ENVIRONMENTAL GEOLOGY SUMMARY OF THE KINGSTON SPRINGS QUADRANGLE, TENNESSEE

ENVIRONMENTAL GEOLOGY SERIES NO. 2

COVER PHOTO: Harpeth River Valley near Kingston Springs by Gary B. Pinkerton.

STATE OF TENNESSEE
DEPARTMENT OF CONSERVATION
DIVISION OF GEOLOGY
NASHVILLE, TENNESSEE
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By
ROBERT A. MILLER

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STATE OF TENNESSEE

WINFIELD DUNN, Governor

DEPARTMENT OF CONSERVATION

GRANVILLE HINTON, Commissioner

DIVISION OF GEOLOGY

ROBERT E. HERSHEY, State Geologist

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By
ROBERT A. MILLER[1]

ABSTRACT

The diverse nature of the geology, soils, and topography, and some aspects of the hydrologic regime of the Kingston Springs quadrangle will have an important impact on potential development there. Five geologic systems are present, having various lithologies and other characteristics relating to engineering, economic geology, and agriculture. The soils, closely related to rock types, are equally varied. Topography ranges from nearly flat flood plains and hilly areas along the Harpeth and South Harpeth rivers to rolling uplands of the Highland Rim, with intervening steep-sided ridges.

The principal limitations to development within the quadrangle are periodic flooding along the Harpeth and South Harpeth rivers and occasional flash-flooding of tributaries, and potentially unstable or inaccessable slopes.

INTRODUCTION

This environmental geology summary is the first of a new series to be published by the Tennessee Division of Geology. The Kingston Springs quadrangle was selected because of its proximity to rapidly expanding suburban areas to the east (e.g. Bellevue), and because of the diverse environmental factors which relate to potential development in the area. It is the purpose of this series to serve as a guide for planners and others concerned with zoning, construction, etc., through the presentation of certain basic data which will not only aid in design and construction, but will also emphasize certain important environmental limitations to development.

The Kingston Springs 7½ minute quadrangle is located in southwestern Davidson, northwestern Williamson, and southern Cheatham counties, approximately 20 miles west of Nashville. It has varied topography, ranging from nearly flat flood plains and hilly areas along the Harpeth and South Harpeth rivers to rolling uplands of the Highland Rim, with intervening steep-sided high ridges. Many of the steep-sloped areas are in forest growth, but the valley areas and uplands are agriculturally developed.

The diverse nature of the geology and soils makes the area unique. Five geologic systems (Ordovician, Silurian, Devonian, Mississippian, and Quaternary) are present, having various lithologies with characteristics relating to engineering, economic geology, and agriculture. The soils, closely related to rock types, are equally varied.

A good transportation system is present in an east-west direction. The quadrangle is crossed by Interstate 40, the Memphis-Nashville route of the Louisville and Nashville Railroad, U. S. Highway 70, and State Route 100. Vehicular movement is restricted in a north-south direction due to the numerous steep ridges.

Four small communities (Kingston Springs, Fairview, Pegram, and Linton) are present within or adjacent to the quadrangle; even so, the population of the quadrangle is small and development has been very limited. Westward urban expansion of the Nashville metropolitan area will, however, soon have an impact on the use of land in this area. It is therefore ideally suited for a land-use study at this time.

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ACKNOWLEDGMENTS

The writer thanks Professor Richard G. Stearns, Vanderbilt University, for his assistance in suggesting areas of emphasis and direction during the work on this report, which was a thesis program. His review of the manuscript and plates at various stages of completion are especially appreciated. Dr. C. W. Wilson, Jr., consulting geologist, Tennessee Division of Geology, accompanied the writer in the field and made helpful suggestions in all stages of the project. His advice and direction throughout the course of this project are most appreciated. Professor Arthur L. Reesman, Vanderbilt University, reviewed the manuscript and assisted through discussions on related geologic problems. Acknowledgment is also due Robert E. Hershey, State Geologist, for his approval of the project, helpful suggestions and review of the manuscript.

Robert Hinton and Carlie McCowan of the U. S. Soil Conservation Service made soil maps available to the writer and also interpreted soil data. This project could not have been completed without their assistance.

Data for the ground-water hydrology sections of this report were provided by the Tennessee Division of Water Resources. Michael J. Mallory and Frank M. Alexander field checked and compiled data on numerous wells in the area. Flood data were made available by the U. S. Army Corps of Engineers, Nashville District, and by the U. S. Soil Conservation Service. The writer thanks these agencies for their assistance. Other surface-water data were provided by George H. Woods of the U. S. Geological Survey. John M. Wilson, State Planning Office, reviewed the hydrologic aspects of the report and offered helpful suggestions. Ron Lederer, Metro Nashville Planning Commission, also reviewed the manuscript. The engineering firms of Barge, Waggoner, Sumner, and Cannon, Inc., and Hart, Freeland, and Roberts, Inc. provided the data for the compilation of the water districts on the water availability map.

ENVIRONMENTAL CONSIDERATIONS

Geology

The basic geologic units to be considered are: (1) unconsolidated alluvial deposits of the valley areas, (2) cherty Mississippian rocks of the upland areas (Fort Payne and Warsaw formations), and (3) pre-Fort Payne rocks (limestones, shales, mudstones, limy shales, and minor sandstone) restricted essentially to the valley and low hill areas. Only the major features of these units as they will bear on environmental considerations in construction and other activities are considered. The geologic map (pl. I) shows the distribution of these rocks. In addition to these units, structural features and economic geology are discussed.

Data related to certain basic engineering geology factors are given in the form of tables at the end of this section (tables 1 and 2, pages 8 and 9). Each rock unit that crops out in the quadrangle is individually rated as to suitability for both intense urban developments and residential and associated developments, since the environmental impact of certain rock features will necessarily vary from one land-use to another. The methodology used to derive these tables is also summarized.

