

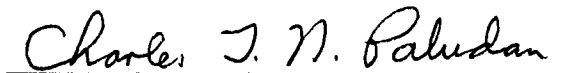
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AUTOMATED INDUSTRIAL SITE SELECTION
USING ELEVATION MODELS AND
DIGITAL IMAGE PROCESSING

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Mary Caroline McKamey

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ABSTRACT

In the past five to ten years, much thought has gone into ways in which the state of Tennessee might compete successfully for large scale industrial development. One service that may be provided in the future for outside industries looking to move to Tennessee would be a comprehensive, personal computer based system to efficiently select the optimal site for plant location. For this thesis research, three steps have been taken toward this goal. First, a computerized system for mapping possible sites based on slope was created on a personal computer connected to a mainframe computer. Second, aerial photographs were converted to digital form and placed on floppy diskettes for use in an image processing system on a personal computer. Third, data base files were created to store information gathered from the first two techniques according to overlying "themes" of information. Though refinements still need to be made, the three steps in automated industrial site selection can be viewed as a platform upon which more sophisticated techniques can be built.

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CHAPTER I

INTRODUCTION

Careful planning of industrial development is vital as industry expands out of the traditional "steel" belt of the nation. Coincidentally, the impact of the personal computer in all aspects of industry in the past few years has been nothing short of phenomenal. Taking advantage of the capabilities of the computer in planning for industrial development is a sensible decision because the planning agency with the capability to automatically pick optimal industrial locations will fare better in successful recruitment of industries than the agency with a disorganized approach to planning.

The value of remotely sensed data in the planning of industrial development is well-known. Previously, this has involved manual interpretation of aerial photographs and examination of land use and land ownership maps. Manual interpretation will always be integral to any system of land use planning, but there are physical parameters that may easily and efficiently be evaluated by using computer compatible tapes and digital computers. Automated evaluation is useful if the area being studied is large. Planning for industrial development on a large scale involves evaluation of numerous parameters that need to be

referenced in many ways and on many occasions. The computer is uniquely suited to the efficient execution of this task. One can, for example, "ask" certain programs for all water bodies with an area of ten acres or less and acceptable water quality within a particular county. This saves the operator from endlessly sifting through pages of information looking for all correct combinations of parameters.

Evaluation of the physical terrain to be considered for industrial development can also be aided with a personal computer. Twenty megabytes (MB) of fixed disk storage is adequate for storage of image processing software and at least fifty digital images of 320 by 200 pixels when a package such as IBM's Personal Computer Image Processing System is used. (PCIPS is a registered trademark of International Business Machines Corporation.) Once seen as too costly a pursuit, digital image processing packages are now available for a few hundred dollars for personal computers (Wilson, 1986).

Another analysis technique that is being assisted with computers is mapping of slope. Rough terrain must be examined for areas which would be too steeply sloped for plants to locate. A recent project by the Remote Sensing Division at the University of Tennessee Space Institute (UTSI) was a program for the Tennessee Valley Authority (TVA) which scans data from Digital Elevation

Model (DEM) computer tapes and picks out areas with acceptable slope for mapping. The bounds of "acceptable" slope can easily be changed to accomodate different planning situations. For the research presented here, the slope program created for the Tennessee Valley Authority was used to select initial sites based on slope and area, and three of them were selected for further analysis.

The sites selected for analysis were digitized from aerial photographs into a form suitable for digital image processing. Drainage patterns and soils were analyzed using image processing techniques. Other researchers have already developed procedures to automatically locate geologic fractures known as lineaments from digital terrain data (Moore and Waltz, 1983). Some of the thesis work consisted of adaptation of techniques originally designed for more diverse image processing applications. Although dedicated mini-computer based systems for site evaluation procedures are available, this research was carried out with the goal of developing a planning system for personal computers, which are owned by most agencies concerned with industrial site planning. The objectives pursued in reaching this goal were 1) development of an automated slope evaluation system, 2) the use of image processing for terrain analysis, and 3) storage

of the information thus created in a data base. Each objective was addressed as completely as possible within the equipment limitations, but further work still needs to be done on refinement of the system. The basic groundwork for pursuing the objectives is explained here.

CHAPTER II

CONSIDERATIONS FOR INDUSTRIAL SITE PLANNING

Introduction

The development of an automated system of industrial planning must not begin with study of the computer, but with the study of basic principles of land use planning. The computer is merely a tool allowing orderly and expedient execution of potential site evaluations; the ultimate decision belongs to the planner or engineer. The physical characteristics of a parcel of land are factors which affect the choice for or against industrial development. Site preparation costs are closely associated with physical terrain. Honea says, "Matters which might be taken into account are foundation conditions, drainage conditions, [and] slope of the land..." (Honea, 1976). The importance of each attribute changes, but objective evaluation of the permanent resources in a certain region is, nonetheless, a worthwhile task. Honea quotes other researchers who have concluded that important physical site characteristics include drainage, soils, and slope. This chapter will discuss the importance of each of these parameters in the context of industrial site selection.

Drainage

The first environmental consideration to be discussed is the behavior of water in a particular area. Often, natural drainage settings are altered with good intention, but without anticipation of unwanted side effects such as gullying, water table depression, and erosional disasters (Garner, 1974). Some consider drainage to be the most important feature of an area considered for industrial location. Way (1978) says,

[Drainage] is probably the most important single identifier of landforms. Drainage pattern analysis can give a great deal of information concerning the parent rock and soil materials...

Drainage factors influencing site selection.

Poorly drained land is difficult to use for construction and is generally undesirable. Likewise, it is undesirable for adjacent land to drain onto a proposed site, or for a legal drain with a dedicated right of way to cross a site (Conway and Liston, eds., 1976).

Recharge of the groundwater supply is related to drainage, also. For example, permeable soils, fractures, and joints which act as seepage corridors allow rapid groundwater recharge for municipal needs (Way, 1978), but could indicate large-scale geologic structures known as lineaments (Moore and Waltz, 1983). To allow recharge of the groundwater, natural drainage

systems (as opposed to closed, or pipe systems) should be used as much as possible (Rubenstein, 1980). These considerations highlight the importance of recognizing what drainage patterns look like, and knowing how aerial data are helpful in analyzing drainage networks.

Analysis of drainage characteristics using aerial data. Drainage patterns can be taken as readily from aerial photographs as from specially-created drainage maps (Garner, 1974). Drainage patterns for a region can be analyzed at scales from 1:40,000 to 1:60,000. At a scale of 1:60,000, spacing between streams ranges from 16mm for coarse textures to less than 2mm for fine patterns (Way, 1978). Though the aerial photography used in this research is at a scale of 1:58,000, the guidelines for determining texture of drainage patterns are nonetheless useful. Spacing of streams is not the only clue to drainage texture; the texture is also closely related to soil properties. Fine textures are associated with high surface runoff and impervious soils. Coarse textured drainage patterns are associated with permeable bedrock and soils and with lower levels of surface runoff than the fine textures. Medium texture, by default, lies in between the fine and coarse, with soils containing mixtures of materials. Figure 1 shows the three different drainage textures (Way, 1978).

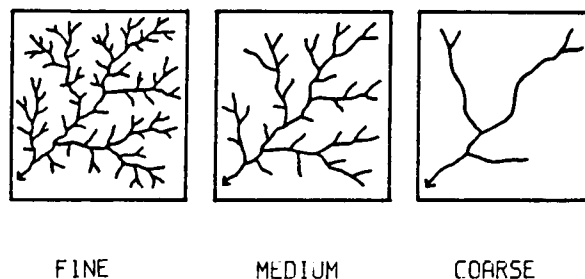


Figure 1. Three drainage textures.

The pattern of the drainage net is highly variable, with the pattern known as "dendritic" being the most common. The medium textured pattern in figure 1 is a good representation of the dendritic pattern. It is characterized by a "treelike branching" of streams and indicates soil and rock uniformity (Way, 1978). Soil tone and tone uniformity are also indicators of drainage quality. Lighter soil tones generally indicate better drainage. Likewise, uniform tone indicates little change in moisture and texture over an area (Way, 1978).

Problems in the detection of the drainage net.

Sometimes, it is difficult to follow a stream course in aerial photography because of dense vegetation and rock outcroppings. In some cases, predawn thermal infrared imagery has been useful in watershed analysis due to the rise of the thermal flux from the water through the

vegetation (Cannon, 1973). Vegetation can give some clues to the drainage characteristics, but ground truthing is necessary because of the range of conditions certain vegetation types can indicate. Fortunately, land use is also a clue to the drainage net. For example, railroads and highways usually follow paths that are naturally occurring, and where they cut into the earth, subsurface materials are revealed (Way, 1978). It is to these subsurface materials that one turns for more information regarding the suitability of land for industrial sites.

Soils

Engineering applications involving soils analysis include the building of dams, pipelines, airstrips, and, of course, industrial plants. Sometimes, the information taken from soil survey maps and aerial photographs is stored in a computer data base. In fact, computers have been used in distinguishing engineering soils since 1969 (Colwell, 1983). Analysis of soils is closely intertwined with the analysis of drainage, as indicated in the previous section. Unsuitable soils generally correspond to unsuitable drainage conditions, and analysis of both provides a convenient cross-check for insuring construction suitability.

Factors influencing site selection. Rarely does a construction project take place in which terrain modification is not important. Even simple leveling of a site can involve difficulty if the natural materials in the area are not well-suited for excavation. In fact, the cost of reshaping the natural landscape of an area is usually the largest single cost in engineering construction projects. Unconsolidated materials are much easier to excavate than hard rock layers. This is why regional engineering soils maps and detailed surveys are so vital in construction design (Colwell, 1983).

