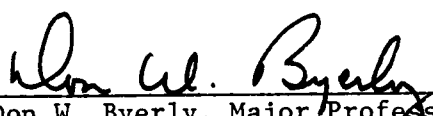
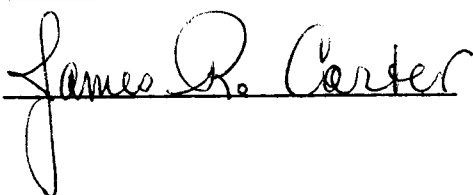


To the Graduate Council:

I am submitting herewith a thesis written by William T. Allen entitled "A Computer Oriented Approach to Environmental Geologic Data Base Construction (With Application to the Athens Quadrangle, Tennessee)." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

  
\_\_\_\_\_  
Don W. Byerly, Major Professor

We have read this thesis and  
recommend its acceptance:

  
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A COMPUTER ORIENTED APPROACH TO ENVIRONMENTAL GEOLOGIC  
DATA BASE CONSTRUCTION (WITH APPLICATION TO  
THE ATHENS QUADRANGLE, TENNESSEE)

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

William T. Allen

March 1980

1415939

## ABSTRACT

This study examines environmental geologic data for applicability to an automated system for the analysis of potential geologic hazards with respect to specific land uses. A computer oriented system to incode, store, manipulate, and display cell based environmental geologic data was developed. Information on combinations of variables is extracted from the data base and manipulated by the user with an interactive computer program (SELECT) to define areas with potential geologic hazards. The data are stored and manipulated as matrices which are part of a data base of environmental geologic information. The new matrices (maps) produced with SELECT are displayed as plotter drawn maps or viewed on a Tektronics graphics terminal.

The system was used to evaluate the Athens, Tennessee quadrangle with respect to potential environmental geologic hazards affecting specific land uses. Information on the geology, hydrology, and soils of the quadrangle was reviewed, and elements of these data (bedrock geology, slope, and flood prone areas) were selected for inclusion in the data base. Environmental geologic criteria for sanitary landfill, construction, and septic tank disposal system sites were established. Based on these criteria SELECT was used to produce maps of the quadrangle showing the potential environmental geologic hazards present relative to each specific use.

## ACKNOWLEDGMENTS

The writer expresses gratitude to Dr. Don W. Byerly who suggested this problem and provided guidance and assistance throughout the course of this study. Drs. G. Michael Clark and James R. Carter read this paper and made many helpful criticisms together with suggestions for solution of problems encountered. The writer is especially grateful to Alice Beauchene for her programming assistance and help with numerous problems encountered during the computer phase of this study.

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## CHAPTER I

### INTRODUCTION

#### Purpose and Extent of This Study

Tennessee's industrial growth and urbanization have created a demand for more intensive use of land. This demand must be met with increased availability of comprehensive environmental geologic data which will insure timely and accurate land use evaluation and planning. In order to satisfy this requirement in an economically feasible manner, a method using a digital computer to incode, store, manipulate and display spatially related environmental geologic data is proposed in this study. The data base in this study is constructed from the lands' physical characteristics, including: bedrock geology, topography (slope), soil characteristics, and hydrology (location of flood prone areas); however it's design will allow inclusion of additional data (such as agricultural, economic, and social information) which may be required in studies for more specialized land use applications.

A method is developed for construction of a data base of environmental geologic data, and a program by which the data can be manipulated and displayed. The method is tested through an environmental evaluation of the Athens, Tennessee quadrangle, with respect to potential environmental hazards affecting specific land uses.

Data on various environmental factors are sorted according to user specified criteria to produce "land use maps." The term "land use maps,"

as applied to maps produced in this study, is limited to maps defining areas of potential environmental hazards for specific land uses.

The 7.5 minute topographic quadrangle, the basic cartographic unit used for this environmental study, could be viable as the basic unit, if this system were to be used state wide. To test the utility of the data base system on more than a single base map unit, the Athens quadrangle was divided into twelve quadrants. Data on each quadrant can be manipulated and displayed separately in the same manner as data on an entire quadrangle.

#### Previous Work

Today there is a greater awareness than in the past that land use decisions that stress the environment must be made with all the best possible information at hand. Peter Flawn's book, Environmental Geology, is a general treatment of environmental problems, which while not citing specifically problems in the thesis area, is useful as an overall view of environmental geology. Design With Nature, by Ian McHarg (1971), is probably the best known book dealing with land use planning relative to active geologic processes and environmental problems.

Specific environmental geologic studies by various agencies have treated areas ranging in size from entire states, to a single quadrangle map or smaller area. A series of maps produced by the Texas Bureau of Economic Geology (1977), classifies land in Texas according to use suitability based on use requirements and the natural character of the land, as determined by the land's physical properties. The Texas study

is intended for use in regional land analysis and as a basis for selecting areas which may prove suitable for specific uses after more detailed analysis. These maps along with an earlier report by the Texas Bureau of Economic Geology, Approaches to Environmental Geology, (1974), although not dealing with a computer oriented data base nor specific problems of the thesis area, do suggest land properties which need consideration in any environmental geologic study.

The Environmental Geology and Hydrology, Madison County, Alabama, (1971), is one of the better examples of an environmental study of a single quadrangle (Meridianville quadrangle). This study provides an excellent example of the elements which may be included in an environmental study. The Illinois Geological Survey's Environmental Geology Notes series were also a source of general information on environmental problems.

The Tennessee Division of Geology has published one areal environmental geologic study entitled, Environmental Geology Summary of the Kingston Springs Quadrangle, Tennessee, (1973). In this study Miller (1973) assigns a "rating" to various factors of soils, bedrock geology, and engineering properties, as to their suitability for specific land uses. Miller's rating system though not used in this study could be applied to a data base system such as proposed in this study. Even though the detailed geology of the Kingston Springs quadrangle differs from the geology of the thesis area, the analysis of geologic, hydrologic, and soil factors with respect to potential hazards is applicable to the Athens quadrangle.

An unpublished thesis at The University of Tennessee, Environmental Geology of The Maryville Quadrangle, (Wiethe, 1972) deals with an area which has bedrock geology similar to that of the thesis area and is therefore useful as a source on possible geologic hazards occurring with these formations.

Computers are widely used to store, manipulate and display geographic, geologic, and environmental data. As an indication of the degree of development in the use of computers fifty four geographic information systems were reviewed by the U. S. Fish and Wildlife Service (FRMS: Technical Report 2.2, 1977). The TVA Land Analysis Laboratory uses the IMGRID computer mapping program for land use analysis and environmental studies. These studies are produced at present only for governmental agencies, with the data included being specified by the user. At the present time the Land Analysis Laboratory is not establishing a data base from the data gathered and digitized for these studies (Patricia Fink, 1978, TVA, personal communication).

#### Method of Investigation

The geology of the Athens Quadrangle has been mapped on a scale of 1:24,000, and abundant data on the soils and hydrology of the area are available. The method chosen for this environmental geologic study is as follows:

1. Review previous studies and determine what data will be required for an adequate environmental geologic evaluation.
2. Arrange the information in a format from which it can be evaluated.

3. Store the information within a data base system.
4. Establish criteria for specific land uses and for identifying potential geologic hazard areas.
5. Using the established criteria, evaluate the study area for specific land uses (with regard to potential geologic hazards), and using the data base system manipulate the information and display the results.

Field investigation was necessary to check locations where existing data conflicted, was incomplete, or where there were areas of special interest, such as sinkholes discovered when the McMinn County landfill was established.

The method used to develop the data base system consisted of:

1. Digitizing the data necessary for an environmental geologic study of the thesis area, and storing it in computer files.
2. Constructing a user oriented program by which stored data could be manipulated and displayed.
3. Testing the system by using it to manipulate and display the information required for an environmental geologic evaluation.

#### Location of the Area

The Athens Quadrangle, an area of approximately 60 square miles, lies nearly in the geographic center of McMinn County, Tennessee (Figure 1). Athens, the county seat of McMinn County is the only city within the study area; however, the towns of Niota and Englewood lie just outside the quadrangle boundaries to the north and east respectively.

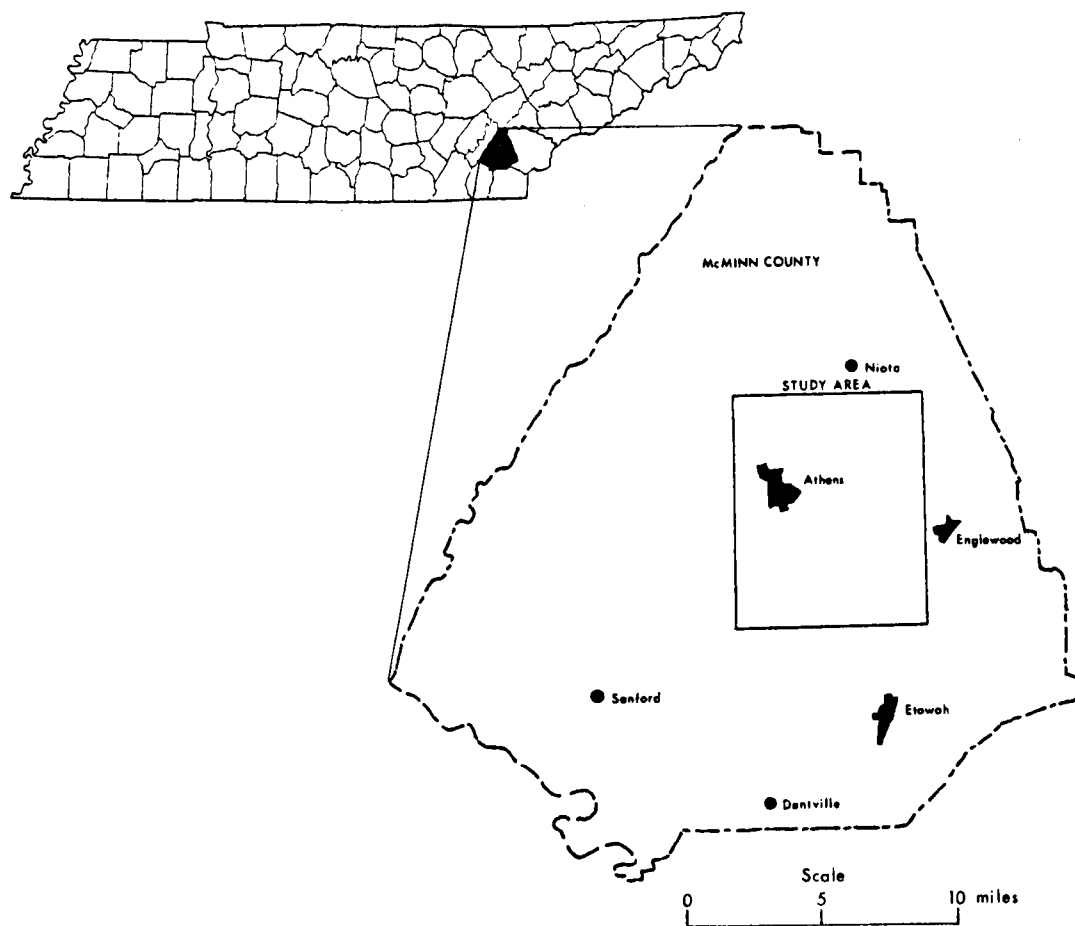


Figure 1. Location map of the study area.



## CHAPTER II

### GEOLOGY OF THE ATHENS QUADRANGLE

#### Stratigraphy

Bedrock in the Athens quadrangle consists of sedimentary clastic and carbonate rocks ranging from Middle Cambrian to Middle Ordovician in age (Figure 2). The strata have been divided into twelve formations on the basis of lithologic character and fossil content. The total sedimentary rock thickness is approximately 1980 meters (6500 feet). A paucity of outcrops is due to a widespread and generally deep cover of regolith. Rodgers (1952) used the variations in the soil and residuum together with structural data from outcrops to construct the large scale (1:24,000) geologic map which was used as the geologic data base for this study.

Although classical stratigraphic nomenclature is not as important to this thesis as is the recognition of the various lithologies present, a brief description of the formations summerized mainly from John Rodgers (1952), is presented below:

#### Conasauga Group

In the study area Rogers (1952) divides the Conasauga Group into an undifferentiated main body of shale, and the Maynardville limestone. The main body of the Conasauga shale is of the northwest phase type (Figure 3) (Rodgers, 1953), consisting mainly of shale with a few lenses and layers of blue limestone. The shale is greenish-gray, noncalcareous,

| Age                  | Group             | Thickness                                                             | Formation or Member                                   |                     |
|----------------------|-------------------|-----------------------------------------------------------------------|-------------------------------------------------------|---------------------|
| MIDDLE<br>ORDOVICIAN | CHICKAMAGUA GROUP | 1000' + (Upper member as much as 100', Marble lenses as much as 100') | <u>Ottosee shale</u><br>Upper member<br>Marble lenses |                     |
|                      |                   | 150' - 220'                                                           | Chapman Ridge Formation                               |                     |
|                      |                   | 35' - 110'                                                            | Holston Formation                                     |                     |
|                      |                   | 700' - 800'                                                           | Athens Formation                                      |                     |
|                      |                   | 40' - 250'                                                            | Lenoir Limestone                                      |                     |
| LOWER<br>ORDOVICIAN  | KNOX GROUP        | 500' - 600'                                                           | Mascot Dolomite                                       |                     |
|                      |                   | 250' - 350'                                                           | Kingsport Formation                                   |                     |
|                      |                   | 300' - 400'                                                           | Longview Dolomite                                     |                     |
|                      |                   | 250' - 800'                                                           | Chepultepec Dolomite                                  |                     |
| UPPER<br>CAMBRIAN    | CONASAUGA GROUP   | 1000' +                                                               | Copper Ridge Dolomite                                 |                     |
| MIDDLE<br>CAMBRIAN   |                   | 200' - 350'                                                           | Conasauga Shale                                       | Maynardville Member |
|                      |                   | 1000' +                                                               |                                                       | (Main Part)         |

Figure 2. Generalized geologic column of the Athens quadrangle (after Rodgers, 1952, and Smith, 1976).

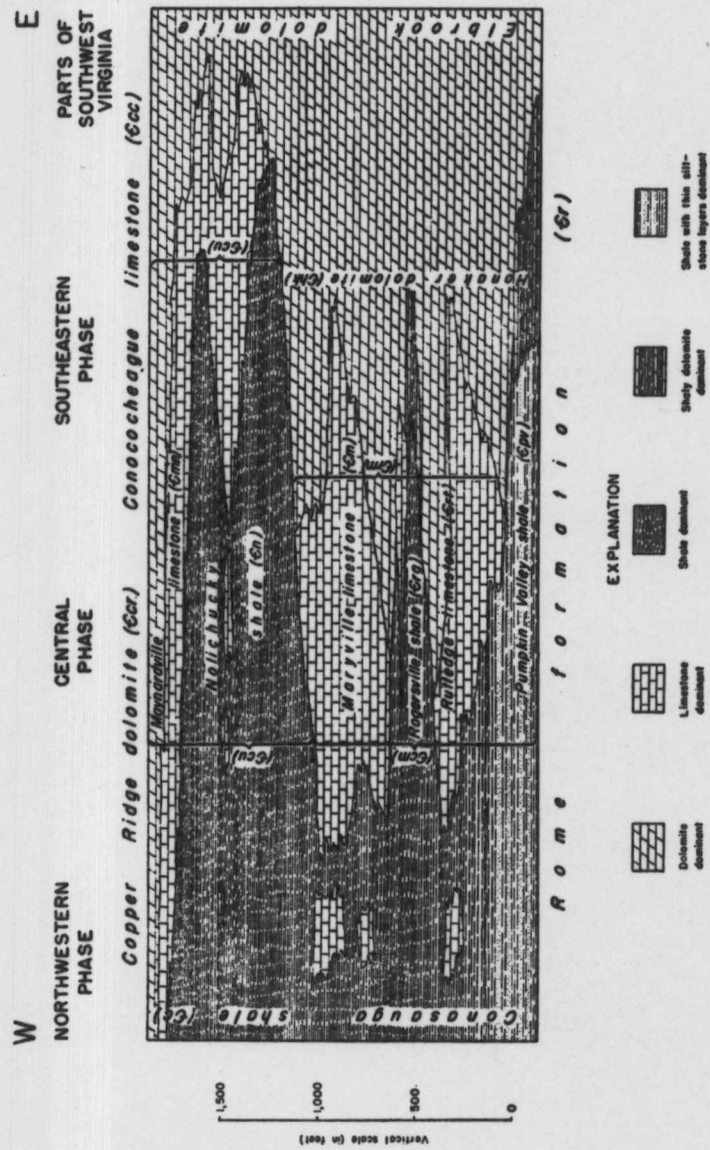


Figure 3. Facies relationships of the Conasauga Group (from Rodgers, 1953).

with dull purplish and brownish shale present in some areas. The limestone present in the shale weathers to orange clay in most exposures, and rarely contains a few thin layers of siltstone. The Conasauga is exposed along road cuts in the valleys of Chestuee and North Mouse creeks. Although there are no continuous exposure where the total thickness can be measured, and most outcrops show contortion and crumpling of the beds, the total thickness has been estimated to exceed 304 meters (1000 feet).

Soils formed by the Conasauga shale are shallow and contain small chips of greenish shale. These soils are classified as the Litz and Sequoia soil series, with the Sequoia dominating in areas where limestone is present.

Maynardville Formation. The Maynardville Formation, within the quadrangle consists of well bedded finely laminated gray dolomite and blue limestone. Some limestone beds have interlayers of dolomite about  $\frac{1}{2}$ " thick; some are oolitic and locally cross-bedded, and some are conglomeratic. Black, layered chert occurs locally near the top of the formation. Northwest of the Chestuee fault the Maynardville is 61 meters (200 feet) thick with the lower half consisting entirely of limestone, and the upper half of dolomite with some limestone layers. Along North Mouse Creek a thin layer of shale may be present. Southeast of the Chestuee fault the Maynardville is about 122 meters (400 feet) thick, and consists mainly of limestone with dolomite confined to the top layers except when present at thin layers in the limestone.

### Knox Group

The Knox is dominantly siliceous dolomite containing abundant chert. The average thickness of the Knox ranges increases from NW to SE, from 762 to 914 meters (2500 to 3000 feet).

Soils formed from the Knox Group are deep clay, and contain abundant chert. The chert content of the Knox derived soil decreases from northwest to southeast across the quadrangle. Soils overlying the Knox belong to the Clarksville, Fullerton, Dewey, Decature, and Bolton soil series.

Copper Ridge Dolomite. The Copper Ridge northwest of Athens (see Plate II), includes gray, fine-grained, massive to well-bedded, dolomite and partly black, knotty, crystalline, massive dolomite, which when broken smells like asphalt (Rodgers, 1952). Southeast of the Chestuee fault (Plate II) the formation contains a middle zone of black dolomite, with upper and lower zones of blue limestone containing a few interlayers of silty dolomite, while northwest of the Chestuee fault the unit is similar but contains less limestone. One or more sandstone layers, .3 to 1 meters (1 to 3 feet) thick, occur at the base of the formation in all areas of the quadrangle southeast of the Knoxville fault, and a few dolomitic sandstone layers occur near the top of the formation throughout most of the area (Rodgers, 1952). Thickness of the Copper Ridge Dolomite ranges from 305 to 381 meters (1000 to 1250 feet).

Soils developed over the formation contain abundant white or light gray chert, except where limestone is present, in which case the chert is darker and includes many blocks of silicified oolite and cryptozoon. Mainly the soils belong to the Clarksville and Fullerton series; however, Dewey soils are developed on the formation in the southeast section of the quadrangle.

Chepultepec Formation. Rodgers (1952) mapped the Chepultepec Formation as a dolomite with the lower one third consisting of a basal sandy member. The dolomite is gray, well-bedded to massive, and commonly shows silty laminae on weathered surfaces. The basal sandy member is mainly of dolomite with thin sandy zones; however, the lower 15 meters (50 feet) contain a number of more massive sands with beds ranging from .3 to 1 meters (1 to 3 feet) in thickness (Swingle, 1959). Total thickness of the formation is 229 meters (750 feet), with the basal member accounting for 76 meters (250 feet).

A deep chert rich clay soil is developed over the Chepultepec formation. Most of the chert is white or light gray in color, but some brown chert may also be found. The Chepultepec chert in the southeast section of the quadrangle is generally porous and occurs in relatively small blocks, whereas to the northwest the chert is more massive and occurs in relatively large blocks. Blocks of sandstone may be found in the soils developed on the basal member. Most soils belong to the Fullerton and Clarksville series, except over the basal sandy member on which Bolton soils are developed.

Longview Formation. Rodgers (1952) recognized the Longview Formation as a gray well-bedded dolomite which contain no limestone. In other areas Rodgers (1953) states that the upper half of the formation consists of dolomite with interbedded light-gray to brown aphanitic limestone. The Longview formation is 91 meters (300 feet) thick in the area.

Clay soils developed over the Longview Formation contain a very large amount of chert, so much in fact the amount of chert is a diagnostic feature of the formation. The chert is massive, light pink or blue in color, and rarely porous. These soils belong to the Clarksville and Fullerton series.

Kingsport Formation. The Kingsport typically consist of a lower unit of blue and tan fine-grained limestone about 15 meters (50 feet) thick, and an upper unit of gray or white fine-grained dolomite (Swingle, 1959). In the study area the formation is approximately 76 meters (250 feet) thick.

Deep clay soils with abundant chert, are developed over the Kingsport formation. The chert is white or green and finely porous. In contrast with the Longview small chert fragments are preponderant, with massive blocks rare. The soils commonly belong to the Dewey or Fullerton series with some belonging to the Clarksville series.

Mascot Formation. The Mascot Formation is a gray, well-bedded dolomite, locally well-laminated. Generally the dolomite becomes lighter in color higher in the unit, and the uppermost part of the formation contains beds of fine-grained blue-gray limestone as thick

as 1.8 meters ( 6 feet) interbedded with fine-grained dense light-gray dolomite (Swingle, 1959).

Soils developed on the Mascot formation are clayey and contain chert. In the soils developed on the upper part of the formation the chert is similar to that of the Kingsport, while chert of the lower part of the Mascot is more abundant, more massive and white in color.

#### Chickamauga Group

All strata which lie between the top of the Knox Group and the base of the Sequatchie (or Juniata) formation are included within the Chickamauga group (Swingle, 1964). The formations of the group are highly variable in lithologic content.

Lenoir Formation. In the study area the Lenoir formation is a medium to dark gray, argillaceous to shaly fossiliferous limestone (Smith, 1976). Upon weathering the argillaceous material is removed first, leaving a concentration of light gray to bluish weathering, nodular limestone on the outcrop surface. The basal beds of the Lenoir, lying unconformably on the Mascot Formation, vary greatly in lithology. In Sweetwater Valley and the extreme southern corner of the quadrangle where the Lenoir crops out the basal beds consist of massive, dove-gray aphanitic limestone similar to the Mosheim limestone near Knoxville. In other areas of the quadrangle these basal beds are greenish, silty, dolomitic limestone which contains angular chert fragments. The thickness of the section of Lenoir outcropping in Sweetwater Valley is 76



meters (250 feet), elsewhere in the area the formation is 12 meters (40 feet) in thickness.