ALLUVIAL DEPOSITS

These stream-deposited materials are the youngest within the quadrangle and may overlie rock units of any geologic age. The major deposits are present within the valleys of the Harpeth and South Harpeth rivers, principally on their flood plains, but older alluvium also veneers large areas within these valleys at elevations appreciably higher than the present flood plains. These higher deposits are ordinarily on old abandoned meander loops. All of the smaller valleys within the quadrangle contain alluvial deposits, but only those deposits of the Harpeth, South Harpeth, and lower valleys of their larger tributaries are shown on the geologic map. Soils maps, however, show in considerable detail the soil units derived from alluvium; they are mapped even in small valleys.

Although alluvium in this area is relatively thin, probably not exceeding 15 feet except where solution features such as enlarged joints or caves may be filled with alluvium, its extent and composition have an important impact on land-use patterns. Alluvium generally forms very fertile, productive soils. First (lowest) and second bottoms composed of alluvium are the most widely cultivated areas in this region. Lower deposits on the present flood plains consist mostly of silt, sand, clay, and some gravel. The higher deposits contain more gravel, and are generally not as fertile, but may be suited for numerous uses in addition to agriculture. The gently rolling character of the terrain, ease of excavation, good septic percolation properties, and proximity to an adequate surface water supply, make this zone attractive to various types of development. Some limitations to the uses of these areas do exist, however. Although they are normally well drained, some soils developed on alluvium have fragipans (impermeable zones) which tend to keep the material excessively wet during rainy periods. Some alluvial areas also have seasonably high water tables not related to fragipans. Also karst features (caves and sinkholes) may be present, having developed in the underlying limestones. For any alluvial area to be used for other than cultivation or recreation, it must be above the highest potential flood. This is the most serious limitation to the use of such areas, and must always be given highest priority in any land-use planning.

CHERTY MISSISSIPPIAN ROCKS

These rocks cap the Highland Rim area in the western and northern parts of the quadrangle as well as ridges and hills throughout the remainder of the quadrangle. The Warsaw Limestone, which caps the flatter upland areas, is probably completely weathered to residuum, but the underlying Fort Payne has many outcrops of highly siliceous limestone, shale, and bedded chert. It is the highly resistant nature of this material that has resulted in the steep slopes necessary for its effective removal by erosion and gravity movements. Included with the cherty residuum is the significant volume of colluvium which has developed from creep, slump, rockfall, and possibly other forms of gravity movements of these siliceous Fort Payne materials. Fort Payne residuum is very thick in some places, up to 50 feet or more of saprolith being common, and this deep weathering, in conjunction with the unconsolidated colluvial wedges and sheets at the base and on the sides of the hills, render the steep slopes (20% and even less) potentially very unstable (Eilender, 1973). Troublesome or even hazardous conditions may result if such slopes are undercut. The normal type of gravity movement (exclusive of creep) which occurs is slope failure (slump) with secondary movement of large joint-blocks of saprolith. The slope map (pl. II) designates such areas (equivalent in great measure to 20% or greater Fort Payne Formation slopes) which may be unstable if excavated or otherwise disturbed.

Where weathered, these cherty rocks are generally easily excavated, especially the Warsaw. The presence of massive, bedded chert in the Fort Payne may present minor excavation problems, but this material can usually be ripped without blasting; however, unweathered Fort Payne may be very difficult to excavate.

Soils formed on the Warsaw are in part mixed with loess (wind-deposited calcareous silt) and are very productive. Fort Payne soils are poor, being very cherty, rapidly drained, erosion prone, and potentially unstable, and are normally left in natural plant growth. It is important to note that the gently rolling areas of Warsaw in the southern, southwestern, and western parts of the quadrangle are well adapted to various land-uses due to several factors. Among these are (1) accessibility, (2) water supply, (3) productive soils, (4) good septic percolation, and (5) ease of excavation. Fort Payne areas, however, are the least adaptable to development for the reasons mentioned previously.

PRE-FORT PAYNE ROCK UNITS

Included in this category are Ordovician, Silurian, Devonian, and Mississippian limestones (the dominant lithology), shales, limy shales, mudstones, and minor amounts of sandstone. In general these rock units form thin to moderately thick residuum, moderately productive soils, and may have an irregular bedrock surface configuration. The limestones exhibit various solution features which may restrict certain uses. These units crop out in the valley areas of the Harpeth and South Harpeth rivers in the eastern and northern parts of the quadrangle.

The limestone units exhibit a wide range in bedding thickness; consequently, there are considerable differences in their weathering features. Excavation difficulty also depends in large measure on the nature of the bedding. These limestones show considerable range in quality as quarry rock (aggregate).

The Chattanooga Shale, which immediately underlies the Fort Payne, is a unique unit and deserves special consideration for several reasons. First, it is used as a structural datum for geologic work throughout this region. It is lithologically distinct (a black, carbonaceous shale), and therefore easily recognizable to the non-geologist. Its weathering features are also important, for it may form potentially unstable slopes where it is weathered into a clayey residuum. The weak nature of this clayey material and the steepness of the slopes it and the overlying Fort Payne form may result in slope failure when excavated. Its soils are strongly acid, thin, and agriculturally unsuitable; therefore it is usually left in natural plant growth.

Other shales and shaly limestones are relatively thin and may be interbedded with the limestones or mudstones in the area. The mudstones (such as zones in the Dixon and Osgood formations) may be several feet thick, but present no special engineering problems other than those normally encountered in limestone areas. The shale zones present only minor excavation difficulty. They may be a nuisance in quarry operations, but in general do not present troublesome or hazardous environmental conditions related to construction.

Some sandstone is present in the Pegram Formation, and thin sandstone is present at the base of the Chattanooga Shale, but due to the steep slopes usually formed by the outcrop of these units and their thinness, they seldom need to be considered in construction planning.

STRUCTURAL FEATURES

Structural features exhibited by rock units are important in any environmental geology study since they influence occurrence and rock properties and thereby may affect various land-uses. A structure contour map, drawn with the base of the Chattanooga Shale as a datum, is included as an overprint on the geologic map (pl. I). Such a map is helpful in predicting the presence of one or more rock units concealed by overburden in various types of excavation. It can be valuable in the selection of quarry sites as well. Such structural data also enable the geologist to compile a more accurate geologic map.