With the initiation of extensive highway programs in the United States in the late 1950's, resource inventory and conservation of scarce materials gained importance. Most projects depend on having suitable construction materials within reasonable hauling distance. Inventories of naturally occurring construction materials are greatly aided with aerial photography because large areas can be evaluated by a trained photogrammetrist in a much shorter time than a field inventory would take. Although no one scale of photograph can satisfy all inventory needs, scales of 1:40,000 and smaller are useful for regional planning studies (Colwell, 1983, Way, 1978). Analysis of the aerial data must combine techniques in a way suitable for the site selection task at hand.

Analysis of soils using aerial data. The Manual of Remote Sensing lists several keys to identifying soils for use as croplands (Colwell, 1983). These keys can be useful for identifying sandy soils, clayey soils, and rocky soils, among others. Table 1, using information from the Manual of Remote Sensing lists recognition keys, soil inferences, deficiencies, and taxonomic class. Though these properties can be distinguished straight from an aerial photograph, digital images can be processed with masks, density slicing, and image arithmetic to enhance features indicative of soil conditions.

Problems in the classification of soils from digital aerial data. Although accuracy of identification of soils by computer can be as high as 95% when compared to agricultural soil survey reports or engineering soils maps, some consistent misclassifications have been reported. A major problem is that techniques do not exist to recognize soils beneath groundcover. Soil interpretation can be made, however, by information given by drainage patterns and topography (Colwell, 1983). In order for the best interpretation to be made, it must be determined at the outset which type of data should be used, including possible scale, season of data collection and film type. For example, if black and white film is decided

TABLE 1
RECOGNITION KEYS FOR USE AS CROPLAND CLASSES

Recognition Key	Soil Inferences	Soil Deficiency
Close drains, visible relief, shadows	Thin, possibly rocky soils	Low water avail- ability, difficult to farm
Low IR reflect- ance, light tone, few streams	Thin soils, low organic matter	Low water avail- ability, low organic matter
Dark mottled tone irregular patterns, bands	Water logged soil or organic soil	Lack of oxygen for roots and micro- organisms
Light tone, mottled, white rims around water bodies	Saline soils	Low ability to supply water
Light tone, dunes, blurred boundaries	Sandy soils	Low water holding capability, erodable
Dark uniform tone, close drains	Clayey soils, churning soils	Poor physical con- dition, low oxygen supply
Light tones, gullies, mining activity	Most productive part of soil lost	Low organic matter poor physical condition

upon, vegetation, which reflects near infrared wavelengths, will not overpower the soils as much as it might otherwise. However, color infrared photographs taken in winter do not lead to this problem. Vegetation conditions can also indicate erosional problems and claypan conditions, and slope characteristics can give additional information about soil problems that are likely to occur (Frazee et al, 1971).

Slope

The final site selection criterion to be discussed is slope of the land. Drainage and excavation procedures, while relating to hydrology and soils, also depend on the slope characteristics of an area. It is obvious how the drainage net varies over the terrain, but just as importantly, soil mechanics based on slope can predispose an area to be unsuitable for construction.

Factors influencing site selection. Steep slopes with active creep pose hazards for route alignment, accessibility, dam construction, and waste disposal (Colwell, 1983). Slope evaluation is being used as a starting point for attracting industries to the area. The exact procedure for evaluating slope with a computer will be discussed in a later chapter. The point to be made here is that developers want to be able to easily select areas with suitable slope characteristics

for their construction application. Once these are selected, other criteria, such as current land use, drainage, and soils can be selectively analyzed.

Analysis of slope using computer compatible tapes.

Rectangular grids of elevations have previously been used in computer analysis of slope and aspect (which is the horizontal direction in which a slope faces, expressed in degrees from the north (Monmonier, 1982)) for areas in eastern Tennessee (Carter, 1986). The programs that allow users to interactively define acceptable slope and receive a map of suitable areas were developed by the Remote Sensing Division at UTSI.

Problems in the analysis of slope. In higher latitudes, evaluation of elevation data arranged in a latitude/longitude format can produce errors in slope calculations due to varying distances along x and y axes with increasing latitude. This problem can be solved by interpolating data in a regular grid and modifying computer programs to read the modified data. Carter (1986) has done this interpolation even for middle latitudes. Another problem is that plotting a map representative of an entire Digital Elevation Model (DEM) takes too much time to be practical, so the option for the user to specify a small window in the DEM for evaluation was incorporated into the slope analysis system used.

Conclusion

Analysis of slope, soils, and drainage are important in industrial site selection. The digital computer can be incorporated into the analysis for increased accuracy and speed compared to manual interpretation methods. Two specific applications include computer analysis of slope and digital processing of aerial photographs. Computer analysis of slope is to be distinguished from digital image processing because no actual image appears on the screen to be processed. A helpful technique that was used in this study for storage of data was the implementation of a data base so that specific criteria could be selected without wasting time manually sifting through data. Though automated techniques will never completely replace photointerpretation, they may help photogrammetrists and engineers do their jobs more efficiently. The effects of automation in industrial site selection could eventually be far-reaching, especially as states not traditionally considered "industrial" compete for industries which are expanding operations out of the steel belt.

CHAPTER III

THE ROLE OF THE COMPUTER IN SITE PLANNING

Introduction

In industrial development, as with any undertaking, application of computer technology to certain problems can only be successful if the actual supporting staff knows how to use the specific techniques. Shelton and McRae (1981) state,

In order to be effective in natural resources and land use planning, ...technologies need to be appropriately applied, meaning the level of sophistication of the technology should match the users' ability to apply it to their own problems.

Fortunately, in the past fifteen years, computer technology has been widely integrated into disciplines involved in planning. Even in countries not normally considered to be high-technology leaders, computers have been successfully integrated into planning. For example, in 1976, researchers at Michigan State University implemented a prototype computerized inventory system in the Dominican Republic to aid in the transfer of agricultural technology (Shelton and McRae, 1981).

Since the time of that project, rapid advancement of computer technology has made powerful and relatively inexpensive systems common in the engineering trades.

Personal computers (PC's) have given even small businesses the opportunity to streamline tedious procedures. They can also be used for the technical applications discussed here. Geographic Information Systems (GIS's), or spatially referenced information management systems, have been developed for PC's (Davis, 1984), and image processing software is also available. In this chapter, the computer used for most of the work in this research will be discussed. This computer is called the IBM AT Personal Computer (IBM AT). Extra hardware options will also be discussed.

The IBM AT

The IBM AT used in this study has two floppy disk drives. In addition, it has a fixed disk drive with 20 megabytes (MB) of memory. For the study of slope using FINDSITE, a program written by the author, the IBM AT was connected as a terminal to a VAX 11-780 host computer. This was because the data sets analyzed for slope were too large to fit onto the 20 MB fixed disk of the IBM AT. In order to be used as a terminal to the VAX 11-780 mainframe, a direct line was used to connect the two computers. Also, a terminal emulation and data transfer program called KERMIT (which was developed at Columbia University) was used on both the IBM AT and the VAX 11-780 to establish terminal capabilities and transfer plotting data to the IBM AT.

When the AT was used as a stand-alone system, to plot the slope maps, for example, it was running under the Disk Operating System, version 3.1 (DOS 3.1) (DOS copyright IBM, 1985). This allowed use of the data base program called dBASE III PLUS (dBASE III PLUS is a registered trademark of Ashton-Tate, Inc.) for data storage and retrieval. As is the case with much specialized software, the work for this study required extra computer equipment, or "hardware."

Additional Hardware

An IBM dot-matrix graphics printer was used because it can create black and white prints of the processed images for quick hardcopy production and storage. A TAXAN RGBvision 425 color graphics monitor was used along with IBM's monitor for the image processing work, and a Houston Instrument DMP-52 pen plotter was used to create mylar overlay maps for use with 1:250,000 scale regional topographic maps.

In general, it is important that the design of a computer system configuration for use in industrial site planning be flexible. Personal computers accept many different hardware connections, and by keeping flexibility high, one does not necessarily have to spend extra money on machines dedicated to specific applications. For many planning and engineering agencies, efficiency and cost-effectiveness must often

take precedence over the convenience of a highly developed, but exclusively dedicated hardware system. All hardware and software development explained in this thesis was conducted with system flexibility in mind and was tested in a pilot study of southern middle Tennessee. Resources available for the pilot study, along with some brief information about the study area are discussed in the following chapter.

CHAPTER IV

RESOURCES FOR THE PILOT STUDY

Introduction

Once the considerations for industrial site development were outlined, and the equipment necessary to automate evaluation was available, effort began to put the procedures to work as a test of smoothness and feasibility. Although the slope analysis system is only in its earliest stage at the time of this writing, it is operational. The image processing package, PCIPS, and the data base package, dBASE III PLUS are commercially available, so no attempt was made to "re-invent the wheel" by duplicating their capabilities. The pilot study in southern middle Tennessee was performed in an attempt to make these seemingly disparate software packages work together toward the goal of selecting potential industrial sites based on slope, drainage, and soils, and to store the resulting data in a well-organized fashion.

The nine-county area selected for the study. The counties initially represented in the pilot study are Coffee, Franklin, Lincoln, Cannon, Grundy, Moore, Bedford, Marshall, and Warren. Figure 2 is a map of the area encompassed by these counties, with Nashville and Murfreesboro as landmarks for the unfamiliar reader.