In the study area the Lenoir is generally thin and covered with slope wash from other outcrop belts, therefore it has not formed a distinct soil type.

Athens Formation. The Athens Formation consist of blue-nodular, calcareous and argillaceous rock, which is more of shaly limestone than a shale. The Athens is not entirely uniform, with some of the upper layers more limy while some lower parts are more shaly, however the differences are not great. Within the study area the thickness of this formation is 244 meters (800 feet). Partial weathering produces a cobbly appearance, which alters to a dimpled appearance, when cobbles fall from more or less vertical faces (Smith, 1976).

Thin clay soils containing an abundance of shale chips are developed over the Athens. The soils belong to the Needmore and Dandridge series.

Holston Formation. The Holston Formation consist of coarse grained, fossil-fragmental, very thick-bedded (1 meter or greater), limestone, which is locally crossbedded and stylolitic. Colors range from cream to buff to pink to red and reddish-brown, with some beds near the base, light to medium-light gray with faint pinkish overtones (Smith, 1976). Thickness of the Holston outcropping on the northwest limb of the Athens syncline ranges from 15 to 38 meters (50 to 125 feet), and on the southeast of limb 6 to 11 meters (20 to 35 feet).

Due to its topographic position just below the Chapman Ridge Sandstone, and the relative thinness of the formation, the Holston is covered by Tellico soils formed mainly from the Chapman Ridge Formation.

Chapman Ridge Formation. In the study area the Chapman Ridge Formation consist of blue-gray fossiliferous, very sandy limestone, grading both laterally and vertically to very calcareous, quartzose sandstone. The sandy limestone and calcareous sandstone phases are locally interbedded, and contain then dark bands or layers of highly ferruginous limey sandstone which pinch and swell laterally and are discontinuous within any one outcrop. Some thin interbeds and lenses of shale are present, being more numerous and laterally more continuous near the top of the formation, but not comprising more than 20% of any 10-foot interval. Formation thickness ranges from 46 to 69 meters (150 to 225 feet), with the greatest variations occurring on the south-east limb of the Athens syncline (Smith, 1976).

Chapman Ridge soils are sandy, deep red in color, and commonly contain weathered blocks of porous, ferruginous quartz sandstone. These soils belong to the Tellico series.

Ottossee Formation. Although similar to the Athens shales, the Ottossee is more uniform and more dominantly shale. The Ottossee consists of blue limy shales or shaly limestone. Some very thin to medium-bedded sandy to very sandy limestones and local thin beds of very calcareous sandstones are present. The formation has fewer and thinner cobbly beds and more sand than the Athens (Smight, 1976). Other

rock types form layers and lenses in the shale, however are of restricted areal extent and occur only in the southwest corner of the quadrangle. Formally mapped as marble and sandy crystalline limestone lenses by Rodgers (1952), these units have been remapped by Smith (1976) in an area which extend along the strike belt and covers parts of seven quadrangles including Athens.

Thin, shaly soils similar to those of the Athens formation are developed over the Ottossee. These soils belong to the Dandridge and Needmore series. Soils formed over layers and lenses of limestones and sandy limestone belong to the Decatur and Tellico series respectively.

### Structure

Three major thrust faults are recognized at the surface within the study area; the Saltville, Knoxville, and Chestuee (see Plate II). The fault traces extend from northeast to southwest across the quadrangle, with the faults dipping to the southeast. The Conasauga shale forms the hanging wall in all three faults, suggesting fault movement along slip planes within the incompetent shale (Rodgers, 1952). In the strike belt between the Saltville and Knoxville faults the beds are essentially a southeast dipping monocline. Also, in this belt in the valley of North Mouse Creek small thrust faults repeat the Maynardville limestone.

Between the Knoxville and Chestuee faults the beds are folded into an anticline and syncline pair with the southeast limb of the anticline being overridden from the southeast by the hanging wall of the Chestuee

fault. The common limb is steeply dipping and partially overturned imparting strong asymmetry to both folds. Several tear faults and a slice of Copper Ridge dolomite occur along the trace of the Chestuee fault. Also, the Conasauga shale in the hanging wall of the Chestuee fault is tightly folded exposing narrow belts of Copper Ridge dolomite.

### Economic Geology

#### General Discussion

Two quarries within the study area, both in limy facies of the Athens Shale, produce stone described as "siliceous limestone" suitable for use as general purpose stone (Hersey and Hamer, 1963). Of the two quarries the McMinn County Highway Department-Athens Quarry is operated only on part time basis, while the Floyd Webb Stone Company quarry has been abandon since 1966 (see Plate I for locations). The Webb Stone Company now operates a quarry beyond the limits of the Athens quadrangle. This quarry produces general purpose stone from the Maynardville Limestone.

At this time there are no known mineral reserves within the study area; however, U. S. Borax and Chemical Company is developing an underground fluorite mine approximately two miles northeast of the quadrangle. This deposit occurs within the Kingsport and Mascot formations. Future exploration may reveal economic deposits in these formations within the study area.

Development of Resources. Economic possibilities exist for the development of limestone and dolomite as crushed stone for aggregate,

and development of shale as bloating material in the manufacturing of brick. Development of these resources is dependent on economic considerations and the geology of the area. The requirements for new and improved roads coupled with new construction related to expansion in the industrial and private sectors will be major factors in determining if and when development of these resources occurs.

Among the economic considerations for establishing quarry sites are: market distance, accessibility, land use in surrounding areas, availability of power, zoning regulations, and land values. Geologic considerations for quarry siting include the nature of the rock and geometry of the deposit as well as the quantity available for quarrying. Other factors such as the topography, hydrology and depth of overburden are equally significant. These aspects of establishing a quarry are discussed in detail by Hershey and Maher (1963).

Limestone Units. The Maynardville Limestone member of the Conasauga Group is an important source of crushed stone for aggregate. It is sound, wears well, and is generally free of deleterious substances (Hershey and Maher, 1963). In this area the Maynardville is generally a slope former on the northwest sides of ridges formed by the Copper Ridge Dolomite and is in a position favorable for quarrying. The formation is of quarryable thickness and the only possible geologic limitation to development is the thickness of the overburden; however a number of good quarry sites do exist.

The Knox group is recognized as an important source of economic products throughout East Tennessee. Limestone and dolomite from the

from the Knox are hard, durable stone suitable for uses are roadmetal, railroad ballast, riprap, filler and base course. The Knox is also used as a source of agricultural limestone, sutcco dash, concrete block facings, and refractories. Potential use of the Knox is as source of metallic magnesium and high-magnesian lime. Much of the area is underlain by Knox, however due to deep weathering, the depth of overburden may be a limiting factor throughout most of the area.

The Lenoir Limestone is of minor economic value because it crumbles rapidly when exposed to weathering, and it is not chemically pure enough for use in cement. In the study area the Lenoir occurs in very narrow strips underlying valleys and is not of quarryable thickness.

Limy facies of the Athens Shale is quarried as a source of general purpose stone within the quadrangle. There are ample reserves available, and the overburden is thin. The only geologic limitation is the change from a limy to more shaly facies moving southwest across the quadrangle.

The Holston Limestone or "Marble" is used for dimension stone, and as a chemical raw material in the production of portland cement, lime, agricultural limestone, and for scrubbers to removal  $\text{SO}_2$  when used in pollution control equipment. Where shattering renders the marble unsuitable for use as dimension stone, it can also be crushed for aggregate, road metal, and similar uses. The restricted areal extent of the Holston limits the development of this formation in the Athens area.

The Chapman Ridge Sandstone is a good source of stone for aggregate, but due to high quartz content it causes crushing problems.

The Chapman Ridge and Holston underlie the Red Hills within the study area and although limited in areal extent, potential quarry sites may exist in the area.

The Ottossee Shale, although more shaly than the Athens, contains interbedded limestone layers, as well as large lenses of "Marble" and quartzose crystalline limestone. Due to the variable lithology of this formation a quarry to produce shale would not be practical, and although the limestone or marble could be produced, the areal extent of these rocks is a limiting factor.

The Shale Units. Clays and shales from the Conasauga group are potential materials for the manufacturing of structural clay products, but they are not suitable for use in ceramic products (Hollenbeck and Tyrell, 1969). The shales may also have potential use in the manufacture of light weight aggregate.

Extensive areas of shales available for development are in wide valleys having shallow shaly soils of low productivity, and low population density. The only likely limitation to development, is that of drainage.

#### Engineering Properties of Area Rock Units

Engineering properties of the formations include the excavation characteristics as well as the suitability of the material for various economic uses. Engineering properties are especially important in foundation stability, and must be considered in any land use evaluation.

Table 1, (Kellberg, 1971), gives the engineering properties for each formation present within the study area.

### Physiography and Geomorphology

#### General Discussion

The study area lies wholly within the Valley and Ridge physiographic province (Figure 4). Where differential weathering and erosion of folded and faulted sedimentary rock has produced a series of subparallel valleys and ridges which trend approximately N45E. Except for synclinal structure of the Red Hills, the structure of the Athens quadrangle is homoclinal with strata dipping SE.

Depending on the underlying bedrock, valleys are either wide and flat or may contain gently rolling hills. Ridges are low, averaging less than 61 meters (200 feet) above the adjacent valley floors, except the Red Hills where the local relief is 176 meters (550 feet). The maximum relief on the Athens Quadrangle is 165 meters (540 feet), with the highest point 396 meters (1300 feet) occurring in the Red Hills, and the lowest elevation 232 meters (760 feet) along Chestuee creek. All elevations on the quadrangle tend to decrease along strike from north-east to southwest across the quadrangle.

A humid climate coupled with widespread carbonate bedrock has produced numerous depressions in the land surface. Also, it is probable that more solution features exist in the subsurface without topographic expression. A concentration of closed depressions (sinkholes) is present in the south central section of the quadrangle and at least two



TABLE 1  
ENGINEERING PROPERTIES OF THE ROCK UNITS PRESENT WITHIN THE STUDY AREA

| Formation     | Rock Type                                  | Comprehensive Strength <sub>3</sub><br>(psi X 10 <sup>3</sup> ) | Modules of Elasticity <sub>6</sub><br>(psi X 10 <sup>6</sup> ) | Depth Range of Overburden | Bedding Characteristics                          | Weathering Characteristics                                                                      | Suitability as Aggregate                     |
|---------------|--------------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------------|---------------------------|--------------------------------------------------|-------------------------------------------------------------------------------------------------|----------------------------------------------|
| Ottosee       | Calcareous shale, limestone lenses         | 5 - 20*                                                         | 5 - 8*                                                         | 0 - 20'                   | Thin bedded slabby to blocky (1"-4")             | Moderate near-surface weathering along joints and bedding planes                                | Poor                                         |
| Chapman Ridge | Calcareous sandstone                       | 15 - 30                                                         | 2 - 6                                                          | 0 - 100'+                 | Medium-bedded, blocky (4'-18')                   | Irregular surface, vertical solution cavities                                                   | Good, hard on crushing equipment             |
| Holston       | Coarse crystalline limestone               | 10 - 20                                                         | 6 - 10                                                         | 0 - 100'+                 | Massive, blocky (1'-3')                          | Irregular surface solution cavities and sinkholes common                                        | Good                                         |
| Athens        | Argillaceous limestone to calcareous shale | NA                                                              | NA                                                             | 0 - 20'                   | Thin to medium bedded, slabby to blocky (1"-10") | Slight weathering of near-surface rock                                                          | Fair to poor depending on shale content      |
| Lenoir        | Argillaceous limestone                     | 10 - 30                                                         | 5 - 8                                                          | 0 - 20'                   | Thin to medium bedded, slabby (1"-6")            | Moderate, near-surface weathering along joints and bedding planes                               | Fair to poor depending on shale content      |
| Knox Group    | Dolomite and limestone                     | 10 - 40                                                         | 6 - 10                                                         | 0 - 150'+                 | Medium-bedded to massive, blocky (6"-3')         | Very irregular surface with cutter-pinnacle development, solution cavities and sinkholes common | Good to excellent depending on chert content |

TABLE 1 (Continued)

| Formation                | Rock Type                                             | Comprehensive Strength<br>(psi X 10 <sup>3</sup> ) | Modules of Elasticity<br>(psi X 10 <sup>6</sup> ) | Depth Range<br>of Overburden | Bedding<br>Characteristics     | Weathering<br>Characteristics                                            | Suitability<br>as<br>Aggregate |
|--------------------------|-------------------------------------------------------|----------------------------------------------------|---------------------------------------------------|------------------------------|--------------------------------|--------------------------------------------------------------------------|--------------------------------|
| Maynardville             | Dolomite and limestone                                | 10 - 30                                            | 5 - 8                                             | 0 - 30'                      | Medium-bedded, blocky (4"-18") | Moderate weathering of near-surface rock along joints and bedding planes | Excellent                      |
| Conasauga<br>(Main Body) | Shale with interbedded lenses and layers of limestone | Shale - 1-5<br>Limestone - 5-20                    | 2 - 6                                             | 0 - 20'                      | Thin-bedded slabby to blocky   | Slight weathering of near-surface rock                                   | Poor                           |

\* Estimate based values for similar lithology.

(Kellburg, 1973)

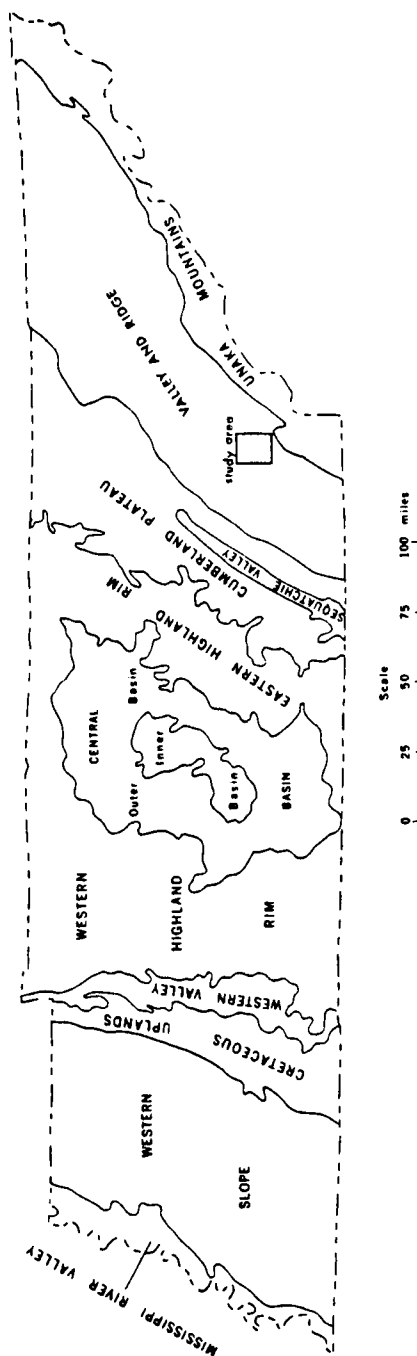


Figure 4. Physiographic map of Tennessee (after Miller, et al., 1972).

small caves occur within the quadrangle: Cook cave in the Maynardville Formation and Cooper Cave in the Copper Ridge Formation. Most closed depressions occur over the Copper Ridge, Kingsport, and Mascot Formations with a lesser number in the Chepultepec and Longview Formations.

The area is drained by three main creeks which are part of the Hiwassee River watershed. These creeks, the Chestuee, Oostanaula, and North Mouse, flow southwest along strike valleys to the Hiwassee River, 10 to 15 miles south of the quadrangle. The drainage pattern is trellis with large subsequent streams, (Chestuee, Oostanaula, and North Mouse) following dominate structural trends and intersected at right angles by smaller resequent and obsequent streams.

### Climate

Climate of the study area is humid continental. Table 2 shows monthly and annual averages for temperature, rainfall, and winds in the study area. Summers are warm and the winters are moderate with frequent rainy periods and short cold spells. There are an average of 195 frost-free days per year with the first frost occurring about October 23, and the last frost around April 11 (McMinn County Soil Survey, 1957). In the winter, periods of extreme cold weather are rare, the temperature is below freezing only a little more than one-half of the winter days. Generally, the ground is frozen to a depth of no more than 2 or 3 inches for no longer than 3 or 4 days at a time. The summer temperatures range from the high 80's (°F) to the low 90's (°F) with the temperatures of 100 degrees or higher rarely occurring. The

TABLE 2  
MONTHLY AND ANNUAL MEAN TEMPERATURE, PRECIPITATION, AND WINDS IN THE STUDY AREA

| Period    | Temperature (°F) | Precipitation (Inches) | Wind Speed<br>and Direction (MPH) |
|-----------|------------------|------------------------|-----------------------------------|
| December  | 42.7             | 5.13                   | 6.7 South                         |
| January   | 42.5             | 5.19                   | 7.2 South                         |
| February  | 45.4             | 4.83                   | 7.7 South                         |
| Winter    | 43.5             | 15.15                  | 7.2 South                         |
| March     | 51.0             | 5.68                   | 8.2 South                         |
| April     | 60.1             | 4.49                   | 7.9 South                         |
| May       | 68.9             | 3.86                   | 6.2 South                         |
| Spring    | 60.0             | 14.03                  | 7.4 South                         |
| June      | 76.3             | 4.07                   | 5.4 South                         |
| July      | 79.6             | 4.50                   | 5.2 South                         |
| August    | 79.1             | 3.75                   | 4.7 South                         |
| Summer    | 78.3             | 12.32                  | 5.1 South                         |
| September | 74.6             | 2.64                   | 5.0 South                         |
| October   | 61.8             | 3.10                   | 5.1 South                         |
| November  | 50.3             | 3.88                   | 6.4 South                         |
| Fall      | 62.3             | 9.62                   | 5.5 South                         |
| Year      | 61.0             | 51.12                  | 6.3 South                         |

(Bacon, 1957, and Environmental Protection Agency, 1975)

summer temperatures are frequently moderated by thunderstorms (Wastewater Facilities Plan, 1975).

The average annual precipitation in the study area is about 52 inches. The wettest period occurs during winter and early spring, and the driest during late summer and early fall. Monthly tabulation of precipitation data are shown in Table 2. The potential of flooding is greatest in early spring when the soils are usually saturated. Snow falls are generally light, melt within a day or two, and are not a significant part of the total precipitation.

#### Lithologic and Topographic Relationships

Structure and lithology are the main factors controlling erosion and weathering rates. Areas with similar structure and similar bedrock tend to develop similar landforms.

The Conasauga shale underlies wide valleys of Chestuee and North Mouse creeks. These valleys are generally flat, but may contain low rounded hills with a local relief up to 18 meters (60 feet). The slopes of the hills seldom exceed 5%, and most often are less than 3%. The Maynardville Formation outcrops on the northwest slopes of ridges formed by the Copper Ridge Dolomite.

The cherty soils of the Knox Group rocks are responsible for the majority of the ridges crossing the study area. The Copper Ridge Formation underlies crests of ridges northwest of Athens, and the long low ridges in Chestuee creek valley.

Topography developed on the Middle Ordovician rocks varies with the changes in lithology. The Lenoir Formation forms linear topographic

lows between hills underlain by the Athens Formation and hills underlain by the Mascot Formation. The highly dissected topography developed on the Athens Formation consists of low irregular hills with generally less than 24 meters (80 feet) of local relief. An often present sandy shale at the base of the formation forms a low elongate ridge paralleling the strike of the beds. The Red Hills is a series of oblong, narrow knobs, parallel to strike, with 61 to 91 meters (200 to 300 feet) of local relief, formed on the resistant sandy soils of the Chapman Ridge Formation. The Ottossee formation has topographic expression as a valley containing irregularly hilly and dissected land which lies between branches of the Red Hills. Layers and lenses of limestone within the Ottossee are not generally detectable by topographic expression.

#### Active Geomorphic Processes

Under present conditions the degradational geomorphic processes are more active in shaping of the topography in the Athens Quadrangle than depositional processes.

The most active agent of erosion in the study area is running water, both in the form of streams and as sheetflow. Where soil has been stripped of its vegetative cover for agriculture or other purposes, it is subject to erosion by sheetflow and to a lesser extent by wind.

Mass-wasting (landslides) is probably the least active degradational process in the study area. Reasons for this include: abundance of vegetative cover, very deep stable soils, and moderate to low relief. Slow soil creep is active on all steeper slopes, however, more rapid

flowage such as earth flows is rare. Naturally occurring landslide type movements such as slumps are also rare. Where slopes have been over steepened by roadcuts or excavations the possibility of mass-wasting is greatly increased.

Subsidence in the form of sinkholes is an active form of mass-wasting which is likely to occur within the area due to the solubility of the underlying carbonate rocks. This activity includes those predominately shale rock units which can contain lenses of carbonate rock, such as the Ottossee.



## CHAPTER III

### HYDROLOGY

#### General Discussion

Availability and quality of water is a vital factor for virtually every land use. Problems may be created by either the presence of excess water or by the lack of water of acceptable quality.

Industrial and domestic water supplies in the Athens, Tennessee area are primarily from ground water sources. The potential for further development of ground water resources is limited, but surface water resources are now being developed which are expected to meet the needs of the area through the year 2000 (Environmental Protection Agency, 1975).

The following sections deal with the hydrologic regime of the study area. Due to the nature of hydrologic boundaries, portions of this study will include information on areas which border the study area.

#### Surface Water

The Athens Quadrangle is drained by three main creeks, which in turn empty into the Hiwassee River, a major tributary to the Tennessee River. The Chestuee Creek watershed is approximately  $67 \text{ Km}^2$  ( $25 \text{ mi}^2$ ), the Oostanaula Creek watershed is approximately  $80 \text{ Km}^2$  ( $31 \text{ mi}^2$ ), and North Mouse Creek watershed covers approximately  $21 \text{ Km}^2$  ( $8 \text{ mi}^2$ ), within the study area. A small area in the extreme southeast corner of the

quadrangle is drained by Crockett Springs Branch which is part of the Conasauga Creek watershed. Boundaries of the watersheds are shown in Figure 5, and Figure 6 is an isohyetal map showing precipitation distribution for McMinn County. Plate I shows the location of surface waters within the study area.

### Ground Water

Ground water in the study area occurs mainly in joints, fractures and along bedding planes in the underlying bedrock; however, in carbonate rocks the openings may be enlarged by solution by circulation of ground water to up to depths of about 350 feet (DeBuchananne, et al., 1956). Shales in East Tennessee have been folded and faulted extensively and when hard and brittle enough to support fractures make good aquifers. Also, those shales containing appreciable quantities of carbonate yield more water than noncalcareous shales due to enlargement of fractures by solution. Shales generally have more uniform hydrologic properties than limestones because fractures in shale are much more closely spaced than those in limestone. Sandstones and noncalcareous shales contain practically no primary openings and the fractures are not readily susceptible to enlargement by solution and therefore usually yield small amount of water (DeBuchananne, et al., 1956).