In addition to the variation in dip of the rock units which is expressed in the structure map, another important structural feature to be considered is the presence of fractures (properly called joints, they are mostly vertical planar cracks). Numerous prominent joints are evident in the Fort Payne and Chattanooga formations (well exposed along Interstate 40). Irregular joints are also present in pre-Chattanooga rocks. The orientation, inclination, and frequency of these joints are important parameters to establish for they may affect excavation and construction planning (e.g. where joints are close together rock breaks readily into small blocks upon excavation). Stability of highway cuts and other excavations may relate to the coincidence of joint cracks with the axis of excavation. Predictability of the orientation of joints in an area could therefore be very useful.

The writer measured joints in the Fort Payne and Chattanooga formations along Interstate 40 in the vicinity of McCrory Lane in the east and east-central area of the quadrangle. Figure 1 shows the percentage of joints in the Fort Payne Formation oriented within specific 5 degree arcs. Figure 2 shows equivalent results for the Chattanooga Shale. These figures show that there is a higher percentage of joints within specific orientations, but that a fair number of readings fall in several other directions.

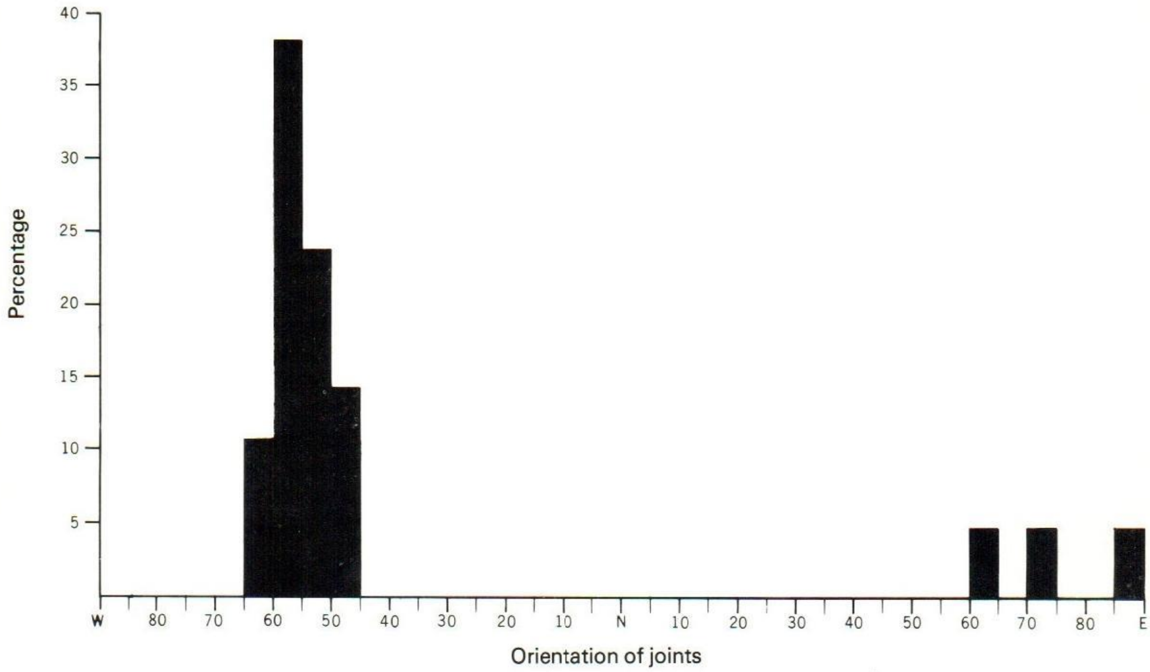

Figure 1. Joint measurements in the Fort Payne Formation

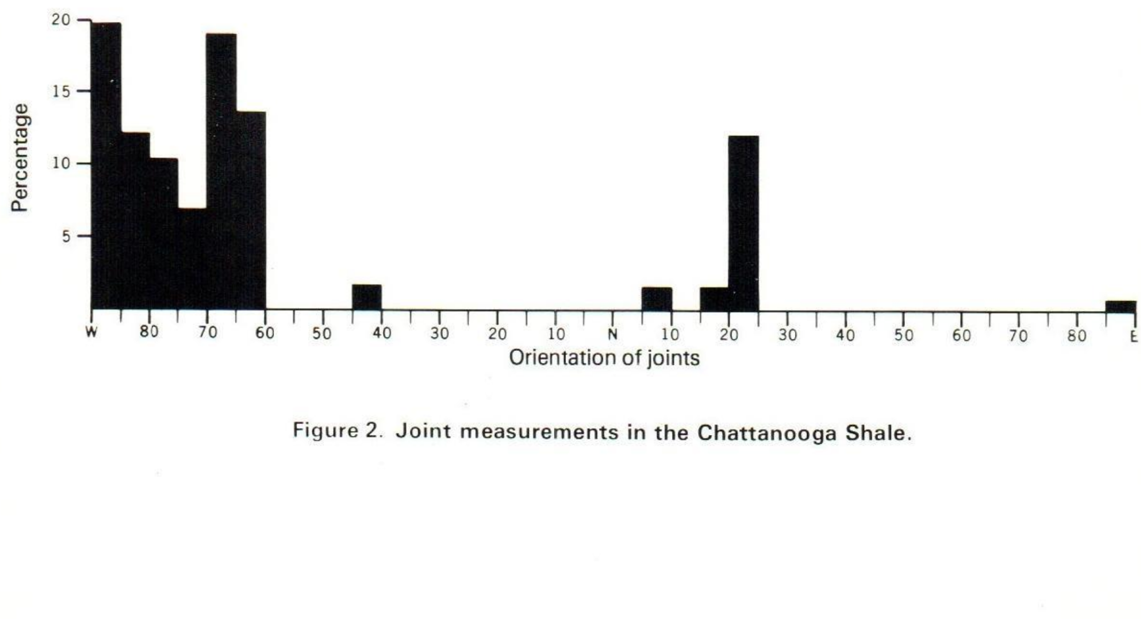

Figure 2. Joint measurements in the Chattanooga Shale.

