Appendix A.) Next the outline of the study area is encoded and punched. These points become the A-outline package for SYMAP. The following step is to code the resources. Each resource inventory becomes an E-value package for SYMAP. The last step is to select the F-map electives, add the job control cards and produce the resource inventory maps. The F-map package is required and has 38 electives which define almost all aspects of the appearance or interpolation of the output map. The job control cards are those cards required by the computing center to call up and execute the programs.

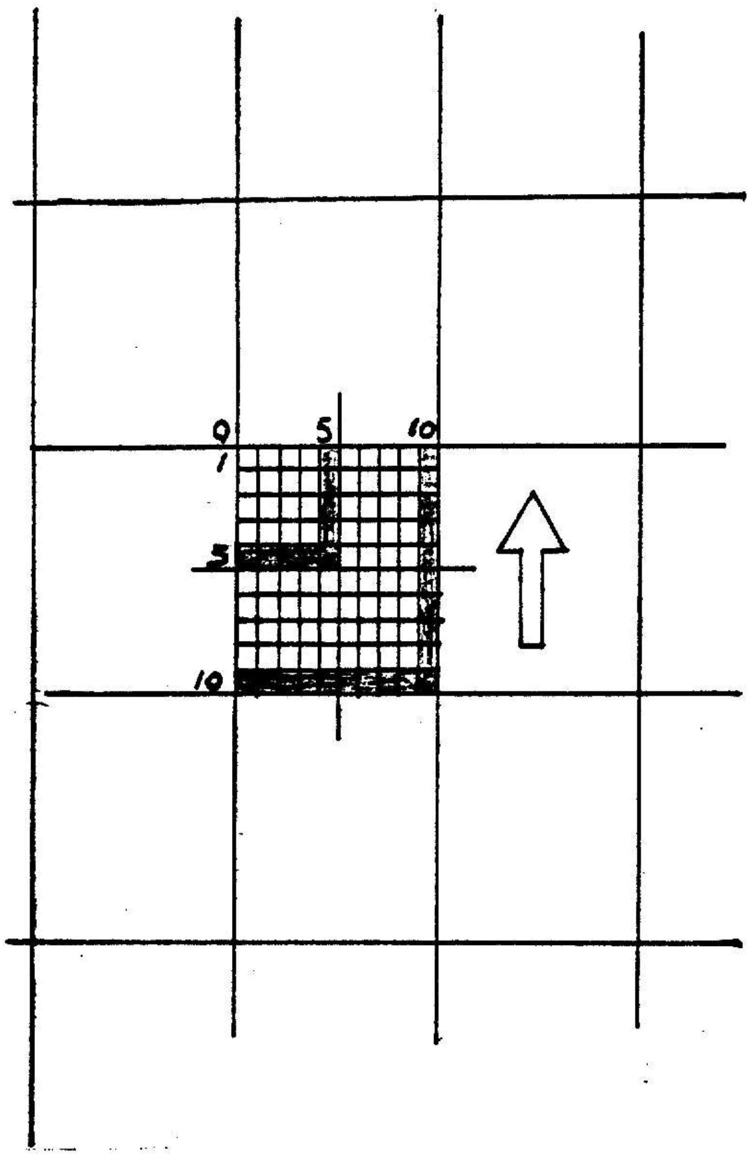


Figure 9. SYMAP Grid.

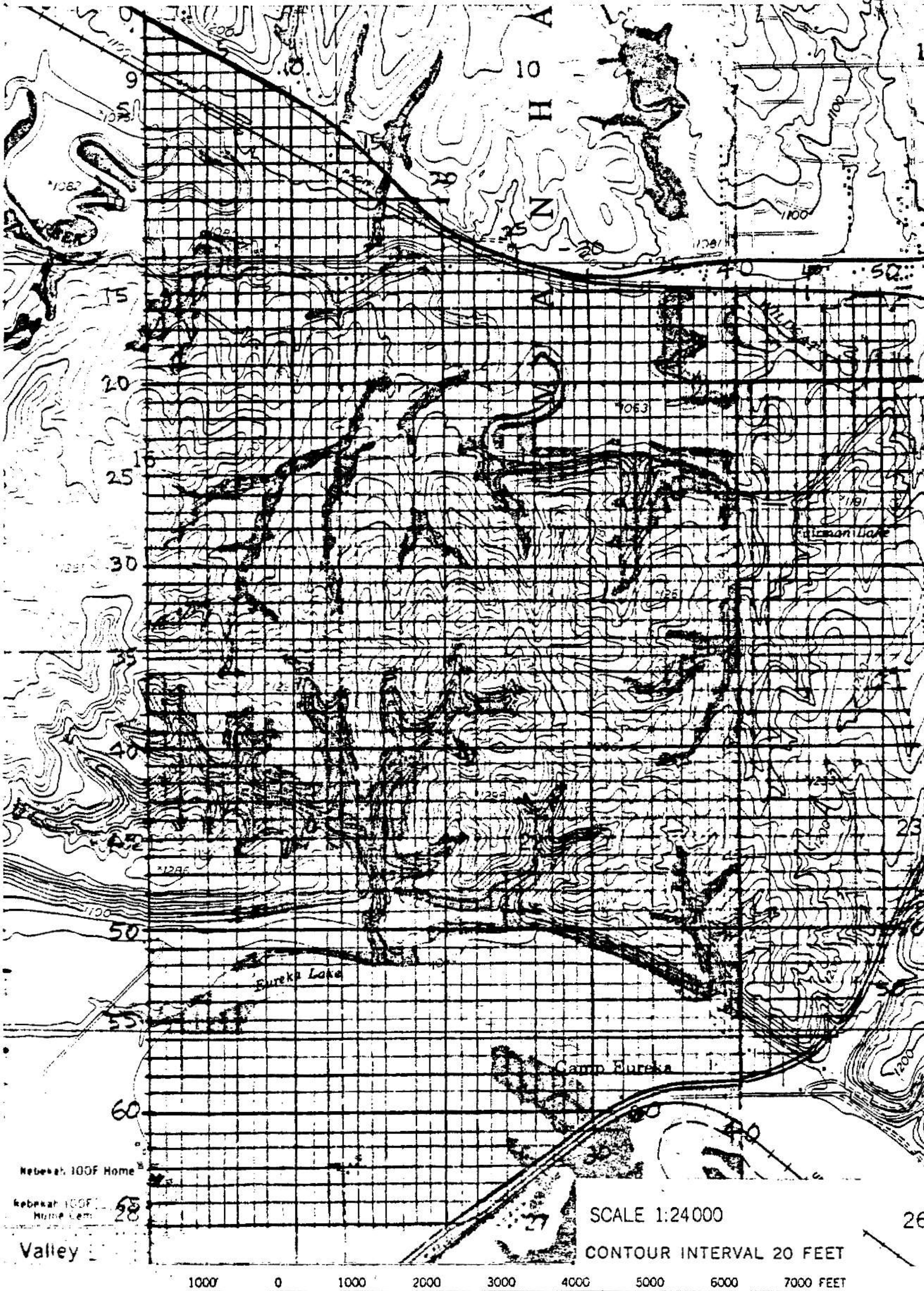


Figure 10. Study Area with SYMAP Grid.
Source: U.S. Geological Survey, Manhattan and Keats Quadrangles.

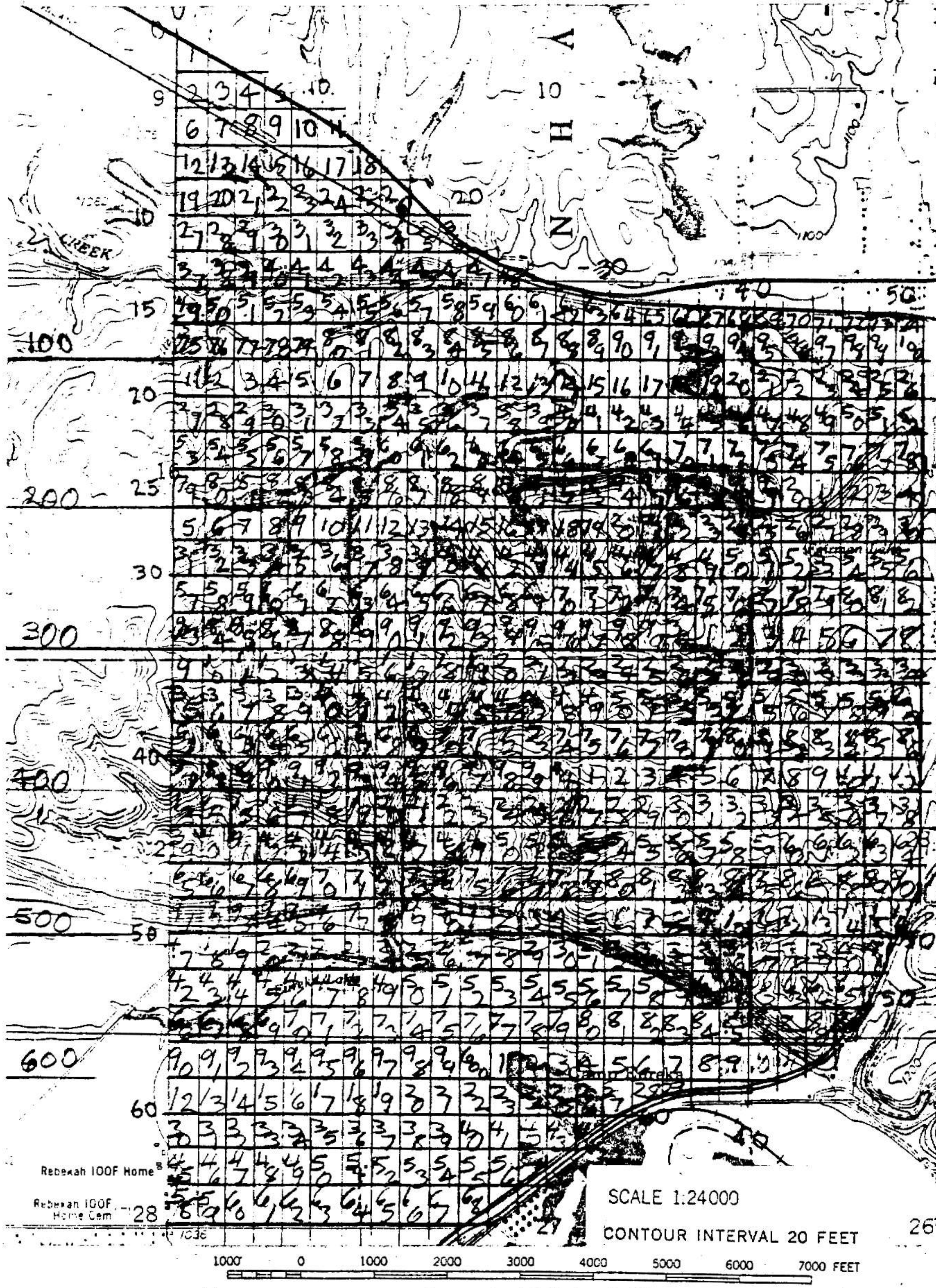


Figure 11. Study Area with Nunbered Grid Cells. Source: U.S. Geological Survey, Manhattan and Keats Quadrangles.

The encoding for the selected study area took about 90 minutes and the card punching about 40 minutes. This became the B-data points package which was stored on magnetic disk. (See Appendix A.) Figures 12-17 show the study area and the resource inventories, mapped with the utilization of the computer process.

With the completion of mapping the inventories, the composite suitabilities can be developed. With the aid of SWAP, this can be done in three stages. The first step is a preparation for SWAP. The first step program will read in the resource types and store them on tapes. (See Appendix B.) In this case the step 1 program read in 3340 (or 668 x 5) resource cards and put them out on storage. Then, in step 2 with SWAP the user chosen weights are applied and the resources are combined. The combined or summed resources are stored on disk automatically and a printout is made with the values listed. SWAP can handle up to eight resources and be programmed to use any one or two digit weighting factor. This can be done for any study area up to 999 cells. (See Appendix C.) The third and last step is to feed these values into the SYMAP program. (See Appendix D.)

With SYMAP and SWAP four composite maps were produced. With the utilization of the C-legends and C-otolegends packages in SYMAP, Wildcat Creek, the railroad, highways, scale and north arrow were added to three of the composite maps. The composite maps 1, 2, 3 and 4 are Figures 18, 19, 20 and 21 respectively. Composite 1 is a basic suitability map using the weights 8, 5, 4, 10 and 4 for soils, slope, vegetation, hydrology and cultural features respectively with five rank groupings. Composite 2 is the same as 1 but the C-legend and C-otolegend have been added. Composite 3 shows the ordinal combination of equal weights for these resources.