The presence of numerous sinkholes in the area combined with the occurrence of a number of high flow rate springs suggest a well developed system of underground drainage. While the presence of interconnected solution cavities in the limestones provide for storage of large volumes

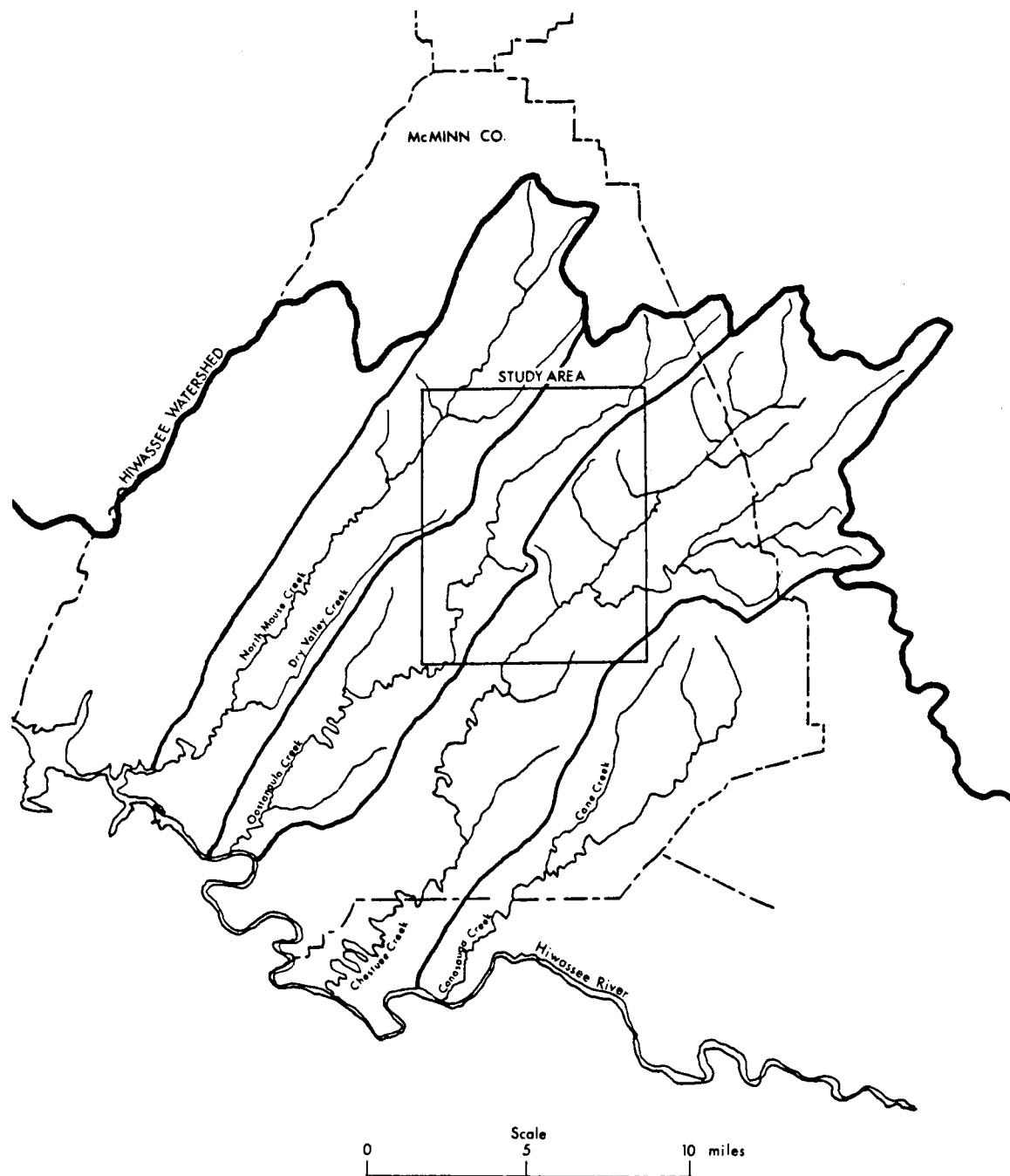


Figure 5. Watershed boundaries of McMinn County.

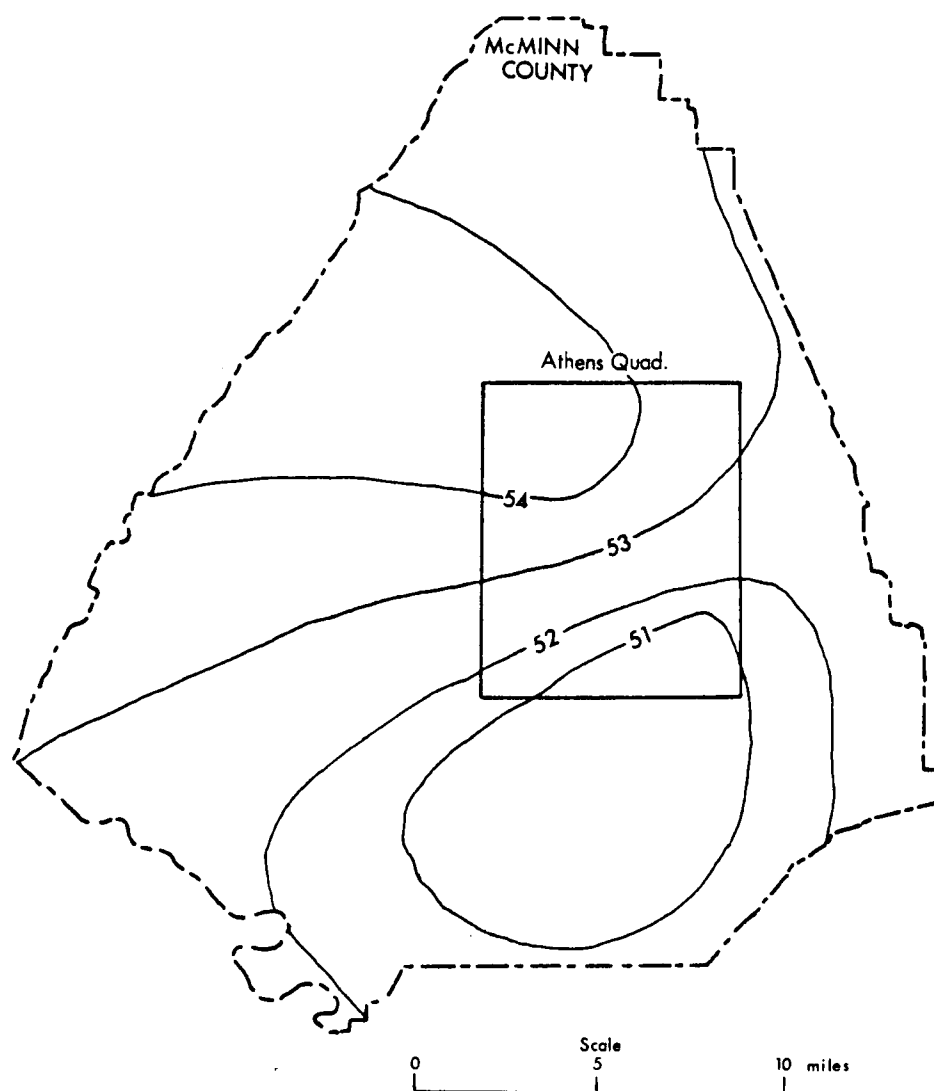


Figure 6. Mean annual precipitation distribution for McMinn County, 1935-1962, in inches (annotated map, TVA Division of Water Control Planning, 1962).

of water the associated sinkholes by which recharge occurs present a hazard in that they provide paths by which surface pollution may enter the ground water regime. The water-bearing properties of each geologic formation present in the study area are shown in Table 3.

The Tennessee Division of Water Resources uses an automatic data processing program to compile ground water data obtained under Tennessee Code Annotated 70-2301. This code requires water well drillers in Tennessee to furnish information on all wells. A current printout of these data for McMinn County shows that 816 wells and 9 springs have been reported. The printout also gives statistics on the average yield, total depth, and depth of overburden for all the wells reported, this information is shown in Tables 4,5, and 6, respectively.

Of the wells drilled in McMinn County 99% obtained good water, .4% had a noticeable sulfur content, .2% had noticeable oil or gas content, and the remainder had other unsuitable qualities not including the presence of iron or salt water. Most wells drilled (83%) were completed in bedrock, 3.6% were completed at the overburden-bedrock contact, and 13.4% were completed in the overburden (Tennessee Department of Conservation, Division of Water Resources, 1978).

The City of Athens is the largest user of water in the study area with an average daily use of 1.85 million gallons. This supply comes mainly from Ingleside Spring with a subordinate amount from Oostanaula Creek. Two industries in the area having their own wells, Athens Hosiery Mill and Plastic Industries, Inc., drawing 239,000 and 10,000 gallons per day respectively from their wells and purchasing 2,400 and 2,500

TABLE 3  
WATER BEARING PROPERTIES OF ROCK UNITS IN THE STUDY AREA

| Geologic Formation                                                                                                                                                                                                                                                                                                          | Water-Bearing Properties                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ottosee Shale                                                                                                                                                                                                                                                                                                               | Groundwater occurs in fractures and solution channels in both the limestones and carbonate shale. Limestones yield small to moderate quantities of water while shales yield larger amounts.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Chapman Ridge Formation                                                                                                                                                                                                                                                                                                     | Groundwater within the Holston is restricted to fractures, with well yield dependent on the size and number of fractures intercepted. This formation generally yields small quantities of water due to the restricted solubility (high quartz sand content) of the rock.                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Holston Formation                                                                                                                                                                                                                                                                                                           | Groundwater occurs in fractures and along bedding planes, most of which have been enlarged by solution. Yield is small to moderate depending on the size and number of fractures present.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Athens Formation                                                                                                                                                                                                                                                                                                            | This formation is quite permeable due to the solubility of both the calcareous shale and argillaceous limestones. The Athens Formation behaves hydrologically as a shale and yield is usually high.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Lenoir Limestone                                                                                                                                                                                                                                                                                                            | Similar to the Athens Formation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); margin-right: 5px;">Knox Group</div> <div> <div>Mascot Dolomite</div> <div>Kingsport Formation</div> <div>Longview Dolomite</div> <div>Chepultepec</div> <div>Copper Ridge Dolomite</div> </div> </div> | Within the Knox Group groundwater occurrence is controlled by fractures which are usually enlarged by solution. Wells in areas which contain more fractures, due to greater folding and faulting of the strata, generally produce unusually large yields of water. Most large fractures occur at depths less than 106 meters (350 feet), thus deeper drilling commonly does not produce larger yields. The presence of a relatively large number of high yield springs (greater than 450 gpm) and their wide geographic distribution indicates that the Knox Group is a good aquifer. Wells in these formations generally yield moderate to large quantities of water dependent on the size and number of fractures. |
|                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Maynardville Member                                                                                                                                                                                                                                                                                                         | Within this formation groundwater is restricted to solution channels developed along bedding planes and fractures. Wells yield small to moderate amounts of water depending on size and number of fractures present.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Conasauga Shale<br>(Main Part)                                                                                                                                                                                                                                                                                              | Groundwater is restricted to small fractures within the shale, however, intense deformation of the shale has resulted in numerous fractures which form an interconnected network. The network of fractures is fairly continuous throughout the formation resulting in uniform hydrologic properties. Well yields are generally moderate to high.                                                                                                                                                                                                                                                                                                                                                                     |

(DeBuchananne, et al., 1956)

TABLE 4  
WELL YIELD, DEPTH, AND OVERBURDEN THICKNESS OF WELLS IN MCMINN COUNTY

|         | Well Yield<br>(GPM) | Well Depth<br>(Feet) | Overburden Thickness<br>(Feet) |
|---------|---------------------|----------------------|--------------------------------|
| Average | 27                  | 170                  | 63                             |
| Maximum | 1000                | 728                  | 290                            |
| Minimum | 0                   | 0                    | 0                              |
| Samples | 740                 | 791                  | 586                            |

(Tennessee Dept. of Conservation, Division of Water Resources, 1978)

TABLE 5  
WELL DEPTH IN MCMINN COUNTY

| Well Depth Required<br>To Obtain Water | Percentage of<br>Wells |
|----------------------------------------|------------------------|
| 50 feet or more                        | 92.3                   |
| 100 feet or more                       | 61.6                   |
| 200 feet or more                       | 20.2                   |
| 500 feet or more                       | .6                     |
| 1000 feet or more                      | .1                     |

(Tennessee Dept. of Conservation, Division of Water Resources, 1978)

TABLE 6  
WELL YIELD IN MCMINN COUNTY

| Well Yield       | Percentage of<br>Wells |
|------------------|------------------------|
| 3 GPM or more    | 39.2                   |
| 10 GPM or more   | 62.3                   |
| 25 GPM or more   | 19.9                   |
| 100 GPM or more  | 4.6                    |
| 500 GPM or more  | 1.1                    |
| 1000 GPM or more | .1                     |

(Tennessee Dept. of Conservation, Division of Water Resources, 1978)

gallons per day respectively from the City of Athens (Water Quality Management Plan, 1975). Englewood, a community outside the Athens Quadrangle, obtains its water from Middle Creek, and supplies some domestic users along Highway 39 east of Athens. All other water users within the study area, not on the Athens or Englewood water systems, obtain their water from wells.

### Water Quality

Aside from problems in several areas of high population and/or industrial development the water quality is generally good. There are no known naturally occurring pollution problems and the low natural concentrations of minerals in the area's waters present no problems in obtaining domestic and industrial water supplies. The problem areas are generally limited to stream segments below certain municipal and industrial waste treatment outfalls. Potential nonpoint sources of pollution include agricultural chemicals, feedlot waste, surface-mining runoff, and storm water runoff from populated areas, including bypass from overloaded sewers. Erosion and sedimentation also create water quality problems especially in areas of farming, timber harvesting, and construction.

Oostanaula Creek receives effluent from the larger of the two Athens municipal wastewater treatment plants and industrial waste from Athens Stove Works, Mayfield Dairy Farms, and animal and milk waste from a large dairy farm. Chestuee Creek receives effluent from the Englewood Municipal Wastewater Treatment Plant and Winchester Trailer Park. North



Mouse Creek receives effluent from the Niota Municipal Treatment Plant by way of Little North Mouse Creek, and industrial waste from the Midland-Ross Corporation together with effluent from Athen's smaller treatment plant which enters North Mouse Creek through Dry Valley Branch (Water Quality Management Plan, 1975). Table 7 shows the pollution sources and receiving streams known to exist within the Athens Quadrangle.

TABLE 7  
SOURCES OF EFFLUENT DUMPED INTO CREEKS WITHIN THE STUDY AREA

| Source                     | Waste Type                                        | Volume (MGD) | Type Treatment                   | Treated Waste Characteristics                                          | Receiving Stream (RM)                       |
|----------------------------|---------------------------------------------------|--------------|----------------------------------|------------------------------------------------------------------------|---------------------------------------------|
| <b>INDUSTRIAL</b>          |                                                   |              |                                  |                                                                        |                                             |
| Athens Stove Works         | Cooling and Sanitary No. 002                      | 0.0144       | None                             | BOD=27mg/l                                                             | Oostanaula Creek (33.3)                     |
|                            | Pickling, Cooling boiler blowdown washer, No. 003 | 0.048        | None                             | SS=325mg/l                                                             | Oostanaula Creek (33.3)                     |
|                            | Cooling, scrubber washer No. 004                  | 0.019        | None                             | SS=2,918mg/l                                                           | Oostanaula Creek (33.4)                     |
|                            | Washwater No. 001                                 | 0.00013      | None                             | BOD=19mg/l<br>SS=29mg/l<br>NH <sub>3</sub> -N=8.8mg/l                  | Oostanaula Creek (33.3)                     |
| Mayfield Dairy Farms, Inc. | Truck washwater                                   | 0.0043       | None                             | SS=160mg/l<br>TDS=520mg/l                                              | Oostanaula Creek (33.7)                     |
|                            | Cooling and boiler blowdown                       | 0.082        | None                             | SS=56mg/l<br>TDS=490mg/l                                               | Oostanaula Creek (33.7)                     |
| Midland Ross Corporation   | Plating wastes                                    | 0.050        | Chemical treatment sedimentation | TDS=1,300mg/l<br>Ca=0.02mg/l<br>Zn=19mg/l<br>NH <sub>3</sub> -N=12mg/l | Unnamed tributary to Dry Valley Creek (0.2) |
|                            | Domestic wastewater                               | 0.005        | Tertiary                         | TBOD=.5 lbs/day<br>TSS=.5 lbs/day<br>NH <sub>3</sub> -N=1.6mg/l        | Unnamed tributary to Chestnut Creek (0.8)   |

TABLE 7 (Continued)

| Source            | Waste Type | Volume (MGD) | Type Treatment | Treated Waste Characteristics                                                               | Receiving Stream (RM)          |
|-------------------|------------|--------------|----------------|---------------------------------------------------------------------------------------------|--------------------------------|
| <b>MUNICIPAL</b>  |            |              |                |                                                                                             |                                |
| City of Athens #1 | wastewater | 3.3          | Tertiary       | TBOD=275 lbs/day<br>TSS=413 lbs/day<br>TNH <sub>3</sub> -N=129 lbs/day<br>Standards A,B,C,D | Oostanaula Creek (30.6)        |
| City of Athens #2 | wastewater | 0.1          | Secondary      | TBOD=2.8 lbs/day<br>TSS=4.2 lbs/day<br>TNH <sub>3</sub> -N=1.4 lbs/day<br>Standards A,B,D,E | Dry Valley Creek (19.5)        |
| City of Nlota     | wastewater | 0.35         | Tertiary       | TBOD=29 lbs/day<br>TSS=44 lbs/day<br>TNH <sub>3</sub> -N=4.7 lbs/day<br>Standards A,B,D,E   | Little North Mouse Creek (4.0) |
| City of Englewood | wastewater | 0.2          | Primary        | TBOD=52 lbs/day<br>TSS=70 lbs/day<br>TNH <sub>3</sub> -N=8.8 lbs/day<br>Standards A,B,D     | Chestuee Creek (42.4)          |

(Water Quality Management Plan, 1975)

## CHAPTER IV

### SOILS

#### General Discussion

The soils of the study area have developed in a climate of moderately heavy rainfall, and moderately high temperatures. Forest cover is mainly deciduous hardwoods, with some pines in the more sandy areas. Slope variations, parent material, and time are primarily responsible for development of many different soil types within McMinn County. Forty-seven soil series are represented in the county, with most of these soils occurring to some extent in the study area. Each soil series is subdivided into phases by the degree of slope on which it occurs, degree of erosion, and soil texture. The number of phases of each soil series ranges from one for the Wolfever series, to twenty-one for the Fullerton.

Most of the soils are moderately to strongly acid; however, some floodplain soils and shallow soils developed over calcareous shale are alkaline to slightly acid.

The dominant texture of the surface layer of the soils is loam to silt loam, with a few sandy areas occurring on floodplains (see Appendix A for soil texture classification). Texture of moderately eroded soils is silty clay loam to loam, while severely eroded soils are silty clay loam. Soil consistency ranges from loose to very plastic, with most soils being moderately pliable to firm. Depth to bedrock ranges from surface outcrops up to 88 meters (290 feet) with the thickest soils

having developed over either cherty dolomitic limestone, stream terraces, or floodplains.

Slopes range from nearly level on floodplains to very steep in the Red Hills. Most limestone and shale valleys are undulating to rolling, while cherty ridges are rolling to hilly.

Approximately 67% of land in the county is suitable for crops requiring tillage, 15% is best suited for pasture, with the remainder suited only for forest (McMinn County Soil Survey, 1957).

Physical properties of the soils within the study area, which are useful in determining suitability for specific land uses, are shown in Table 8. The wide range of soils present in this area, and variations occurring over small distances are important considerations in site selection for land uses where soil properties required, are critical.

#### Distribution of Soils

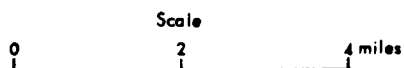
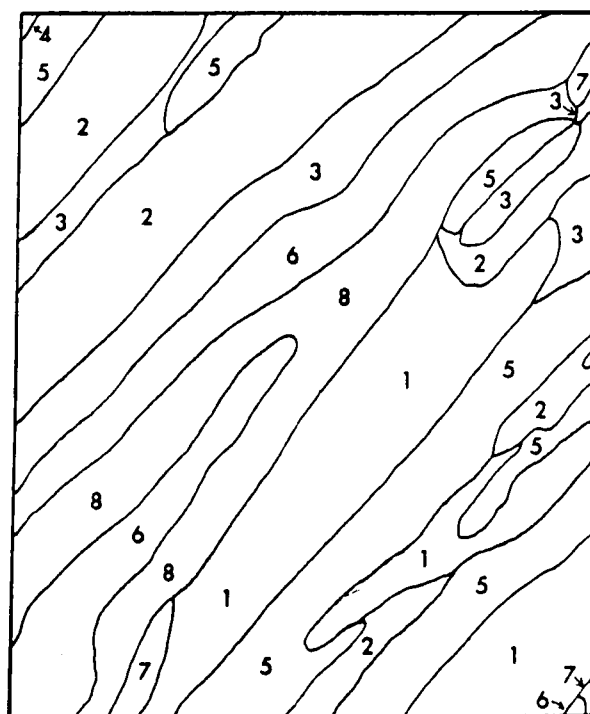
When two or more soils are geographically related and have similar land use suitability characteristics they may be classed as a soil "association." Eight soil associations are recognized in the Athens quadrangle. The soils when grouped according to association have boundaries which are, in most cases, practically coincident to the mapped boundaries of the bedrock units (Plate II). Location and extent of these associations are shown in Figure 7. The following paragraphs briefly describe which bedrock formations underlies each soil association and the drainage classification (see Appendix A) of the association.