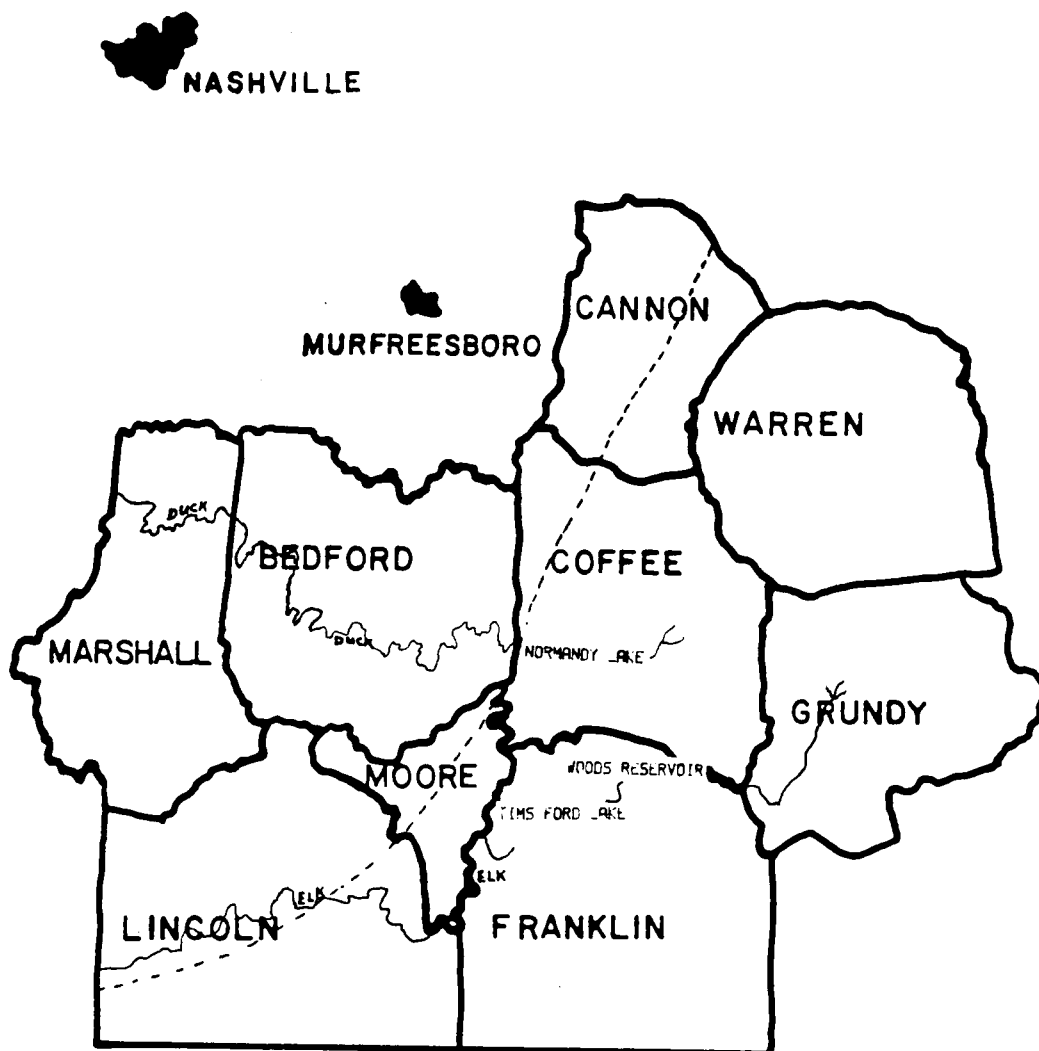


Figure 2. Nine-county area selected for pilot study.

Approximate scale 1:1,000,000.

This nine-county area is located in two physiographic regions: the eastern Highland Rim and the Central Basin. The Highland Rim is about 25 miles wide in the east and is about 400 feet higher than the Central Basin. Rocks in the Eastern Highland Rim include limestone, the cause of many sinkholes. Soils are relatively infertile, thus the name "Barrens" given to the inner edge of the Eastern Highland Rim. The study area is drained by the Elk and the Duck Rivers, and has very fertile soils. The Basin is the result of erosion on an anticline extending into Alabama (Folmsbee, 1969). On figure 2, the dashed line separates the highland rim (east) from the central basin (west).

As evidenced by current research at UTISI, the population in southern middle Tennessee is keenly interested in industrial and high technology development. Tennessee's endeavors in rural industrialization have been successful in the past decade; the Nissan Motor Corporation near Smyrna has employed thousands of people, while the General Motors Saturn project near Spring Hill will employ thousands more. This aggregation of counties in southern middle Tennessee was chosen for the thesis pilot study because of the importance of industrial recruitment to the area, and also because of the convenience of ground-truthing and other necessary field work.

Data Available for the Area

Although field work was necessary for checking the accuracy of the computer-generated slope data, three "remote" media were available for analysis over the area. Each medium was useful for a specific application within the study. The three used in this work include maps at a scale of 1:250,000, color infrared aerial film positives at approximately 1:58,000, and computer-compatible DEM tapes accurate at a scale of 1:250,000.

Maps at a scale of 1:250,000. These maps are for sale by the United States Geological Survey (USGS) in Reston, Virginia. Each covers 2° longitude by 1° latitude with a contour interval of 100 feet. The projection used for the maps is the Transverse Mercator, which is used as a base for the Universal Transverse Mercator (UTM) plane coordinate system. This coordinate system is used in the program FINDSITE discussed in Chapter V.

The nine-county study area straddles two available maps: Columbia, Tennessee, and Chattanooga, Tennessee. From these maps, visual inspection revealed several 10 kilometer square "windows" within the nine-county area with what appeared to be relatively flat terrain. Some of these windows were evaluated by the slope analysis program.

Aerial photographs at a scale of 1:58,000.

Aerial photographs are available as a product of the National Aeronautics and Space Administration (NASA) Earth Resources Aircraft Program. The high altitude photography was flown with U-2 and RB-57F aircraft at altitudes above 60,000 feet (18,000 meters). Color infrared film positives at a size of nine inches square were used in this study. The photographs were flown during late winter of 1981 by NASA for the National High Altitude Photography program. These photographs were the most recent ones available for the study area in color infrared. They were chosen from microfiche catalogs of available photography sent out by the NHAP monthly. Late winter data were chosen so that vegetation (which reflects in the near infrared) would not overwhelm other ground characteristics.

Digital Elevation Models at a scale of 1:250,000.

As a part of its National Mapping Program, the USGS distributes a form of digital cartographic data known as the DEM. The data consist of regular arrays of elevations, and are available at a scale of 1:250,000 for most of the United States. These are the data used in the slope analysis program. The following characteristics pertain to the digital data:

1. Regular arrays of data cast on the latitude/longitude coordinate system.
2. Coverage of $1^{\circ} \times 1^{\circ}$.
3. Origin of data at the southwest corner of the map.
4. Spacing of elevation points by three arc-seconds.
5. Total array size of 1201 x 1201 elevation points.

Programs designed to process the data must also be able to read header information contained at the beginning of the DEM and also within each 1 x 1201 profile in the data. The headers give information including the ground planimetric system, map projection, units of measure, minimum and maximum elevations, row and column identification for each profile, and the local datum (Elassal and Caruso, 1985). While the header information is useful for possible report generation, it is not used directly by the slope evaluation procedure in this research.

Conclusion

The pilot study in southern middle Tennessee examined parts of a nine-county area originally designated for study by the Southern Middle Tennessee High Technology Initiative in the preliminary slope analysis automation. Maps at 1:250,000, aerial

photographs at 1:58,000, and DEM's at 1:250,000 were all used in selecting potential industrial sites based on slope, soils, and drainage. The word "potential" must be emphasized, because property ownership has not been conclusively established at this time. The next chapter discusses the data collection from these procedures.

CHAPTER V

OVERVIEW OF SOFTWARE FOR THE STUDY

Introduction

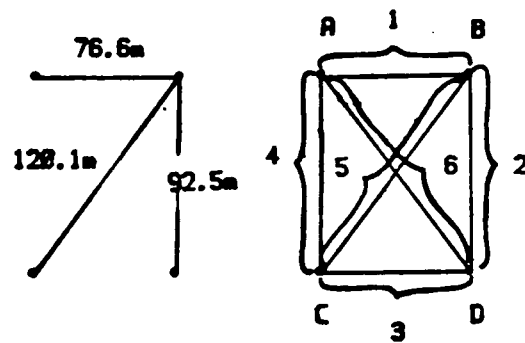
Three software components were used in the pilot study in southern middle Tennessee: FINDSITE, for mapping based on slope; PCIPS, IBM's image processing package, and dBASE III PLUS, the relational data base used to store information gathered from the first two sources. The data base should allow incorporation of site selection into the GIS in use at UTSI.

Automated Site Selection Based on Slope

To develop Tennessee's potential for competing for industry, several research efforts at UTSI have been directed toward issues pertinent to the attraction of new industry to the area. One of these issues is mapping based on automated slope evaluation. The ultimate goal in this case is a microcomputer-based system to scan elevation data and produce a map of all areas with slopes less than a certain user-defined maximum. Because of the importance of such a project, an initial phase was contracted by TVA to the UTSI Remote Sensing Division to test the feasibility for such a system and to develop the software needed for basic operation. In the first phase there have been two main goals: automation and simplicity.

Goal of automation. The data to be analyzed by the computer consist of a grid of elevations covering 1° latitude by 1° longitude. Every group of four contiguous elevation points, which is a grid of elevations, forms a small rectangle for which slope between all contiguous points can be calculated. In each such "cell" there are six possible slope calculations -- four for the points forming the cell border, and two more for the diagonals of the cell. Refer to figure 3. What the computer program must do is select the maximum of the six slopes for all cells in the data set and compare each maximum slope with a user-defined parameter of maximum acceptability so that it will "know" which areas are flat enough to be put on the map. Once this is done, the program must generate code to drive a plotter to produce a map of all areas meeting the slope criteria. All of these procedures must be combined into as few steps as possible for speed and simplicity.