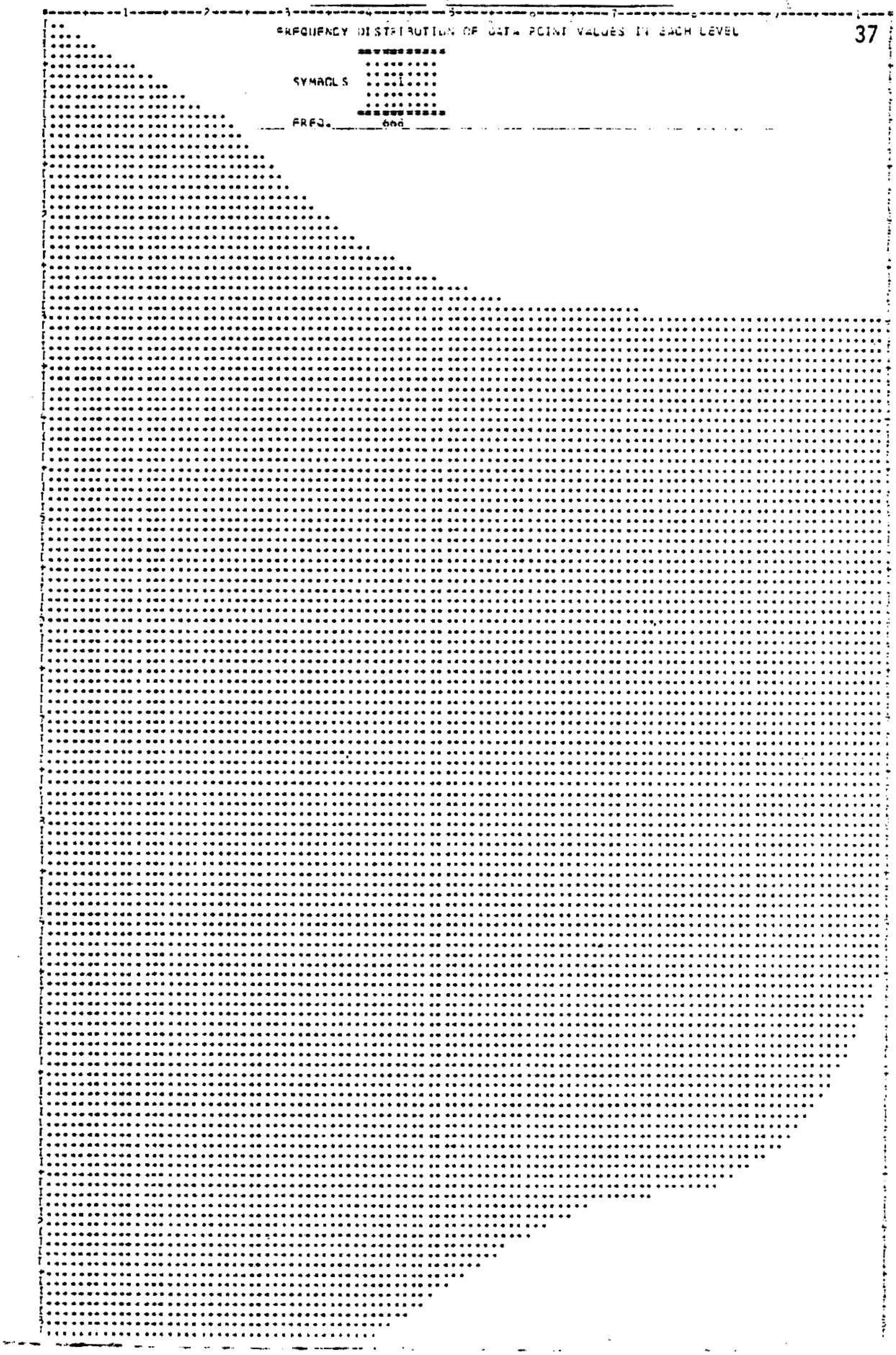


FIGURE 12. STUDY AREA.

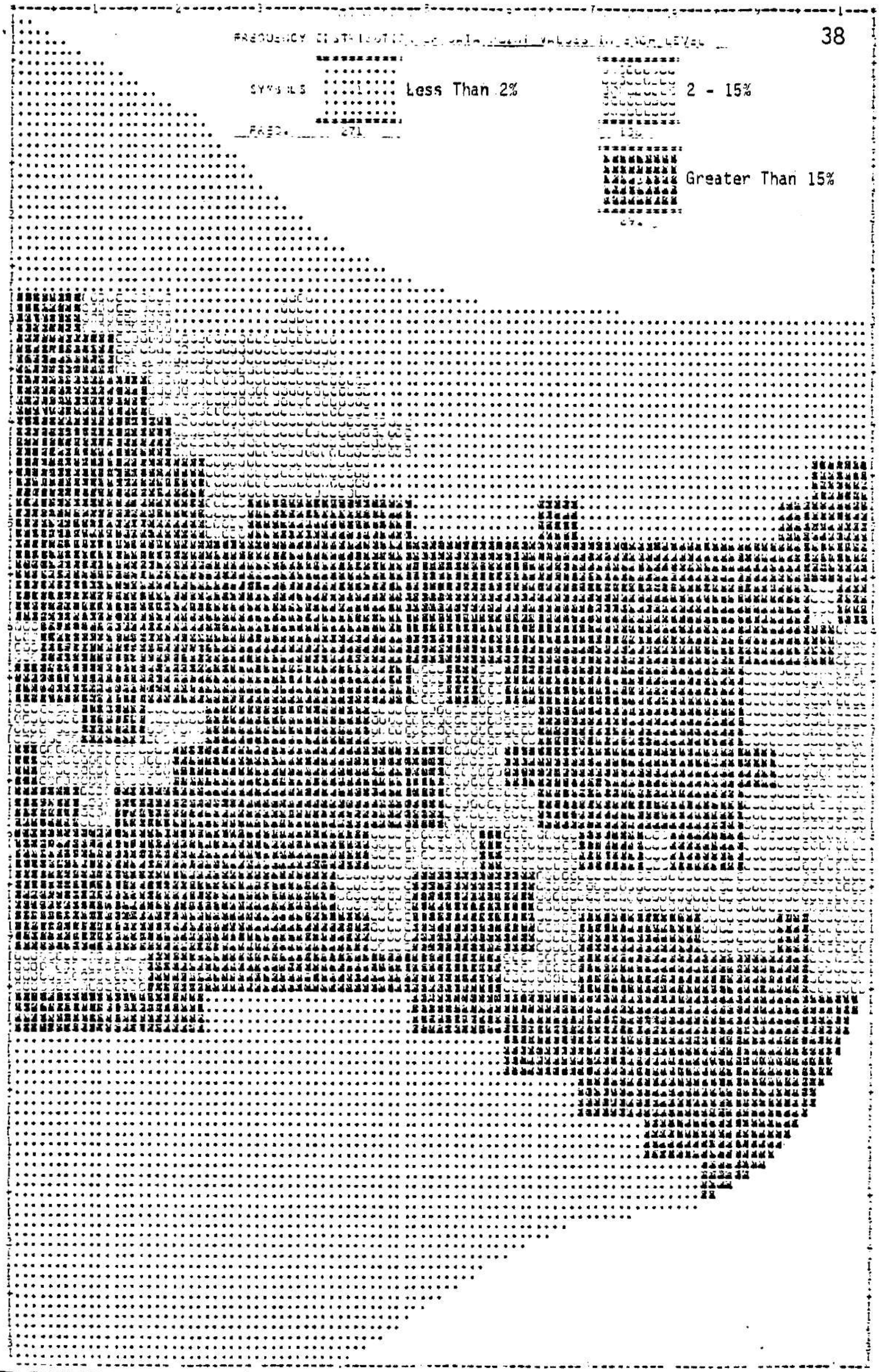


FIGURE 13. SLOPE MAP.

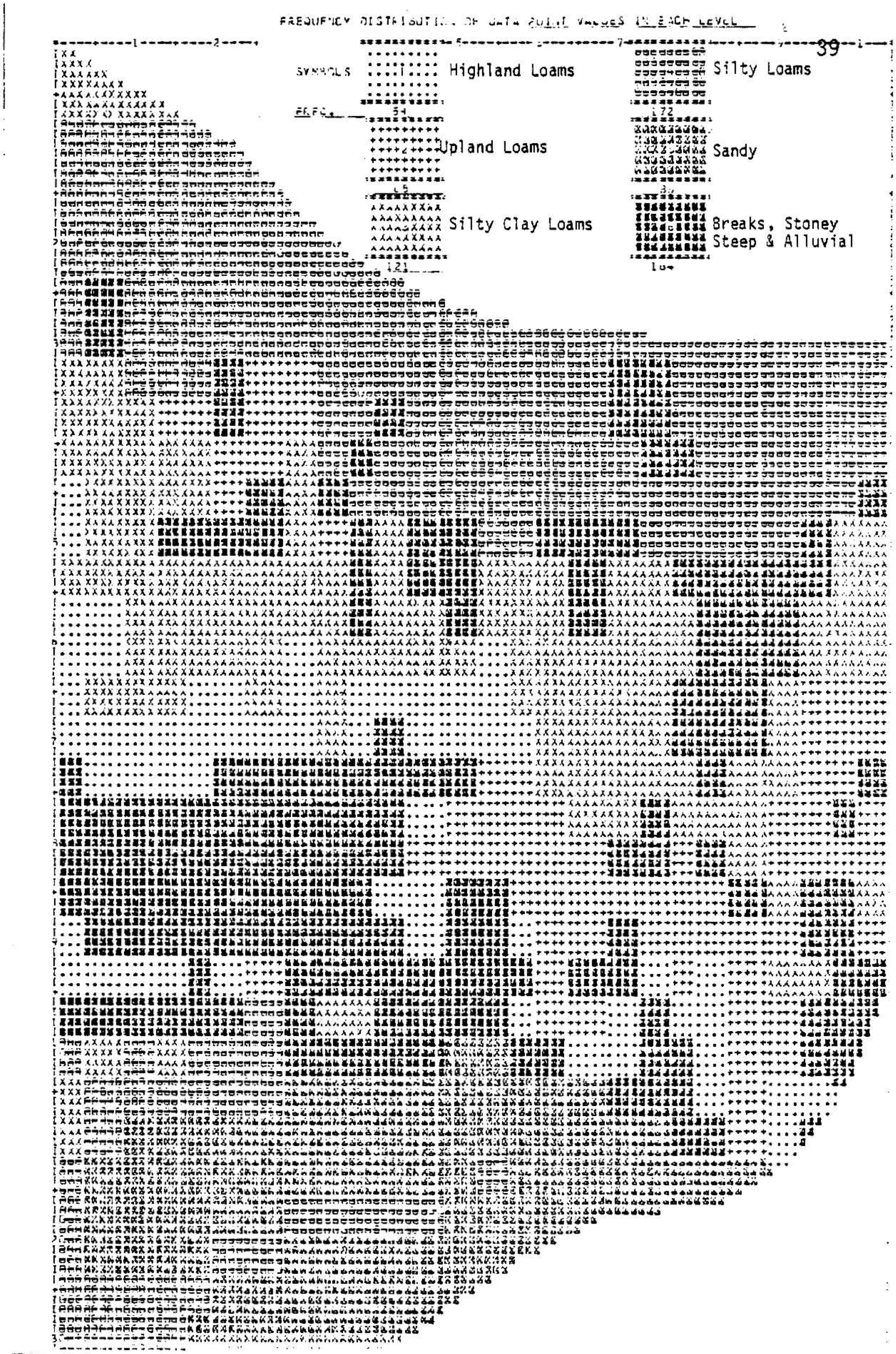


FIGURE 14. SOILS MAP.

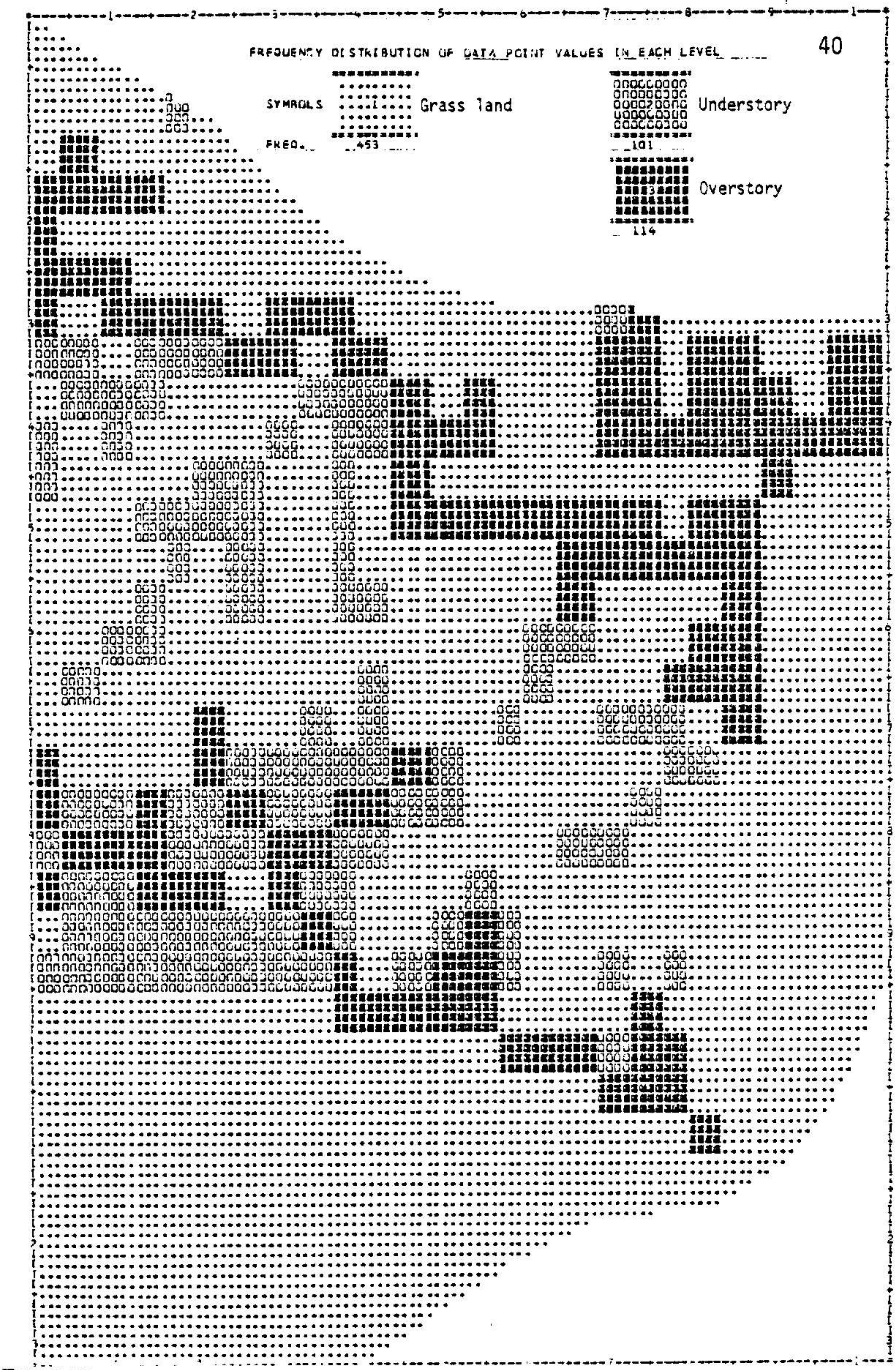


FIGURE 15. VEGETATION MAP.