Stream lineations within the quadrangle were also measured because it is very likely that certain distinct orientations of stream channels have been controlled by solution widening of joints in the bedrock. In compiling the data, each ½ mile lineation was used as a single unit, no lineation of less than ½ mile being used. Figure 3 shows the results for measurements made in the Kingston Springs quadrangle only.

Similar measurements were also made for the eight surrounding quadrangles. Figure 4 shows the percentages of lineations within specific 5 degree arcs for these eight quadrangles plus the Kingston Springs quadrangle.

Although there is generally coincidence of frequency of stream segment orientations within the Kingston Springs quadrangle and the surrounding eight quadrangles, there is little agreement with the orientation of joints measured in the Fort Payne and Chattanooga. It is possible that streams flowing on pre-Chattanooga rocks are controlled by older joint sets not present in Chattanooga and younger rocks.

On the other hand, perhaps, numerous joint sets are present and control stream lineations away from the area of measurement but are not evident in the narrow area of measurement along Interstate 40.

The writer's interpretation is that the best approach to predicting joint problems in excavation planning in this area is to measure as many orientations as close as possible to the specific area to be disturbed. This may be the only practical approach to determining the orientations.

ECONOMIC GEOLOGY

Mineral resources are important in an overall planning report for zoning. It may be necessary to allow for the future removal of valuable commodities, especially those which may be needed for construction in the area (e.g. limestone, shale, clay, sand, and gravel). Consideration must be given to the potential for reclamation and the future use of such land for other purposes.

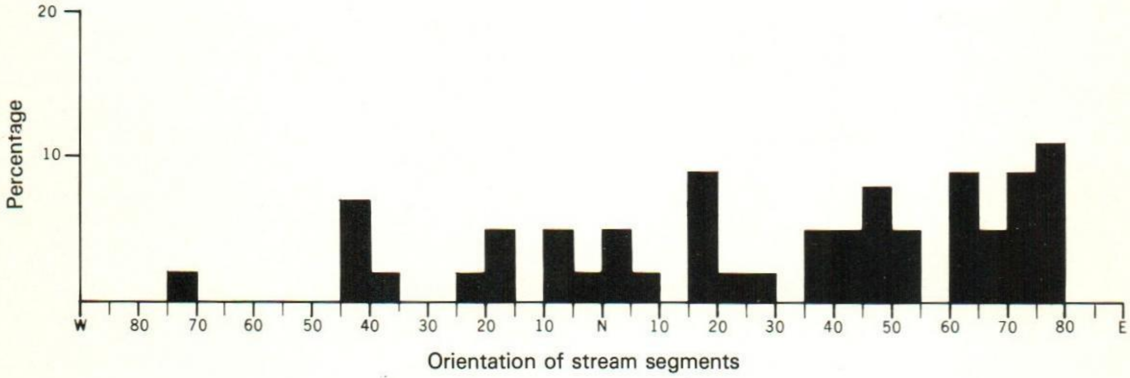

Figure 3. Stream segment lineation measurements, Kingston Springs quadrangle.

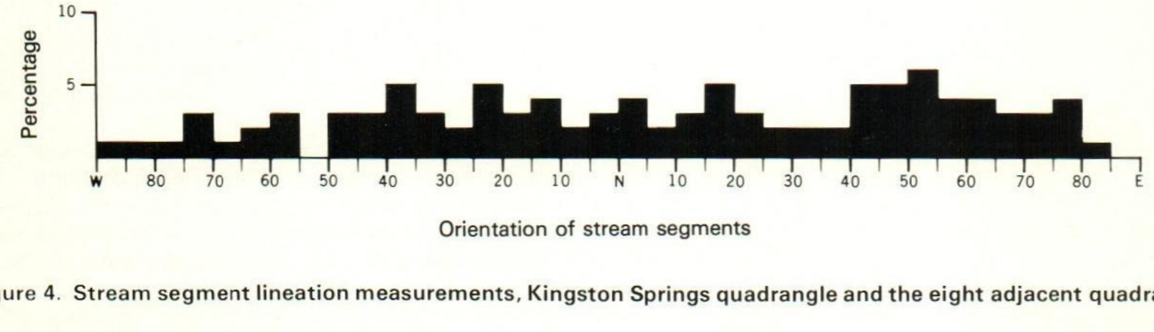

Figure 4. Stream segment lineation measurements, Kingston Springs quadrangle and the eight adjacent quadrangles.

The most important mineral resources in this quadrangle are the construction materials, limestone and chert. Seven quarries have been operated in the past, and chert gravel has been obtained from creek beds. No quarries or chert gravel operations are presently active.

This particular quadrangle is not an important mineral producer, but resources will be considered anyway as an example in planning, and also as development occurs construction materials will be needed that will be more expensive if they must be brought in from other areas. The following is a list of abandoned limestone quarries shown by number as they appear on the accompanying geologic map (pl. I). Included are the dimensions and the rock unit (or units) quarried.

Map no. 1a and 1b - Width, 200 to 500 feet; face, 20 to 60 feet; units quarried, Brassfield, Osgood, Laurel, and Lego formations.
Map no. 2 -------------Length, 650 feet; width, 200 feet; face, 30 feet; unit quarried, Laurel Limestone.
Map no. 3 ------------Length, 1200 feet; width, 750 feet (max.); face, 30 feet; unit quarried, Laurel Limestone.
Map no. 4 -------------Length, 800 feet; width, 400 feet; face, 15 feet; unit quarried, Laurel Limestone.
Map no. 5 -------------Length, 600 feet; width, 60 to 75 feet; face, 5 to 15 feet; unit quarried, Laurel Limestone.
Map no. 6 -------------Length, 225 feet; width, 50 to 75 feet; face, 60 feet; units quarried, Laurel and Lego limestones.
Map no. 7 ------------Small, unmeasured; unit quarried, Laurel Limestone.

The Laurel Limestone was the most widely used material. It is described lithologically in the legend on the geologic map. Although the Lego Limestone is equally as acceptable as the Laurel for aggregate, the other limestones are not as good quality stone. They are either too thin or contain too much chert, argillaceous matter, quartz sand or silt, or glauconite; and hence are restricted in their usefulness as general purpose stone.