Inherent in the goal of automation is the objective of flexibility so that a potential user is not locked into a regimented set of slope values or areas. Digital Elevation Models (DEM's) are available for most of the United States. All DEM's at a scale of 1:250,000 have the same data format, and can theoretically be read by the program developed at UTSI for analyzing slope.



$$\begin{aligned} \text{SLOPE1} &= (\text{ELEV(A)} - \text{ELEV(B)}) / 76.6 = 100 \\ \text{SLOPE2} &= (\text{ELEV(B)} - \text{ELEV(D)}) / 92.5 = 100 \\ \text{SLOPE3} &= (\text{ELEV(C)} - \text{ELEV(D)}) / 76.6 = 100 \\ \text{SLOPE4} &= (\text{ELEV(A)} - \text{ELEV(C)}) / 92.5 = 100 \\ \text{SLOPE5} &= (\text{ELEV(B)} - \text{ELEV(C)}) / 128.1 = 100 \\ \text{SLOPE6} &= (\text{ELEV(A)} - \text{ELEV(D)}) / 128.1 = 100 \end{aligned}$$

Figure 3. Slope determination for grid of elevations.

Additionally, because slope standards may vary between industries, interactive user specification of slope was a high priority for the system. Ideally, the entire analysis system including the DEM's and FINDSITE should go on a PC so that expensive mainframe time will not be needed. At this point, both the DEM's and FINDSITE reside and are run on the VAX 11-780. At this point, in order to avoid enormous bills for central processor unit (CPU) time on the VAX 11-780, the program to analyze slopes has been set up to analyze a small, user defined window of data, allowing it to run on the VAX 11-780 in less than one hour, and allowing a map to be plotted from data transferred from the VAX 11-780 to the IBM AT configured with the plotter in thirty to fifty minutes. An estimated one and one half hours of VAX 11-780 time would be required to run the analysis on the entire DEM file, costing about \$500 when all costs are included. In contrast, with the windowing capability, from the time the user logs on until the time the map is finished should take about one hour and less than \$100 for VAX 11-780 CPU time. Time and cost varies, of course with the size of the user-defined window and the maximum acceptable slope.

Goal of simplicity. Although more simplicity will be a much more realistic goal once the system has been downloaded onto a PC, certain steps have been taken to make the program easy to run for new users. For example, the user is prompted for maximum acceptable slope, and for which DEM (either Columbia or Chattanooga) is to be analyzed. The commercial program KERMIT is used to transfer the output of the program to the IBM AT for subsequent plotting. This system was developed with flexibility and ease of operation in mind. User-friendliness will continue to be updated as further refinement takes place.

Equipment for using the system. To review, hardware and storage needed for using the slope evaluation procedure include:

1. IBM AT computer with a 20MB hard disk, 1024KB main memory
2. VAX 11-780 mainframe computer
3. Cable connecting the IBM AT to the VAX 11-780
4. Houston Instrument DMP52 pen plotter
5. Floppy disks for data archival
6. Digital Elevation Model-grid of elevations for analysis.

Software necessary for using the procedure
include:

1. Microsoft Disk Operating System, version 3.1
(MS DOS 3.1)
2. FINDSITE.EXE - FORTRAN 77 program to evaluate
slopes. This program was written by the author.
3. SET?.DAT - BASIC programs to drive the plotter
(The symbol "?" represents a file number.). These
programs are generated by FINDSITE.
4. KERMIT.EXE - Resident on both the VAX 11-780
and IBM AT. It is used to transfer plotter code to IBM
AT so that the plotter can create the map

Final maps. Because the original DEM data were
interpolated from 1:250,000 scale base maps into a
regular rectangular grid, some sites may not be
practical. For example, there may be sites in lakes.
Lag time between the creation of certain roads and
production of TVA quad sheets prevents all information
that might be necessary from being on the most recent
maps (and therefore, the most recent DEM's) available.
When positioned correctly on the 1:250,000 scale base
maps, flat drainage beds are closely approximated by the
plotted data. This was also evident in the field
inspections. The advantage of the dot representation is
that small or large sites can be chosen from the same
map.

Personal Computer Image Processing System

Automated evaluation of slope is only the first step in selecting industrial sites. Other programs in addition to FINDSITE enable more detailed analysis of areas determined to have acceptable slope characteristics. The software package for the IBM line of personal computers used for further analysis is called PCIPS. It provides menu-driven capability to enhance digitized images. For this study, the software was used on an IBM PC instead of the IBM AT because it was already configured with the two necessary monitors. One monitor (a monochrome monitor) is used by PCIPS for the menu, while another monitor (color graphics monitor) is used to display images.

Capabilities. Much of the information in this and the next section was extracted from the PCIPS manual that accompanied the software package (IBM, 1985). The image processing system can perform the following functions:

1. Load/save images
2. Extract pixels from one image and insert them into another
3. Coloring control
4. Image display
5. Save/load color mapping tables
6. Parallelepiped multispectral classification

7. Histogramming and statistics collection
8. Contrast enhancement
9. Spatial filtering (3 x 3 convolution)
10. Image arithmetic
11. Zoom, reduce, and invert an image
12. Annotate image or histogram displays
13. Print image or histogram displays.

Although the system is entirely menu-driven, it allows user specification for histogramming, annotation, spatial filtering, and image arithmetic.

Input. The digital images to be used by PCIPS require 64KB of memory and consist of 200 raster lines of 320 pixels each. Each pixel occupies one eight-bit byte of memory, so 2^8 , or 256 dynamic intensity levels are represented; they range from 0 (dark) to 255 (light). Only four colors can be shown on the screen at one time, but one of three color palettes can be selected for use. Because of the relative flexibility of the system in image requirements, any image, as long as it is in the correct format, can be processed. Additionally, if only a very large image is available, any 200 x 320 pixel area of the image can be extracted and "imported" for use with PCIPS. This makes PCIPS capable of evaluating aerial or satellite data, medical images, or even images used in examination of flaws in industrial equipment.

Procedure for video digitizing. Aerial

photographs used with PCIPS were digitized using a Vicom digital image processing system equipped with a video camera and a nine-track tape drive. Video digitization creates a two dimensional light intensity function $f(x,y)$ where x and y refer to two dimensional spatial coordinates and $f(x,y)$ is a level of brightness associated with x and y and represents a picture element or "pixel" for each position digitized (Gonzalez and Wintz, 1977). When presented on a graphics monitor, the brightness levels are assigned to their associated x and y coordinates on the screen, creating an image of the digitized object. The digitized images are commonly stored on disk or tape; in this case, images were initially stored on tape and later transferred to disk for use with PCIPS.

Color infrared film positives which were digitized were nine inches square and were illuminated from behind with a light box during digitization. The camera used is a vidicon type camera, meaning it is equipped with a photoconductive detector which produces high resolution images. The camera is aimed at the specific part of the photograph needed for study. It can be moved toward or away from the film positive so that either part or all of it can be captured on camera. Proper aiming is facilitated by a television display located next to the

camera mount. Once the camera was properly aligned, the image was digitized to the VICOM's mass storage, and then it was transferred to tape.

Conversion to proper form for PCIPS. Since there was no tape drive for the IBM PC used in this work, the images were transferred to diskette for processing with PCIPS. This was done using the VAX 11-780 (which has a tape drive) as a host computer and the IBM AT as a receiving terminal. In terms of memory requirements, each digital image contains 512 raster lines with 512 pixels in each row (this is commonly denoted as a 512 x 512 image). Since each pixel requires one byte of computer memory, 512 x 512 bytes, or 256 KB are necessary for storage of one image. Smaller sections from these images were "imported" for use with PCIPS, which processes images of only 64 KB. The diskettes used with the IBM PC regular disk drive can each hold 360 KB of data. Therefore, only one image can fit on one diskette. The images were, however, transferred to PC mass storage along with all the PCIPS programs for convenience.

Before PCIPS can use any image on diskette, it must receive information about the image, such as size, and which area of the image it is to process. There is a menu selection in PCIPS called "import" which allows the system to take any 200 x 320 pixel area within an

arbitrarily sized image and use it for processing. The most important constraints on the image to be imported are (1) the image rows must contain less than 4000 pixels each, and (2) only one byte per pixel is allowed. The images digitized on the Vicom satisfy these constraints. Table 2 summarizes the PCIPS "Import" command operations. Once a set of parameters are specified by the user, it can be saved for use with other images for uniformity. Note that Sx and Sy allow the user to skip pixels so that more of the overall image can be used. There is, however, a loss of resolution proportional to the number of pixels skipped.

The user interactively specifies all of these parameters on a screen set up with a schematic diagram on which the user specifies the parameters listed in Table 2. Once the parameters are all specified, PCIPS takes the image and stores it in a buffer for normal processing techniques. With an image stored on diskette, the entire Import procedure takes about two minutes to complete.

Once aerial data are digitized and processed, it is convenient to store the drainage and soil information interpreted from the images in a regular format for easy retrieval by future users. The use of a relational data base, which can selectively retrieve data for a user is another important part of this study. The data storage

TABLE 2
IMAGE SPECIFICATION PARAMETERS FOR PCIPS

Name of parameter	Description
Ws	Width of source image in pixels
Hs	Height of source image in lines
Wa	Width of imported sub-image
Ha	Height of imported sub-image
dx	Offset from left of image to starting pixel of imported area
dy	Offset from top of image to starting pixel of imported area
Sx	Number of pixels to skip in x direction
Sy	Number of pixels to skip in y direction
bx	X location of image in buffer
by	Y location of image in buffer

is similar to the concept of the Geographic Information System, though not as sophisticated. The data base used to store the soils and drainage information from the processed digital images is called dBASE III PLUS.

dBASE III PLUS

The dBASE III PLUS software package is currently in use in the Small Computer Information Processing System (SCIPS), a Geographic Information System set up on the IBM PC in the Remote Sensing Division at UTSI.