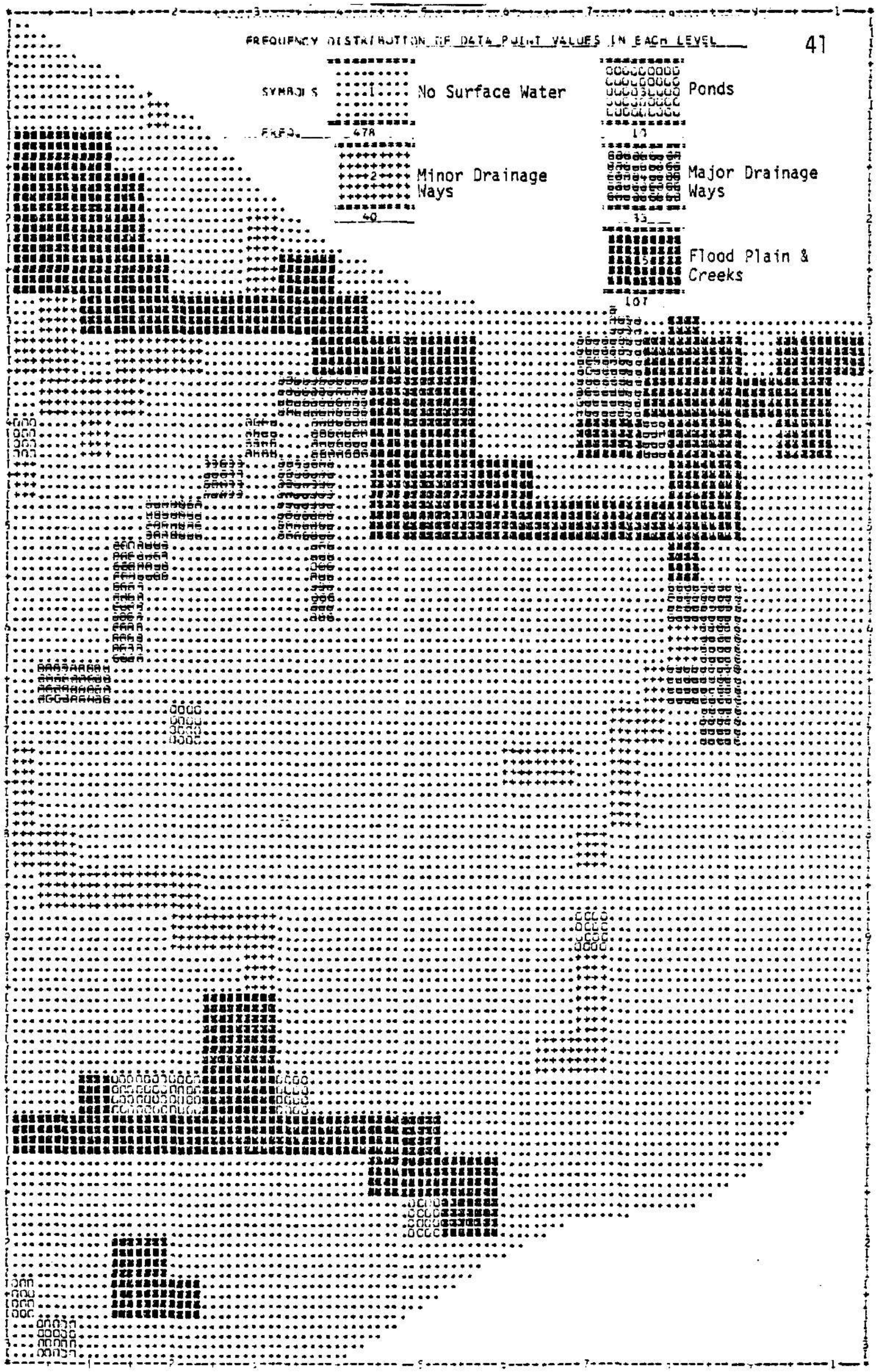


FIGURE 16. HYDROLOGY MAP.

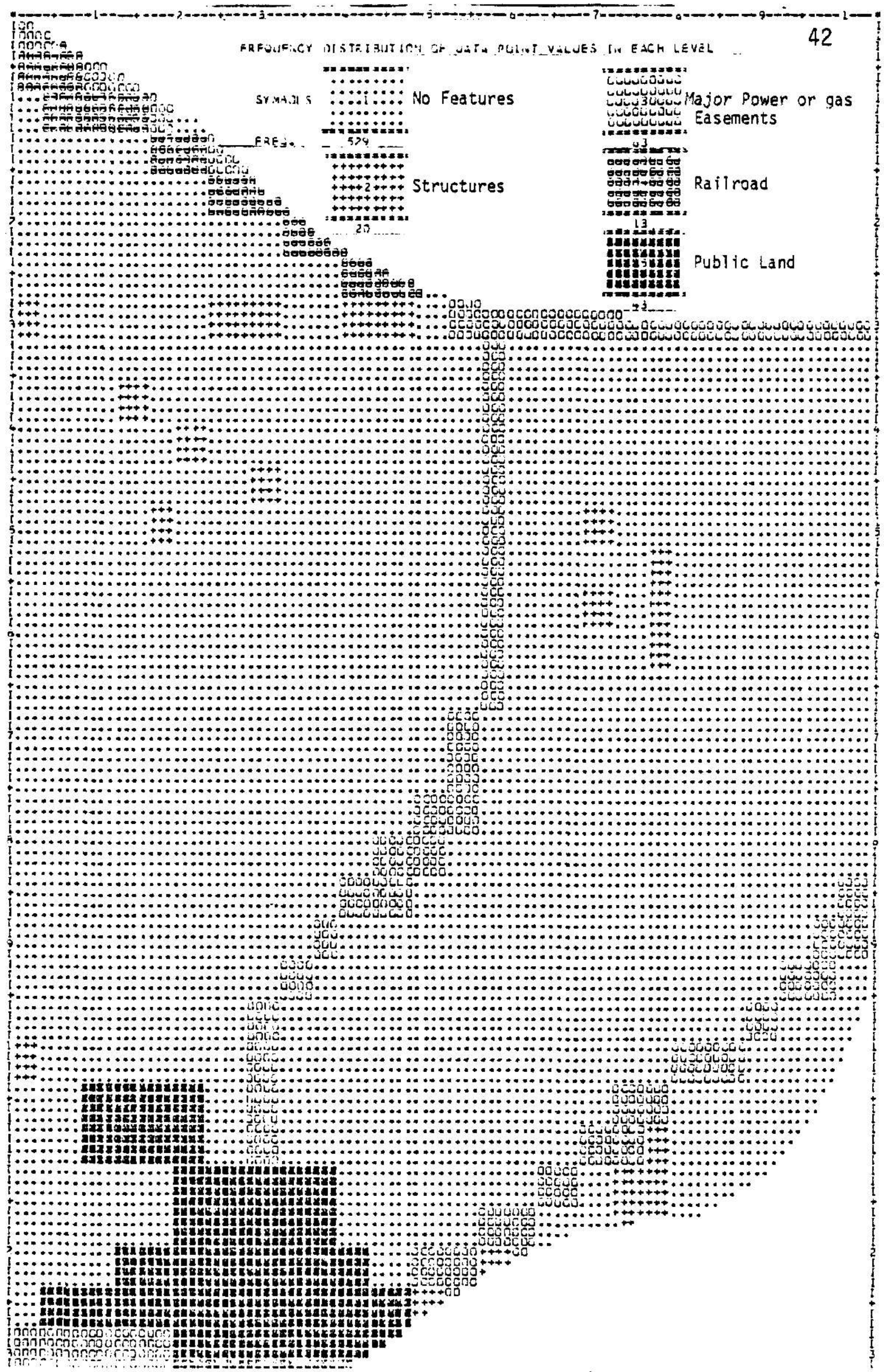


FIGURE 17. CULTURAL FEATURES MAP.

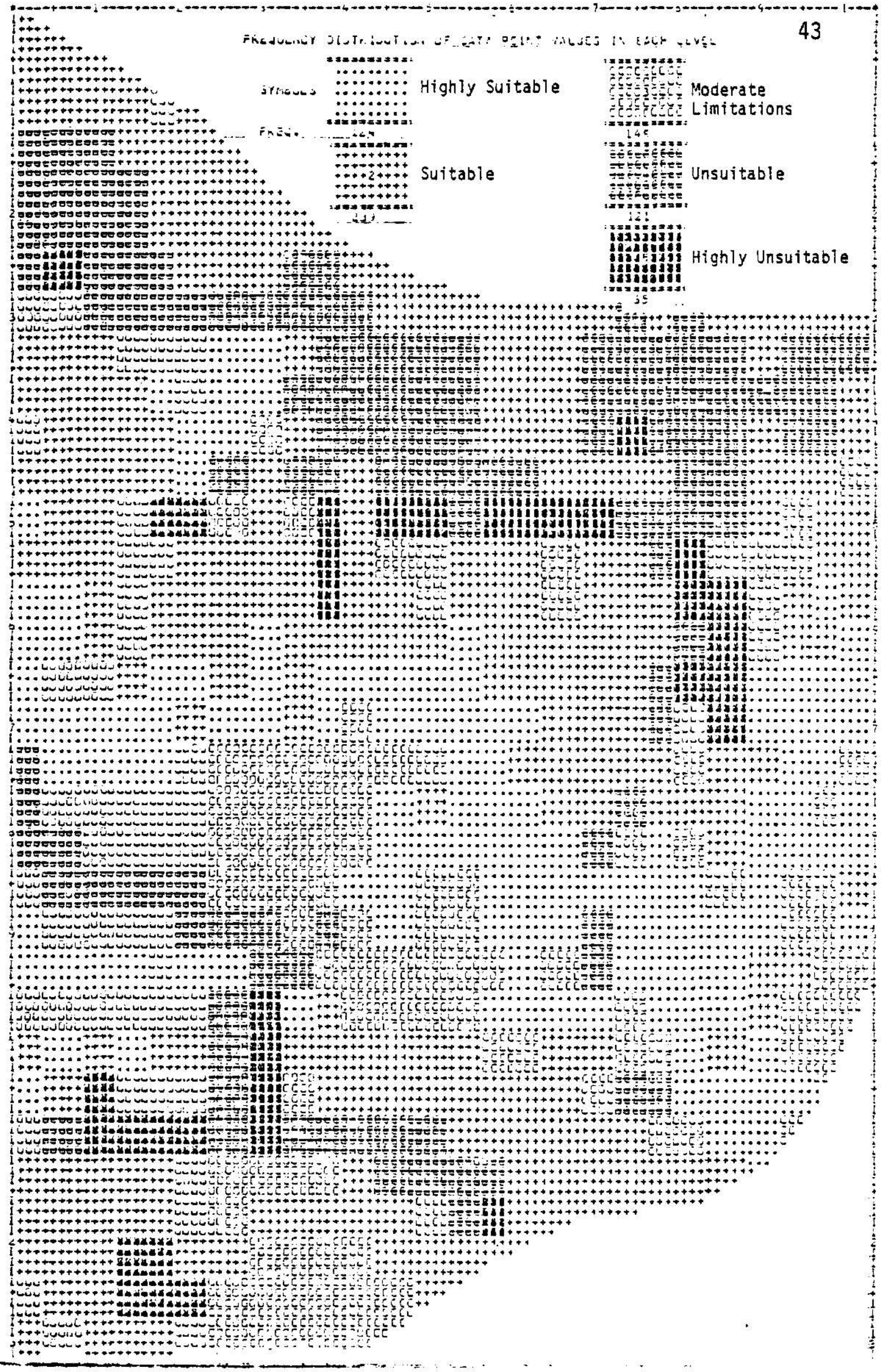


FIGURE 18. COMPOSITE SUITABILITY MAP 1.

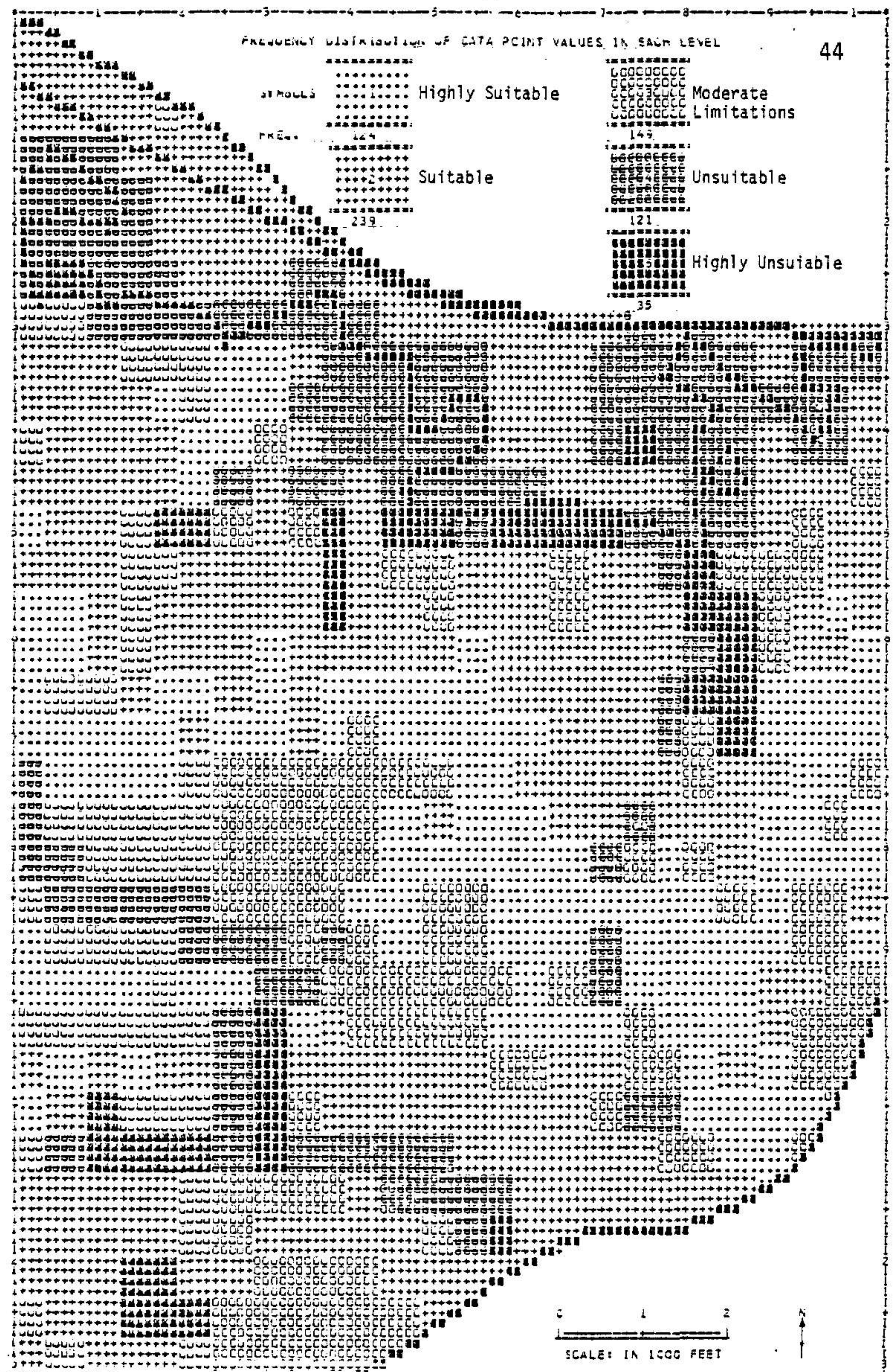


FIGURE 19. COMPOSITE SUITABILITY MAP 2.