Fragmental chert for construction purposes (principally as roadbase fill material) is available in many areas within the quadrangle, being derived from the weathering of the Fort Payne Formation. Although the overlying Warsaw produces chert, it occurs in blocks too large for most uses.

Chert gravel is present in the flood plains of most of the streams, and also in some higher level alluvial deposits on old abandoned meander loops. It is present with varying mixtures of sand, silt, and clay. Although it is likely that gravel has been taken from stream beds, no chert or gravel pits were found in the quadrangle.

ENGINEERING GEOLOGY FACTORS

Intense urban developments

This category of land-use, as used herein, includes the following types of structures and activities:

Structures

(1) Industrial buildings and associated structures.
(2) High-density construction (high-rise structures, apartment complexes, large shopping centers, high-density residential subdivisions).
(3) Rail facilities.
(4) Air facilities.
(5) Sanitary landfills.
(6) Extensive networks of major roads.
(7) Other extensive paved surfaces (large parking areas).
(8) Sewage disposal plants.
(9) Water treatment plants.
(10) Extensive utility excavations and related structures.

Activities

(1) Movement of large vehicles and equipment.
(2) Dense vehicular traffic.
(3) Storage of large volumes of materials.

Certain engineering geology considerations in planning for such structures and activities are summarized in table 1 in which each rock unit that crops out in the quadrangle is rated on a 1 to 5 scale for three parameters—stability, bedrock surface configuration, and excavation difficulty. The highest rating is 5 (very stable material), and the lowest rating is 1 (highly unstable material). A rating of 1 may preclude certain uses.

The following is a summary of the methodology used to derive the ratings shown in table 1:

Stability of rock material, saprolith or residuum.—The assumption is made that the number and type of structures and the types of activity associated with this land-use class require highly stable materials. In this case, as in others, there is no practical basis for defining five separate ratings, and only three are defined. The form of gravity movement considered here is slump.

Rating	*Basis*
5	No stability problem.
3	Susceptible to moderate gravity movement. (vertical section of 10 feet or less subject to movement).
1	Deep weathering, extensive jointing, susceptible to major slope failure (vertical section > 10 feet subject to movement).

Bedrock surface configuration.—An even bedrock surface is considered the ideal condition. Cutter-pinnacle development not only creates problems in excavation, but may result in uneven load distribution of structures as well. Shallow pinnacles will interfere with the excavation of foundations not required to be in bedrock, perhaps necessitating blasting. If pinnacles are deep enough, the irregularity is likely to be much less important.

Rating	*Basis*
5	Generally even bedrock surface, regardless of depth below surface to bedrock (< 5 feet relief on excavation site).
3	Moderately irregular bedrock surface (5-10 feet relief), pinnacles > 5 feet deep.
1	Extensive cutter-pinnacle development on site (> 10 feet relief), pinnacles < 5 feet deep.

Excavation difficulty.—These ratings are based on the experience of blasting technologists dealing with rock units similar to those in the quadrangle. Factors to be considered are: (1) degree of consolidation of the material, (2) bedding thickness, (3) jointing, and (4) material composition.

Rating	*Basis*
5	Unconsolidated material, blasting unnecessary, ordinary digging required.
4	Semiconsolidated or otherwise weak material which may be ripped (shale, chert beds in residuum, some thin-bedded siltstone).
3	Thin-bedded limestone, rock breaks readily with minimum blasting.
2	Medium-bedded limestone with moderately even bedrock surface, blast transmitted uniformly.
1	Massive-bedded limestone with cutter-pinnacle development, siliceous limestone, massive sandstone. Rocks break with difficulty even by blasting, large rocks left after initial blast require secondary drilling and blasting.

Residential and associated developments

The types of structures included within this category are:

(1) Low- to medium-density subdivisions.
(2) Small apartment units.
(3) Schools, churches.
(4) Small shopping centers and individual business structures.
(5) Small paved areas.
(6) Moderately extensive road networks.
(7) Septic fields.
(8) Utility excavations.

The following is a summary of the methodology used to derive the ratings shown in table 2:

Stability of rock material, saprolith, or residuum.—As in intense urban developments, the assumption is made that high material stability is required in residential and associated developments. However, small gravity movements are more of a problem here since preventive measures must be undertaken in many individual cases rather than on a larger scale as in intense urban construction.

Rating	*Basis*
5	No stability problem.
3	Moderate susceptibility to gravity movement. (vertical section < 5 feet subject to movement).
1	Deep weathering, extensive jointing, susceptible to moderate or major slope failure (vertical section > 5 feet subject to movement).

Bedrock surface configuration.—Most structures included within this category will not require deep foundations; consequently, only shallow pinnacles are apt to create serious problems. The ideal condition is assumed to be deep residuum with an even bedrock surface (no shallow pinnacles).

Rating	*Basis*
5	Generally even bedrock surface, or no pinnacles within 5 feet of surface.
3	Cutter-pinnacle development with shallow pinnacles (< 5 feet deep).

Note: Although undesirable, rock outcrops or shallow pinnacles on a construction site do not preclude most types of construction in this class, hence no 1 rating is necessary.

Excavation difficulty.—Although most structures within this category will not require foundation blasting, certain situations might require it, and the blasting characteristics of various materials will be important in road building and utility excavation.

Rating	*Basis*
5	Unconsolidated material.
4	Semiconsolidated or otherwise weak material which may be ripped (shale, chert beds in residuum, some thin-bedded siltstone).
3	Thin-bedded limestone.
2	Medium-bedded limestone with moderately even bedrock surface.
1	Massively bedded limestone with cutter-pinnacle development, siliceous limestone, massive sandstone.

Hydrology

The planning process must consider the availability and quality of water as one of its most vital aspects. Virtually every land-use must, to some extent, be either dependent on the availability of water, or must contend with problems created by the presence of unwanted water.