The practicality of using a data base such as dBASE III PLUS for storage and retrieval owes itself to the categorization of data into user-defined "themes" of information. For example, a file could be created with data pertaining to soil characteristics. Each file is further subdivided into very specific "fields" of information, such as water content, for a theme file on soils. After having logged information into dBASE III PLUS, once a theme file has been selected for retrieval, the user can select information based on certain characteristics contained within the specific fields. For example, if a user were interested in soils with high saline content, medium texture, and poor drainage within Franklin and Lincoln Counties, he or she could ask (using dBASE III PLUS commands) for only a list of soil areas with these properties. The time saved when examining large amounts of data can be substantial.

Summary

There were three main software packages used in this study: Findsite, to find potential industrial sites based on slope; PCIPS, the image processing package for analyzing digitized aerial photographs; and dBASE III PLUS, the data base for organized storage of the information produced from using the other packages. These three packages were used to help select and study three areas in southern middle Tennessee for slope, soil, and drainage characteristics.

CHAPTER VI

DATA COLLECTION AND EVALUATION

Introduction

Data for the evaluation of potential industrial sites were gathered from the system of automated mapping based on slope. For the three windows (small, user-defined geographic areas within an entire DEM) of data analyzed, five aerial images covering the areas of interest were digitized for further inspection. The drainage net was first considered, and then the ground conditions were examined, both through digital image processing. The steps in analysis are detailed here.

Slope Evaluation

Windows. Three windows of elevation data were evaluated using the automated slope evaluation system for areas with slopes less than or equal to 0.5%. To produce such a map, a maximum acceptable slope of 0.5% was fed into the evaluation program. Early field work on data run at 0.5% revealed an average slope over ten areas selected by the computer of approximately 0.83% with a standard deviation of 0.38. This discrepancy between field-calculated slope and the slope calculated by the program FINDSITE could be due to the small size of the sites surveyed compared to the sampling interval of the elevations on the DEM tapes. While the DEM

elevations are 92.5 meters apart on the north-south axis and 76.6 meters apart on the east-west axis, the elevations calculated in the field were only 100 feet on each axis. These measurements were made using a theodolite on a tripod with two perpendicular bubble levels. The distance from the sighting cross hair in the theodolite to the ground was recorded. Next, a surveyor's tape was used to measure 100 feet from the theodolite. At this distance, a ten foot measuring rod was sighted through the theodolite, and the height sighted in the cross hair was recorded. The absolute difference between this height and the height to the ground at the level was calculated and divided by 100 feet. A diagram of the procedure is presented in figure 4.

The first window contained the towns of Winchester and Cowan, Tennessee. Approximate UTM coordinates for the lower left and upper right corners of this window were 580 kilometers (km) E, 3890 km N, and 592 km E, 3900 km N, respectively. The second window contained the communities of Huntland and Elora, Tennessee. The approximate lower left and upper right UTM coordinates for this window were 555 km E, 3875 km N, and 565 km E, 3885 N. The third window evaluated contained no apparent urban areas, but did contain State Highway 53, a secondary, all-weather road. Approximate

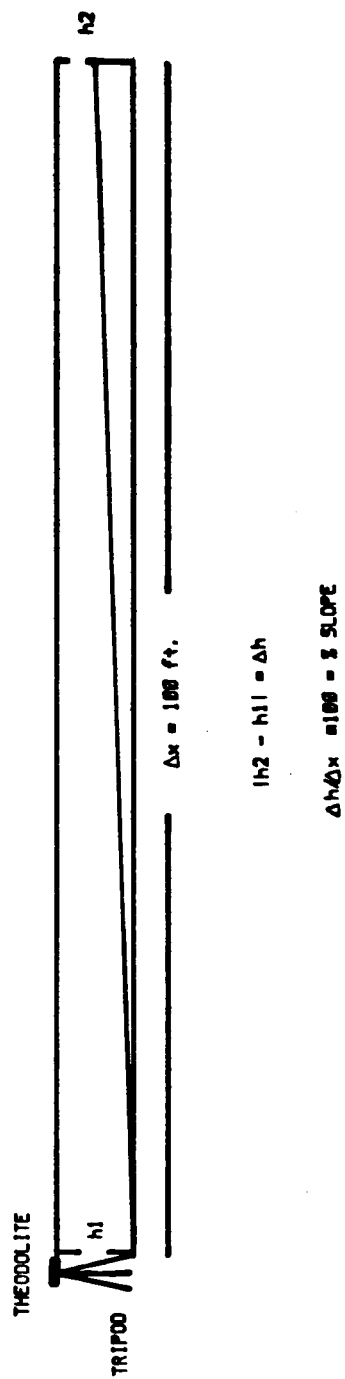
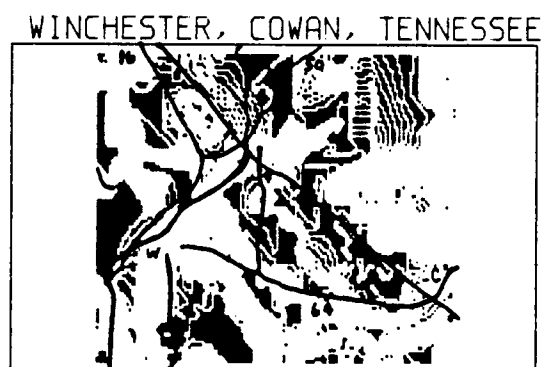


Figure 4. Slope determination in the field.

corner coordinates for this window were 580 km E, 3935 km N, and 590 km E, 3945 km N. The computer-assisted slope maps for each window are reproduced as figures 5, 6, and 7. Blackened areas correspond to those areas estimated by the slope evaluation program to have slopes of less than or equal to approximately 0.5%. Names of urban areas (if any) and major roads and other locational markings were added manually to the maps.

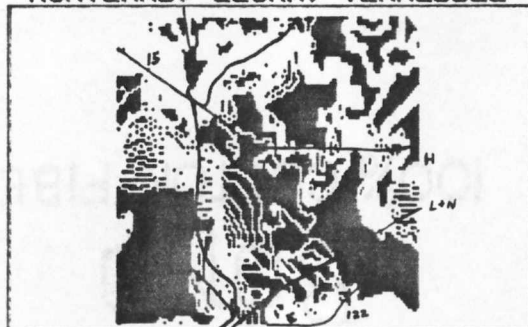


MAXIMUM SLOPE: 0.5 %

SCALE=1:250,000

Figure 5. Winchester and Cowan area.

HUNTLAND, ELORA, TENNESSEE



MAXIMUM SLOPE: 0.5 %

SCALE=1:250,000

1

Figure 6. Huntland and Elora area.

FREDONIA AREA, TENNESSEE



MAXIMUM SLOPE: 0.5%

SCALE=1:250,000

Figure 7. Highway 53 and Fredonia area.

Findings. Inspection of the computer-generated slope maps revealed many large, flat areas in each window selected. Since the video digitizing camera could not capture an entire aerial film positive covering a mapped region, flat urban areas and areas with adequate road access were specifically focused upon during video digitization. As a result, a total of five images were created for soil and drainage evaluation. They are: (1) Winchester; (2) Cowan; (3) Huntland; (4) Elora; and (5) State Highway 53 near Fredonia. Two of these, the urban areas of Winchester and Huntland, are used as examples in this chapter.

Image Processing for Drainage Evaluation

The goal of image enhancement is to produce a modified image that is more suitable for a specific analysis technique than the original, unmodified image (Gonzalez and Wintz, 1977). The nature of the enhancement may vary, but there are a few basic principles that are worth noting. In a digital image, edges and areas of sharp contrast are characterized by high frequency data. By the same token, smooth, or "blurred" image components are characterized by low frequencies. The drainage patterns can be enhanced by using a process to make edges and lines (high frequency data) stand out from the rest of the image.

A digital "filter" designed to pass high frequency data and attenuate low frequencies, then superimpose the high frequency information back onto the original image, is implemented by a square convolution mask of pixels. In PCIPS, the mask is three pixels on a side, and when it is convolved with, or passed over the image, the center pixel takes on a new intensity value determined by a weighted sum of the surrounding pixels. Different weights in the mask result in different kinds of enhancement. There exist masks that will bring out directional patterns, and PCIPS provides, along with five prefabricated masks, a "general" mask with weights determined by the user (IBM, 1985).

A procedure developed by Moore and Waltz (1983) to enhance lineaments was modified for use on PCIPS, on the hypothesis that drainage patterns would show up more clearly, also. In support of this statement, it was said, "Lineaments on the land surface are formed by a variety of landscape elements, including . . . drainage . . . alignments," (Moore and Waltz, 1983). For their work, and for this work, color infrared photographs were used because of sharp detail due to better atmospheric haze penetration of light in this region of the electromagnetic spectrum (0.8 through 1.1 micrometers).

The five enhancement steps adapted from the Moore and Waltz technique are:

1. Remove high frequency components from the image. This step was not always necessary.
2. Perform a series of directional high-pass filters to bring out lines in all directions.
3. Remove high frequency noise in the images resulting from step 2. (This step is optional.)
4. Increase the dynamic intensity range of pixels in the image ("histogram stretch").
5. Add the directionally enhanced images back onto the original image, and perform a histogram stretch on the final image.

Whereas Moore and Waltz used eight directional filters, only four were used in this work: North-South, East-West, Northwest-Southeast, and Northeast-Southwest. The weighted matrices for all steps are shown in figure 8.