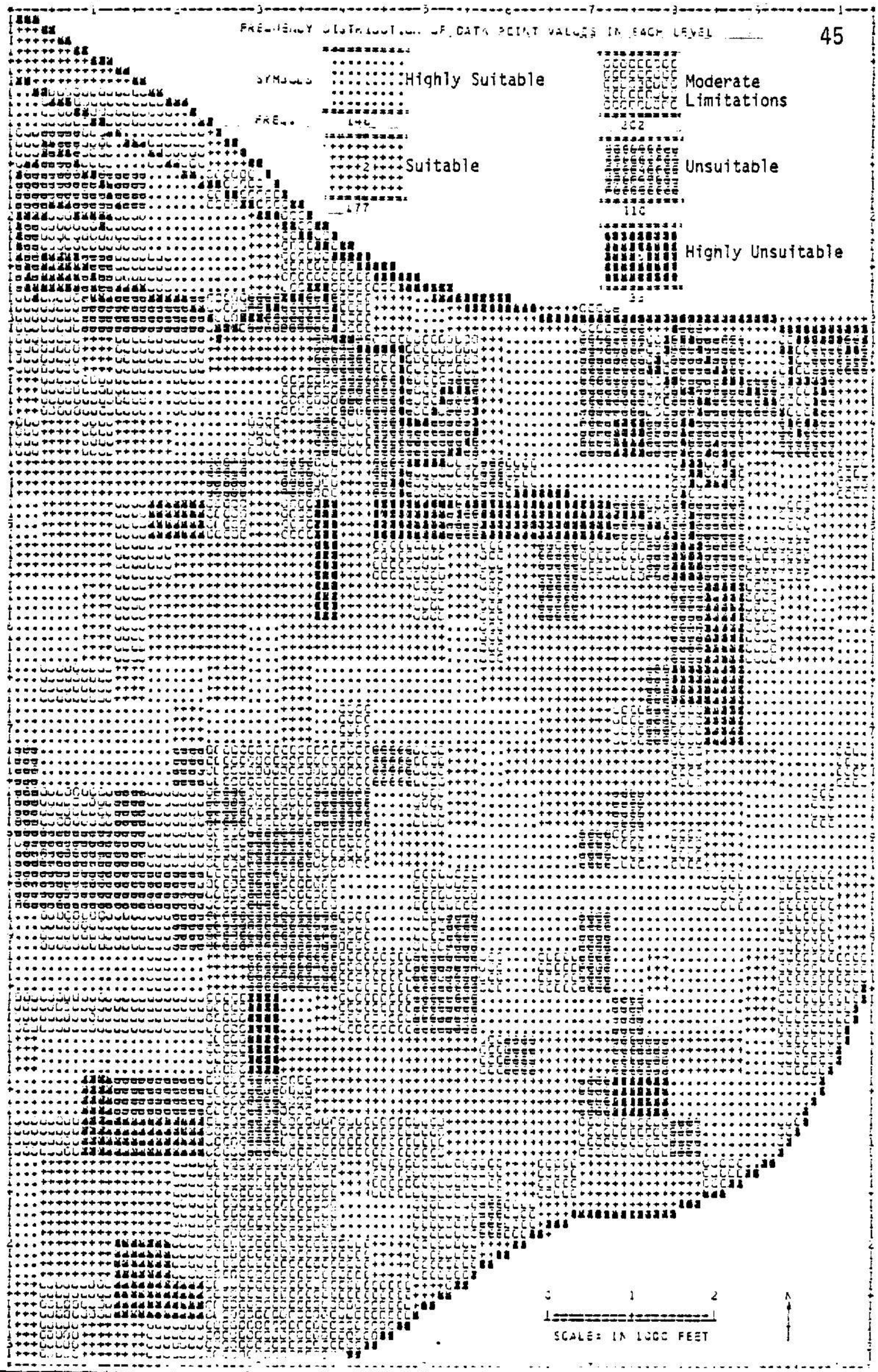


FIGURE 20. COMPOSITE SUITABILITY MAP 3.

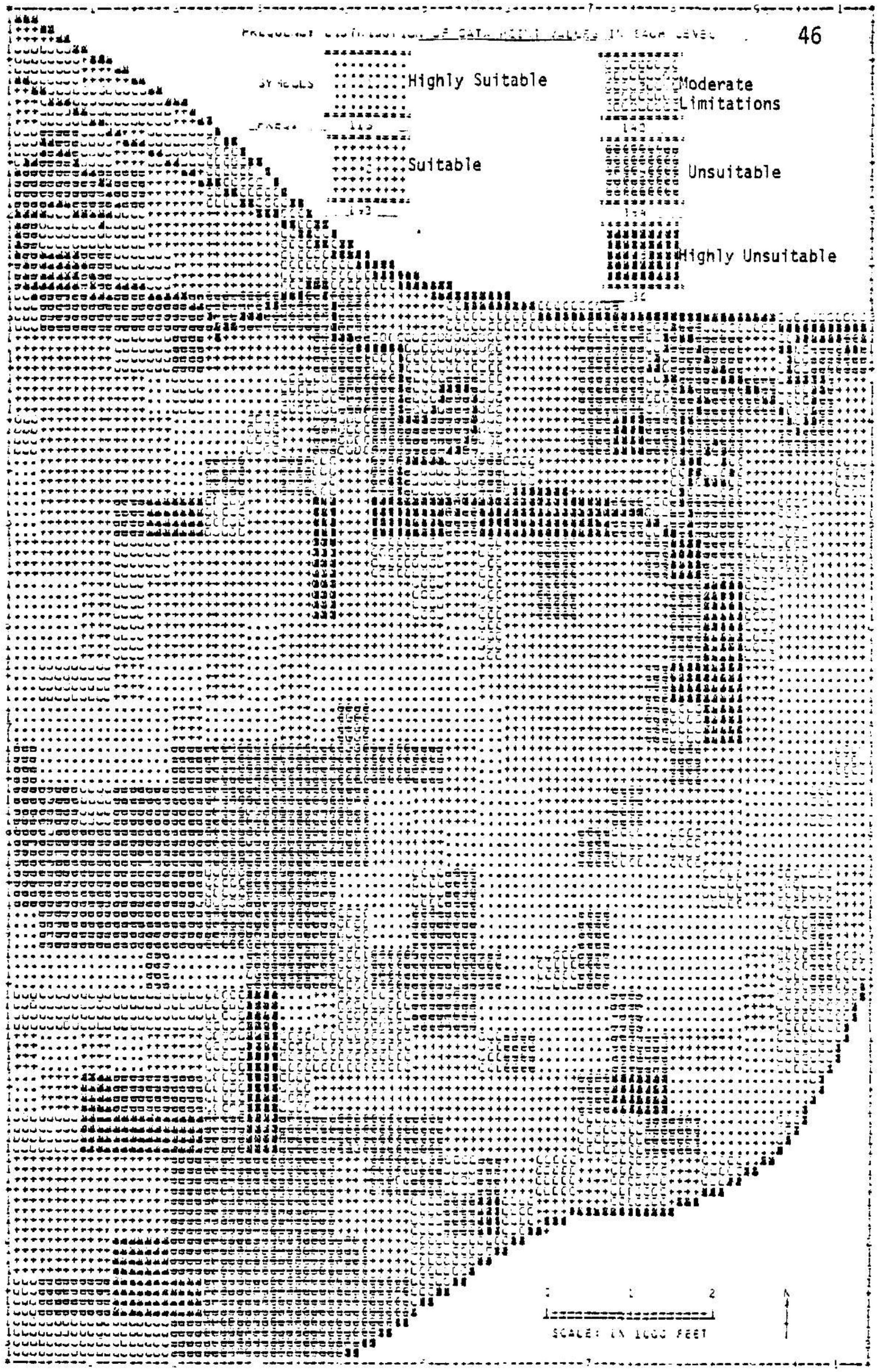


FIGURE 21. COMPOSITE SUITABILITY MAP 4.

And, composite 4 uses a weighting system of 11, 3, 7, 9 and 5 for soils, slope, vegetation, hydrology and cultural features respectively. The areas with lighter values are more suitable for development.

The computer software used for this study includes: SYMAP which is written in FORTRAN IV and SWAP which is written in PL-1. The computer hardware used for this study includes a keypunch (with drum card capabilities), a card reader, disk storage space, an 8 character per inch line printer and the IBM 360 series computer. SWAP is now a permanent program at Kansas State University. The format for the execution of the permanent file of SWAP is listed in Appendix E.

Comparison of Both Approaches to the Study Area

Computer mapping can be a very time consuming process if approached by a novice. A class in general computer science is helpful in undertaking this type of study. Learning how to use and apply computer mapping is an advantage too. For this project, learning the process was one of the major objectives of the study. Learning to improve the process and make it easier for others who will follow, was another objective. One can familiarize one's self with SYMAP in a couple of hours. This does not make one a master, but at least one would know enough to feel his or her way through a simple program. Once the first map has been produced the numerous options of SYMAP can be investigated.

Experimentation was performed with a digitizer (a computer encoding device) for both proximal and conformant mapping. It was found that the digitizer was too accurate for this type of procedure. The reason for this is, the digitizer is accurate to the thousandths place (.001). For example if the digitizer were used a point of 1.0 could be digitized as 0.998 or 1.002. This is not useful in coding centroids of grid cells. As discussed before, conformant mapping was investigated and rejected because of its awkward application to grid cell mapping.

At current (1980) prices the cost of each SYMAP run was between $6.00 and $7.00. To use SWAP for composite mapping an additional cost of $2.00 to $3.00 was added. This cost is reduced to less than $1.00 if SWAP is on permanent file with the computer being used. This eliminates the need to run the program through every time a composite map is made. The computer maps that were used for this study cost $73.66. These maps reproduce well with standard photocopy equipment. The overlay method could cost more or less depending on materials used. A photographic process with halftone screens for the gray values could be very expensive. If markers or print paper are used, the cost would be much less. The markers on print paper system would have to be reproduced photographically. In general the cost of computer mapping is not prohibitive.

Because the study area was larger; and more people worked on the "Manhattan West Resources Analysis" it is difficult to make a comparison of time spent. However, for this site it took about four hours to code and punch the grid coordinates, and eight hours to code and punch the five resources and the control cards. With computer submission time of half an hour per map a whole study like this can be done in twenty hours. This assumes that one has a study area selected and is familiar with computer mapping. With the overlay method in the "Manhattan West Resources Analysis," there were six people working about eight hours each or a total of 48 man hours. This also assumes that a site is selected, and one has an adequate graphic arts ability. The study area for the "Manhattan West Resources Analysis" is larger but the two are comparable because the computer method could have used a larger grid cell and covered the same area. There would be a little less detail because of interpolation of a cartographic information into grid cells, but, the larger area would be workable.

Figure 22 shows the comparison of the overlay method and the computer grid method for the slope inventory. This comparison graphically depicts the interpolation for the grid. Figure 23 compares the ordinal composite maps (which utilize an equal weighting system) of both methods. It is evident that both methods are remarkably similar. When a comparison is made of this composite (3) with the weighted composite there is a major difference in suitable land. (See Figure 24.)

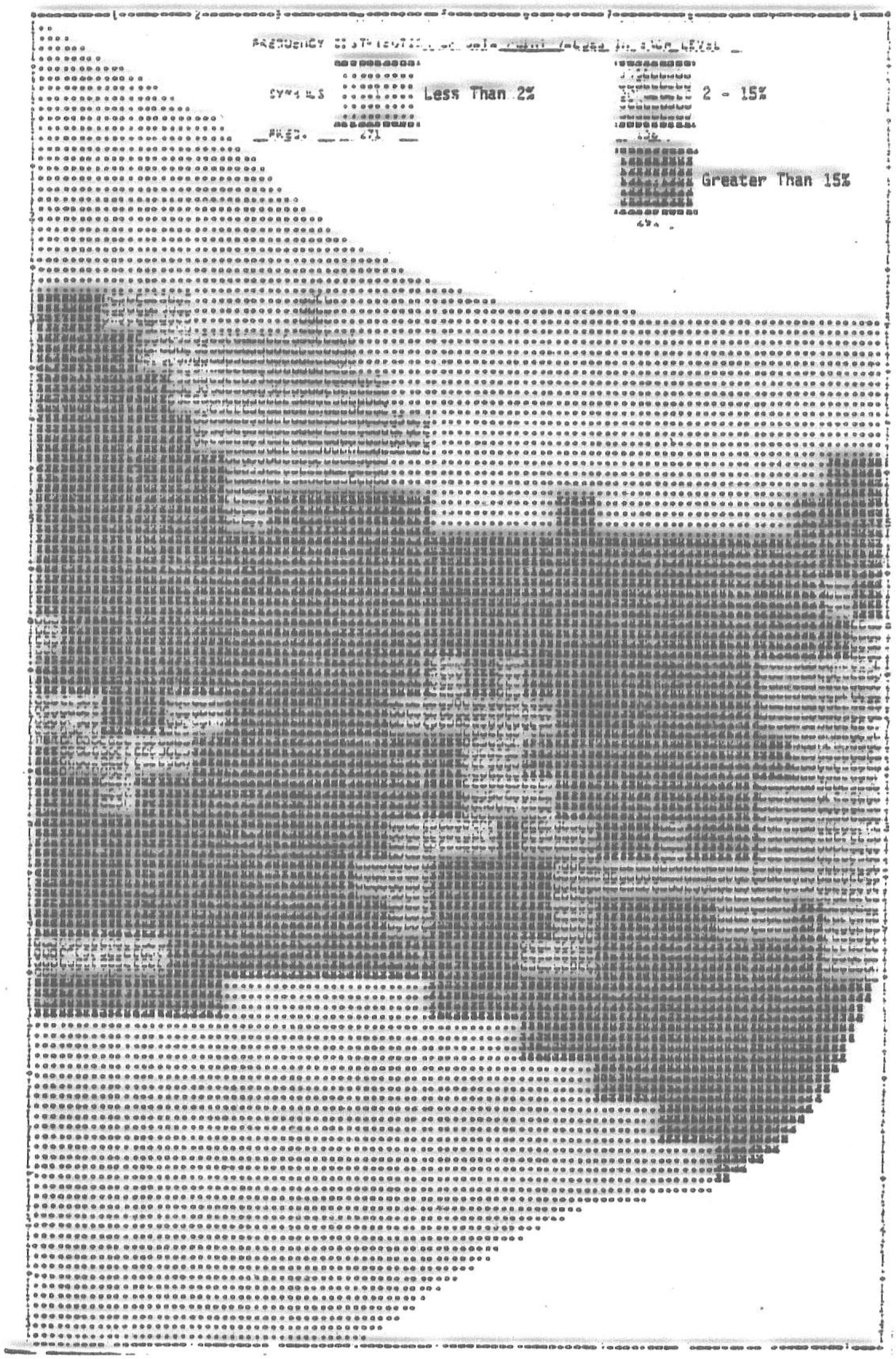
In summary the preparation for the two processes is about equal. The cost of computer mapping could be higher, but much faster. This assumes that SWAP is used with SYMAP or one of the programs from Table 1 is used. The important difference between the two methodologies is that computer mapping with weighting capability has greater potential for analysis.