The Dewey-Fullerton-Emory association is present on relatively low ridgelands formed by the dolomitic limestones of the Mascot,

TABLE 8  
PHYSICAL PROPERTIES OF SOILS WITHIN THE STUDY AREA

| Soil         | Depth<br>Bedrock<br>(Feet) | Liquid<br>Limit | Plasticity<br>Index | Shrink<br>Swell<br>Potential | Permability<br>(Minutes/Inch) |
|--------------|----------------------------|-----------------|---------------------|------------------------------|-------------------------------|
| Alcoa        | 1.5 - 2                    | 36-55           | 15-26               | Low-Mod                      | 45                            |
| Apison       | 2 - 3                      | 20-40           | 4-18                | Low                          | 75                            |
| Abernathy    | 5 - 12                     | *               | *                   | Low                          | 30                            |
| Bolton       | 10 - 30                    | *               | *                   | Low                          | 45                            |
| Bruno        | 5 - 16                     | *               | *                   | Low                          | 5                             |
| Clarksville  | 12 - 40                    | *               | *                   | Low                          | 30                            |
| Cumberland   | 3 - 20                     | 41-70           | 8-35                | Low-Mod                      | 45                            |
| Cotaco       | 2 - 7                      | 12-35           | 0-15                | Low                          | 30                            |
| Dandridge    | 1 - 4                      | 35-60           | 15-35               | Low                          | 75                            |
| Decatur      | 2 - 18                     | 37-60           | 11-25               | Mod                          | 45                            |
| Dewey        | 4 - 20                     | 27-68           | 12-34               | Mod                          | 60                            |
| Etowah       | 3 - 15                     | 25-60           | 10-25               | Low                          | 30                            |
| Emory        | 4 - 15                     | 25-45           | 4-20                | Low                          | 30                            |
| Fullerton    | 5 - 40                     | 25-50           | 10-25               | Low                          | 45                            |
| Farragut     | 1.5 - 4                    | 35-60           | 12-28               | Low-Mod                      | 75                            |
| Greendale    | 5 - 12                     | 20-35           | 3-12                | Low                          | 30                            |
| Guthrie      | 5 - 20                     | 20-50           | 4-25                | Low                          | 75                            |
| Holston      | 2 - 15                     | 21-52           | 5-22                | Low                          | 45                            |
| Hermitage    | 4 - 12                     | *               | *                   | Low                          | 30                            |
| Hayter       | 2 - 8                      | *               | *                   | Low                          | 30                            |
| Huntington   | 4 - 15                     | *               | *                   | Low                          | 30                            |
| Hamblen      | 4 - 15                     | 22-40           | 3-17                | Low                          | 30                            |
| Litz         | .5 - 4                     | *               | *                   | Low                          | 75                            |
| Lehew        | .5 - 2                     | *               | *                   | Low                          | 30                            |
| Leadvale     | 4                          | 23-58           | 3-26                | Low                          | 75                            |
| Lindside     | 4 - 15                     | *               | *                   | Low                          | 30                            |
| Montevallo   | .5 - 2                     | *               | *                   | Low                          | 75                            |
| Monongahela  | 5 - 15                     | 20-40           | 1-15                | Low                          | 75                            |
| Melvin       | 4 - 15                     | *               | *                   | Low                          | 45                            |
| Needmore     | .5 - 4                     | 43-65           | 20-35               | Mod                          | 75                            |
| Neubert      | 3 - 12                     | 20-30           | 2-10                | Low                          | 15                            |
| Ooltewah     | 5 - 12                     | *               | *                   | Low                          | 30                            |
| Pace         | 4 - 12                     | *               | *                   | Low                          | 75                            |
| Purdy        | 4 - 15                     | *               | *                   | Low                          | 75                            |
| Prader       | 4 - 15                     | *               | *                   | Low                          | 45                            |
| Sequoia      | .5 - 4                     | 43-74           | 20-40               | Mod                          | 75                            |
| Sequatchie   | 5                          | 15-32           | 2-15                | Low                          | 30                            |
| Staser       | 5                          | 20-35           | 3-15                | Low                          | 30                            |
| Talbolt      | 0 - 8                      | 40-80           | 20-45               | Mod                          | 75                            |
| Tellico      | 1 - 7                      | 15-55           | 4-20                | Low-Mod                      | 45                            |
| Tyler        | 4 - 15                     | *               | *                   | Mod                          | 75                            |
| Waynesboro   | 2 - 20                     | *               | *                   | Low-Mod                      | 45                            |
| Wolftever    | 4 - 12                     | *               | *                   | Low                          | 75                            |
| Whitesburg   | 3 - 8                      | *               | *                   | Low                          | 45                            |
| Jefferson    | 2 - 10                     | 15-35           | 2-15                | Low                          | 30                            |
| Barbourville | 2 - 3                      | *               | *                   | Low                          | 15                            |

(U.S. Dept. Agriculture, Soil Conservation Service, 1979)



#### SOIL ASSOCIATIONS

- |          |                                 |
|----------|---------------------------------|
| <b>1</b> | Dewey-Fullerton-Emory           |
| <b>2</b> | Fullerton-Clarksville-Greendale |
| <b>3</b> | Decatur-Dewey-Emory             |
| <b>4</b> | Litz-Cotaco                     |
| <b>5</b> | Sequoia-Litz-Cotaco             |
| <b>6</b> | Needmore-Dandridge              |
| <b>7</b> | Dandridge-Needmore              |
| <b>8</b> | Tellico-Neubert                 |

Figure 7. Location and extent of soil associations within the Athens quadrangle (after Bacon, 1957).

Kingsport, Longview, and Chepultepec formations. Soils of the association range from well drained to excessively drained.

The Fullerton-Clarksville-Greendale association occurs on cherty ridges and surrounding flatter areas which overlie the Longview, Copper Ridge, and Chepultepec formations. Drainage ranges from well drained to excessively drained.

The Decatur-Dewey-Emory association occurs in valleys which overlie the Kingsport and Mascot formations. Drainage ranges from well drained to excessively drained.

Areas covered by the Litz-Cotaco association are characterized by narrow strips of Cotaco soils along drainageways with the Litz soils occupying valley floors. Litz soils are shallow shaly silt loam soils which occur over acid shale (Conasauga), while the Cotaco soils are developed on local alluvium. Cotaco soils are imperfectly to poorly drained while the Litz soils are somewhat excessively drained.

The Sequoia-Litz-Cotaco association occurs on undulating to rolling valley land overlying the Conasauga shale and Copper Ridge formations. The general drainage ranges from moderately well drained to somewhat excessively drained.

The Needmore-Dandridge association overlies the Athens and Ottosee formations just southeast of Athens. In the hilly areas Dandridge soils are prevalent, while the Needmore soils are dominant in more level areas. Hamblen, Whitesburg, Tellico, and Neubert soils are found on floodplains along the streams within the association. The Dandridge and Needmore soils range from moderately well drained to somewhat excessively drained, while the bottomland soils are somewhat poorly drained to well drained.



The Dandridge-Needmore association occupies only a minor acreage within the study area. This association differs from the Needmore-Dandridge only in that it occurs on steeper slopes and the depth to bedrock is less.

The Tellico-Neubert association occurs on the steepest slopes within the area. The association overlies the Holston formation which due to high quartz content is more resistant to erosion. Tellico soils are well drained to excessively drained, while the Neubert soils range from moderately well drained to well drained.

## CHAPTER V

### GEOLOGIC AND HYDROLOGIC HAZARDS

As a result of increasing population and greater concentration of people into urban and suburban areas loss of life and property due to geologic related events have become a problem of major concern. Recognition of areas where interference with natural processes may cause geologic or hydrologic hazards is of prime importance in planning for future developments.

#### Surface Movements

In Tennessee, slump is the most common type of gravity movement of surficial material (Miller et al., 1972). Slump, characterized by outward and downward movement (often involving backward rotation) of a curved slice of semi-consolidated or unconsolidated material, usually results from undercutting at the base of a slope or an escarpment. Though slumps may occur naturally, such as by stream erosion, many slumps are due to oversteepening of slopes during construction projects. The addition of moisture to slope material which increases its weight, plasticity and the hydrostatic pressure within the material increases the potential for slump. Development of slope lands for subdivisions and other uses may increase the amount of soil moisture due to the presence of drain fields and activities such as lawn and garden watering. Impoundments created during the preparation of construction sites can cause saturation of soils or allow infiltration of large

quantities of water down to impermeable zones (such as clay layers), increasing the likelihood of slump occurrence. Slump is a potential hazard in the Athens area where steep slopes are underlain by thick soils.

Within the Red Hills section of the Athens quadrangle where shallow soils occur on steep slopes, rock falls or slides could occur. Rock falls and slides develop along zones of weakness such as bedding planes, joints, and fractures. Cuts through consolidated material if made perpendicular to the dip of bedding planes have a high potential for slide occurrence. This potential hazard is increased with the presence of shale zones and steep dip angles.

The hazard of naturally occurring major landslides within the study area is minimal due to the apparent state of equilibrium which has been reached on the slopes over past millenia. Actions which may potentially disturb this equilibrium, must be well planned to avoid creating conditions conducive to slope failure.

Collapse or subsidence of the earth's surface, a serious potential hazard, can result from removal of support by pumping large volumes of fluids from weakly consolidated formations, improper mining methods, or as is the case in the study area, dissolution of carbonate rocks by ground water. Depressions of the land surface in the Athens area have developed when "roofs" of caves or solution channels, become weakened and can no longer support the weight of the overburden. The development of sinkholes, as shown in Figure 8, may be accelerated by either rapid withdrawals or abnormal influxes of water through the underground

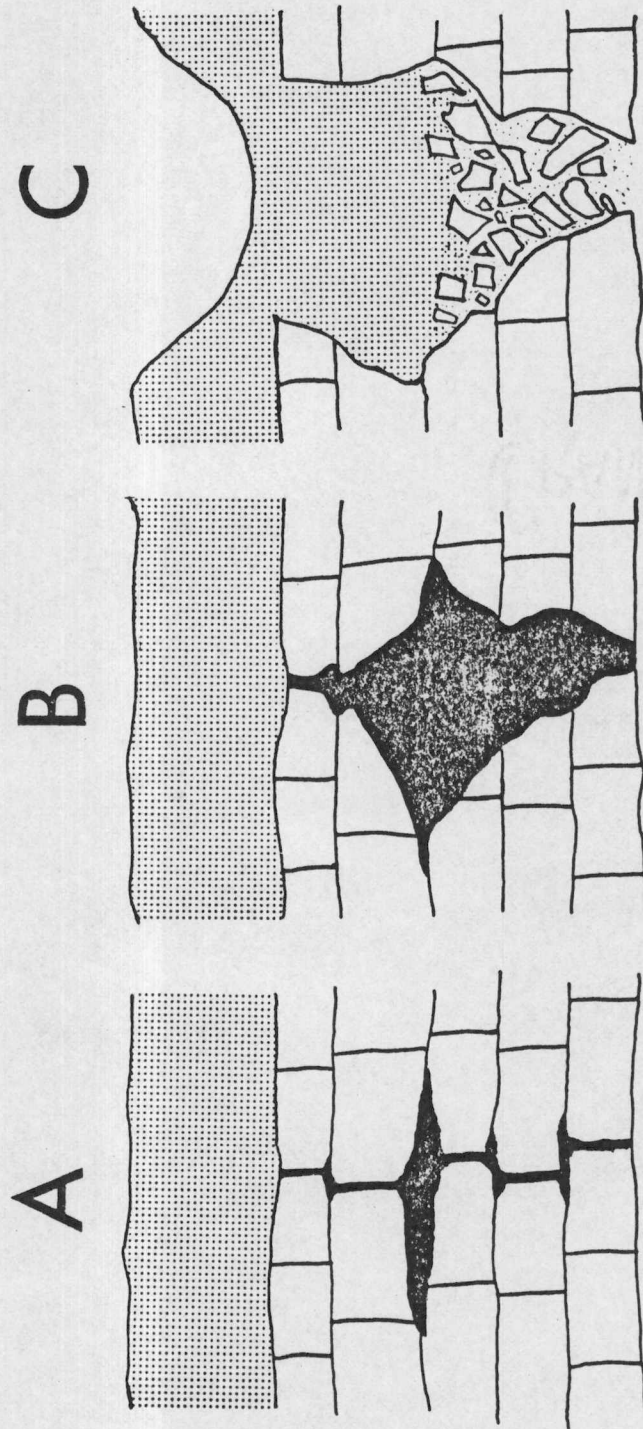


Figure 8. Idealized sinkhole development (after Miller, et al., 1972).

drainage system. Alteration of surface and subsurface water regimes wrought by urban and suburban development can accelerate sinkhole development. Increased surface runoff due to "roofing over," or creation of an impervious land surface, may drain into formally filled or partially filled solution channels flushing them out and accelerating the development of a previously inactive subsurface drainage system. Conversely surface runoff containing debris and/or heavy sediment loads could partially or completely block existing subsurface drainage resulting in local flooding and possible modification to the subsurface drainage pattern (Kellberg, et al., 1973). Collapse of solution cavities may also be triggered by surface loading, high precipitation, vibrations from traffic, blasting or earthquakes.

Since dissolution of carbonate rocks is a natural process, permanent control of this form of subsidence is practically impossible; however, with the proper geologic information areas prone to collapse problems can be avoided or plans instituted to avert acceleration of the process.

Subsidence in the study area resulting from settling of fill dirt is a more common problem than collapse of solution cavities. Subsidence of this type is a problem when structures are built either on unequally compacted fill or constructed partly on fill and partly on well-compacted undisturbed material. This problem can be easily avoided by limiting foundations to sites wholly on equally compacted fill or to areas of well compacted undisturbed material.

### Hydrologic Hazards

Due to the moderate relief and the absence of sizable rivers, wide spread flooding has not occurred in the Athens quadrangle. Localized flooding does occur on the floodplains of the area streams and in areas where drainage has been impaired. Presently most of the land included in the areas prone to inundation by a 100 year flood is used for agriculture or forest lands, however, some land development has occurred in flood prone areas around the city of Athens. Because flooding is a natural phenomenon, to avoid property damage from flooding the use of flood prone lands should be restricted to agricultural, recreational, and forest development. The danger of localized flooding exists where areas have undergone drainage pattern modifications that decrease infiltration and increase surface runoff. The development of previously open land for roads, parking lots, and structures can remove land formally available for infiltration of precipitation. Also, the infiltration capacity can be reduced where drain field increase soil moisture, or where soil is compacted during construction or by activities like mowing or heavy foot traffic. Construction projects also may eliminate small tributaries causing an increase in the discharge of undisturbed drainageways. These conditions cause flooding by increasing the amount of runoff beyond the capacity of existing drainage, and by elimination of previous open drainageways leaving some areas without an outlet for drainage.

Sediment eroded from land under development may exceed by 20,000 to 40,000 times that from farms and woodlands (Wolman and Schech, 1969).

Such a massive increase in sediment can choke existing drainage creating a flood potential during subsequent periods of peak runoff.

The abundance of sinkholes over much of the Athens quadrangle is a serious threat to the quality of the groundwater, which is the major water source for most of the area. Sinkholes afford direct access for fluid movement between the surface drainage and aquifers, consequently surface pollution may enter aquifer directly without passage through a soil zone which normally provides some degree of filtration. Solution channels within the carbonate rocks allows rapid flow through a system capable of spreading pollution faster and to a broader area than in less soluble rocks. Groundwater recharge areas especially where sinkholes are observable must be recognized as such and their use restricted in order to avoid contamination of ground water supplies.

#### Earthquakes

The Athens area is not within an active earthquake zone; however, based on the distribution and intensities of past earthquakes Algermissen (1969) designates East Tennessee as a zone of moderate seismic risk (Figure 9). The maximum intensity expected to occur in a zone of moderate seismic risk corresponds to a magnitude between 5.2 and 5.7 on the Richter scale or VII on the Modified Mercalli Intensity Scale (Kellberg, et al., 1973). The damage to be expected from an earthquake with intensity of VII is described by Wood and Neumann (1931) as: "negligible in building of good design and construction; slight to moderate in well-built ordinary structures; and considerable poorly

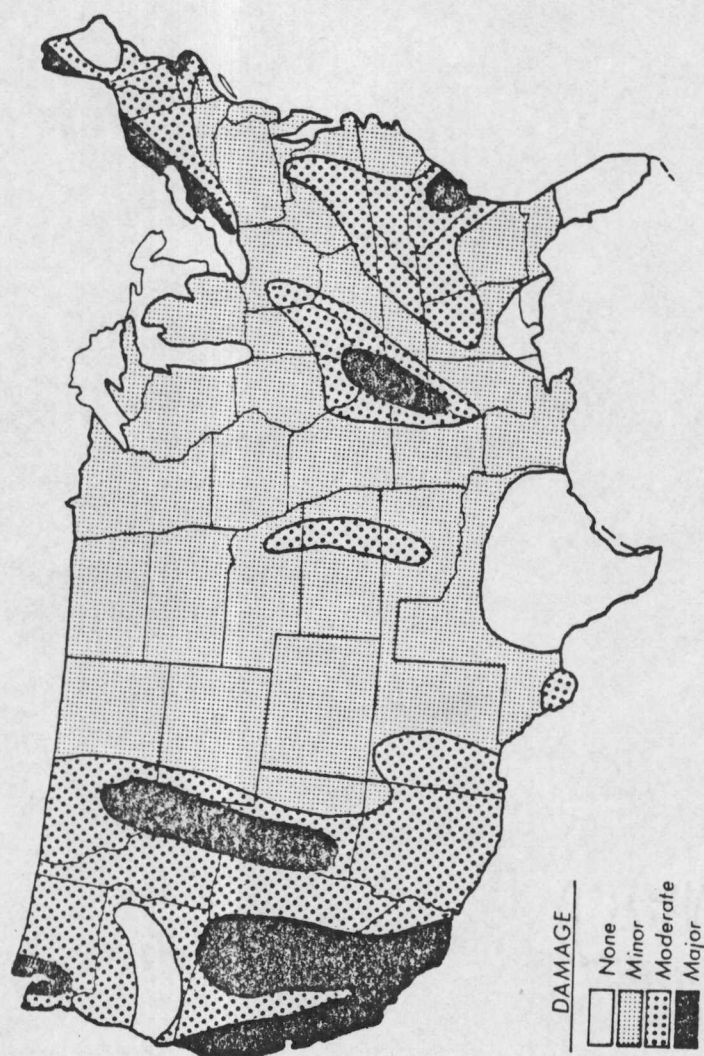


Figure 9. Seismic risk zones of the United States  
(after Algermissen, 1969).



built or badly designed structures." It should be noted that any earthquake regardless of intensity is a potential trigger for surface movements.

A T.V.A. analysis of the earthquake history within a 50 mile radius of the Athens area shows 43 earthquake epicenters (Richard Hopkins, TVA, 1979, personal communication). Figure 10 shows the location and intensities of these past earthquakes, and Figure 11 shows the percent of probability of an earthquake of any given intensity occurring within any one year.

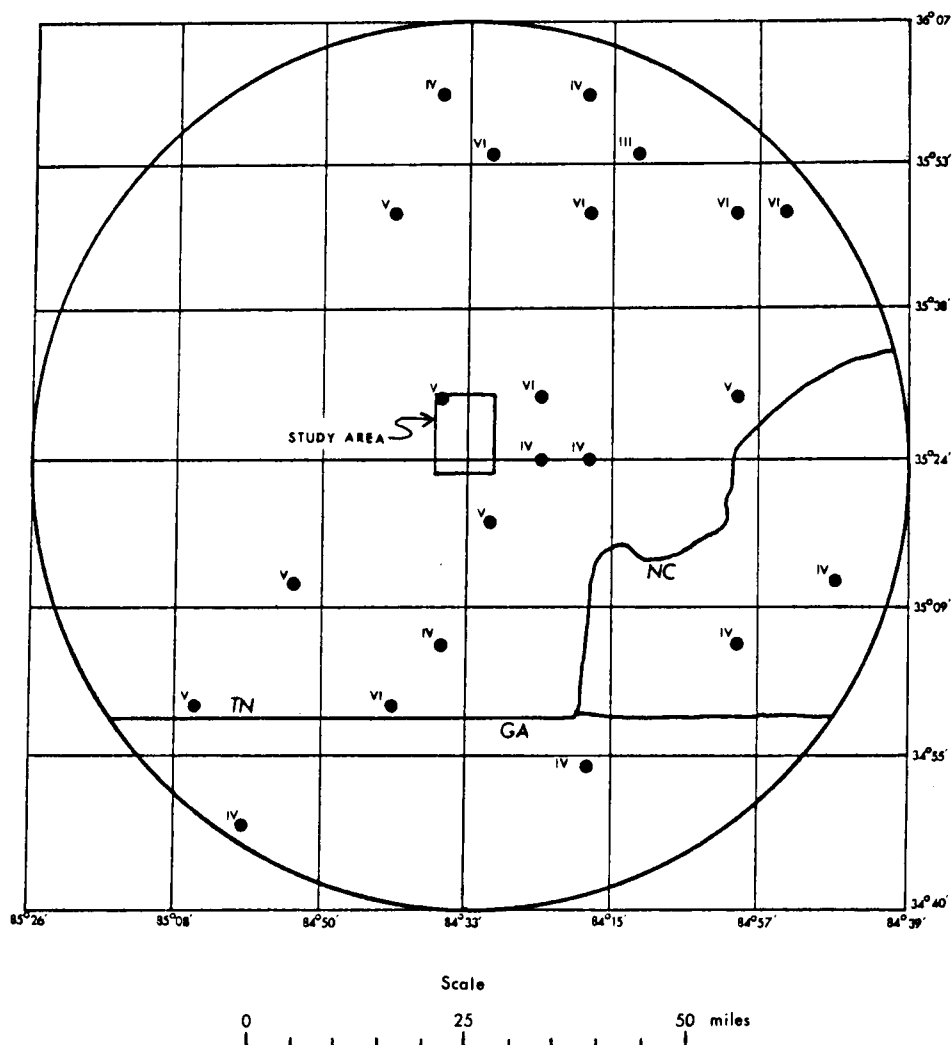


Figure 10. Locations and intensities of past earthquakes within a 50 mile radius of the study area (from Richard Hopkins, TVA, 1979, Personal communications).

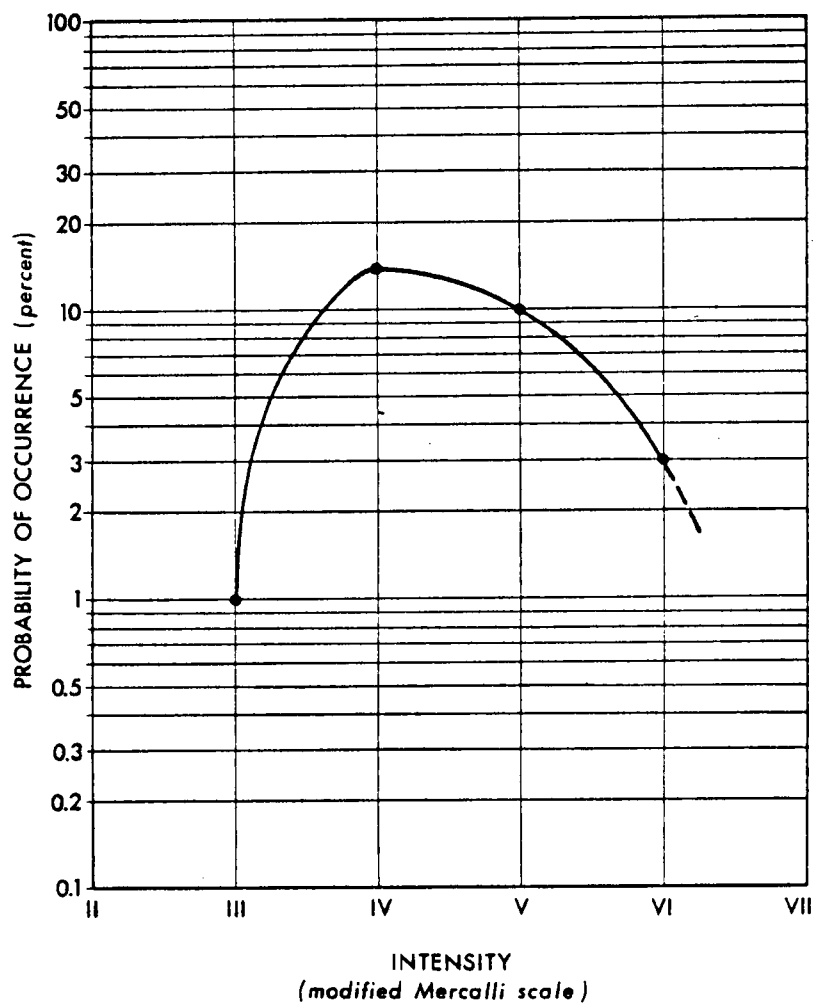


Figure 11. Earthquake probability within the study area (data from Richard Hopkins, TVA, 1979, Personal communications).