The directional masks were created using the PCIPS "general" filter. Two original images and their enhanced counterparts are presented as figures 9 through 12.

$$\begin{vmatrix} -1 & 2 & -1 \\ -2 & 4 & -2 \\ -1 & 2 & -1 \end{vmatrix}$$

NORTH-SOUTH

$$\begin{vmatrix} -1 & -2 & -1 \\ 2 & 4 & 2 \\ -1 & -2 & -1 \end{vmatrix}$$

EAST-WEST

$$\begin{vmatrix} -2 & -1 & 2 \\ -1 & 4 & -1 \\ 2 & -1 & -2 \end{vmatrix}$$

NE-SW

$$\begin{vmatrix} 2 & -1 & -2 \\ -1 & 4 & -1 \\ -2 & -1 & 2 \end{vmatrix}$$

NW-SE

Figure 8. Weighted matrices for drainage enhancements

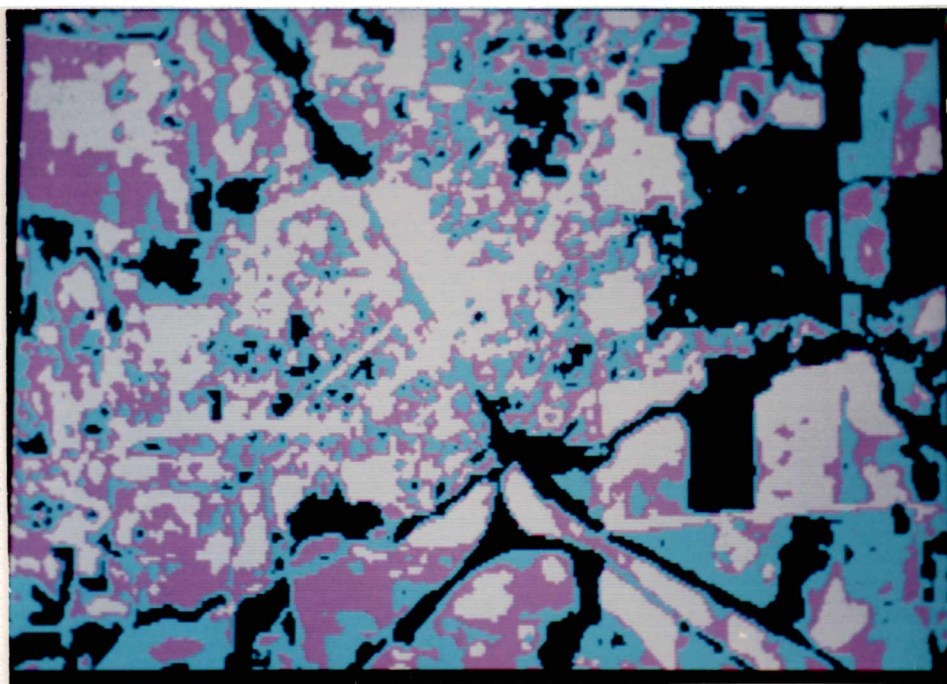


Figure 9. Original image for Winchester.

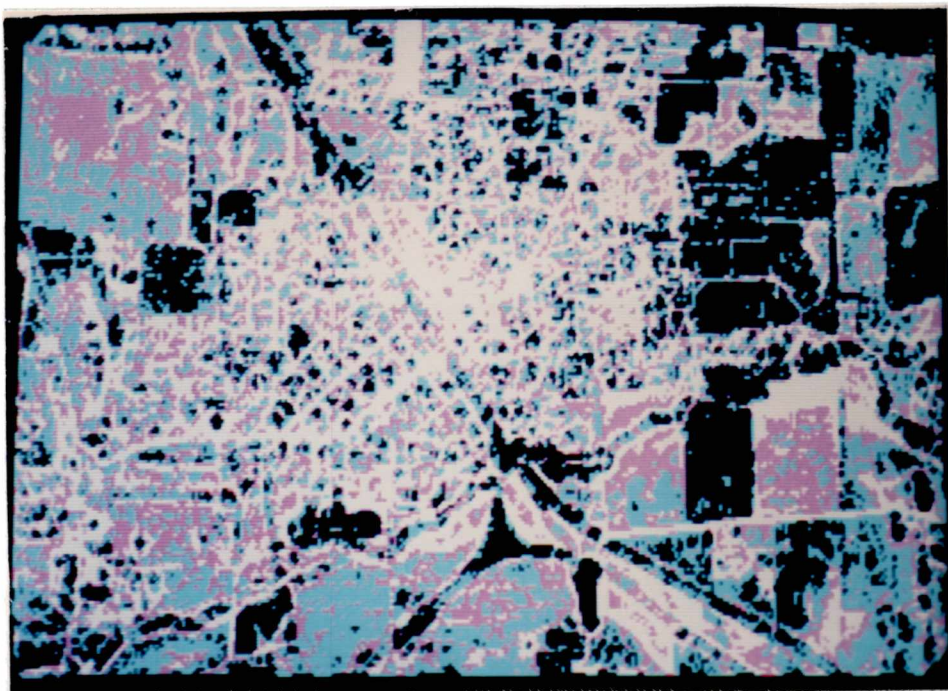


Figure 10. Drainage enhanced image for Winchester.

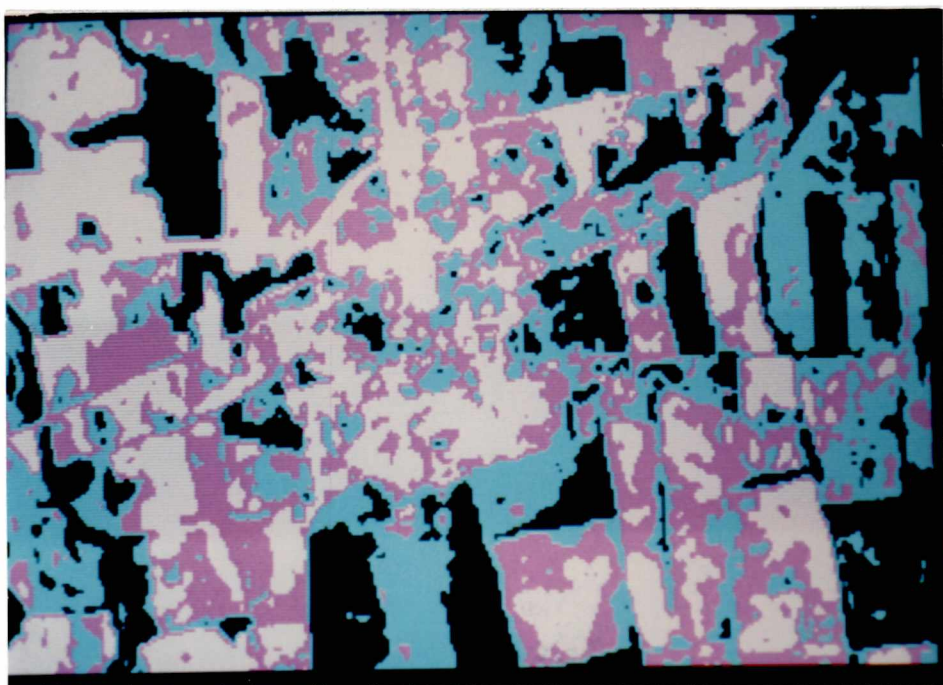


Figure 11. Original image for Huntland.

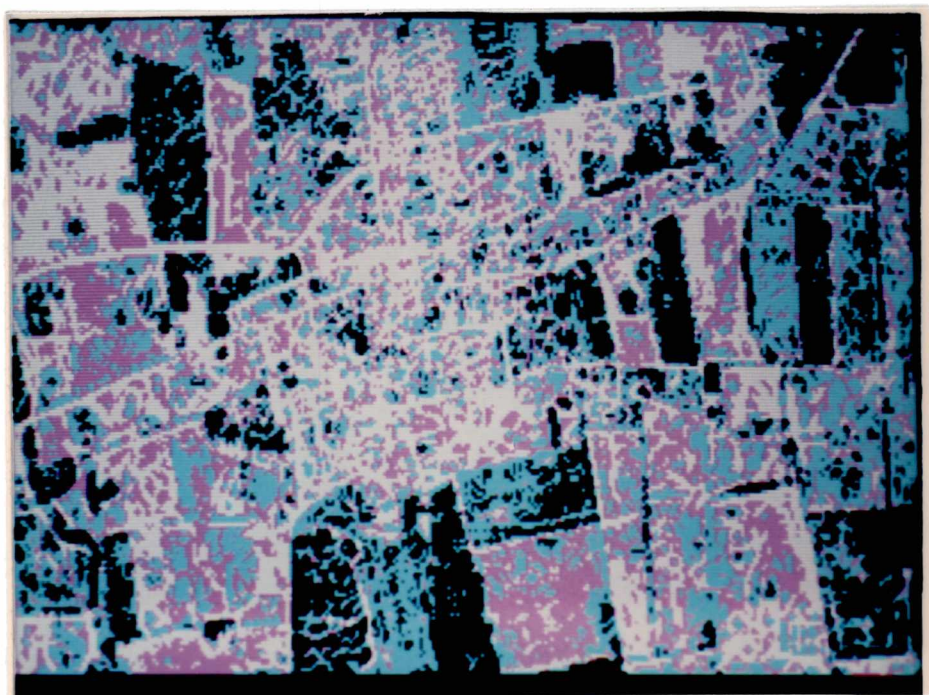


Figure 12. Drainage enhanced image for Huntland.

Results. Only the most obvious drainage channels were evident on the enhanced images. Possible reasons for this result include inadequate resolution for detailed work using PCIPS with images of this scale. Aerial photographs of larger scale might have alleviated this problem. A somewhat unexpected result did occur: transportation arteries stood out clearly on the processed images. This would lead to the conclusion that scale did play a role in the lack of adequate drainage enhancement. Another problem was the limited number of colors that could be displayed at one time on the screen. This made it imperative to partition the histogram of intensity levels versus number of pixels such that intensity ranges of interest contained enough color delineation. A procedure called "histogram stretching" was employed to spread the pixels out among a larger number of intensity levels. Histogram stretching increases the dynamic intensity level of the image, making better use of the colors that represent the intensity ranges (Gonzalez and Wintz, 1977).