In the original, pages 50, 51 and 52 are each preceded by a plastic overlay that allows comparison of the overlay and computer grid methods for slope inventory.

*The plastic overlay has been scanned independently. (Number followed by a)

*The computer grid has also been scanned independently. (Number followed by b)

*Finally, the two have been scanned together, giving the reader the combined effect of both methods as intended by the author. (Number followed by c)


Less Than 2%
2 - 15%
Greater Than 15%

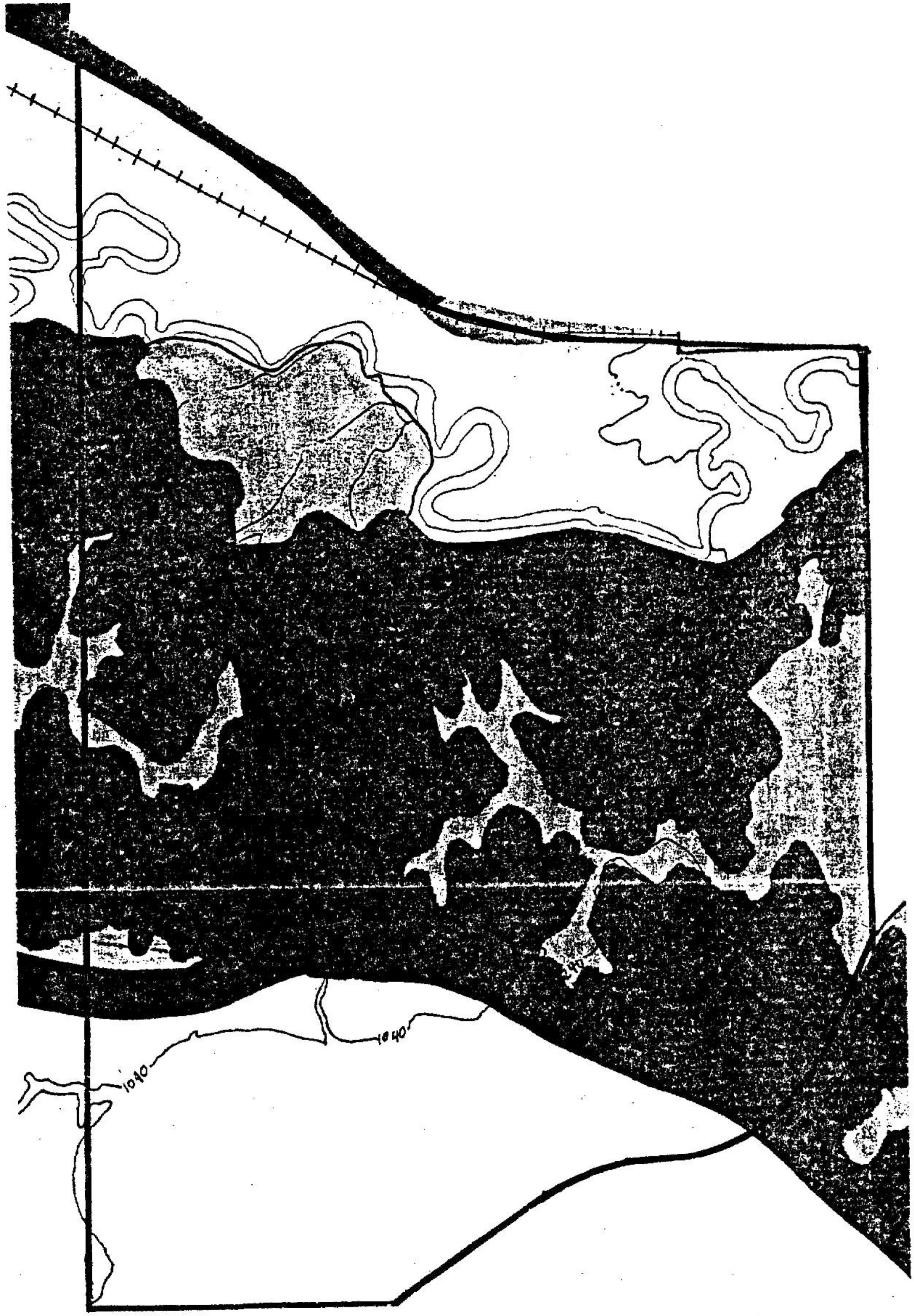


Figure 22. Comparison of the Two Methods for Slope.

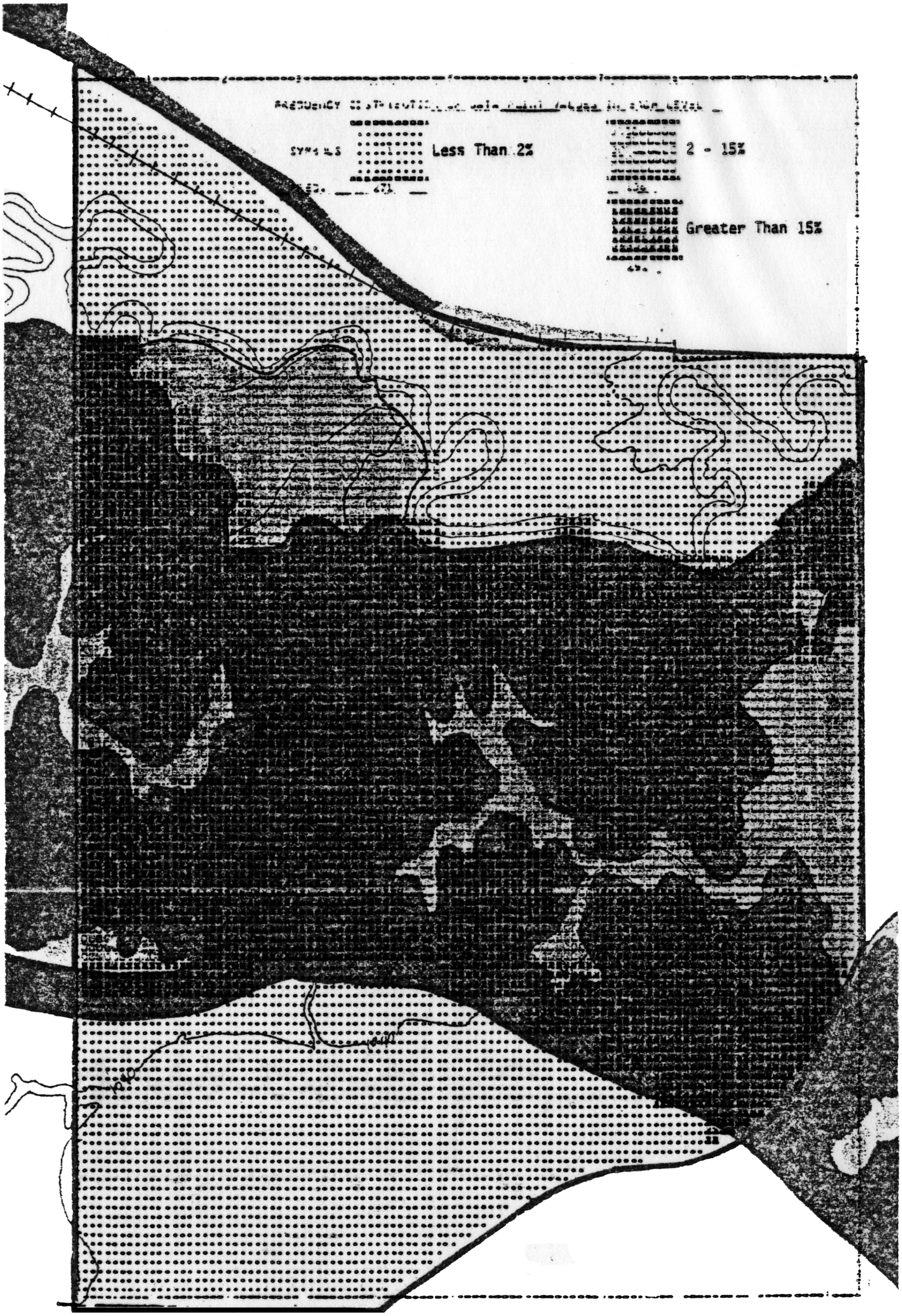


Figure 22. Comparison of the Two Methods for Slope.

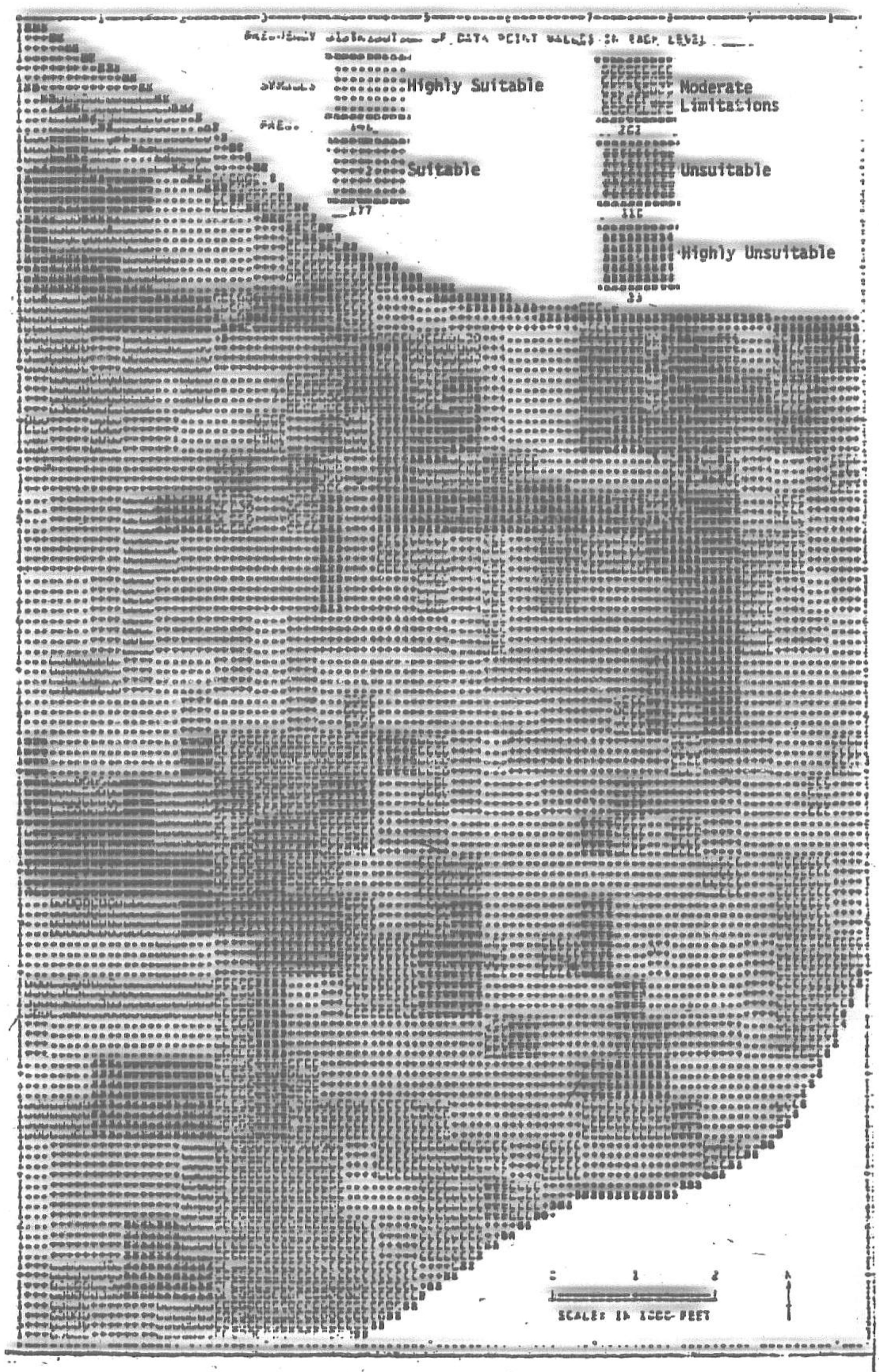

Highly Suitable
Moderate Limitations
Suitable
Unsuitable
Highly Unsuitable

Figure 23. Comparison of the Two Methods for Composite Suitability Map 3 (Unweighted Composite).