## CHAPTER VI

### CREATION, MODIFICATION, AND APPLICATION OF THE DATA BASE SYSTEM

The primary step in creation of a computer-oriented data base consists of choosing environmental elements which will best characterize land capabilities and possible hazards, that are compatible with present day techniques of storing and displaying the data. Because it is desirable that the system have capabilities of managing data on a broad, perhaps state wide basis, the detail (resolution) of the data must be somewhat limited.

In this study a data "cell" is used as the basic unit to represent information in the data base. The shape and size of the cells are constant and independent of the areal extent of the values represented. Polygons were not used because of the complexity of the boundaries resulting from variations in the data values. While one cell may be easily compared to another cell, comparison of two or more polygons (with different boundaries) requires a complex program to define the boundaries of intersection. The less complex comparison of cells allows faster manipulation of data, and easy modification or correction of the data files (matrices).

Selection of cell size was based on two requirements: (1) The restriction of the total number of cells to an amount allowing reasonable computation and digitization times: (2) A tolerance for the resolution of boundaries allowing the use of data acquired at different

scales from various sources. The cell used in the data base represents a ground area 150 meters wide (E-W), by 144 meters high (N-S), or about 5.33 acres. The user must be aware that features with areal extents covering less than half the cell area are not represented by the cell value. Also, features that may cover an entire cell could be obscured if the feature was distributed among several cells, but covering less than half of any individual cell. The limitations of the resolution in this method must be taken into consideration when evaluating data value boundaries. The user must recognize that an area represented by one value may occur within a data cell of an entirely different value.

The system provides only a preliminary evaluation of areas meeting environmental requirements for particular land uses (as opposed to providing all the necessary data for a complete site specific environmental evaluation).

This study incorporates bedrock geology, occurrence of flood prone areas, and slope of the land surface as the basic elements for indicators of land use suitability with respect to potential environmental hazards. Soils data were proposed to be included in the data base; however, it proved impractical to digitize these data in a manner compatible with the other elements of the data base. Basically the problem in trying to digitize the soil data lay in the existence of almost two hundred separate and distinct soil phases within McMinn County, each having a highly variable areal extent and very complex geometry. It was more feasible to combine elements of slope and geologic data producing an interpretative map that indicates areas where certain soil series would

most likely occur. This is possible because slope and parent material on which the soils were developed are major factors in determining soil type. While this interpretative approach to soil mapping enables the user to define general areas of similar soil properties, detailed soil information requires large scale maps and field investigations.

After selecting the elements to be included in the data base, it was necessary to format them in such a manner that they could be digitized compatibly into the data base. In order to insure that each element or data set could be manipulated and compared to the other data sets all elements had to be digitized from base maps of the same scale, with the same number and arrangement (same number of rows and columns) of data points (cells). Compiled information not already on a 7.5 minute quadrangle (base map) had to be rescaled prior to digitization.

The two reasons for selecting the 7.5 minute quadrangle (1:24,000 scale) as the base map are first, the availability of topographic, geologic and numerous other data previously mapped at this scale, and secondly, this map size provides adequate detail for most initial environmental studies.

Digitization of data from the base map was accomplished by two methods, one manual and one computer controlled. Since digitization programs for general use are not presently available at The University of Tennessee, the program DETERMINATE written by David Callahan with documentation by Joel Haden was made available for this study with the proviso that details of the program would not be published. DETERMINATE uses the Tektronix graphics terminal and data tablet to

digitize areal boundaries (polygons) and assign values to these areas. After digitization of the polygons the program DETERMINATE can create a matrix from the data. It is necessary for data files to be in a matrix format, in order to allow easy modification of the data point values, comparison of files, and the creation of new files with data abstracted from one or more existing data files. As a check of the matrices produced by DETERMINATE a grid overlay was used on each base map, with cell values being checked against the DETERMINATE matrix values. The grid used on the base map was 96 rows by 75 column producing 7200 cells, with each cell representing an area of  $70,788 \text{ m}^2$  ( $232,243 \text{ ft}^2$ ). Initially the base map was divided into 12 subdivisions with each subdivision consisting of 24 rows by 25 columns (600 cells). This division was made primarily to reduce the loss of computer time when an error was made while digitizing a map with the DETERMINATE program; however, a secondary consideration was the use of these subdivisions to demonstrate the operation of the data base system in selecting working areas.

Using the grid overlay as a check a number of errors were found and corrected in the matrices. In this manual checking system a value judgement had to be made as to which map value is "most" representative of each cell. DETERMINATE, when generating a matrix, also assigns a value to the matrix position based on the value of the largest area in the cell position. In comparison between DETERMINATE matrices and the grid overlay system, a very close correlation of boundary edges occurred, this together with the nature of the errors (random columns

of incorrect values) found suggest the errors in DETERMINATE matrices occurred during digitization of the data rather than in compilation of the matrices.

After digitization of the data and correction of the matrices, the matrices were stored as computer files. In order to use this data base, a system for recall, sorting, and display of the data was needed. To accomplish these functions the program SELECT was developed. SELECT is a user oriented, interactive program by which the data base can be accessed, and new matrices (maps) generated according to user specifications as to desired location, type of data, and range of data values. The program allows the user to create special matrices (maps) consisting of combinations of a number of data values from one data matrix (such as geology) grouped into categories, as in the lithologic map (Figure 12) where all the limestones make up one category, dolomites another, and shales a third. These special matrices may also be used with the basic data matrices to produce new "maps" as in the case where an interpretative soil properties "map" is used with the basic data matrices (slope, geologic, and hydrologic data) to produce a land use map.

The output from SELECT is a matrix which can be printed out on the line printer as is, or stored and used to produce different types of maps with SURFACE II, other "canned" graphics programs, or the writer's plotting program (Appendix C).

#### Configuration and Operation of the Data Base System

For each of the three data elements (geology, hydrology, and slope), twelve data files corresponding to the twelve subdivisions on the base





Figure 12. Computer generated lithologic map of the Athens quadrangle.

map as shown in Figure 13, are stored in the computer. Each of these thirty-six files is given a unique name which indicates the data element and base map subdivision that the file represents. For example, geologic data files are named: G01, G02, G03, . . . , G12. The first letter (G) denoting data type (geologic), and the following two digit number the base map subdivision. Hydrologic and slope data files are named in a similar manner using "H" and "S" as the first letters respectively. The range of values which is represented in the files is dependent on the number of divisions the user makes in each of the data elements upon initial digitization. In this study fourteen geologic formations were coded, with unique two digit numbers for digitization. Divisions of each data element with the corresponding numerical values assigned to them are shown in Table 9. The user when running the program SELECT must use the exact numerical value which represents each division for the computer to recognize it. In this data base the numerical value is always a two digit number followed by a decimal point, as shown in Table 9.

The program SELECT (see Appendix B) was designed to allow the data base user to construct a matrix (map) which contains values representing sections within the study area where criteria specified by the user are met. SELECT allows the user to specify which data elements are to be examined, the data element divisions to be included in the matrix, and the new values to be assigned to the divisions. Options available within the program allow the user to select whether the entire study area is to be examined or one of the subdivisions.

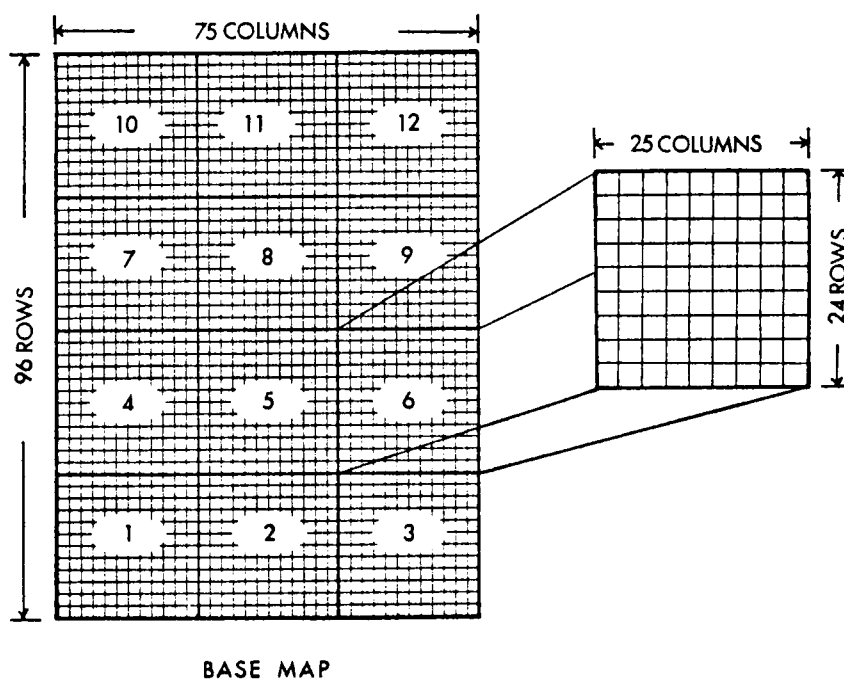


Figure 13. Base map subdivisions used in generating matrices.

TABLE 9

NUMERICAL CODES OF DATA ELEMENTS PRESENT IN THE DATA BASE

| DATA ELEMENT<br>SUBDIVISION     | VALUE ASSIGNED<br>TO MATRIX |
|---------------------------------|-----------------------------|
| Geologic                        |                             |
| Conasauga Shale                 | 05.                         |
| Maynardville Limestone          | 10.                         |
| Copper Ridge Dolomite           | 15.                         |
| Chepultepect Dolomite           | 20.                         |
| Basal Sandy Member              | 25.                         |
| Longview Dolomite               | 30.                         |
| Kingsport Formation             | 32.                         |
| Mascot Dolomite                 | 34.                         |
| Lenoir Limestone                | 36.                         |
| Athens Shale                    | 38.                         |
| Holston Limestone               | 40.                         |
| Ottosee Shale                   | 42.                         |
| Upper Member                    | 44.                         |
| Marble Lenses                   | 46.                         |
| Hydrologic                      |                             |
| No Flood Hazard                 | 66.                         |
| Inundated by a "100 Year" Flood | 20.                         |
| Slope                           |                             |
| 0 - 8%                          | 08.                         |
| 8 - 15%                         | 15.                         |
| 15% or more                     | 25.                         |

Also, the user may combine several matrices previously generated into a new matrix; however, this option is limited due to the large number of possible combinations. However, it is a simple procedure for anyone with some previous instruction to modify this program to combine any matrices generated by merely changing the matrix name.

The operation of SELECT is as follows: the user is asked if he desires to work with the entire study area or one of the twelve subdivisions. The next question asks if the user wants to create a special matrix on which a number of values are combined into categories. If a "No" answer is given here, the program ask what hydrologic criteria the user wants on the new matrix, what geologic criteria, and what slope criteria. These are single values as opposed to a number of values which would be selected to make up categories if a special matrix were being created. Once a value is chosen for each data element the program reads either all the files (if the entire area is being evaluated) or only the geologic, hydrologic, and slope data files on one subdivision selected if that option was chosen. SELECT now generates a new matrix by scanning the file(s) of each data element. When values matching the specified criteria are encountered at the same matrix position in all three element files a value of "1" is assigned to the corresponding position in the new matrix. Other values are assigned to the remaining matrix positions of the new matrix denoting which if any of the specified criteria were met, these values and the conditions corresponding to them are shown in Table 10. At this point in the program the user is asked if a copy of the hydrologic, slope, and geologic base maps should be

TABLE 10  
MATRIX CONDITION CODES ASSIGNED BY SELECT DENOTING CELL VALUES

| ELEMENTS FOR WHICH SPECIFIED<br>CRITERIA IS TRUE | VALUE ASSIGNED TO<br>NEW MATRIX |
|--------------------------------------------------|---------------------------------|
| Slope                                            | 1                               |
| Hydrologic                                       | 2                               |
| Geologic                                         | 3                               |
| Slope, Geologic                                  | 4                               |
| Slope, Hydrologic                                | 5                               |
| Geologic, Hydrologic                             | 6                               |
| Slope, Geologic, Hydrologic                      | 7                               |
| None                                             | 8                               |

saved. If a special map is to be made later, on the entire study area it is necessary to have a copy of these matrices stored on the computer system. Once this is done it is not necessary to repeat the operation unless the files are deleted. The program now asks if a hard copy of the map (matrix) resulting from the values selected should be printed out. At this point whether user chooses to print out a hard copy of the new matrix or not, a copy is stored in the computer system for later use. After this "map" has been stored the user is asked if another map is to be made (up to five maps can be generated), if a "no" answer is given the program ends.

When special "maps" are being made the user selects which data element is to be used as a source for basic information, how many categories are to be included on the map, how many values are in each category, and which values belong to each of the categories. With this option the category value is equivalent to order number in which the categories were selected. For example the value of the first category made is one, the next category has a value of two, and so on. If it is desired that two categories be made with values of one and three respectively this can be accomplished without changing the program by specifying three categories and responding with "0" when asked how many values are to be included in the second category. As in the previous option a hard copy of the new matrix is available and a copy is automatically stored in the computer system.

After the user generates matrices with the "special map" option, the computer asks if a composite map generated from a number of the

special maps is desired. With this option the user is asked how many of the special matrices are to be used for the composite map and what the file number is for each of them. The file number corresponds to the order in which the matrices were generated, that is the first special matrix made has a file number of one, the second is two and so on. The maximum number of special matrices which can be combined into a composite map is four. To generate a composite map the special matrix files are scanned, when the value "1" is found in the same position on all matrices a value of "50" is assigned to the corresponding position on the composite map. If a value of "3" is found on any of the matrices the corresponding position on the composite map is assigned a value of "0." As long as a "0" is not present in the same position on any of the matrices and a "2" is found, the corresponding composite map position is assigned the value "20." The composite matrix can be printed out if desired and a copy is automatically stored under the file name Compos.

A flow chart for SELECT (Figure 14) shows the path taken by the program when certain options are selected, and at which points in the program output is produced. Table 11 lists the operations available with the use of each option shown on Figure 14. Table 11 lists the names of the files produced by SELECT when each of the options is selected. The user should be aware of the fact that files produced by SELECT will be lost if the program is rerun without changing file names generated by the previous run.



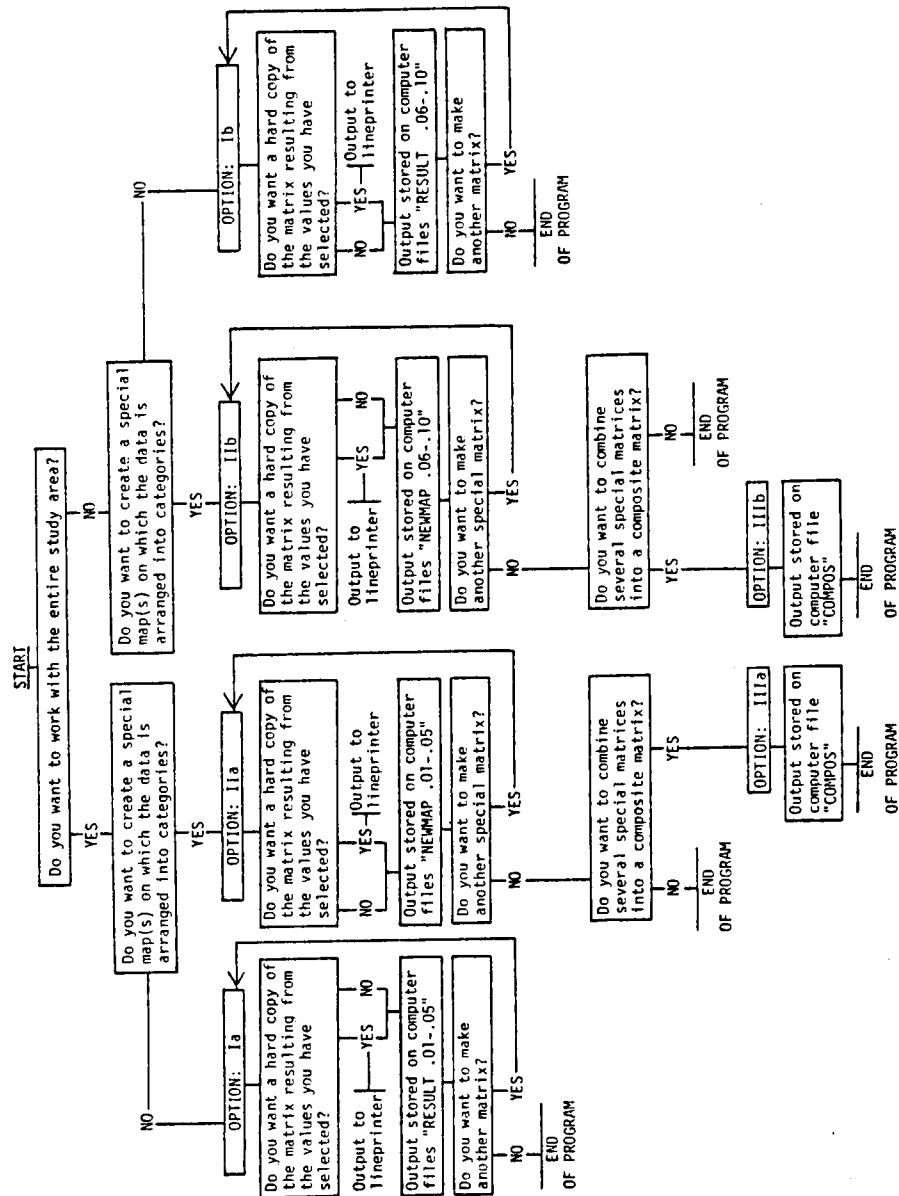


Figure 14. Flow diagram for the program SELECT.

TABLE 11  
OPTIONS AVAILABLE AND FILES PRODUCED BY SELECT

| OPTIONS                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                             | FILE NAMES GENERATED<br>BY OPTIONS |     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|-----|
| Ia.                                                                                                                                                                           | This option allows the user to select a value for each data element (geologic, hydrologic, and slope). A new matrix is then generated with values denoting which selected values are present within the study area and their location. The matrix generated by this option covers the entire study area.                                    | Result                             | .01 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Result                             | .02 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Result                             | .03 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Result                             | .04 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Result                             | .05 |
| IIa                                                                                                                                                                           | This option allows the user to create special matrices by selecting a data element and arranging the values of the element into categories. A new matrix is then generated with values denoting the presence and extent of the categories selected within the study area. The matrix generated by this option covers the entire study area. | Newmap                             | .01 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Newmap                             | .02 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Newmap                             | .03 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Newmap                             | .04 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Newmap                             | .05 |
| IIIIa                                                                                                                                                                         | This option may be selected if the preceding option was used to generate special "category type" matrices. The option allows the user to select and combine previously generated special matrices into a composite matrix. This matrix covers the entire study area.                                                                        | Compos                             |     |
| <p>The following "b" options perform the same functions as their "a" counterparts, except the work area consists of a subdivision of the study area selected by the user.</p> |                                                                                                                                                                                                                                                                                                                                             |                                    |     |
| Ib                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                             | Result                             | .06 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Result                             | .07 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Result                             | .08 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Result                             | .09 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Result                             | .10 |
| IIb                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                             | Newmap                             | .06 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Newmap                             | .07 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Newmap                             | .08 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Newmap                             | .09 |
|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             | Newmap                             | .10 |
| IIIIb                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                             | Compos                             |     |

### Computer Hardware Used

Digitization of the data was accomplished using a Tektronics graphics terminal and data tablet in conjunction with an interactive program (DETERMINE) on a DEC 10 system. The program SELECT was run on a DEC 10 system (interactive mode) using on line disk storage for data files. Alphanumeric terminals were used to create or modify files used or generated by SELECT. The matrices (maps) generated by SELECT were sent directly to the line printer or used to produce plotter drawn maps. In production of plotter maps the matrices were sent across a DEC 10—IBM interface together with a CalComp plotter program (Appendix C) and the necessary IBM job control language. After computation (batch on the IBM 360-65/70), a plot of the matrix was produced on the CalComp plotter.

The computer hardware used in this study should not be considered a limiting factor for running SELECT, storage of the data base, or display of the maps produced. SELECT can be modified to run on systems which are not interactive, and the matrix format of the data base files used and produced by SELECT is compatible with other methods of data storage and display.

## CHAPTER VII

### ENVIRONMENTAL GEOLOGIC CONSIDERATIONS

#### FOR SPECIAL LAND USES

Each land use has a range of environmental conditions under which it can operate while avoiding serious environmental impacts that might limit the land for other uses. The acceptable range of environmental conditions may be very limited as is the case for establishing a sanitary landfill, or broad as in the construction of a house. In more cases than not economic factors are considered more important than environmental considerations in site selection. Where economic factors take precedent over environmental considerations an area may require extensive modifications of existing conditions and/or the acceptance of some degree of environmental degradation. This chapter defines environmental geologic requirements of site locations for sanitary landfills, construction sites, and septic tank sewage disposal systems.

#### Geologic Considerations for Sanitary Landfill Sites

A sanitary landfill is a system for disposing solid wastes material by burial in the ground in a manner that does not permit pollution of the surrounding environment. Landfill operations include: excavation of trenches, the transport of fill material and the spreading, compaction, and covering of waste material with soil on a daily basis. Basic site requirements for landfills include: adequate thicknesses of residuum that can be worked in wet or dry conditions; an area of sufficient size

to handle waste over a long period of time; reasonable accessibility to waste sources; and the absence of any geologic or hydrologic conditions which would promote the spread of pollution.

Relief and slope are the most important elements of topography for site selection considering erodability and stability (with respect to gravity movements) of the lands' surface. Areas of high relief are more subject to effects of surface erosion and gravity movements than areas of low relief; however, even in areas of low relief where slopes are locally steep there is an increase in degradation. Sanitary landfill sites should be located in areas of low to moderate relief with gentle to moderate slopes (15% or less), in order to minimize the risk of gravity movements, reduce the amount of erosion, and insure safe conditions for operation of equipment on the site.

Hydrology is also important in site selection for landfills. Without adequate evaluation and planning, water supplies, could become polluted by waste products from these sites. To limit possible pollution of surface waters the following requirements/restrictions should be considered in site selection:

1. Sites in flood prone areas should not be considered due to possible removal of fill material and leachates from the landfill by flood waters.
2. Maximum separation of landfill sites and surface water bodies is necessary to allow for infiltration of any surface runoff from the landfill; and the landfill should be located and constructed in such a manner that slope-wash is minimum

and the only water which enters the landfill is that precipitation which falls directly on the site.