TABLE 1. INTENSE URBAN DEVELOPMENTS, RATINGS OF ENGINEERING GEOLOGY FACTORS

[Highest rating is 5, lowest 1. Methodology for derivation of ratings preceeds table in text]

Formation	*Stability*	*Bedrock surface configuration*	*Excavation difficulty*	*Special characteristics*
Alluvium	3	----	5	Excavations subject to minor slump.
Warsaw Limestone	5	----	5	Probably completely weathered to residuum.
Fort Payne Formation	5-1 (2)	3	5-1 (4)	In general, slopes > 20% are potentially unstable.
Chattanooga Shale	5-1 (2)	5	4	Weathered slopes may be unstable.
Pegram Formation	5	5-3 (5)	1	
Brownsport Formation	5	3	3	
Dixon Formation	5	3	3-2 (2)	
Lego Limestone	5-3 (5)	3	2	Excavations in Lego residuum subject to minor slump.
Waldron Shale	5	5	4-3 (4)	
Laurel Limestone	5-3 (5)	3-1 (3)	2-1 (2)	Excavations in Laurel residuum subject to minor slump.
Osgood Formation	5	3	3-2 (2)	
Brassfield Limestone	5	3	3-2 (2)	
Mannie Shale	5	5	4	
Fernvale Limestone	5-3 (5)	3-1 (3)	2-1 (2)	Excavations in Fernvale residuum subject to minor slump.
Sequatchie Formation	5	5	3-2 (3)	
Arnheim Formation	5	5-3 (5)	3	
Leipers Formation	5	5-3 (5)	3	

Notes: When range is shown, average is given in parentheses. Dashes indicate item not applicable.

TABLE 2.—RESIDENTIAL AND ASSOCIATED DEVELOPMENTS, RATINGS OF ENGINEERING GEOLOGY FACTORS

[Highest rating is 5, lowest 1. Methodology for derivation of ratings preceeds table in text]

Formation	*Stability*	*Bedrock surface configuration*	*Excavation difficulty*	*Special characteristics*
Alluvium	3	---	5	Excavations subject to minor slump.
Warsaw Limestone	5	---	5	Probably completely weathered to residuum.
Fort Payne Formation	5-1 (2)	5	5-1 (4)	In general, slopes > 20% are potentially unstable.
Chattanooga Shale	5-1 (2)	5		Weathered slopes may be unstable.
Pegram Formation	5	5-3 (5)	1	
Brownsport Formation	5	3	3	
Dixon Formation	5	3	2	
Lego Limestone	5-3 (5)	3	2	Excavations in Lego residuum subject to minor slump.
Waldron Shale	5	5	4-3 (4)	
Laurel Limestone	5-3 (5)	3	2-1 (2)	Excavations in Laurel residuum subject to minor slump.
Osgood Formation	5	3	3-2 (2)	
Brassfield Limestone	5	3	3-2 (2)	
Mannie Shale	5	5	4	
Fernvale Limestone	5-3 (5)	3	5-2 (2)	Excavations in Fernvale residuum subject to minor slump.
Sequatchie Formation	5	5	3-2 (3)	
Arnheim Formation	5	3	3	
Leipers Formation	5	3	3	

Notes: When range is shown, average is given in parentheses. Dashes indicate item not applicable.

TABLE 3.—HARPETH RIVER FLOOD RECURRENCE INTERVALS AND DISCHARGES

Average recurrence interval (years)	*Discharge (cubic feet/second)*
2	20,500 or more
5	31,800 or more
10	39,500 or more
25	49,200 or more
50	56,300 or more
100	63,400 or more

The hydrologic regime (the total environment of water including the surface and subsurface) and related developments which are of prime importance in the Kingston Springs quadrangle are: (1) flood potential, (2) surface-water availability, (3) ground-water availability, (4) water quality, and (5) existing water utility systems.

FLOOD POTENTIAL

Flooding is the most commonly encountered environmental limitation to land-use. No single natural hazard creates as many problems as does the possibility of periodic inundation. Yet this problem, in relation to planning, is a relatively easy one to solve. Given flood data and a topographic map, flood-prone areas can be accurately mapped. Various government agencies have collected flood history and other hydrologic and topographic data on rivers in Tennessee. Such data have been compiled by the U. S. Geological Survey on the Harpeth River at the Belleview gaging station (next station upstream from the Kingston Springs quadrangle) since April 1920. Also, records have been kept for the Kingston Springs gaging station since October 1924. Other discontinuous data are available for certain prior years, in the case of the Belleview station back to 1902. The U. S. Soil Conservation Service completed a flood study of the South Harpeth River in 1964.

The flood projection map (pl. III) shows the flood of record for the Harpeth River (actually only two floods which peaked at different segments of the river within the quadrangle boundary). The "Standard Project Flood" is a term used by the Corps of Engineers to designate the largest flood that can be expected from the most severe combination of meterological and hydrological conditions that are considered reasonably characteristic of the geographical region involved. Such parameters as rainfall, existing hydrologic conditions at the time of the rainfall, and topography are involved in the definition (U. S. Army Corps of Engineers, 1968, p. 26). It is pointed out, however, that even larger floods are theoretically possible (presumably as a result of an abnormal combination of factors including unique meteorological conditions and increasing urbanization which will result in additional runoff). Data sufficient to delineate "Standard Project Flood" for this segment of the Harpeth River are not yet available. The two floods are included in the flood of record projection shown for the Harpeth River on the map. The flood of 1948 was exceeded in magnitude downstream from the mouth of the South Harpeth River by the flood of 1946, indicating a significant augmentation of discharge by this tributary.

The flood of February 13, 1948, had a maximum discharge at the Belleview gaging station of 40,000 cubic feet per second (cfs). The worst flood prior to 1948 for this upstream area was reported to have occurred in 1902. At the Kingston Springs station the record discharge of 60,000 cfs was recorded January 7, 1946. The worst flood at this station prior to 1946 was also in 1902 when a stage approximately 3 feet lower than that of 1946 was reached (U.S.G.S., 1964, p. 54-55).

Studies of the South Harpeth River by the U. S. Soil Conservation Service show that a total of 83 damaging flood events occurred during the 20 year period from January 1943, through December 1962. The flood projection map shows the limits of known flooding for the South Harpeth River within the quadrangle. This projection does not represent a single flood, but rather is a composite of various events compiled from cross sections throughout the length of the river (U. S. Soil Conservation Service, 1964).