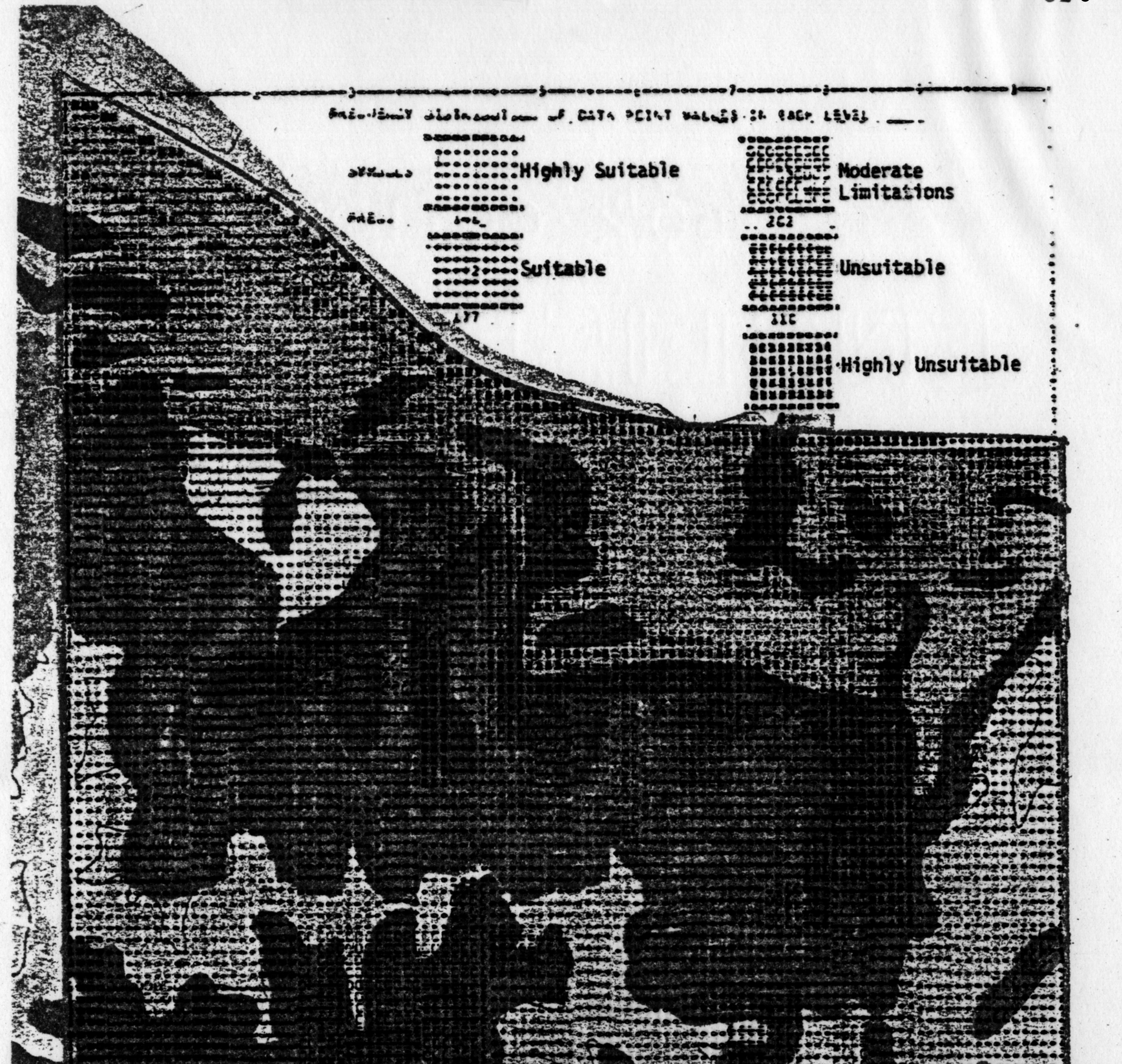
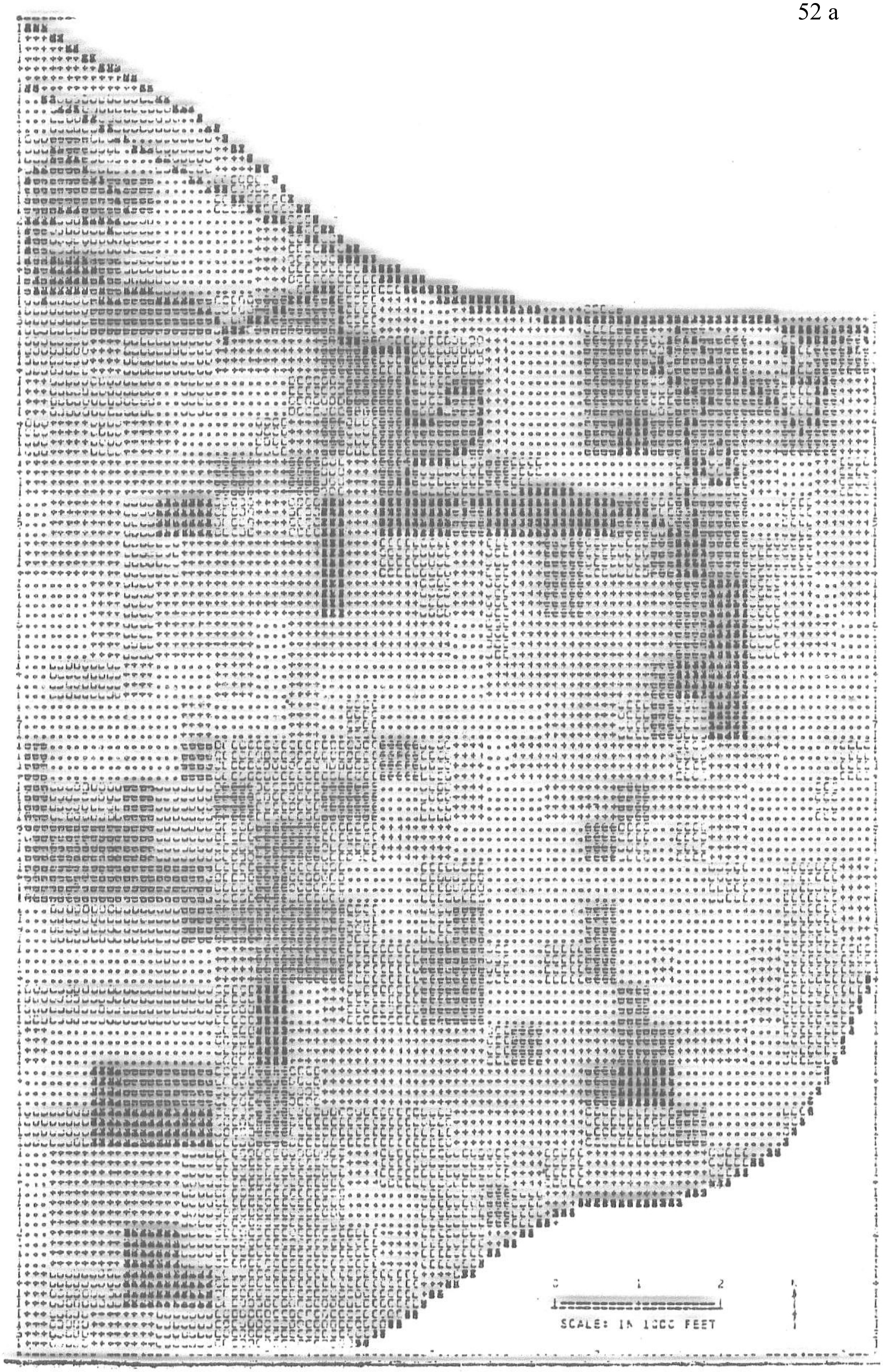


Figure 23. Comparison of the Two Methods for Composite Suitability Map 3 (Unweighted Composite).



(Unweighted)

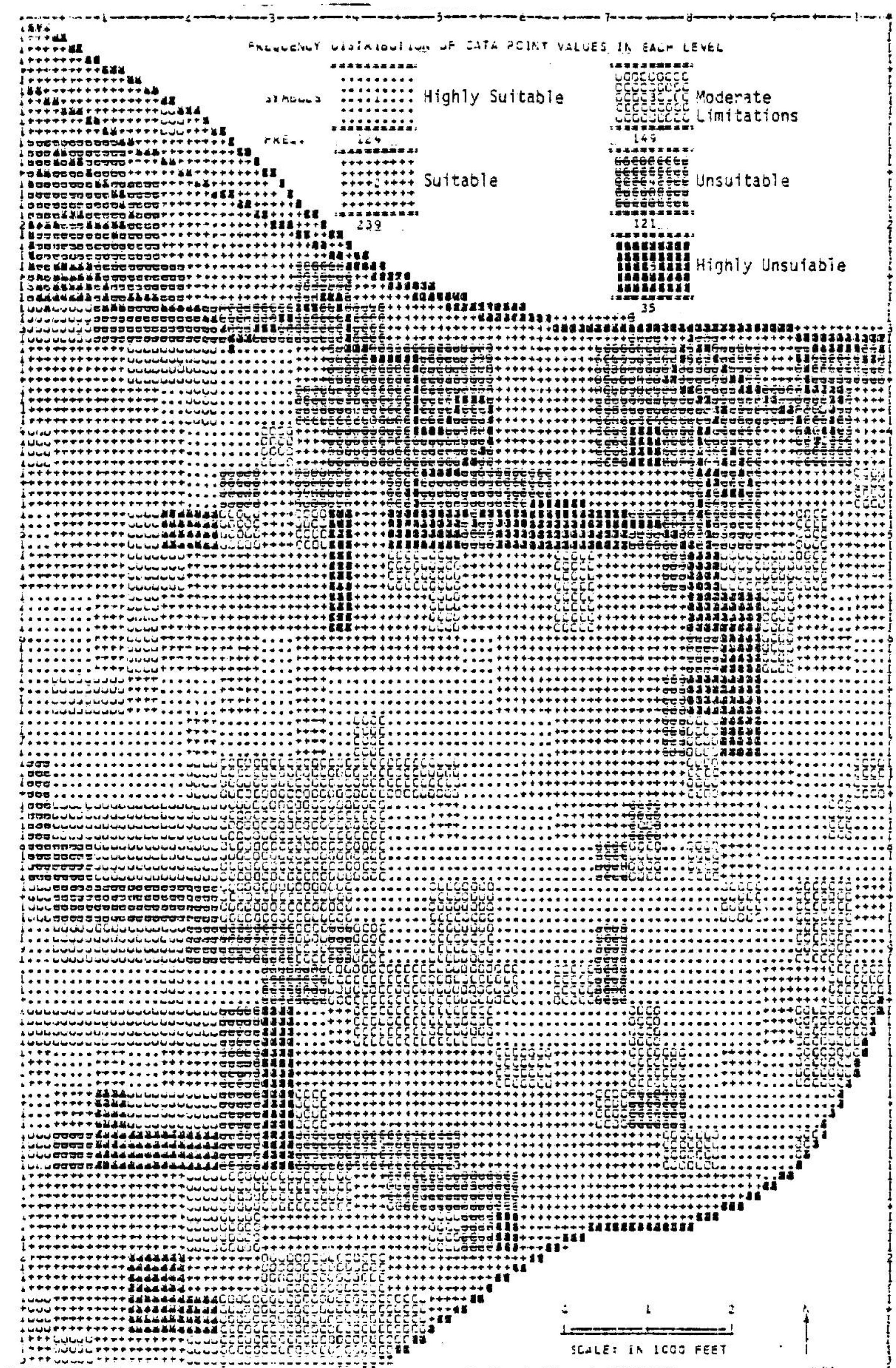


Figure 24. Comparison of Weighted and Unweighted Composite Maps 2 and 3.

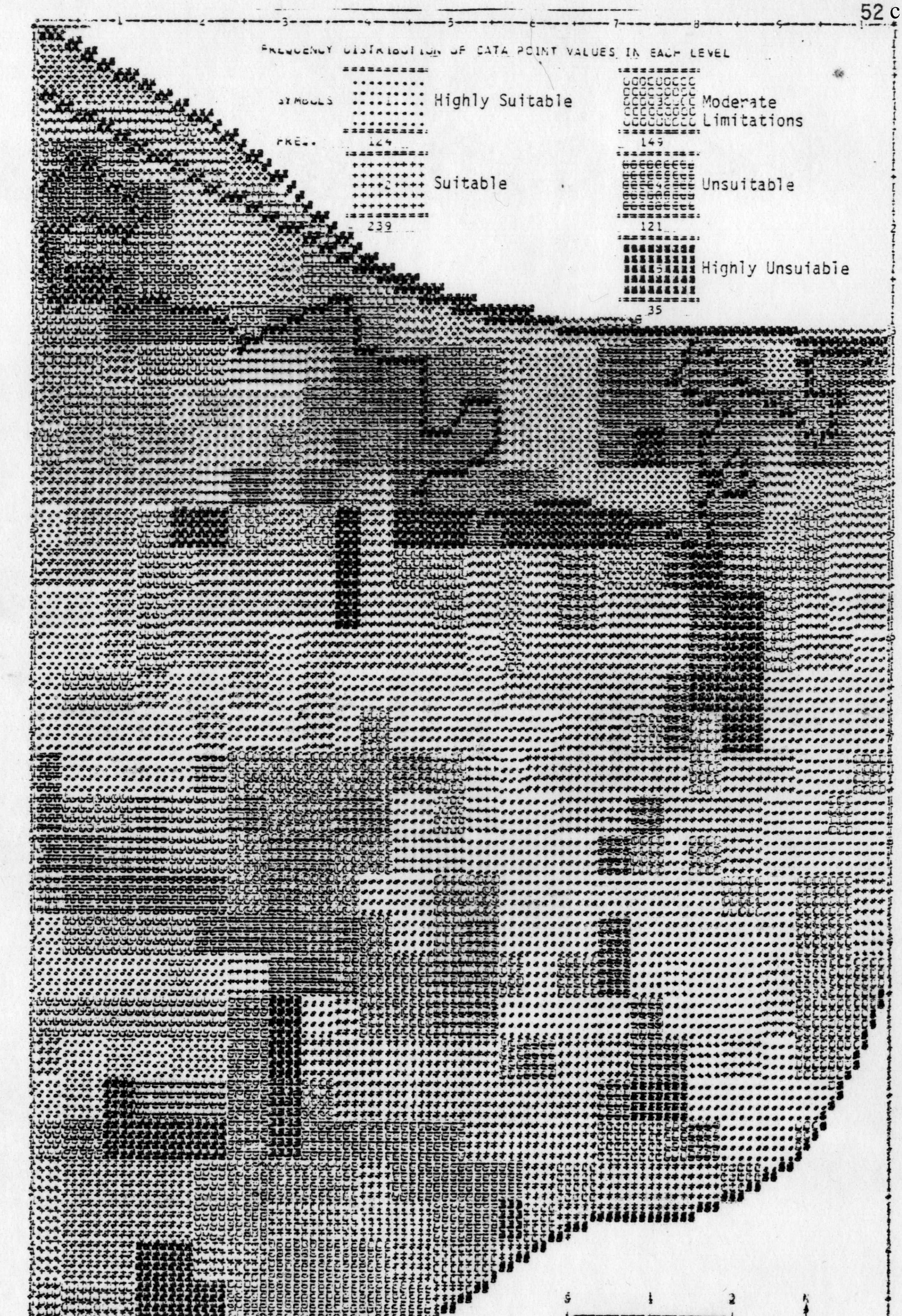


Figure 24. Comparison of Weighted and Unweighted Composite Maps 2 and 3.