Groundwater contamination occurs when landfill leachates reach ground water supplies without adequate filtration. To prevent contamination adequate thicknesses of residuum (the thickness being dependent on type and condition of the material) must be present to isolate landfill leachates from groundwater supplies. Because purification takes place in the zone of aeration through the processes of; ion-exchange, complexing, aerobic bacterial actions, and absorption-adsorption (Miller, et al., 1972), it is necessary to locate landfills in soils of low permeability to allow maximum time for purification of leachates. Residuum with moderate to high clay content, thus low permeability, is desirable; however, the clay content must not be so high that the material becomes unworkable in wet weather. Other desirable properties of the residuum for a landfill site include compactability, homogeneous composition, and the absence of large "loose" blocks or rock.

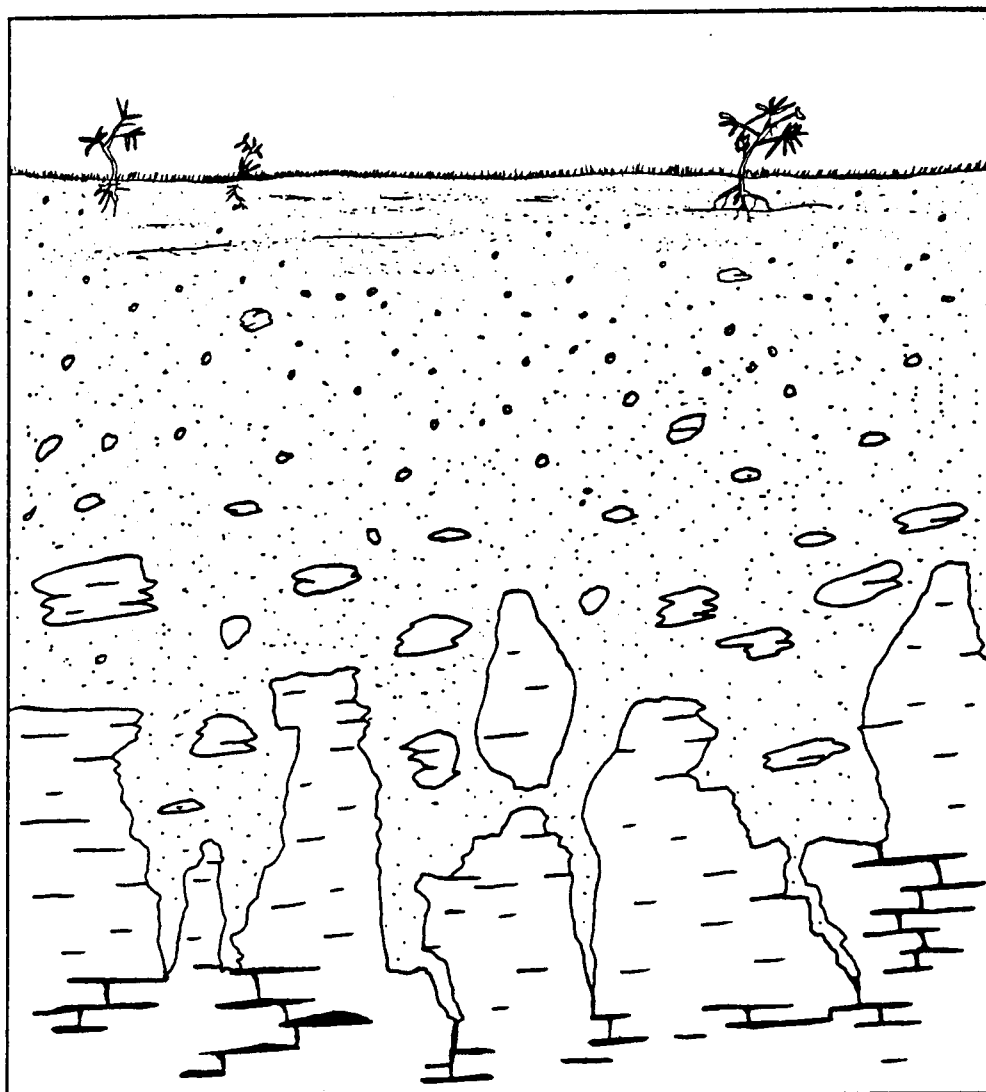
Area which contain sinkholes, highly permeable residuum, or other zones of high permeability such as sand or gravel beds, must be avoided as these conditions could provide direct access for the movement of landfill leachates into groundwater supplies. Those sections of the study area underlain by shales are unsuitable for landfill sites due to good hydrologic properties of the shale formations and the thin soils developed over them.

The nature of the underlying bedrock is also a major factor in establishing a sanitary landfill. When potential landfill sites are underlain by carbonate bedrock, cutter and pinnacle development (Figure 15) at the residuum-bedrock contact is a limiting factor for excavation. Although most of the study area is underlain by carbonate bedrock, the residuum is generally of sufficient depth to allow for landfill excavations. Waste material should never be placed directly on the bedrock surface as openings (joints, fractures, solution channels, etc.) may provide direct access for movement of leachates into the zone of saturation. Miller and Maher (1972) recommend a minimum of 3 meters (10 feet) of undisturbed residuum be left over bedrock belonging to the Knox Group. Generally this thickness of soil will remove enough readily decomposed organics and coliform bacteria to make the leachate bacteriologically safe (Brunner and Keller, 1971).

#### Geologic Considerations for Septic Tank Sewage Disposal Systems

Sites for septic tank disposal systems require soil and slope conditions under which the effluent can be absorbed and filtered before entering ground or surface waters.

How well a septic tank system functions is largely dependent on soil permeability. Permeability must be high enough for effluents to be dispersed by the system without saturating the soil. Soil texture (the relative proportions of individual sand, silt, and clay particles in the soil mass) is the main determinate of soil permeability, with soil structure and consistency as subordinate factors. Based on texture



Nominal Scale  
0 5 10 meters

Figure 15. Idealized cross section of cutter and pinnacle development.



alone, high clay content generally results in soils of low permeability while permeability of sandy soil is relatively high. Soils with low permeabilities where the absorption rate is greater than or equal to 75 minutes per inch (such as those developed over shales in the Athens area) are unsuitable for subsurface disposal (Buntley, 1976).

Slope of the land is important to both construction, and efficient operation of the disposal system. On slopes steeper than 15% operation of a septic tank system is severely impaired, on 8-15% slopes the configuration of the absorption field may require modification to insure good operation, while 0-8% slopes generally presented no limitation.

Hydrologic factors are important both for efficient operation of the disposal system and in preventing pollution of water supplies. Location of the water table with respect to the absorption field trenches influences the movement and filtration of the effluent. If the water table rises to or above the level of the drain tile of the absorption field the saturated soil cannot absorb effluent. Likewise, when flooding occurs the soil is saturated and can not absorb the effluent, thus flood prone areas should not be considered for this application.

In areas where bedrock lies close to the surface insufficient soil may be present to filter the effluent which may enter the groundwater supply at the bedrock-residuum contact or through joints or fracture in the bedrock. Bender (1971) recommends a minimum of 4 feet of soil between the bottom of the absorption field trenches and bedrock. Consequently, those parts of the study area where the bedrock

is less than 2 meters below the surface (such as those underlain by shale) are not suitable for septic tank sewage disposal systems.

#### Geologic Consideration for Construction

In selecting construction sites two prime considerations are surface stability and the absence of flood potential. The areas which lie on a flood plain which would be inundated by a 100 year flood, present severe limitation as construction sites. Surface stability is determined by a number of parameters including soils, lithology, slope, and structure. In the study area there are no soils with high shrink-swell potential, and no active faults or other similar structural hazards. However, the presence of steep slopes and an irregular residuum-bedrock contact where limestone occurs do affect the surface stability and degree of difficulty for foundation construction.

An even bedrock-residuum contact is considered ideal; however, in the study area cutter and pinnacle development has occurred to various degrees on the carbonate bedrocks which underlie the majority of the area. With intense urban development foundations are deep and highrise structures must be anchored in bedrock, if cutter and pinnacle development is encountered in excavation for foundations uneven load distribution could result (Miller, 1973). Residential and associated developments require only shallow foundations therefore only in areas of shallow lying pinnacles (less than 2 meters) would any serious foundation construction problems exist. Intense weathering of the carbonate bedrock has produced deep residuum in most of the study

area; however, on steep slopes (15% or higher) the residuum has been thinned by erosion thus pinnacles may lie near the surface.

Thin soils and higher likelihood of gravity movements make residential developments on steep slopes expensive and difficult to maintain, while slopes ranges of 0-8% and 9-15% are generally satisfactory. Site selection for intense urban construction is similar to that for residential construction but requires areas of maximum stability where the amount of materials which have to be moved (blasted or dug) is minimal. Under these restrictions areas with slope ranges greater than 15% must be ruled out, slopes in the 8-15% range classified as marginal (due to the amounts of material which would have to be moved), and 0-8% slope range areas should contain the best sites.

It should be noted that road construction will require some blasting with cuts made through most hills, thus good route planning and a thorough geologic survey are necessary to minimize construction cost.

## CHAPTER VIII

### SPECIFIC LAND USE MAPS BASED ON ENVIRONMENTAL GEOLOGIC DATA

This chapter deals with the construction of geologic hazard maps as an initial survey of land within the study area for use as: sanitary landfills, general construction sites, and septic tank sewage disposal system sites. Through application of the program SELECT, environmental geologic requirements for each land use as discussed in Chapter VII are applied to generate individual land use maps. A brief description of the data values used to generate each map is given in the following paragraphs, together with an explanation as to why the particular values were chosen to represent the criteria specified in Chapter VII.

Three matrices in the data base were used to generate all maps. A slope base map (Figure 16) was digitized from 7.5 minute topographic map (U.S. Geological Survey, 1964) of the Athens Quadrangle, by the evaluation of contour line spacing. The "hydrologic" base map (Figure 17) was digitized from TVA Flood Hazard Boundary maps (1978) which show areas which would be inundated by 100 year floods. Bedrock geology was taken from Rodgers (1952) Geologic Map of the Athens Quadrangle. A figure of the digitized base map is not shown (due to size limitation and the number of formations); however, a lithologic map (Figure 12, page 63), generated from this data is used as a source for generating the land use maps.

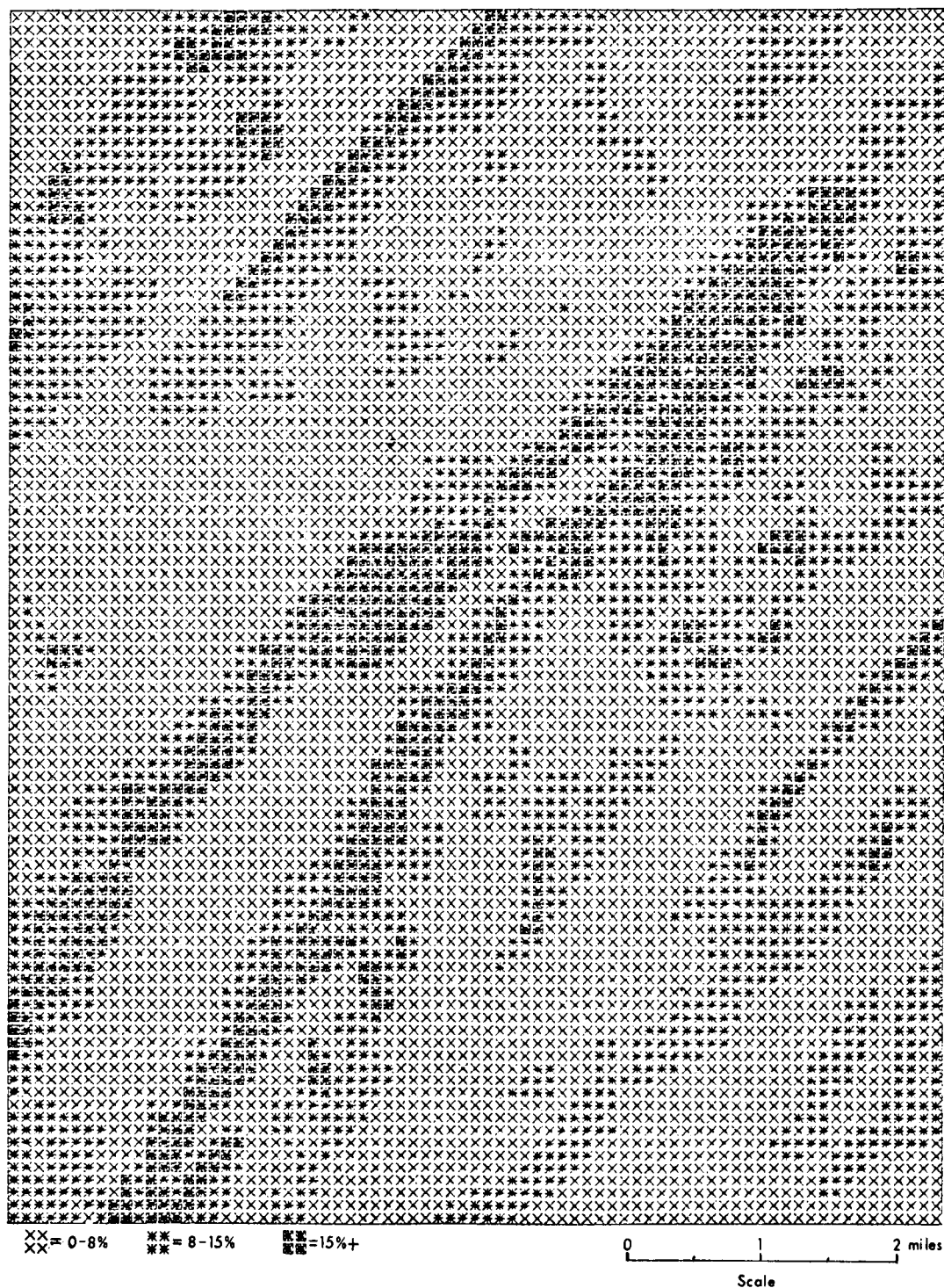


Figure 16. Computer generated slope map of the Athens quadrangle.

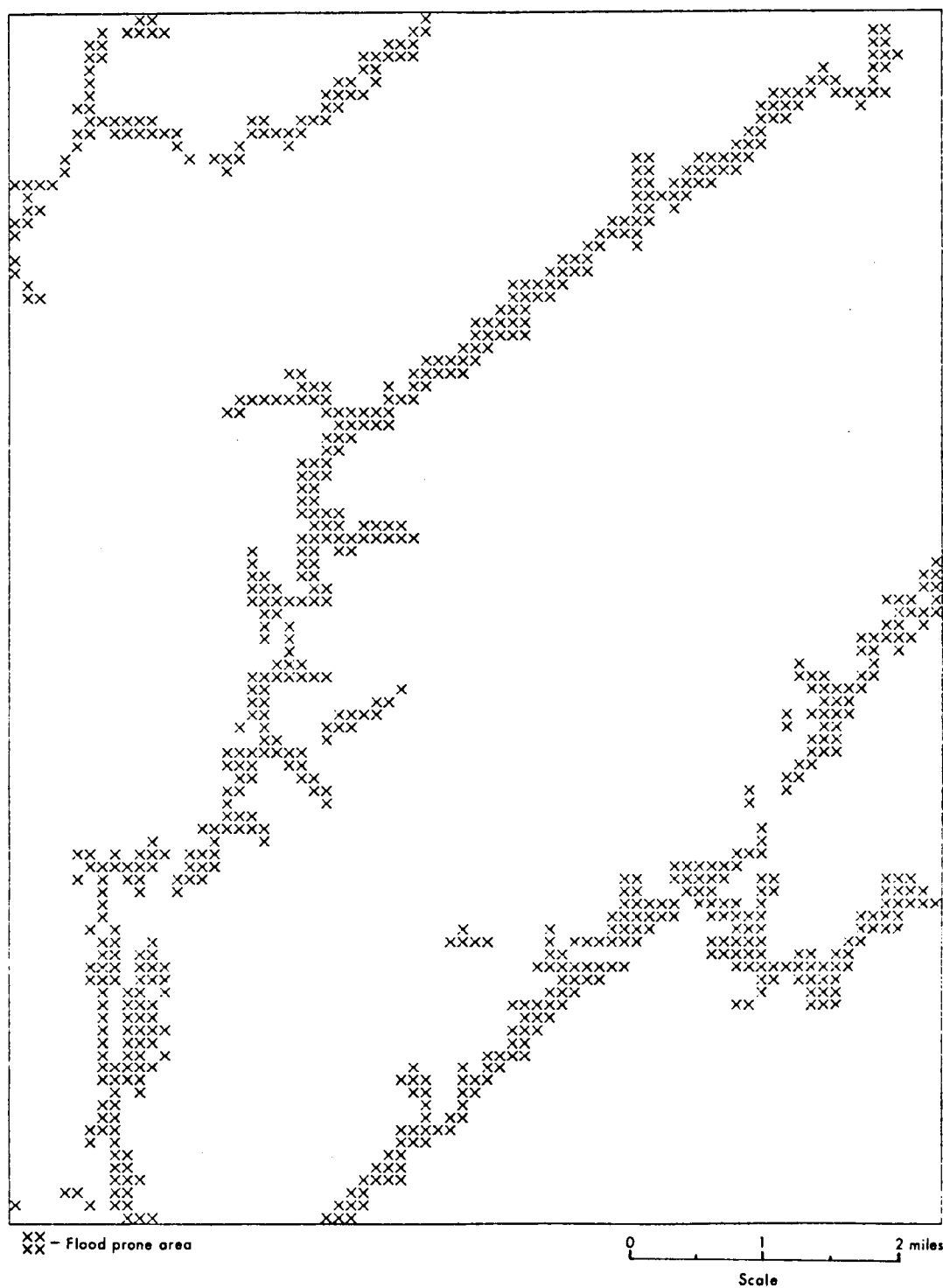


Figure 17. Computer generated map of sections of the Athens quadrangle which would be inundated by a 100 year flood.

A land use map for potential sanitary landfill sites is shown in Figure 18. Slope value ranges used from the slope base map are: 0-8% slopes classed as acceptable, 8-15% slopes classed as marginal, and 15% and greater as unacceptable for this land use. On the hydrologic base map the value for areas which may be inundated by a 100 year flood are classed as unacceptable, with nonflood prone areas acceptable. From the lithologic map, areas underlain by shale are classed as unacceptable, and areas underlain by limestones and dolomites (combined for this map) are acceptable. Although no soil base map was used in this evaluation for reasons stated earlier, a soils "interpretation" can be made from available data. Because soil types in this area are primarily dependent upon parent material inferences about soil types can be made from the lithologic map. The soils developed on shale are not suited for landfills therefore, these areas are classed as unacceptable. The same "interpretative" technique can be used to eliminate areas of cutter-pinnacle development (near surface). Soils over the carbonate bedrocks are generally deep except where subjected to rapid erosion as on steep slopes. Therefore, slopes of 15% and greater (underlain by carbonate bedrock) are interpreted as areas of possible near surface cutter and pinnacle development and classed as unacceptable.

Foundation stability and potential flood hazards were the criteria used for selecting construction sites. Flood prone areas were classed as unacceptable, with nonflood prone areas acceptable. For residential construction sites (Figure 19) areas of 15% and greater slope are unacceptable, while 0-8% and 8-15% slope ranges are acceptable. For

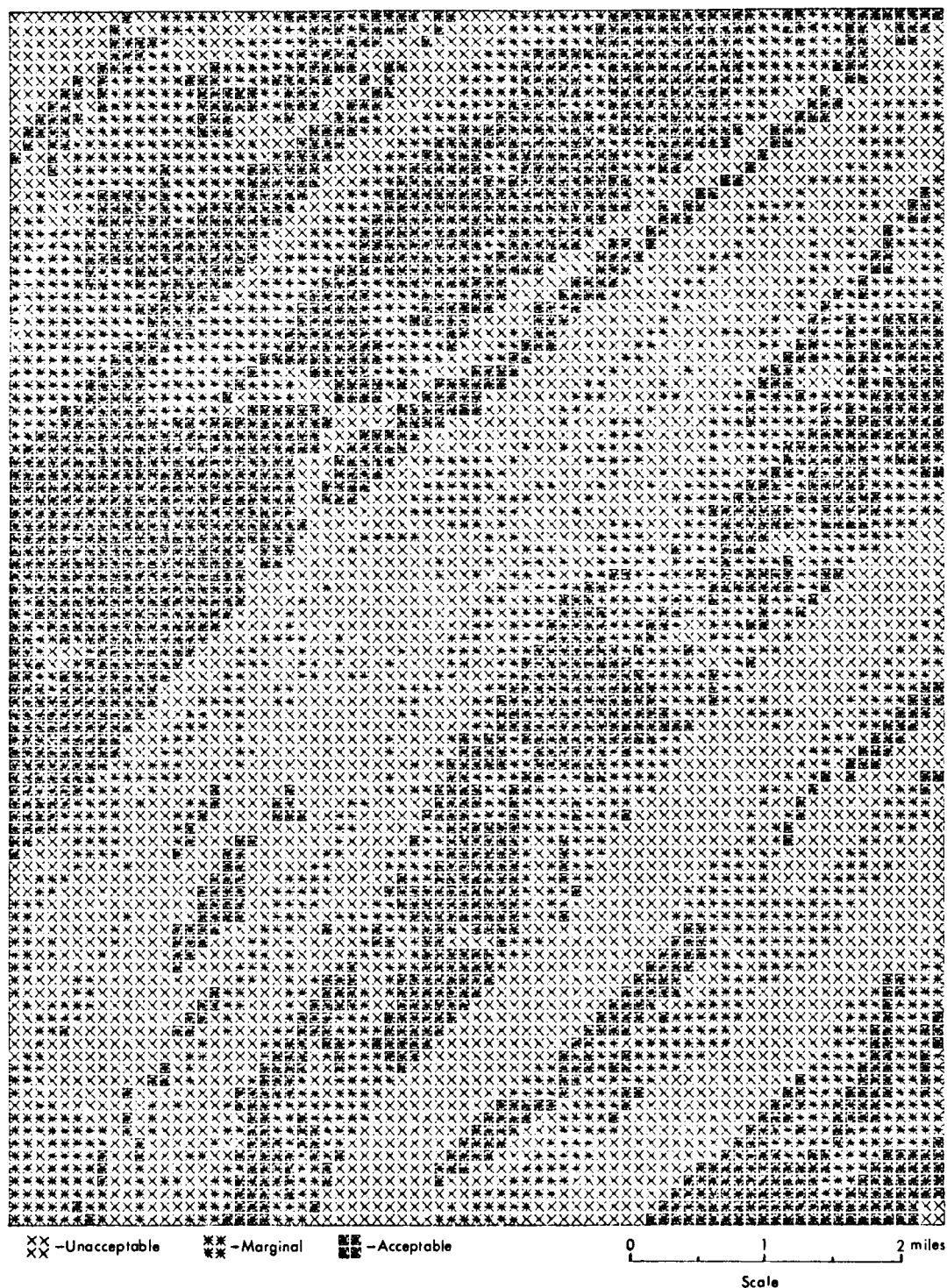


Figure 18. Computer generated map of potential sanitary landfill sites, Athens quadrangle, Tennessee.