Image Processing for Soils Evaluation

Digital filters represented by a weighted convolution matrix were again used in an attempt to evaluate ground conditions such as waterlogging and formation of sinkholes, a common problem in the eastern Highland Rim area due to limestone formations.

Removal of high frequency components of the images followed by careful histogram modification was used to this end. The PCIPS "median" filter, replaces the central pixel under the weighted matrix with the median of all 9 pixels under the window. An averaging filter, the PCIPS "smoothing" filter, replaces the central pixel with the average of all the neighbor pixels in the matrix. This would have been much more sensitive to high-intensity "spikes" of data in the image than the median, which produces the middle value in a sorted list of the 9 pixel values in the matrix (IBM, 1985). Once the low pass "median" filter was applied, the resulting image was added back to the original, and an edge enhancement filter was applied so that roadways would at least be evident. The low pass, soil enhanced images, along with their final histograms are presented in figures 13 through 16.

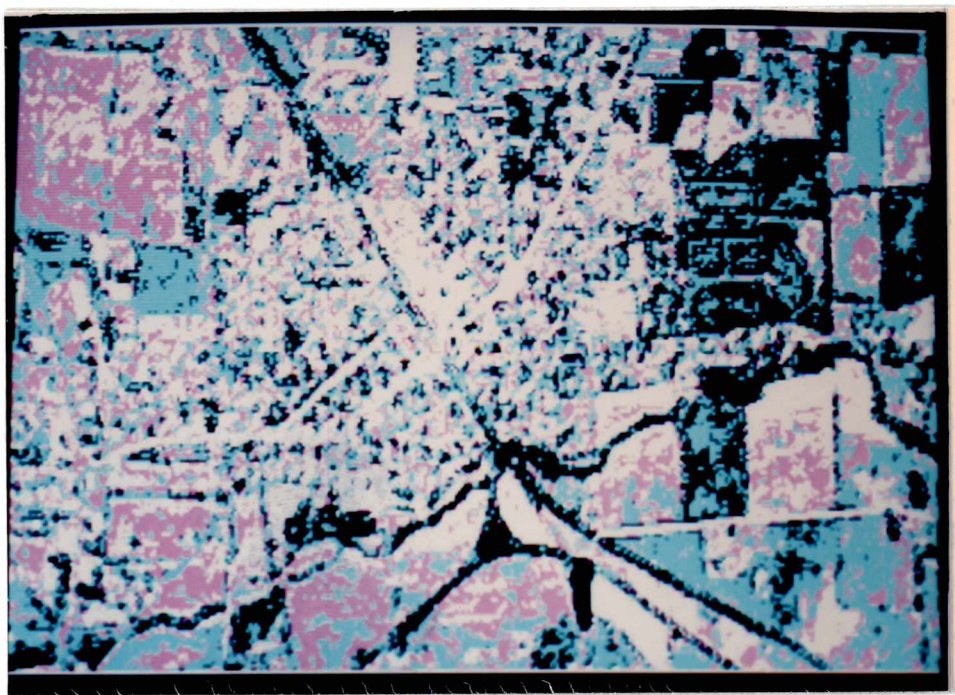


Figure 13. Soil enhanced image for Winchester.

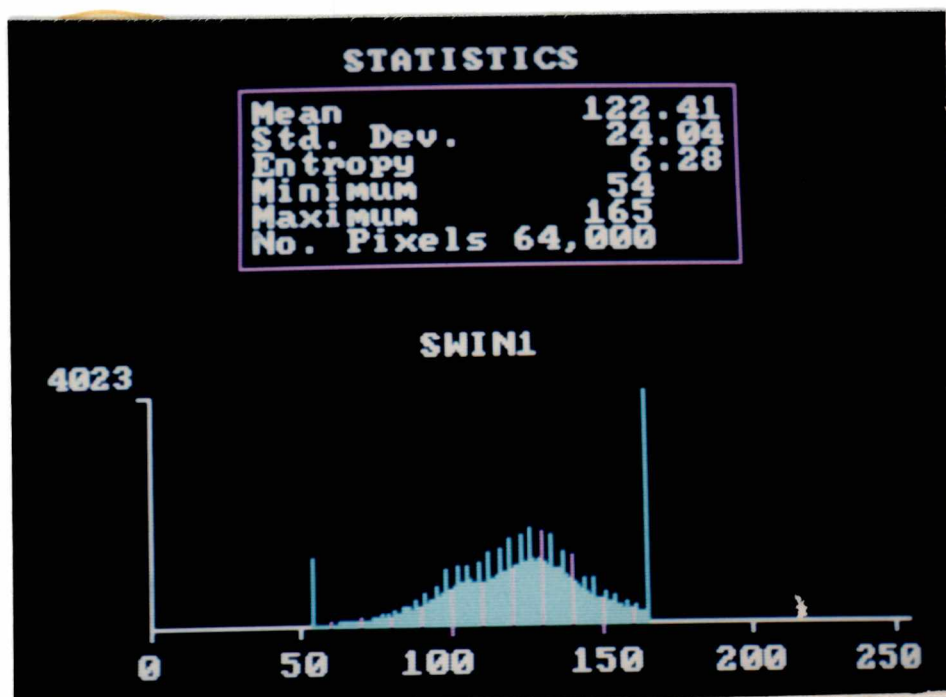


Figure 14. Histogram for figure 12.

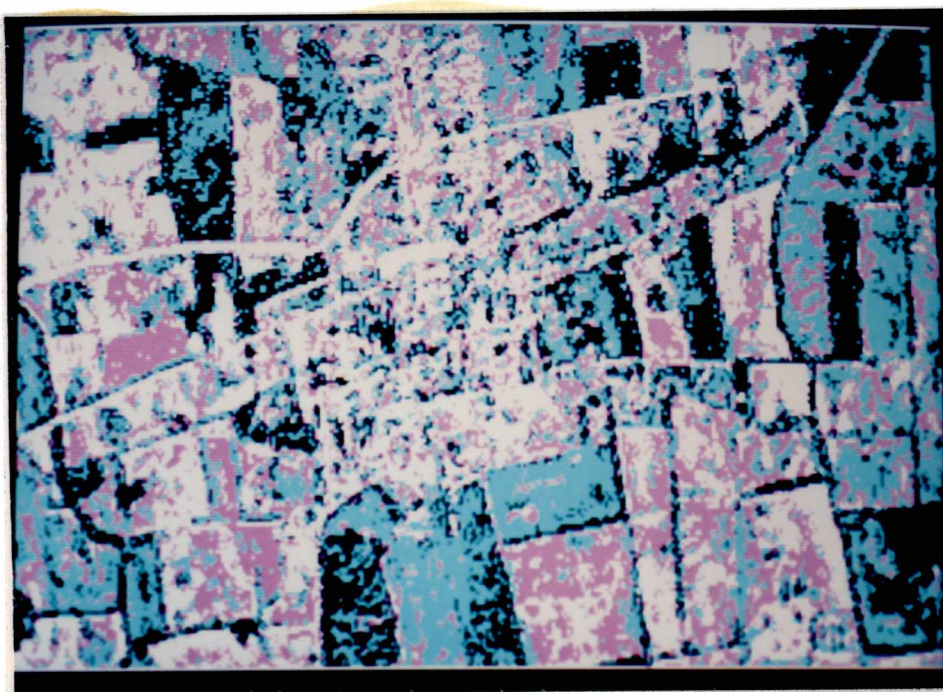


Figure 15. Soil enhanced image for Huntland.

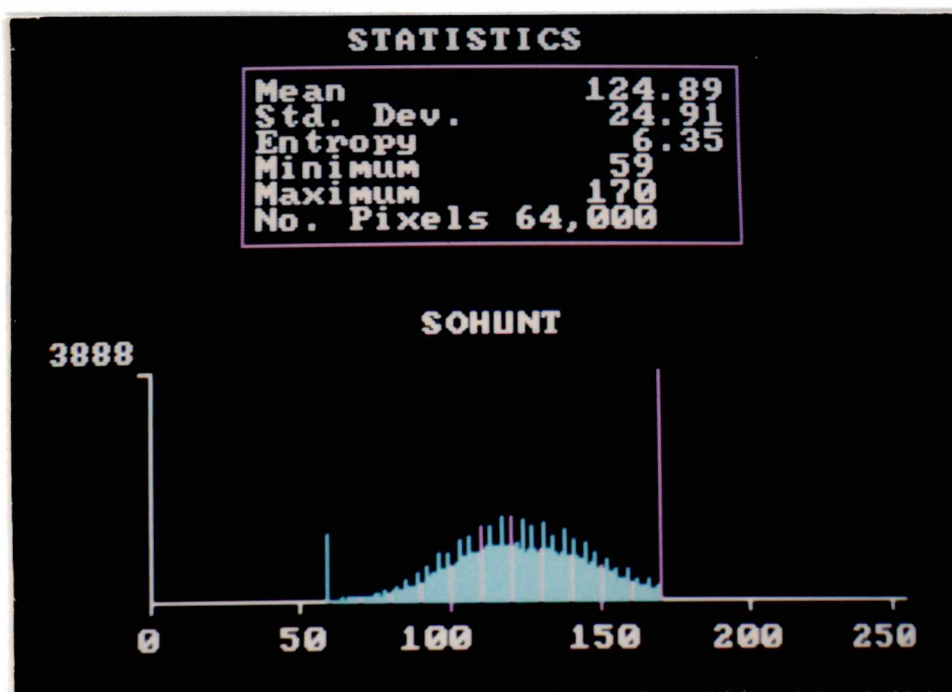


Figure 16. Histogram for figure 14.