(Unweighted)

Chapter 5

SUMMARY

Limitations of the Study

An important aspect of this study was the decision of what tasks could be performed given the computer programs available. Specifically, how to perform the weighting process without doing it by hand. This was solved by the design and implementation of SWAP. If GRID or a program like it were available there would be no need for SWAP.

Another problem, which was not solved, involved the investigation of FLEXIN, a subroutine of SYMAP. It was not determined if FLEXIN would be capable of performing the weighting procedure of SWAP. The consultant at the Kansas State University Computer Center, David Brooks, was undecided with this question. He noted that the weighting and addition could probably be done with FLEXIN, but it would not be as efficient as SWAP. Efficiency is lost because FLEXIN is a subroutine which would have to be called up for every E-value data number. This would increase the computer execution time and consequently the cost. It is unknown if FLEXIN could handle eight different resources. To answer these questions, experimentation should be performed with FLEXIN. No programs were run or executed with FLEXIN in this study.

Another problem not addressed in this study involves the grid cells of the computer maps. The cells of the maps in this report are not identical. Some of the cells are 4x4 print characters, down and across, and some are 4x3 print characters, down and across. This is not a major problem, and does not affect the results. At present it is thought by the consultant at the Kansas State Computer Center, David Brooks, that lack of a *uniform* grid cell size is an idiosyncrasy of SYMAP.

Improvements to the Study

A continuation of this study might involve incorporating a visual analysis with this technique. With SYMAP and SWAP, models for visual resource analysis could be developed. These models would permit investigation of effects of different weighting scales. Which weighting scale is most effective for determining agricultural suitability, recreation suitability or location of power line easements, could be investigated. This would be an important and logical extension of this study. Another study might involve the comparison of SYMAP and SWAP with GRID or a similar program. The efficiency in both time and cost would be useful to compare. Another investigation might involve different size study areas. The application of SWAP and SYMAP to a county scale or one acre size lots would document the flexibility of this type of analysis. The reliability and accuracy at different scales is important to potential users of this system. An investigation into the adaptation of remote sensing to the computer method of this study would be significant for future study, as well.

After reading this report and the SYMAP user's guide it should be possible for others to perform studies like the example used herein.

Conclusions

It is important to remember the objectives of this study. Computer mapping of ecological determinants for identifying land use suitability as reviewed and applied herein could be an effective planning tool. The use of a digital computer with the programs SYMAP and SWAP has potential for rapid and flexible analysis. The design and implementation of SWAP (SYMAP Weighting Analysis Program) could have possible application at other computer centers where SYMAP is available. The combination of SWAP and SYMAP as applied to the experimental study proved to be methodologically sound. Users of this system may select up to eight physical characteristics of the land they wish to consider in their analysis and may assign any one or two digit weights they wish applied to these characteristics. By these means, the method makes it possible to look at land use suitability with a variety of objectives. The more traditional McHarg approach does not have the capability for this kind of rapid analysis.

The method presented in this study deals with physical land use suitability characteristics. This method is not the final word on land use planning. As exhibited in Figure 1, this analysis is only one part of one step in the preparation of a comprehensive community development plan. Even within an analysis of the physical characteristics, factors such as environmental impacts, carrying capacity and visual analysis should be included. It is not the objective or conclusion of this study to use computer analysis as a single tool. Computer mapping of land use suitability is not a cure-all or panacea. Caution should be used with the application of this model. This can only be a beneficial tool when it is used in conjunction with other social, political, and economic factors that influence land use decisions.

It is also recommended that anyone who wishes to perform this kind of study seek advice and information from the user services for the computer processing center that is being used. Current information on disk and tape storage as well as job control language is available from their consultants.

REFERENCES

Becker, Robert H. Computer Visualizations as Aids to Forest Recreation Management. Journal of Forestry, 1976, 74, 820-822.

Belknap, Raymond K., and Furtado, John G. The Natural Land Unit as a Planning Base. Landscape Architecture, 1968, 58, 145-147.

Catanese, Anthony J., and Snyder, James C. Introduction to Urban Planning. New York: McGraw Hill, 1979.

Cross, Richard Hunter III. A Case Study of Computer-Aided Transmission Line Siting. Harvard Library of Computer Graphics 1979 Mapping Collection, NS, Vol. IV (Cambridge: Harvard University, Laboratory for Computer Graphics, 1979), pp. 13-34.

Ford, Kristina. Remote Sensing for Planners. New Brunswick: Center for Urban Policy Research, 1979.

Harvard Laboratory for Computer Graphics and Spatial Analysis. Lab-Log. Cambridge: Harvard University, 1978.

Harvard Laboratory for Computer Graphics and Spatial Analysis. SYMAP: User's Reference Manual. Cambridge: Harvard University, 1975.

Hopkins, Lewis D. Methods for Generating Land Suitability Maps: A Comparative Evaluation. Journal of the American Institute of Planners, 1977, 43, 386-400.

Kiefer, Ralph M., and Robbins, Micheal L. Computer Based Land Use Suitability Maps. Journal of the Surveying and Mapping Division ASCE, 1973, 99, 39-63.

Krueckenberg, Donald A., and Silvers, Arthur L. Urban Planning Analysis: Methods and Models. New York: John Wiley & Sons, Inc., 1974.

McHarg, Ian L. Design with Nature. Garden City: Doubleday, 1969.

Phillips, Richard L. Computer Graphics in Urban and Environmental Systems. Proceedings of the IEE, 1974, 62, 437-452.

Pottawatomie-Riley Counties Water and Sewer Plan. Oblinger-Smith Corp., 1971.

Shearer, R. M. et al. Manhattan West Resources Analysis. Unpublished manuscript, Kansas State University, 1979.

Sheehan, David E. A Discussion of the SYMAP Program. Harvard Library of Computer Graphics 1979 Mapping Collection, NS, Vol. II (Cambridge: Harvard University, Laboratory for Computer Graphics, 1979), 167-179.

Simonds, John O. Earthscape. New York: McGraw Hill, 1978.

Steinitz, Carl. SYMAP: Sophistication-on-Hudson. Landscape Architecture, 1968, 58, 136.

U.S. Army, Corps of Engineers. Flood Plain Information Wildcat Creek, Manhattan: 1974.

U.S. Bureau of the Census. Census Use Study: Computer Mapping Report No. 2. Washington, D.C., 1969.

U.S. Department of Agriculture. Soil Conservation Service. Soil Survey of Riley County and Part of Geary County, Kansas: 1975.

U.S. Department of the Interior. Planning for Wildlife and Man. Washington, D.C., 1974.

Van Driel, Nicholas J. Computer Mapping for Guiding Suburban Development. Ekistics, 1977, 264, 266-272.

Walesh, Stuart G. et al. Land Data Management System for Resource Planning. Journal of the Water Resources Planning and Management Division ASCE, 1977, 103, 177-192.

Weisenburger, Ray B. The Process of Urbanization: The Planning Process. Manhattan, Kansas: Kansas State University, 1967.

THIS BOOK CONTAINS NUMEROUS PAGES WITH THE ORIGINAL PRINTING ON THE PAGE BEING CROOKED.

THIS IS THE BEST IMAGE AVAILABLE.

APPENDIX A.

Program to Generate Disk Storage of Grid Cell Centroids (B-Data Points).

```
//            EXEC PGM=IEBGENER
//SYSPRINT  DC  SYSOUT=A
//SYSIN     DC  DUMMY
//SYSUT2    DC  CSN=OSBL2.MAP2,UNIT=3330,VCL=SER=KSCC04,CISP=(NEW,CATLG),
//  CCB=(RECFM=FB,BLKSIZE=6400,LRECL=80),SPACE=(6400,(8,1))
//SYSUT1    DC  *
                 0.1       0.1
                 0.3       0.1
                 0.3       0.3
                 0.3       0.5
                 0.3       0.7
                 0.5       0.1
                 0.5       0.3
                 0.5       0.5
                 0.5       0.7
                 0.5       0.9
                 0.5       1.1
                 0.7       0.1
                 0.7       0.3
                 0.7       0.5
                 0.7       0.7
                 0.7       0.9
                 0.7       1.1
                 0.7       1.3
                  .         .
                  .         .
                  .         .
                 6.5       0.1
                 6.5       0.3
                 6.5       0.5
                 6.5       0.7
                 6.5       0.9
                 6.5       1.1
                 6.5       1.3
                 6.5       1.5
                 6.5       1.7
                 6.5       1.9
                 6.5       2.1
99999
/*
```

CENTROIDS OF GRID CELLS

APPENDIX B.

Program to Generate Tape Storage of Resource Inventories.

```
//IEBGENER JOB (447544745,CAA1C8L2,,8),'IOCO - BROCKS',
// TIME=(,59),MSGLEVEL=(1,1)
/*TAPE9
// EXEC RINGWTR,PARM=9M3908
//STEP1 EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSIN DD DUMMY
//SYSUT2 DD DSN=DS8L2.TEST,UNIT=TAPE625C,DISP=(NEW,CATLG),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=1600),LABEL=1,
// VOL=SER=9M3908
//SYSUT1 DD *
```

Step 1

APPENDIX C.

Documentation of SWAP (SYMAP Weighting Analysis Program).

SYMAP INTEGRATION OF WEIGHTED POINTS

PROGRAM AND PROCEDURES

Written for:
Tom Burdett
Graduate Student
Regional & Community Planning

KSU INFORMATION SERVICES PROJECT

May 15, 1980

Computing Center
Kansas State University

TABLE OF CONTENTS.

ABSTRACT.

A request was made by a user, to have a program written which would do the following:

1. Create a file form card input.
2. Read a set of weights.
3. Use the weight values in conjunction with the file to specify new values.
4. To output this information in a format suitable to the SYMAP softward package.

This was done and the following is the result of Mr. Burdett's request.

INPUT/OUTPUTS

STEP1 (See Appendix B.)

IN 80 column cards containing resource inventory information. Column 20 is the only column used in step 2.*

OUT A disk data set containg the card images.

STEP2

IN

Number of cases	Fixed Decimal 3
Number of resources	Fixed Decimal 1 **
Weight for each resource	Fixed Decimal 2
Resource names	Character 10

OUT Echo checks of all the above inputs to be verified by the user.

Data set containing the new values generated by multiplying column 20 of step 1's output with the weigh for that group, in a format of x(10) f(10) x(60), to be used by SYMAP.

Note: All inputs are in fixed formats and must be in the order specified, and are placed on seperate cards.

NOTE: DO NOT USE THIS FORM WHEN ORDERING NEW OR REVISED CARD FORM COMPOSITION.

IBM

INTERNATIONAL BUSINESS MACHINES CORPORATION

INFORMATION RECORDS DIVISION
MULTIPLE-CARD LAYOUT FORM

Form X24-6599-1
Printed in U.S.A.

Company ______________________

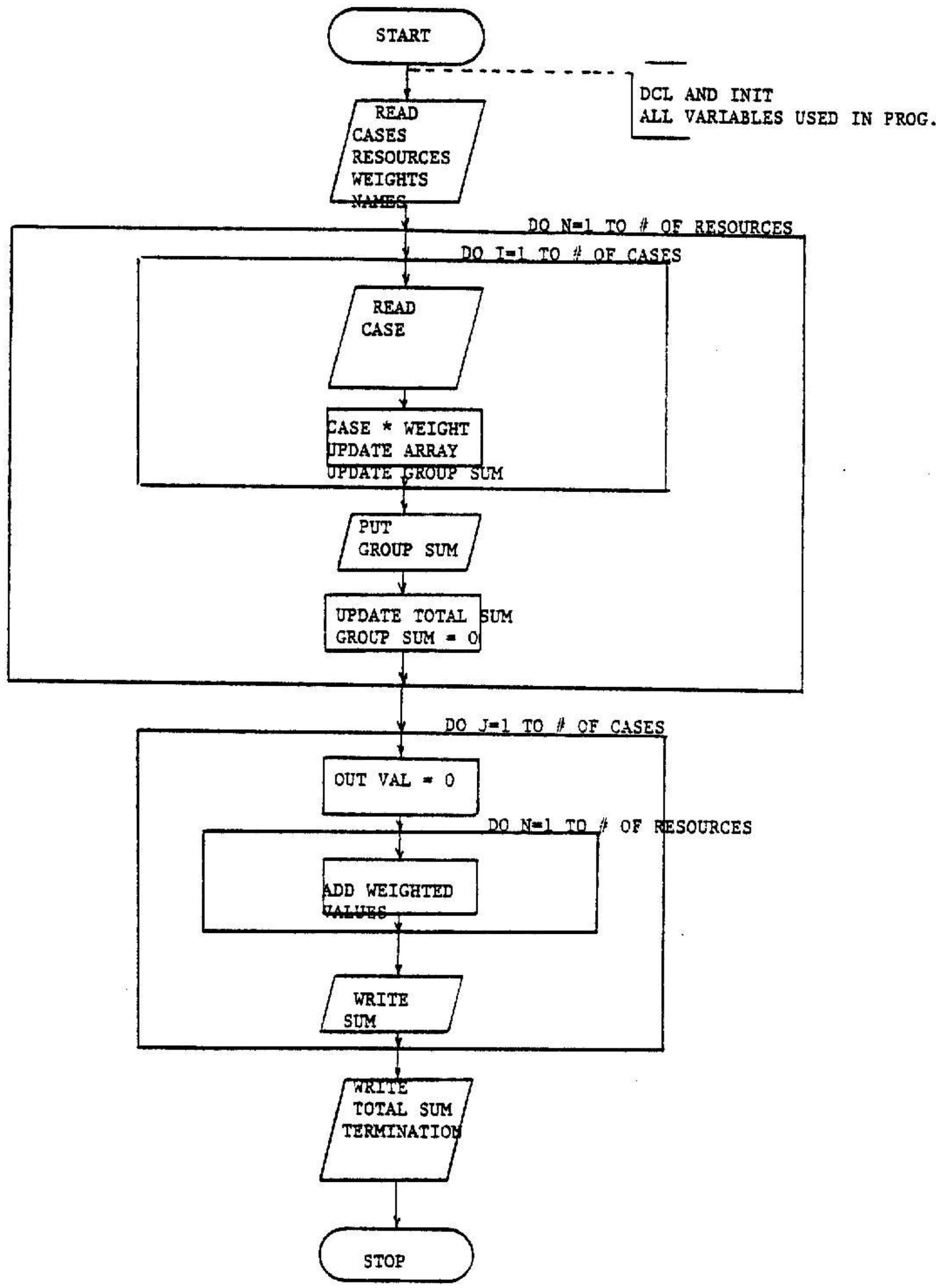
Application ______________________ by ______________________ Date __________ Job No. __________ Sheet No. __________

NUMBER OF CASES (up to 999 right justified)

NUMBER OF RESOURCES (from 1 to 8)

WEIGHTS TO BE APPLIED TO EACH RESOURCE (8 at 2 characters each right justified)

RESOURCE NAMES (8 at 10 characters each left justified)


START
DCL AND INIT
ALL VARIABLES USED IN PROG.
READ
CASES
RESOURCES
WEIGHTS
NAMES
DO N=1 TO # OF RESOURCES
DO I=1 TO # OF CASES
READ
CASE
CASE * WEIGHT
UPDATE ARRAY
UPDATE GROUP SUM
PUT
GROUP SUM
UPDATE TOTAL SUM
GROUP SUM = 0
DO J=1 TO # OF CASES
OUT VAL = 0
DO N=1 TO # OF RESOURCES
ADD WEIGHTED
VALUES
WRITE
SUM
WRITE
TOTAL SUM
TERMINATION
STOP

INFORMATION ON PERMANENT FILES.