Figure 19. Computer generated map of potential residential construction sites, Athens quadrangle, Tennessee.

urban construction (Figure 20) 15% and greater slope is also classed as unacceptable, and 8-15% slopes are marginal (due to potential excavation problems), while 0-8% slopes are acceptable.

Sites for septic tank disposal systems require soils of sufficient depth and permeability for absorption and filtration of effluent. The shallow soils of low permeability developed in areas underlain by shales are classed as unacceptable. Slopes in the 15% and greater range are unacceptable, 8-15% slopes are marginal (due to potential shallow depth to bedrock), while 0-8% slope are acceptable. As the same values have been chosen for sanitary landfills the same map (Figure 18) would be produced for septic tank disposal system sites.

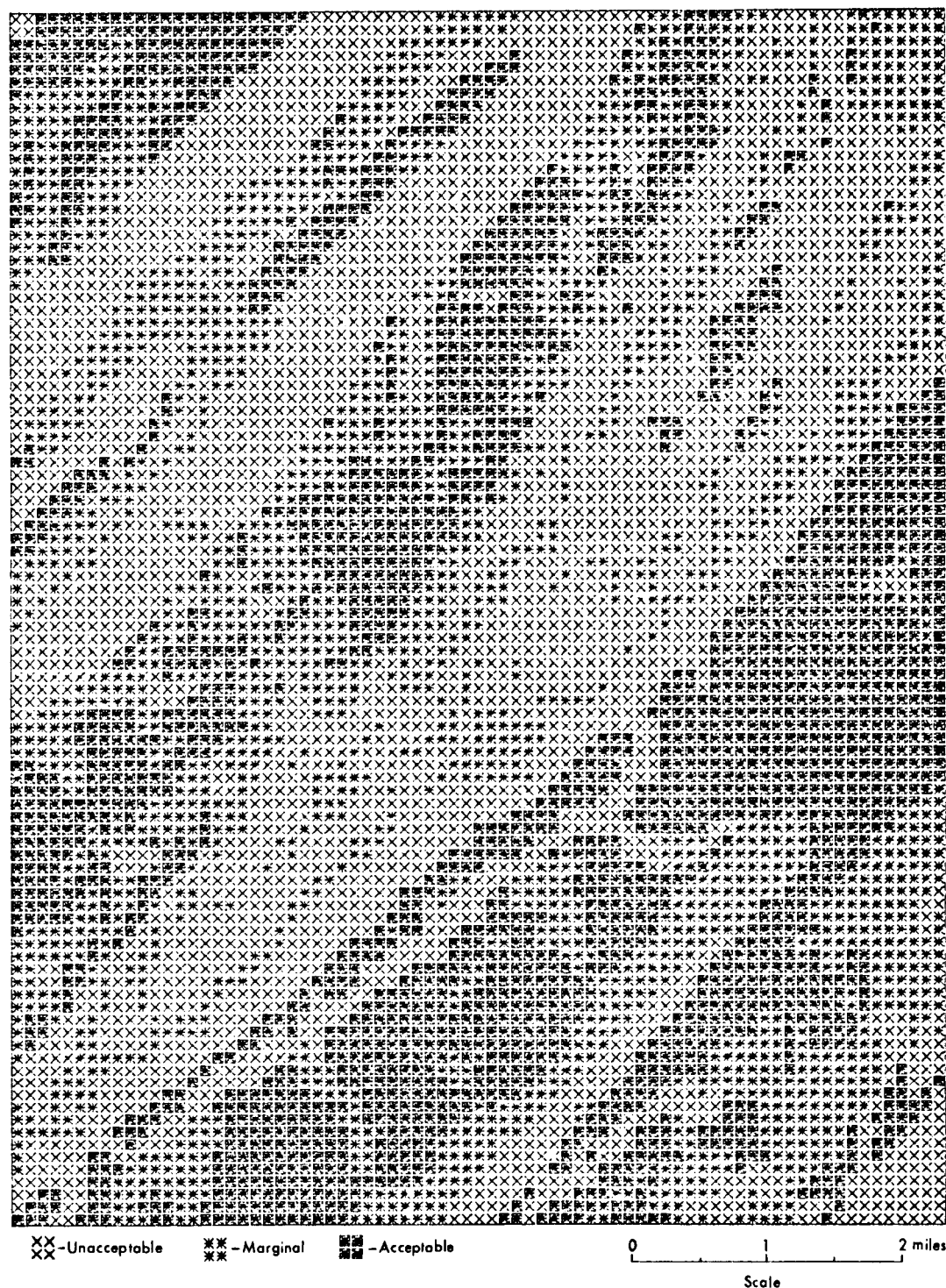


Figure 20. Computer generated map of potential urban construction sites, Athens quadrangle, Tennessee.

## CHAPTER IX

### SUMMARY

Land use maps were generated from a data base of geologic, hydrologic, and topographic, information on the Athens quadrangle. The data base was drawn from various sources of existing information after an initial study of the bedrock geology, hydrology and soils of the area. The program SELECT was written to extract information from the data base and arrange it in a readily comprehensible format. In using SELECT the user indicates which data are to be used to generate each land use map. Various options are available to the user for combining any mixture of data elements, including data from previously generated maps. As a test of the system specific land use maps of the Athens area were produced using criteria established in this study for: sanitary landfills, general construction sites, and septic tank disposal system sites. Through the use of this system the user can produce a graphic representation of combined geologic, hydrologic and topographic data elements which would be difficult to visualize by viewing individual maps.

### Conclusions

This study demonstrates the viability of the data base system for storing and manipulating environmental geologic data. Land use maps generated with the system provide the user with a good initial survey of the location and areal extent of areas potentially suitable for a

proposed land use. The system appears viable for application on a state wide basis using the 7.5 minute quadrangle as the base unit.

Advantages of the data base system include: the system's ability to store large volumes of information and manipulate it with great speed, at a small fraction of the cost of manual systems; the availability of data to users at a number of separate locations through the use of remote computer terminals; and a graphic presentation formatted in a style which allows nongeologically oriented viewers to readily distinguish areas of suitability and unsuitability on the land use maps. The advantages of data handling capacity and cost effectiveness are achieved only if the system is operated on a large scale and used sufficiently to justify the initial cost of establishing the system.

Disadvantages inherent with the data base system include: the requirement to prescale data, to match the base unit used in the data base prior to digitization of new information; the initial cost in terms of computer time and man-hours to digitize data upon the establishment of the systems; and the limitations of data resolution mostly imposed by time required for digitization, and the amount of computer time required to handle greater amounts of data.

A major problem encountered in the course of this study was the noncompatibility of soil data for integration into the data base. Although a number of approaches were tried, the numerous different soils present and their highly variable areal extents made digitization in a format compatible with the data base unworkable.

A number of minor problems were encountered in the digitization of information into the data base. The first problem encountered was the absence of a digitization program at The University of Tennessee Computer Center. This difficulty was overcome by borrowing a program from David Callahan (a graduate student at the school of Architecture). After digitization, a number of errors were found in the matrices in the data base, but this problem was readily corrected by using a grid overlay to check the original maps against the matrices in the data base.

## BIBLIOGRAPHY

## BIBLIOGRAPHY

- Algermissen, S. T., 1969, Seismic Risk Studies in the United States. U.S. Dept. Commerce, Environmental Science Service Administration, p. 20.
- Bacon, S. R., 1957, Soil Survey, McMinn County Tennessee. U.S. Dept. Agriculture, Soil Conservation Service, Series 1948, No. 4.
- Bell, F. F., 1976, Plant and Soil Science 2130. Dept. Plant and Soil Science, The University of Tennessee, Knoxville.
- Bender, W. H., 1971, Soils and Septic Tanks. U.S. Dept. Agriculture Soil Conservation Service Agriculture Information Bull. 349.
- Brunner, E. R., and Keller, D. J., 1971, Sanitary Landfill Design and Operation. Environmental Protection Agency Report SW-65ts, p. 53-54.
- Buntley, G. J., 1976, Soil Factors Affecting the Operation of Septic Tank Sewage Disposal Systems. Agricultural Extension Service Publication 739, The University of Tennessee, Knoxville.
- DeBuchananne, G. D., and Richardson, R. M., 1956, Ground Water Resources of East Tennessee. Tenn. Div. Geology, Bull. 58, Part 1.
- Environmental Protection Agency, 1975, Bradley-McMinn Counties 201 Wastewater Facilities Plan. E.P.A. Project No. C470347, Hiwassee Utilities Commission.
- Flawn, P. T., 1970, Environmental Geology. Harper and Row, New York.
- Federation of Rocky Mountain States Inc., 1977, Comparison of Selected Operational Capabilities of Fifty Four Geographic Information Systems. FRMS Technical Report 2.2. Information Systems Technical Laboratory, FRMS, Fort Collins, Colorado.
- Geological Survey of Alabama, 1971, Environmental Geology and Hydrology Madison County, Alabama. Geol. Survey Alabama, Atlas Series 1.
- Hershey, R. E., and Maher, S. W., 1963, Limestone and Dolomite Resources of Tennessee. Tenn. Div. Geology, Bull. 65.
- Hughes, G. M., 1972, Hydrogeologic Considerations in the Siting and Design of Landfills. Illinois State Geol. Survey, Environmental Geology Notes No. 51.
- Hollenbeck, R. P., and Tyrrell, M. E., 1969, Ceramic Evaluation of Clays and Shales of East Tennessee. Tenn. Div. Geology, Report of Investigation No. 25.



- Kellberg, J. M., 1973, Engineering Geology of Knox County, Tennessee. Tenn. Div. Geology, Bull. 70, p. 82-93.
- McHarg, I. L., 1971, Design with Nature. Doubleday & Company, Inc., New York.
- Miller, R. A., and Maher, S. W., 1972, Geologic Evaluation of Sanitary Landfill Sites in Tennessee. Tenn. Div. Geology, Environmental Geol. Series No. 1.
- \_\_\_\_\_, 1973, Environmental Geologic Summary of the Kingston Springs Quadrangle, Tennessee. Tenn. Div. Geology, Environmental Geol. Series No. 2.
- Rodgers, J., 1953, Geologic Map of East Tennessee with Explanatory Text. Tenn. Div. Geology, Bull. 58, Part II, p. 46-97.
- \_\_\_\_\_, 1952, Geologic Map of the Athens Quadrangle, Tennessee. U.S. Geol. Survey.
- Smith, M. O., 1976, Stratigraphy and Structure of the Middle Ordovician Rocks in the Vicinity of Calhoun, McMinn County Tennessee. Unpublished doctoral dissertation, The University of Tennessee, Knoxville.
- Swingle, G. D., 1959, Geology, Mineral Resources, and Ground Water of the Cleveland Area, Tennessee. Tenn. Div. Geology, Bull. 61.
- Thornbury, W. D., 1969, Principles of Geomorphology, 2nd Ed. John Wiley & Sons, Inc., New York.
- U.S. Dept. Agriculture, Soil Conservation Service, 1968, An Appraisal of Potentials for Outdoor Recreational Development in McMinn County, Tennessee.
- U.S. Dept. Housing and Urban Development, Federal Insurance Administration, 1977, Flood Hazard Boundary Map (1-6) McMinn County, Tennessee UNINC. Areas.
- \_\_\_\_\_, 1978, Flood Insurance Study City of Athens, Tennessee, McMinn County, with Maps 2, 3, and 5.
- Tennessee Valley Authority, 1957, Floods on Oostanula Creek in Vacinity of Athens, Tennessee. TVA Div. Water Control Planning, Report No. 0-5637 and Supplement No. 1.
- \_\_\_\_\_, 1964, Chestuee Creek Water Shed Project Evaluation Report. TVA Office of Tributary Area Development.

Tennessee Dept. of Conservation, Div. Water Resources, 1978, Well and Spring Data for McMinn County, p. 102-103.

Tennessee Dept. Public Health, Div. Water Quality Control, 1975, Water Quality Management Plan for the Lower Tennessee River Basin, p. 39-184.

Wermund, E. G., 1974, Approaches to Environmental Geology. University of Texas, Austin.

Wiethe, J. D., 1972, The Environmental Geology of the Maryville Quadrangle. Unpublished masters thesis, The University of Tennessee, Knoxville.

Wood, H. O., and Neumann, F., 1931, Modified Mercalli Intensity Scale of 1931. Seismol. Soc. America Bull., v21, p. 277-283.

Wolman M. G., and Schick, P. A., 1967, Effects of Construction on Fluvial Sediments, Urban and Suburban Areas of Maryland. Water Resources Research v. 3, p. 451-462.

## APPENDICES

## APPENDIX A

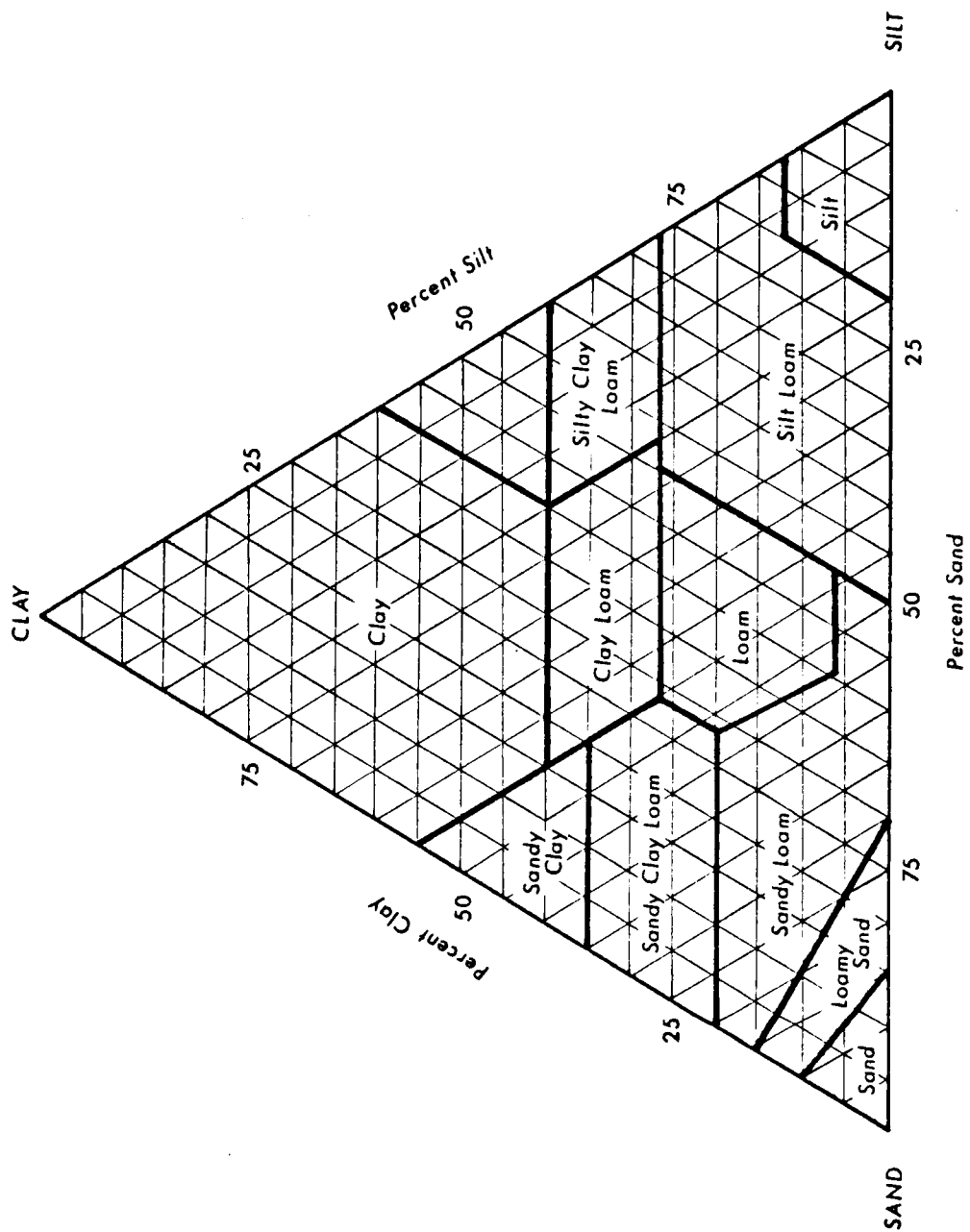


Figure 21. Soil Texture Classification (from Bell, 1976).

## SOIL DRAINAGE CLASSES

Very Poorly Drained. -- Water is removed from the soil so slowly that the water table remains at or on the surface the greater part of the time. Soils of this drainage class usually occupy level or depressed sites and are frequently ponded.

Poorly Drained. -- Water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly at or near the surface during a considerable part of the year. Poorly drained conditions are due to a high water table, to a slowly permeable layer within the profile, to seepage, or to some combination of these conditions. Poorly drained soils may be light gray from the surface downward, with or without mottlings. In places, poorly drained soils have slightly thickened dark-colored surface layers. (Henry, Waverly, Melvin and Guthrie).

Somewhat Poorly Drained. -- Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Imperfectly drained soils commonly have a slowly permeable layer within the profile, a high water table, additions through seepage, or a combination of these conditions. Somewhat poorly drained soils are uniformly grayish, brownish, or yellowish, in the upper A B and C horizons. In places, somewhat poorly drained soils have thick, dark A horizons, high in organic matter, and faint evidences of gleying immediately beneath the A horizon. (Johnsburg, and Lawrence)

Moderately Well Drained. -- Water is removed from the soil somewhat slowly, so that the profile is wet for a small but significant part of the time. Moderately well drained soils commonly have a slowly permeable layer within or immediately beneath the solum, a relatively high watertable, additions of water through seepage, or some combination of these conditions. Moderately well drained soils have uniform colors in the A horizons and upper B horizons, with mottling in the lower B and in the C horizons. In places, profiles have thick, dark A horizons and yellowish or grayish faintly mottled B horizons. (Grenada, Tilsit)

Well-Drained. -- Water is removed from the soil readily but not rapidly. Well-drained soils are commonly intermediate in texture, although soils of other textural classes may also be well drained. Well-drained soils are free of mottlings (except for fossil gley), and horizons may be brownish, yellowish, grayish, or reddish. They may be mottled deep in the C horizon or below depths of several feet. Well drained soils commonly retain optimum amounts of moisture for plant growth after rains or additions of irrigation water. (Baxter, Decatur, Memphis, Ruston and Vicksburg)

Somewhat Excessively Drained. -- Water is removed from the soil rapidly. Some of the soils are shallow and stony. Many of them have little horizon differentiation and are sandy and very porous. Somewhat excessively drained types are free of mottling throughout the profile and are brown, yellow, gray, or red. (Bruno, Eustis, and Ramsey)

Excessively Drained. -- Water is removed from the soil very rapidly. Excessively drained soils are commonly shallow or stony, and may be steep, very porous, or both. Shallow soils on slopes may be excessively drained. (Bruno, Crevasse)