Major flooding occurs in this area principally during the months of December through March, but floods may also occur in any other month, especially flash flooding of smaller streams. No flood data, however, is presently available on other streams in the quadrangle.

The data in table 3 represents various discharges of flood proportions compiled for the Harpeth River at the Kingston Springs gaging station (May and others, 1970, p. A-24).

The maximum discharge of 60,000 cfs, recorded January 7, 1946, therefore essentially represents a "100 year flood." It should be emphasized that these figures are *averages* and do not imply a history of consistent frequency. Two or more "100 year floods" are possible within any given year, but such an occurrence is highly improbable, as it might be said that the chance of only one occurring in any given year is about one percent (.01).

SURFACE-WATER AVAILABILITY

Although too much water can be an obvious problem in the planning process (flooding), too little water can be a serious disadvantage as well, for much of the water necessary for domestic and industrial use must also come from the streams. Except for rare periods of drought which have resulted in extremely low flow conditions for a few days, water for considerable development is available in the Kingston Springs quadrangle. Data substantiating this normal adequacy of flow has been recorded by the gaging stations.

The largest stream draining the Kingston Springs quadrangle is the Harpeth River. Major tributaries are the South Harpeth River and Brush Creek. Turnbull Creek enters the Harpeth River in the White Bluff quadrangle on the west, but the Harpeth reenters the Kingston Springs quadrangle to the north just below the confluence.

The average discharge at the Belleview gaging station for the period 1920-1965 was 558 cfs, and a period of no flow was recorded October 5-10, 1922. The drainage area of the Harpeth River at this gaging station is 408 square miles (U.S.G.S., 1971, p. 151). At the Kingston Springs gaging station the average discharge for the period 1924-1965 was 937 cfs, with a minimum discharge of 12 cfs recorded September 18, 1939. The drainage area of the Harpeth River at this gaging station is 687 square miles (U.S.G.S., 1971, p. 154). The significant difference in discharge (and in minimum flow) between these stations is attributable to the augmentation of flow downstream from the Belleview station primarily by Turnbull Creek, South Harpeth River, and Brush Creek. However, no flow data is available for these streams.

The lowest monthly mean discharge for the years 1951-1960 for the Kingston Springs station was 37.1 cfs recorded in September 1956. This is equal to 24,800,000 gallons per day (gpd). The record low flow of 12 cfs in 1939 was 7,756,000 gpd. The lowest monthly mean discharge at the Belleview station for the years 1951-1960 was 4.23 cfs, recorded in September 1953. This is equal to 2,734,000 gpd (U.S.G.S., 1964, p. 54-55).

It is evident that in the segment of the Harpeth River below the mouth of the South Harpeth River, the flow is normally far in excess of any reasonable projected demands. Even the low flow of record far exceeds the daily capacity of the pumping station presently in operation at Kingston Springs. In the event consumption increases at an abnormally high rate, increased contingency storage could meet demand for those short periods of low flow that might be experienced.

In the segment above the mouth of South Harpeth River, flow is also normally in excess of feasible projected demands, but more frequent low flow periods (and lower discharges during these periods) might require greater storage than the downstream segment.

GROUND-WATER AVAILABILITY

Most of the area within the Kingston Springs quadrangle is not serviced by a water utility district, hence the availability of ground water is an important factor in land-use planning. Prediction, with a reasonable degree of accuracy, of how deep a well must be drilled to obtain water and the frequency of the yield needed for the area is of great value. Such information has been made available for this quadrangle and its surrounding areas by the Tennessee Division of Water Resources. This agency has data on 12 wells in the Kingston Springs quadrangle and 59 additional wells in areas adjacent to the quadrangle boundaries.

The following is a summary of the data for the 12 wells in the Kingston Springs quadrangle:

Average yield — 13 gpm
Maximum yield — 44 gpm
Minimum yield — 3 gpm
Average depth — 142 feet
Maximum depth — 262 feet
Minimum depth — 70 feet

The cumulative well yield frequencies for the quadrangle are:

3 gpm or more — 100%
10 gpm or more — 50%
25 gpm or more — 17%
100 gpm or more — 0%

The following are the cumulative well depth frequencies:

Wells having to go deeper than 50 feet — 100%
Wells having to go deeper than 100 feet — 75%
Wells having to go deeper than 200 feet — 8%
Wells having to go deeper than 500 feet — 0%

Table 4 summarizes the data for individual wells (and two springs) within the quadrangle. The numbers correspond to those on the water availability map (pl. IV). The principal source of water for these wells is the Fort Payne Formation. The deep, porous residuum and saprolith, and the presence of jointing in the weathered material and bedrock allow considerable storage of ground water. In the pre-Chattanooga rocks, water storage depends primarily on solution-widened joints and bedding planes.

The 59 additional wells in the adjacent area are in a zone 2½ minutes wide (about 2¼ miles) around the quadrangle boundaries. The following are summaries of the data on these wells plus the 12 within the Kingston Springs quadrangle:

Average yield — 18 gpm
Maximum yield — 300 gpm
Minimum yield — 0 gpm
Average depth — 146 feet
Maximum depth — 1669 feet
Minimum depth — 40 feet

The cumulative well yield frequencies for the area are:

3 gpm or more — 83%
10 gpm or more — 51%
25 gpm or more — 18%
100 gpm or more — 3%
500 gpm or more — 0%

The following are the cumulative well depth frequencies for the area:

Wells having to go deeper than 50 feet — 79%
Wells having to go deeper than 100 feet — 46%
Wells having to go deeper than 200 feet — 3%
Wells having to go deeper than 500 feet — 0%

TABLE 4.—INDIVIDUAL WATER WELL DATA, KINGSTON SPRINGS QUADRANGLE

Well no.	Well depth (in feet)	Aquifer depth (in feet)	Yield (gpm)	Elevation (in feet)	Water level elevation (in feet)	Geologic Unit
1	173	150	3	800	---	* Ft. Payne Fm.
2	262	245	10	560	---	Wayne Group
3	70	60	30	530	500	---
4	160	145	20	630	545	* Ft. Payne Fm.
5	145	130	5	800	680	* Ft. Payne Fm.
6	140	134	12	805	734	* Ft. Payne Fm.
7	140	130	7	820	720	* Ft. Payne Fm.
8	107	105	44	805	765	* Ft. Payne Fm.
9	95	85	9	850	792	---
10	150	130	3	840	720	---
11	160	140	11	825	735	---
12	100	75	3	620	600	---
13	(spring)	---	1	570	570	Wayne Group
14	(spring)	---	25	700	570	Ft. Payne Fm.