Results. In the final images, the black and blue areas indicate vegetated areas, with the black areas representing either roadways or farmland and the blue areas representing forest vegetation. These colors indicate that their brightness was low on the photographs and does not correspond to the normal reflective wavelengths. On the other hand, the white areas indicate uncultivated farmland and urban land (which appears brighter on the photograph), while magenta areas indicated excessive water in the soils. These interpretations were confirmed by examination of the original color infrared aerial photographs. As with the drainage-enhanced images, the resolution supported by PCIPS is too limited for all but the least speculative of interpretations.

Results of the Pilot Study

Automated mapping based on slope. This procedure seems promising for site location. The plotting data are stored in file form, so multiple maps can be made without running the evaluation program over and over. The overlay maps generated are accurate when properly placed on the corresponding 1:250,000 scale topographic map. Field work, as mentioned previously, yielded a mean slope of 0.83% with a standard deviation of 0.38. To the eye, the sites selected by the computer program appeared very flat, and on the map, drainage ditches,

hills, and other areas of steep slope were appropriately blank, while flat farmland and flat barren land were shaded. Difficulties with the overlays included slight offset from the requested eastings and northings in the windows of data analyzed. Fine tuning of the point plotting location equation in the program should alleviate this problem, and this correction is currently being undertaken by the author. The data on the map are correct, but must be lined up slightly to the right and up from the lower left easting and northing selected by the user.

Digital image processing. While the capability to produce maps based on maximum acceptable slope appears to be useful, the usefulness of digital image processing seem limited at this time. It is possible that a larger scale of image may work better in image processing for site planning applications. For convenient archival purposes, the original and processed digital images stored on a fixed disk alongside Geographical Information System (GIS) software and the slope mapping system should prove more convenient than manually locating film positives for viewing on a light table. Additionally, the fact that the aerial photographs are digitized onto tape and disk allows for the possibility of improvements to the image processing

capabilities of the IBM PC and AT. If the ability for displaying more than four colors at one time were realized, the images would still be available for processing.

One of the most distressing problems with PCIPS is the assignment of colors to intensity levels. The "gray levels" are black for lowest intensity, light blue for second lowest intensity, magenta for second highest intensity, and white for highest intensity. While the choices of black and white for low and high intensities are logical, blue and magenta are confusing. It would probably have been better to use actual gray levels instead of the confusing array of colors for representation of intensity levels. The other two foreground color palletes are equally illogical in their progression from low to high intensity ranges. Everything else about PCIPS is very well thought out, however.

Data base storage. Entry of the pertinent data from the digital images into dBASE III PLUS presented no difficulty, but spatial referencing of the data will have to be undertaken. One way of doing this would be to tablet digitize the four corners of each image, knowing three distinct UTM coordinates, and entering the pertinent data base information as the digitizing program calls up the SOILINFO theme file.

This capability would require some slight modifications to the tablet digitizing program. The data base information is now available for analysis in the Geographical Information System (GIS).

Conclusion

Data important in site selection were gathered. The first information collected was from the maps generated by the automated slope evaluation program. Once areas were selected from these maps, the corresponding color infrared photographs of the areas were digitized and processed using a series of directional high pass filters for drainage evaluation, and low pass filtering followed by histogram modification for soils evaluation. The image processing work did not result in very useful images. For the drainage evaluation, scale of the images seemed to be the most significant limitation. For the soil evaluation, although obvious water-logging could be detected, the color progression from low intensity to high intensity in PCIPS was the cause of some confusion. It appears that archival storage of images in PCIPS form may prove as useful as the actual processing work. Now that the information taken from the photographs has been stored in dBASE III PLUS, integration into the Geographical Information System appears to be a reasonable future goal.

CHAPTER VII

RECOMMENDATIONS AND CONCLUSIONS

Recommendations

There are several recommended modifications that would result in a more unified planning environment and simpler operation. First, if the slope evaluation and mapping programs and data were downloaded onto the IBM AT, monetary savings compared to mainframe operation would be substantial. Additionally, all the steps related to logging onto the mainframe and transferring data would be eliminated. In order to download without dedicating the entire IBM AT to the task, additional fixed disk storage on the order of 80 megabytes would be necessary. This would also allow several Digital Elevation Models to be stored.

With the slope evaluation and mapping system on a personal computer (PC), the plotter data could be routed to a device (the plotter) rather than to files, further simplifying operation. The advantage to bypassing file storage is speed of plotting the final map. The disadvantage would be the time wasted running the evaluation program over and over if multiple maps were made of the same area. Ideally, an interactive prompt would ask the user if data were to be sent to the plotter or to files.

Naturally, this would involve the most difficulty for the programmer, but it would make for a more refined overall system.

As for image processing capabilities, there is little to be done. The software package is ideal for small laboratories, but the problems with the color display discussed in Chapter VI are noteworthy. It would behoove the laboratory personnel to take advantage of future software updates if color display capability were improved.

The final recommendation is to write the necessary programs in dBASE III PLUS to interface data gathered to the GIS used in the lab. Once this is done, the SOILINFO data base file (created to store information gathered from the processed aerial photos) can be linked to programs for tablet digitizing, multitheme analysis, and map plotting. The theme files already in the GIS include transportation routes, vegetation types, natural terrain features, and developed areas. Soil and drainage information will be a welcome addition to this montage.

Conclusions

The purpose of this study was to automate and simplify some basic techniques used by planners in industrial siting applications. The techniques discussed are all based on computers. Though the title

of "planner" does not necessarily indicate a technical bent, the infiltration of computers into almost every facet of life allows the assumption of some degree of computer literacy on the part of the planner. All software discussed is interactive, meaning user responses are answered immediately. The software is not so simple as to patronize the user, but it is simple for almost any PC user, and all of it is fully documented. The complete documentation for the slope evaluation and mapping system is contained in a report by Paludan et al (1986). Documentation for PCIPS and dBASE III PLUS is included in the software purchase.

The collection of software and hardware described in this work is a fledgling system for industrial site planning. The goals of automation and simplicity have been put into practice as much as possible. The recommended changes mentioned previously will do much to streamline and simplify operations further.

The techniques developed in this study are by no means perfect, but nevertheless, they are useful additions to the planner's toolbox, especially as the parameters evaluated in planning for industry become more sophisticated. It is possible that competition for basic and high technology industry by a region may hinge on the local competitor's ability to provide relatively quick and accurate assessments of land suitability.

Automated slope evaluation and mapping, image processing for further terrain evaluation, and data base management of information could contribute much to that ability. At the very least, the techniques discussed herein will provide a foundation on which to build a sophisticated industrial site selection system.

BIBLIOGRAPHY

Bibliography

Cannon, P.J., 1973, The Application of Radar and Infrared Imagery to Quantitative Geomorphic Investigations, Remote Sensing of Earth Resources, Vol. 2, pp. 503-519.

Carter, J.R., Associate Professor of Geography, University of Tennessee, Knoxville, 1986, personal communications.

Conway, H.M., and Liston, L.L., eds., 1976, Industrial Facilities Planning, Atlanta, GA: Conway Publications, Inc., p. 143.

Colwell, R.N., ed., 1983, Manual of Remote Sensing, second edition. Falls Church, VA: American Society for Photogrammetry and Remote Sensing.

Davis, M.H., 1984, A Geographical Information System for the Big South Fork National River Recreation Area, Unpublished Master's Thesis, University of Tennessee, Knoxville.

Elassal, A.A., and Caruso, V.M., 1985, Digital Elevation Models, USGS Digital Cartographic Data Standards, R.B. McEwen, R.E. Witmer, and B.S. Ramey, eds., Alexandria, VA: U.S. Geological Survey, pp. 1-4.

Folmsbee, S.J., Corlew, R.E., and Mitchell, E.L., 1969, Tennessee; A Short History, Knoxville, TN: University of Tennessee Press, pp. 9-11.

Frazer, C.J., Myers, V.I., and Westin, F.C., 1971, Remote Sensing for Detection of Soil Limitations in Agricultural Areas, Proceedings of the Seventh International Symposium on Remote Sensing of Environment, Ann Arbor, MI: Willow Run Laboratories, pp. 327-344.

Garner, H.F., 1974, The Origin of Landscapes, A Synthesis of Geomorphology, NY: Oxford University Press.

Gonzales, R.C., and Wintz, P., 1977, Digital Image Processing, Reading, MA: Addison-Wesley.

Honea, R.B., 1976, Toward the Modelling of Land-Use Change: a Spatial Analysis Using Remote Sensing and Historical Data, NASA Contractor Report CR 144221, Huntsville AL: NASA George C. Marshall Space Flight Center.

International Business Machines, Personal Computer Image Processing System (user's manual), Armonk, NY: International Business Machines Corporation, 1985.

Monmonier, M.S., 1982, Computer-Assisted Cartography, Principles and Prospects, Englewood Cliffs, N.J.: Prentice-Hall, Inc., p. 192.

Moore, G.K., and Waltz, F.A., 1983, Objective Procedures for Lineament Enhancement and Extraction, Photogrammetric Engineering and Remote Sensing, 45:5, 641-647.

Paludan, C.T.N., Luke, G.M., and McKamey, M.C., 1986, Automated Industrial Site Searches Based on Slope, Unpublished Project Report, University of Tennessee Space Institute.

Rubenstein, H.M., 1980, A Guide to Site and Environmental Planning, NY: John Wiley and Sons, p. 131.

Shelton, R.L., and McRae, S.D., 1981, Integrated Technology for Development Planning, Harvard Library of Computer Graphics, 1981 Mapping Collection: Computer Mapping of National Resources and the Environment Plus Satellite Derived Data Applications, Vol. 15, P.A. Moore, ed., Cambridge, MA: Harvard University, Lab for Computer Graphics and Spatial Analysis, pp. 80-88.

Way, D.S., Terrain Analysis, NY: McGraw-Hill, 1978.

Wilson, A.C., 1986, What's New in Imaging at EI '86, Digital Design, Vol. 16, No. 11., pp. 57-60.

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