## APPENDIX B





```

213      WRITE (3,230) ((GEO(I,J),J=1,40),I=1,96)
      WRITE (3,231) ((GEO(I,J),J=41,75),I=1,96)
      DO 20 J=1,96
      IF (SL(I,J).EQ.X.AND.HY(I,J).NE.Y.AND.GEO(I,J).NE.Z)
      IFS (I,J)=1
      IF (HY(I,J).EQ.Y.AND.SL(I,J).NE.X.AND.GEO(I,J).NE.Z)
      IFS (I,J)=2
      IF (GEO(I,J).EQ.Z.AND.SL(I,J).NE.X.AND.HY(I,J).NE.Y)
      IFS (I,J)=3
      IF (SL(I,J).EQ.X.AND.GEO(I,J).EQ.Z.AND.HY(I,J).NE.Y)
      IFS (I,J)=4
      IF (SL(I,J).EQ.X.AND.HY(I,J).EQ.Y.AND.GEO(I,J).NE.Z)
      IFS (I,J)=5
      IF (GEO(I,J).EQ.Z.AND.HY(I,J).EQ.Y.AND.SL(I,J).NE.X)
      IFS (I,J)=6
      IF (SL(I,J).EQ.X.AND.HY(I,J).EQ.Y.AND.GEO(I,J).EQ.Z)
      IFS (I,J)=7
      IF (SL(I,J).NE.X.AND.HY(I,J).NE.Y.AND.GEO(I,J).NE.Z)
      IFS (I,J)=8
      CONTINUE
      WRITE (5,216)
      FORMAT (10) 'WOULD YOU LIKE A HAND COPY OF THE MAP (MATRIX)
      1 RESULTING FROM THE VALUES YOU JUST SELECTED ??
      1 ** ANSWER YES OR NO **
      READ (5,101) YES
      IF (YES.EQ.N) GOTO 218
      WRITE (3,230) ((RES(I,J),J=1,40),I=1,96)
      WRITE (3,231) ((RES(I,J),J=41,75),I=1,96)
      FORMAT (1A,40F3.0)
      FORMAT (1A,35F3.0)
      OPEN (UNIT=23,FILE=MAPS(55),ACCESS='SEQUENT')
      WRITE (23,220) ((RES(I,J),J=1,75),I=1,96)
      FORMAT (75F3.0)
      CLOSE(UNIT=23)
      FLAG=FLAG+1
      SS=SS+1
      IF (FLAG.EQ.5) GOTO 600
      GO TO 124
      STOP
      TT=0
      FLAG=0
      GO TO 735
      WRITE (5,765) FLAG,CATMAP(TT)
      FORMAT (10) 'YOU HAVE CREATED',12,' MAP(S), AND STORED THEM
      1 IN YOUR FILE.',10 ' THE LAST ONE UNDER THE NAME OF',A9,'.'
      1 DO YOU WANT TO CREATE ANOTHER MAP (THE MAXIMUM NUMBER YOU
      1 CAN STORE IS 5) ** ANSWER YES OR NO **
      READ (5,770) YES
      FORMAT (1A)
      IF (YES.EQ.N) GOTO 772
      GO TO 735
      WRITE (5,773)
      FORMAT (10) 'DO YOU WANT TO COMBINE SERIAL MAPS (NEWMAPS 1-4)
      1 IN TO ONE COMPOSIT MAP ??? ANSWER YES OR NO **
      READ (5,770) YES
      IF (YES.N) GOTO 955
      GO TO 745
      WRITE (5,783)
      FORMAT (10) 'ON WHICH MAP WOULD YOU LIKE TO CHANGE THE VALUES
213      WRITE (3,230) ((GEO(I,J),J=1,40),I=1,96)
214      WRITE (3,231) ((GEO(I,J),J=41,75),I=1,96)
215      DO 20 J=1,96
216      IF (SL(I,J).EQ.X.AND.HY(I,J).NE.Y.AND.GEO(I,J).NE.Z)
217      IFS (I,J)=1
218      IF (HY(I,J).EQ.Y.AND.SL(I,J).NE.X.AND.GEO(I,J).NE.Z)
219      IFS (I,J)=2
220      IF (GEO(I,J).EQ.Z.AND.SL(I,J).NE.X.AND.HY(I,J).NE.Y)
221      IFS (I,J)=3
222      IF (SL(I,J).EQ.X.AND.GEO(I,J).EQ.Z.AND.HY(I,J).NE.Y)
223      IFS (I,J)=4
224      IF (SL(I,J).EQ.X.AND.HY(I,J).EQ.Y.AND.GEO(I,J).NE.Z)
225      IFS (I,J)=5
226      IF (GEO(I,J).EQ.Z.AND.HY(I,J).EQ.Y.AND.SL(I,J).NE.X)
227      IFS (I,J)=6
228      IF (SL(I,J).EQ.X.AND.HY(I,J).EQ.Y.AND.GEO(I,J).EQ.Z)
229      IFS (I,J)=7
230      IF (SL(I,J).NE.X.AND.HY(I,J).NE.Y.AND.GEO(I,J).NE.Z)
231      IFS (I,J)=8
232      CONTINUE
233      WRITE (5,216)
234      FORMAT (10) 'WOULD YOU LIKE A HAND COPY OF THE MAP (MATRIX)
235      1 RESULTING FROM THE VALUES YOU JUST SELECTED ??
236      1 ** ANSWER YES OR NO **
237      READ (5,101) YES
238      IF (YES.EQ.N) GOTO 218
239      WRITE (3,230) ((RES(I,J),J=1,40),I=1,96)
240      WRITE (3,231) ((RES(I,J),J=41,75),I=1,96)
241      FORMAT (1A,40F3.0)
242      FORMAT (1A,35F3.0)
243      OPEN (UNIT=23,FILE=MAPS(55),ACCESS='SEQUENT')
244      WRITE (23,220) ((RES(I,J),J=1,75),I=1,96)
245      FORMAT (75F3.0)
246      CLOSE(UNIT=23)
247      FLAG=FLAG+1
248      SS=SS+1
249      IF (FLAG.EQ.5) GOTO 600
250      GO TO 124
251      STOP
252      TT=0
253      FLAG=0
254      GO TO 735
255      WRITE (5,765) FLAG,CATMAP(TT)
256      FORMAT (10) 'YOU HAVE CREATED',12,' MAP(S), AND STORED THEM
257      1 IN YOUR FILE.',10 ' THE LAST ONE UNDER THE NAME OF',A9,'.'
258      1 DO YOU WANT TO CREATE ANOTHER MAP (THE MAXIMUM NUMBER YOU
259      1 CAN STORE IS 5) ** ANSWER YES OR NO **
260      READ (5,770) YES
261      FORMAT (1A)
262      IF (YES.EQ.N) GOTO 772
263      GO TO 735
264      WRITE (5,773)
265      FORMAT (10) 'DO YOU WANT TO COMBINE SERIAL MAPS (NEWMAPS 1-4)
266      1 IN TO ONE COMPOSIT MAP ??? ANSWER YES OR NO **
267      READ (5,770) YES
268      IF (YES.N) GOTO 955
269      GO TO 745
270      WRITE (5,783)
271      FORMAT (10) 'ON WHICH MAP WOULD YOU LIKE TO CHANGE THE VALUES
740      WRITE (5,740) 0
      FORMAT (A4)
      IF (O.EQ.'GEO') MAP=1
      IF (O.EQ.'SLOP') MAP=2
      IF (O.EQ.'HYDR') MAP=3
      WRITE (5,781)
      FORMAT (10) 'HOW MANY CATEGORIES DO YOU WANT TO DIVIDE THIS
      1 MAP IN TO ??
      READ (5,785) N
      FORMAT (I2)
      DO 50 I=1,N
      WRITE (5,710) I
      FORMAT (10) 'HOW MANY VALUES DO YOU WANT IN CATEGORY',12)
      READ (5,785) M
      IF (M.EQ.0) GOTO 50
      TOUT(I)=M
      DO 40 R=1,M
      WRITE (5,721) R,I
      READ (5,725) XX(R,I)
      CONTINUE
      FORMAT (10) 'ENTER VALUE',12,' FOR CATEGORY',13)
      FORMAT (F3.0)
      CONTINUE
      IF (MAP.NE.2) GOTO 752
      OPEN (UNIT=50,FILE='SLOP.RAS',ACCESS='SEQUENT')
      READ (50,750) ((DAT(I,J),J=1,75),I=1,96)
      FORMAT (75F3.0)
      CLOSE (UNIT=50)
      GOTO 60
      IF (MAP.NE.1) GOTO 755
      OPEN (UNIT=51,FILE='GEO.RAS',ACCESS='SEQUENT')
      READ (51,750) ((DAT(I,J),J=1,75),I=1,96)
      CLOSE (UNIT=51)
      GOTO 60
      OPEN (UNIT=92,FILE='HYDR.RAS',ACCESS='SEQUENT')
      READ (52,750) ((DAT(I,J),J=1,75),I=1,96)
      CLOSE (UNIT=52)
      DO 70 I=1,96
      DO 70 J=1,75
      DO 70 T=1,U
      M=TOUNT(T)
      IF (DAT(I,J).EQ.XX(C,T)) RES(I,J)=T
      CONTINUE
      OPEN (UNIT=40,FILE='CATMAP(TT)',ACCESS='SEQUENT')
      WRITE (40,730) ((RES(I,J),J=1,75),I=1,96)
      CLOSE (UNIT=40)
      FORMAT (75F3.0)
      FLAG=FLAG+1
      TT=TT+1
      IF (FLAG.EQ.5) GOTO 745
      GO TO 720
      STOP
      UU=5
      FLAG=0
      GO TO 617
      WRITE (5,642) FLAG,MAPS(UU)
      FORMAT (10) 'YOU HAVE CREATED',12,' MAP(S), AND STORED THEM
      1 IN YOUR FILE.',10 ' THE LAST ONE UNDER THE NAME OF',A9,'.'
740      WRITE (5,740) 0
741      FORMAT (A4)
742      IF (O.EQ.'GEO') MAP=1
743      IF (O.EQ.'SLOP') MAP=2
744      IF (O.EQ.'HYDR') MAP=3
745      WRITE (5,781)
746      FORMAT (10) 'HOW MANY CATEGORIES DO YOU WANT TO DIVIDE THIS
747      1 MAP IN TO ??
748      READ (5,785) N
749      FORMAT (I2)
750      DO 50 I=1,N
751      WRITE (5,710) I
752      FORMAT (10) 'HOW MANY VALUES DO YOU WANT IN CATEGORY',12)
753      READ (5,785) M
754      IF (M.EQ.0) GOTO 50
755      TOUT(I)=M
756      DO 40 R=1,M
757      WRITE (5,721) R,I
758      READ (5,725) XX(R,I)
759      CONTINUE
760      FORMAT (10) 'ENTER VALUE',12,' FOR CATEGORY',13)
761      FORMAT (F3.0)
762      CONTINUE
763      IF (MAP.NE.2) GOTO 752
764      OPEN (UNIT=50,FILE='SLOP.RAS',ACCESS='SEQUENT')
765      READ (50,750) ((DAT(I,J),J=1,75),I=1,96)
766      FORMAT (75F3.0)
767      CLOSE (UNIT=50)
768      GOTO 60
769      IF (MAP.NE.1) GOTO 755
770      OPEN (UNIT=51,FILE='GEO.RAS',ACCESS='SEQUENT')
771      READ (51,750) ((DAT(I,J),J=1,75),I=1,96)
772      CLOSE (UNIT=51)
773      GOTO 60
774      OPEN (UNIT=92,FILE='HYDR.RAS',ACCESS='SEQUENT')
775      READ (52,750) ((DAT(I,J),J=1,75),I=1,96)
776      CLOSE (UNIT=52)
777      DO 70 I=1,96
778      DO 70 J=1,75
779      DO 70 T=1,U
780      M=TOUNT(T)
781      IF (DAT(I,J).EQ.XX(C,T)) RES(I,J)=T
782      CONTINUE
783      OPEN (UNIT=40,FILE='CATMAP(TT)',ACCESS='SEQUENT')
784      WRITE (40,730) ((RES(I,J),J=1,75),I=1,96)
785      CLOSE (UNIT=40)
786      FORMAT (75F3.0)
787      FLAG=FLAG+1
788      TT=TT+1
789      IF (FLAG.EQ.5) GOTO 745
790      GO TO 720
791      STOP
792      UU=5
793      FLAG=0
794      GO TO 617
795      WRITE (5,642) FLAG,MAPS(UU)
796      FORMAT (10) 'YOU HAVE CREATED',12,' MAP(S), AND STORED THEM
797      1 IN YOUR FILE.',10 ' THE LAST ONE UNDER THE NAME OF',A9,'.'

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1 DO YOU WANT TO CREATE ANOTHER MAP (THE MAXIMUM NUMBER YOU
1 CAN STORE IS 5) ** ANSWER YES OR NO ** )
READ (5,122) YES
FORMAT (A1)
IF (YES.EQ.'N') GOTO 616
WRITE (5,618)
FORMAT (' WHICH SUBSECTION OF THE STUDY AREA WOULD YOU LIKE
1 TO WORK WITH ??')
READ (5,620) F
FORMAT (I3)
WRITE (5,622)
FORMAT (' WOULD YOU LIKE TO CREATE A SPECIAL MAP(S) ON
1 WHICH SERIAL VALUES ARE COMBINED INTO NEW CATEGORIES ??
1 ** ANSWER YES OR NO **')
READ (5,624) YES
FORMAT (A1)
IF (YES.EQ.'Y') GOTO 800
WRITE (5,602)
FORMAT (' INPUT SLOPE VALUE (0-8% = 8.0-15% = 15.0 AND FOR 15% OR
1 GREATER THE VALUE IS 25.0)')
READ (5,603) X
FORMAT (F3.0)
WRITE (5,604) X
FORMAT (' THE SLOPE VALUE SELECTED IS',F4.0/' ** IS THAT
1 CORRECT ?? ANSWER YES OR NO **')
READ (5,605) YES
FORMAT (A1)
IF (YES.EQ.'N') GO TO 1
WRITE (5,607)
FORMAT (' INPUT HYDROLOGIC CRITERION (20.=FLOOD HAZARD AREA,
1 60.=NO FLOOD HAZARD)')
READ (5,603) Y
WRITE (5,608) Y
FORMAT (' THE HYDROLOGIC VALUE SELECTED IS',F4.0/' ** IS THAT
1 CORRECT ?? ANSWER YES OR NO **')
READ (5,605) YES
IF (YES.EQ.'N') GO TO 606
WRITE (5,610)
FORMAT (' INPUT GEOLOGIC CRITERION')
READ (5,603) Z
WRITE (5,611) Z
FORMAT (' THE GEOLOGIC CRITERION SELECTED IS',F4.0/' ** IS THAT
1 CORRECT ?? ANSWER YES OR NO **')
READ (5,605) YES
IF (YES.EQ.'N') GO TO 609
OPEN (UNIT=20,FILE=SLOPE,ACCESS='SEQUIN')
OPEN (UNIT=21,FILE=HYDRO,ACCESS='SEQUIN')
OPEN (UNIT=22,FILE=GEOLOG,ACCESS='SEQUIN')
READ (20,612) ((SLOP(I,J),J=1,25),I=1,24)
FORMAT (25F3.0)
READ (21,612) ((HYD(I,J),J=1,25),I=1,24)
READ (22,612) ((GEOLO(I,J),J=1,25),I=1,24)
CLOSE (UNIT=20)
CLOSE (UNIT=21)
CLOSE (UNIT=22)
DO 613 J=1,25
DO 613 I=1,24
IF (SLOP(I,J).EQ.X.AND.HYD(I,J).NE.Y.AND.GEOLO(I,J).NE.Z)
1 RESU (I,J)=1
IF (HYD(I,J).EQ.Y.AND.SLOP(I,J).NE.X.AND.GEOLO(I,J).NE.Z)
1 RESU (I,J)=2
IF (GEOLO(I,J).EQ.Z.AND.SLOP(I,J).NE.X.AND.HYD(I,J).NE.Y)
1 RESU (I,J)=3
IF (SLOP(I,J).EQ.X.AND.HYD(I,J).EQ.Z.AND.HYD(I,J).NE.Y)
1 RESU (I,J)=4
IF (SLOP(I,J).EQ.X.AND.HYD(I,J).EQ.Y.AND.GEOLO(I,J).NE.Z)
1 RESU (I,J)=5
IF (GEOLO(I,J).EQ.Z.AND.HYD(I,J).EQ.Y.AND.SLOP(I,J).NE.X)
1 RESU (I,J)=6
IF (SLOP(I,J).EQ.X.AND.HYD(I,J).EQ.Y.AND.GEOLO(I,J).EQ.Z)
1 RESU (I,J)=7
CONTINUE
GOTO 630
WRITE (3,614) ((RESU(I,J),J=1,25),I=1,24)
FORMAT (1X,40F3.0)
OPEN (UNIT=23,FILE=MAPS,ACCESS='SEQUIN')
WRITE (23,615) ((RESU(I,J),J=1,25),I=1,24)
FORMAT (25F3.0)
CLOSE (UNIT=23)
FLAG=FLAG+1
UU=UU+1
IF (FLAG.EQ.6) GOTO 616
GO TO 640
STOP
VV=1
FLAG=0
GO TO 888
WRITE (5,842) FLAG,SACMA(VV)
FORMAT (' YOU HAVE CREATED',I2,' MAP(S), AND STORED THEM
1 IN YOUR FILE.',I7) THE LAST ONE UNDER THE NAME OF',A7,'.'/'
1 DO YOU WANT TO CREATE ANOTHER MAP (THE MAXIMUM NUMBER YOU
1 CAN STORE IS 5) ** ANSWER YES OR NO ** )
READ (5,843) YES
FORMAT (A1)
IF (YES.EQ.'Y') GOTO 888
WRITE (5,846)
FORMAT (' DO YOU WANT TO COMBINE SERIAL MAPS INTO
1 ONE COMPOSITE MAP ?? ANSWER YES OR NO ** )
READ (5,843) YES
IF (YES.NE.'N') GOTO 960
GO TO 890
WRITE (5,802)
FORMAT (' WITH WHICH BASIC DATA MAP DO YOU WISH TO WORK ??
1 ** ANSWER SLOPE,HYDRO,OR GEOLO **')
READ (5,803) D
FORMAT (A5)
IF (D.EQ.'SLOPE') MAP=1
IF (D.EQ.'HYDRO') MAP=2
IF (D.EQ.'GEOLO') MAP=3
WRITE (5,801)
FORMAT (' HOW MANY CATEGORIES DO YOU WANT TO DIVIDE THIS
1 MAP IN TO ??')
READ (5,805) N
FORMAT (I2)
DO 90 K=1,N
DO 90 K=1,N
WRITE (5,810) K
FORMAT (' HOW MANY VALUES DO YOU WANT IN CATEGORY',I2)
READ (5,805) M
KOUNT (K)=M
DO 90 L=1,M

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95      WRITE (5,R20) L,K
820      READ (5,R25) XX(L,K)
825      CONTINUE
90      FORMAT (1, ENTER VALUE',12, FOR CATEGORY',13)
      FORMAT (F3.0)
      CONTINUE

      IF (MAP.NE.3) GOTO 821
      OPEN (UNIT=22,FILE=GEOL(F),ACCESS='SEQIN')
      READ (22,R30) ((GEOL(I,J),J=1,25),I=1,24)
      CLOSE (UNIT=22)
      GOTO 828

821      IF (MAP.NE.2) GOTO 822
      OPEN (UNIT=21,FILE=HYDRO(F),ACCESS='SEQIN')
      READ (21,R30) ((HYD(I,J),J=1,25),I=1,24)
      CLOSE (UNIT=21)
      GOTO 828

822      OPEN (UNIT=20,FILE=SLOPE(F),ACCESS='SEQIN')
      READ (20,R30) ((SLOP(I,J),J=1,25),I=1,24)
      CLOSE (UNIT=20)
      DO 80 I=1,24
      DO 80 J=1,25
      DO 80 K=L,N
      M=KOUNT (K)
      DO 80 L=1,M
      IF (MAP.NE.3) GOTO 826
      IF (GEOL(I,J).EQ.ZZ(L,K)) RESU(I,J)=K
      GOTO 80

826      IF (MAP.NE.2) GOTO 827
      IF (HYD(I,J).EQ.YY(L,K)) RESU(I,J)=K
      IF (SLOP(I,J).EQ.XX(L,K)) RESU(I,J)=K
      CONTINUE
      OPEN (UNIT=23,FILE=SMCAMA(V),ACCESS='SEQOUT')
      WRITE (23,R30) ((RESU(I,J),J=1,25),I=1,24)
      FORMAT (25X3.0)
      CLOSE (UNIT=23)
      FLAG=FLAG+1
      VV=VV+1
      IF (FLAG.EQ.6) GOTO 890
      GO TO 840

828      STOP
955      OPEN (UNIT=40,FILE=CATHAP(1),ACCESS='SEQIN')
      READ (40,92) ((HY(I,J),J=1,75),I=1,96)
      CLOSE (UNIT=40)
      FORMAT (75F3.0)
      OPEN (UNIT=40,FILE=CATHAP(2),ACCESS='SEQIN')
      READ (40,92) ((SL(I,J),J=1,75),I=1,96)
      CLOSE (UNIT=40)
      OPEN (UNIT=40,FILE=CATHAP(3),ACCESS='SEQIN')
      READ (40,92) ((GEQ(I,J),J=1,75),I=1,96)
      CLOSE (UNIT=40)
      DO 93 I=1,96
      DO 93 J=1,75
      IF (HY(I,J).EQ.1.AND.SL(I,J).EQ.1.AND.GEQ(I,J).EQ.1)
      1 RES(I,J)=40
      IF (HY(I,J).EQ.2.OR.SL(I,J).EQ.2.OR.GEQ(I,J).EQ.2)
      1 RES(I,J)=20
      IF (HY(I,J).EQ.3.OR.SL(I,J).EQ.3.OR.GEQ(I,J).EQ.3)
      1 RES(I,J)=0
      CONTINUE
      OPEN (UNIT=41,FILE='CONURR.MAP',ACCESS='SEQOUT')
      WRITE (41,94) ((RES(I,J),J=1,25),I=1,24)
      CLOSE (UNIT=41)
      STOP
      END

      WRITE (41,92) ((RES(I,J),J=1,75),I=1,96)
      CLOSE (UNIT=41)
      OPEN (UNIT=40,FILE='CONURR.MAP',ACCESS='SEQIN')
      READ (40,920) ((DAT(I,J),J=1,75),I=1,96)
      CLOSE (UNIT=40)
      FORMAT (75F3.0)
      STOP
      OPEN (UNIT=40,FILE=SMCAMA(6),ACCESS='SEQIN')
      READ (40,94) ((HY(I,J),J=1,25),I=1,24)
      CLOSE (UNIT=40)
      FORMAT (25F3.0)
      OPEN (UNIT=40,FILE=SMCAMA(7),ACCESS='SEQIN')
      READ (40,94) ((SL(I,J),J=1,25),I=1,24)
      CLOSE (UNIT=40)
      OPEN (UNIT=40,FILE=SMCAMA(8),ACCESS='SEQIN')
      READ (40,94) ((GFQ(I,J),J=1,25),I=1,24)
      CLOSE (UNIT=40)
      DO 94 I=1,24
      DO 94 J=1,25
      IF (HY(I,J).EQ.1.AND.SL(I,J).EQ.1.AND.GEQ(I,J).EQ.1)
      1 RES(I,J)=40
      IF (HY(I,J).EQ.2.OR.SL(I,J).EQ.2.OR.GEQ(I,J).EQ.2)
      1 RES(I,J)=20
      IF (HY(I,J).EQ.3.OR.SL(I,J).EQ.3.OR.GEQ(I,J).EQ.3)
      1 RES(I,J)=0
      CONTINUE
      OPEN (UNIT=41,FILE='COMPOS.MAP',ACCESS='SEQOUT')
      WRITE (41,94) ((RES(I,J),J=1,25),I=1,24)
      CLOSE (UNIT=41)
      STOP
      END

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## APPENDIX C

```

//FMAP JOB (42221,***** ,BINS,T-1),ALLEN,MSGLEVEL=(2,1)
//DSPPOOL EXEC FORTGCLG,GOREG=12RK
//FORT.SYSIN DD *
      DIMENSION Z(96,75),IRAY(664)
      DATA FIFTY/'50.'/
      DATA TWENTY/'20.'/
      DATA ZERO/' 0.'/
      READ (5,11) ((Z(I,J),J=1,75),I=1,96)
11    FORMAT (25A3)
      CALL PLOTS (IRAY,664,25.0)
      CALL FACTOR (0.40)
      YY=0.25
      XX=0.25
      YMAX=25
      XMAX=25
      HEIGHT=0.20
      Y=YMAX
      DO 20 I=1,96
      Y=Y-YY
      X=0
      DO 10 J=1,75
      ZZ=Z(I,J)
      IF (ZZ.EQ.FIFTY) GOTO 15
      IF (ZZ.EQ.TWENTY) GOTO 25
      IF (ZZ.EQ.ZERO) CALL SYMBOL (X,Y,HEIGHT,4,0.0,-1)
30    X=X+XX
10    CONTINUE
20    CONTINUE
      GO TO 35
15    CALL PLOT (X-0.1,Y-0.1,3)
      CALL PLOT (X+0.1,Y-0.1,2)
      CALL PLOT (X+0.1,Y+0.1,2)
      CALL PLOT (X-0.1,Y+0.1,2)
      CALL PLOT (X-0.1,Y-0.1,2)
      CALL PLOT (X-0.05,Y-0.05,3)
      CALL PLOT (X+0.05,Y-0.05,2)
      CALL PLOT (X+0.05,Y+0.05,2)
      CALL PLOT (X-0.05,Y+0.05,2)
      CALL PLOT (X-0.05,Y-0.05,2)
      CALL SYMBOL (X,Y,HEIGHT,11,0.0,-1)
      GO TO 30
25    CALL SYMBOL (X,Y,HEIGHT,11,0.0,-1)
      GO TO 30
35    CALL PLOT (-0.125,0.875,3)
      CALL PLOT (18.625,0.875,2)
      CALL PLOT (18.625,24.875,2)
      CALL PLOT (-0.125,24.875,2)
      CALL PLOT (-0.125,0.875,2)
      CALL PLOT (0.0,0.0,999)
      CALL EXIT
      END
//GO.PLOTTAPE DD SYSOUT=P
//GO.SYSIN DD *

```

## VITA

William T. Allen was born in Asheville, North Carolina on February 21, 1948. He graduated from J. H. Rose High School in Greenville, North Carolina, in 1967. He attended Western Carolina University from 1967 to 1970, at which time he joined the United States Air Force. In 1974 he was discharged from the Air Force and returned to Western Carolina University where he graduated in 1976 with a Bachelor of Science degree in Geology. He entered The University of Tennessee in September 1976 and graduated in March 1980 with a Master of Science degree in Geology.