Who to see in the Computing Center:	Dennis Reith
What is needed:	Account number Data Set Save Card
What is supplied by Computing Center:	Volumn number to place data set

There are several things you the user need to know about setting up permanent files for your data sets at the Computing Center.

First, there is a naming convention which states that you must name your data set as follows:

DSMMM.XXXXXXXX.XXXXXXXX...

where DS is mandatory
where MMM is the last three digits of the users account number
where XXXXXXXX is a name of the users choice and meets the other requirements for names used on the computer.

After seeing Mr. Reith, you will then have a volumn on which to place your data set. Other information is also required on job control language cards. Information such as:

- Disposition
- Space to be allocated
- Unit on which to be allocated
- Volumn number to place the data set
- DCB information such as:
  - Record format
  - Record length
  - Blocksize

The above information is furnished in the listing of this program. All the new user would have to do is change the data set names (DSN=) the volumn number (VOL=SER=) and submit the data set save card to Mr. Reith.

For any further help, please see the consultant on duty at Cardwell hall.

USING DATA SETS
KANSAS STATE UNIVERSITY

Disposition DISP=(XXXX,YYYY)

XXXX is either NEW,OLD or MOD or SHR

YYYY is either KEEP,DELETE,CATLG

Disposition is the current status of a data set when it is used. Specify new catlg when creating a data set for the first time. Thereafter use shr.

Space SPACE=(AAAA,(BB,CC))

AAAA is either TRK or CYL for tracks or cylinders.

BB is the number of tracks to be allocated first and CC is the number of tracks to subsequently be allocated if the first is not enough. Normally use tracks for small data sets. Refer to IBM Direct Access Storage Reference Summary for detailed information.

Unit UNIT=XXXX

XXXX is either 3330,3350 or a TAPEYYYY where YYYY is either 1600,800 or 6250 and stands for bytes per inch on the tape. Normally a tape is specified as TAPE6250 to efficiently use the storage capacity of the tape.

Volumn VOL=SER=XXXXX

where XXXXX is a number assigned by the Supervisor of Operations. For a disk storage the number will resemble KSCCXX where XX are the changing parameters. For tape, XXXXX will be the tape label also assigned by the Supervisor or Operations.

DCB DCB=(RECFM=AA,LRECL=BB,BLKSIZE=CC)

AA is the record format and is usually FB for fixed blocked records.

BB is the logical record length and is 80 for cards images.

CC is the blocksize and must be a multiple of the record size.

ie. if blocksize = 80 blocksize could be 800,1600,2400 or any other multiple of 80.

Information about efficient blocksize based on known record lengths can also be obtained from the IBM Direct Access Storage Reference Summary.

Any consultant of the Computing Center will be helpful in furnishing any information that you may not understand.

Listing of Source Code with JCL

```
//BURDETT JOB (447544745,CAAIC8L2,,3),'IOOC - BROOKS',
// TIME=(,29),MSGLEVEL=(1,1)
/*TAPE9
// EXEC PGM=IEFBR14
//DD1 DD DSN=DS043.TEST,DISP=(OLD,DELETE)
//STEP1 EXEC PL1LFCLG
//PL1L.SYSIN DD *
 EVAL: PROCEDURE OPTIONS(MAIN);
 DCL 01 VALUE2,
    02 DELIMIT CHAR(5) INIT ('99999'),
    02 FILLER CHAR(15) INIT (' ');
 DCL NUM_OF_CASES FIXED DEC(3) INIT (0),
        NUM_OF_RESOURCES FIXED DEC(1) INIT (0),
       GROUP_WEIGHTS(8) FIXED DECIMAL(2),
       NAME_OF_RESOURCES(8) CHARACTER(10),
       GROUP_SUM FIXED DECIMAL(6),
       01 VALUE,
       02 FILLER CHAR(10) INIT (' '),
       02 OUT_VAL PIC '9999999999',
    02 FILLER2 CHAR(60) INIT (' '),
       TOTAL_SUM FIXED DECIMAL(8);
 DCL 01 TABLE,
          02 FILLER CHAR(19) INIT (' '),
          02 WANT_IT PIC '9',
          02 FILLER1 CHAR(60) INIT (' ');
 GROUP_SUM = 0;
 TOTAL_SUM = 0;
 PUT FILE(SYSPRINT) PAGE EDIT(
 'YOU HAVE ELECTED TO USE THE FOLLOWING VALUES',
 'AS INPUT TO THIS PROGRAM.',
 'PLEASE VERIFY THAT THEY ARE IN FACT THE VALUES',
 'YOU WISHED TO USE.',
 'IF THEY ARE NOT CORRECT, CHECK INPUT CARDS,',
 'MAKE NECESSARYCORRECTIONS, AND RE-RUN PROGRAM.')
 ((6) (COL(15),A));
 GET FILE(SYSIN) EDIT(NUM_OF_CASES)(COL(1),F(3));
 GET FILE(SYSIN) EDIT(NUM_OF_RESOURCES)(COL(1),F(1));
 GET FILE(SYSIN) EDIT(GROUP_WEIGHTS)(COL(1),(8) F(2));
 GET FILE(SYSIN) EDIT(NAME_OF_RESOURCES)(COL(1),(8) A(10));
 PUT FILE(SYSPRINT) SKIP(3) EDIT (
 'VALUE FOR NUMBER OF CASES PER RESOURCE INVENTORY',
 'VALUE IS:   ',NUM_OF_CASES)
 (COL(5),A,COL(5),A,F(3));
 PUT FILE(SYSPRINT) SKIP(2) EDIT(
 'THE NUMBER OF RESOURCES USED IN THIS PROGRAM IS:   ',
 NUM_OF_RESOURCES)
 (COL(5),A,F(1));
 PUT FILE(SYSPRINT) SKIP(2) EDIT(
 'THE GROUP WEIGHTS ARE AS FOLLOWS:   ',
```

```
GROUP_WEIGHTS)
(COL(5),A,(8) (F(2),COL(40)));
PUT FILE(SYSPRINT) SKIP(2) EDIT(
'THE NAMES OF THE RESOURCES ARE AS FOLLOWS:  ',
NAME_OF_RESOURCES)
(COL(5),A,(8) (A(10),COL(49)));
DCL ARRAY(8,999) FIXED DEC(2);
DO N = 1 TO NUM_OF_RESOURCES BY 1;
  DO I = 1 TO NUM_OF_CASES BY 1;
    READ FILE(INPUT) INTO (TABLE);
    OUT_VAL = WANT_IT * GROUP_WEIGHTS(N);
    GROUP_SUM = GROUP_SUM + OUT_VAL;
ARRAY(N,I) = OUT_VAL;
  END;
PUT FILE(SYSPRINT) SKIP(3) EDIT (
'GROUP SUM FOR  ',NAME_OF_RESOURCES(N),'  IS',GROUP_SUM)
(COL(20),A,A(10),A,X(3),F(6));
  TOTAL_SUM = TOTAL_SUM + GROUP_SUM;
  GROUP_SUM = 0;
END;
DO J=1 TO NUM_OF_CASES;
OUT_VAL = 0;
DO N=1 TO NUM_OF_RESOURCES;
OUT_VAL = ARRAY(N,J) + OUT_VAL;
END;
  WRITE FILE(OUT) FROM(VALUE);
END;
WRITE FILE(OUT) FROM (VALUE2);
PUT FILE(SYSPRINT) SKIP(3) EDIT(
'THE TOTAL SUM FOR THIS RUN IS',TOTAL_SUM)
(COL(20),A,X(1),F(8));
PUT FILE(SYSPRINT) SKIP(3) EDIT(
'THIS PROGRAM ENDED NORMALLY')
(COL(20),A);
PUT FILE(SYSPRINT) PAGE;
END;
//GO.SYSIN DD *
668
5
6 510 4 4
SOILS      SLOPE      HYDROLOGY CULTURAL  VEGETATION
//GO.INPUT DD DSN=OS8L2.TEST,DISP=SHR
//GO.OUT DD DSN=OS043.TEST,DISP=(NEW,CATLG),UNIT=3330,
// VOL=SER=KSCC04,SPACE=(TRK,(5,5)),DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
// EXEC DSLIST
//SYSIN DD DSN=OS043.TEST,DISP=SHR
```

APPENDIX D.

SYMAP Program to Produce a Composite Map.

```
//GO          EXEC SYMAP
//FT11F001 DD DSN=DS8L2.MAP2,DISP=SHR
-//FT12F001 DC DSN=CS043.TEST,DISP=SHR
//GC.SYSIN DC *
A-OUTLINE              AAAAA              0.8
                 0.C          0.0
                 0.5          1.1
                 0.9          1.6
                 1.1          1.9
                 1.3          2.4

                 5.8          4.2
                 5.9          3.4
                 6.1          2.9
                 6.6          2.0
                 6.6          0.0
                 C.C          0.0
99999
B-DATA                 BBBBB              0.8
C-CTO                  CCCCC
     OXAVL      0.005        0.000
                0.578        1.031
                0.759        1.270
                0.946        1.488
                1.278        1.816
                1.500        2.109
                1.617        2.363
                1.735        2.717
                1.782        3.007
     OXAVL      0.405        C.007
                1.500        1.999
                1.657        2.328
                1.78C        2.707
                1.822        2.992
                1.854        3.262
                1.921        5.006
                1.938        5.181
     OXAVL      1.040        0.024
                0.946        0.124
                0.821        C.220
                0.872        C.325
                0.963        C.414
                1.074        0.608

                1.97C        4.963
                2.051        5.028
                2.031        5.103
                1.991        5.158
     OXAVL      8.247        2.005
                7.561        2.986
                7.358        3.328
                7.291        3.593
                7.284        4.023
                7.157        4.334
                6.940        4.646
                6.671        4.829
                6.278        5.027
                5.884        5.190
99999
C-LEGENDS            CCCCC
     125     65      0          1          2        N
     126     65                                     A
     126     65     2                               |
     127     65      |----------+----------|     ---+---
     127     65     2 ----------------------        |
     128     65                                     |
     128     65     2                               +
     129     65        SCALE: IN 1000 FEET          |
99999
E-VA                 EEEEE
MAP
MANHATTAN RESCURCES ANALYSIS

     3      5.
     8
    13      2.C
    25
    31
    36
    37
99999
999999
 /*
```

B-DATA
E-VAL

UNIT → 11

UNIT → 12

APPENDIX E.

Program to Execute Permanent File of SWAP
At Kansas State University.

```
/*TAPE9
// EXEC PGM=IEFBR14
//DD1 DD DSN=DS043.TEST,DISP=(OLD,DELETE)
//STEP1     EXEC PGM=SWAP,COND=EVEN
//STEPLIB  DD DSN=DS043.SYMAP.INTER,DISP=SHR
//GO.SYSIN DD *
668
5
 3 510 4 4
SOILS      SLOPE      HYDROLOGY CULTURAL  VEGETATION
//GO.SYSPRINT DD SYSOUT=A
//GO.INPUT DD DSN=DS8L2.TEST,DISP=SHR
//GO.OUT DD DSN=DS043.TEST,DISP=(NEW,CATLG),UNIT=3330,
// VOL=SER=KSCC04,SPACE=(TRK,(5,5)),DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
/*
```

Tom Burdett

COMPOSITE COMPUTER MAPPING OF ECOLOGICAL DETERMINANTS FOR IDENTIFYING LAND USE SUITABILITY

by

THOMAS DEE BURDETT

B.S., University of Utah, 1977

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF REGIONAL AND COMMUNITY PLANNING

Department of Regional and Community Planning

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

As the natural environment becomes a more important political issue and physical planning problem, new quick methods of quantitative analysis need to be developed. This report is the product of an investigation into a method of environmental analysis. This method is computer mapping of ecological determinants for depicting land-use suitability.

A site outside of Manhattan, Kansas was selected and the information that pertains to land-use suitability (soils, slope, hydrology, vegetation, and cultural features) was mapped using the computer program SYMAP. The technique used a grid coordinate system for defining the location of data or information cells, used to create the shaded half tone maps. A weighting system (linear combination) was developed and applied, to establish overall composite suitability maps. This was accomplished with the design and implementation of a new computer program called SYMAP Weighting Analysis Program or SWAP. The results of this procedure are recorded and compared with the graphic overlay approach.

The results show that the production of composite suitability maps with SYMAP and SWAP is fast, efficient and has a greater potential for analysis. The cost of this computer mapping technique is not prohibitive, but some cartographic accuracy was lost due to grid cell interpolation.

It was found that the method of land-use suitability based on ecological determinants using a weighting system is viable. More research into the application of computer mapping for planning analysis is suggested.