* Formation inferred from geologic map.

TABLE 5.—WELL WATER ANALYSES, KINGSTON SPRINGS QUADRANGLE AND SURROUNDING AREA

	pH	Iron	Sulfate	Total Hardness	Calcium
Average	7.7	.03	183	238	162
Maximum	8.0	.05	285	300	185
Minimum	7.5	.00	80	200	120

All values, except pH, in parts per million.

TABLE 6.—SPRING WATER ANALYSES, KINGSTON SPRINGS QUADRANGLE AND SURROUNDING AREA

	pH	Iron	Sulfate	Sodium Chloride	Total Hardness	Calcium	Dissolved solids
Average	6.7	1.47	12	25	117	73	184
Maximum	6.7	4.40	23	37	140	90	218
Minimum	6.7	.00	4	13	90	50	143

All values, except pH, in parts per million.

The average yield and well depth, and cumulative yield frequencies for the Kingston Springs quadrangle alone match fairly well with the equivalent data for the area. This reinforces the notion that the average for the limited (12 well) data in the quadrangle are meaningful.

Seven springs in the area have also been measured. The cumulative yield frequencies are:

3 gpm or more — 71%
10 gpm or more — 57%
25 gpm or more — 43%
100 gpm or more — 14%
500 gpm or more — 0%

It should be emphasized that these percentages are derived from a single reading for the springs measured. For more accurate results, periodic readings throughout the year, closely correlated with amount of precipitation, should be made.

WATER QUALITY

The relative "purity" of both surface and ground water has an impact on planning in the fields of health, industrial development, agriculture, recreation, and others. Water quality of an acceptable standard for one use might well be totally unacceptable for others. The sources of potential contamination to both surface and ground water are summarized herein, and may be used as a broad guide in the first stages of the planning process. Surface and subsurface water quality are discussed in separate subsections. Criteria (most recent amendment) adopted by the Water Quality Control Board for pollution control in Tennessee are available from that agency and may serve as a guide to planners for determining the limitation on effluents or other forms of waste disposal that might affect water quality.

Surface-water quality

Practically the entire drainage of the Kingston Springs quadrangle is within the Harpeth River basin. A public hearing on the Harpeth River basin, conducted by the Tennessee Water Quality Control Board, October 15, 1970, included the definition of specific sources of effluent within the basin. In the transcript of that hearing thirteen sewage waste and six industrial waste discharges were listed which either directly or indirectly enter the Harpeth River within or upstream from the Kingston Springs quadrangle (Tennessee Stream Pollution Control Board, 1970).

It should be emphasized that those points of discharge in upstream areas have ample distance for some natural diminishment of pollution levels due to aeration and dilution from increased water discharge. However, their potential cumulative effect on downstream quality must be taken into consideration. Even low levels of some forms of contamination may affect certain types of water use and since the upstream region of the Harpeth River at Franklin and at Belleview is currently in a phase of rapid expansion, there is great potential for pollution.

Other sources of stream pollution exist in the area, but these are not directly observable effluent and so are far more difficult to assess quantitatively. Some of these sources are colliform bacterial contamination from septic fields, livestock organic waste, fertilizer, pesticide, fungicide and other chemical residues from agricultural and domestic applications, improperly operated landfills, dumps, and others.

Ground-water quality

The quality of ground water can be defined by the amounts of two categories of undesirable material contained—dissolved or suspended matter derived from the rock material in the area and contaminants in the form of bacteria, chemicals, and other foreign matter from farms, etc. Data for dissolved and suspended material is available for only 3 wells in the quadrangle and the surrounding area. Table 5 is a summary of this data for the 3 samples (file data, Tennessee Division of Water Resources).

Of the 12 scheduled wells in the Kingston Springs quadrangle, 9 had water containing no sulfur, iron, oil, or gas. For the composite area, 59 of the 71 wells contained no sulfur, iron, oil, or gas.

Table 6 is a summary of water quality for 3 springs sampled in the composite area (file data, Tennessee Division of Water Resources).

EXISTING WATER UTILITY SYSTEMS

The total problem of water supply, whether services providing treated water are present or not, must be considered in the planning process. The capacity of an existing water treatment plant may therefore determine whether expanded industrial, commercial, or residential needs will have to be met through new sources. Demand for expanded capacity from existing plants will depend on the quantity of water available from streams, wells, or springs. The distance prospective users are from an existing utility district will influence the decision of whether to extend the facilities or to require new sources of water. In the event of extension of existing services, ease of excavation and suitable topographic (water pressure) conditions must be evaluated.

Two water utility districts presently directly supply users in the Kingston Springs quadrangle. They are the South Cheatham Utility District, serving the Kingston Springs-Pegram area, and the Fairview Water System, which has the same boundaries as the city of Fairveiw. The Fairview System is supplemented by the Harpeth Valley Utility District. The limits of these systems are shown on the accompanying water supply map (pl. IV).

The South Cheatham Utility District has 580 connections serving approximately 2030 persons. The source of the water is the Harpeth River. The plant has two pumps with a combined capacity of 640 gallons per minute. The treatment plant capacity is 461,000 gallons per day. The storage tank, plus the plant clear well, have a capacity of 409,000 gallons. Treatment includes coagulation, sedimentation, filtration, and disinfection. The following is a breakdown of the approximately 92,000 gallons per day average use (Cheatham County Regional Planning Commission, 1971).

Domestic	86,000 gallons per day
Commercial	3,000 gallons per day
Lost	3,000 gallons per day

The Fairview Water System has 250 connections serving an estimated population of 825. Previous to the availability of the Harpeth Valley Utility District service, the only source of water for the system was Horntavern Spring in the Fairview quadrangle near the headwaters of Brush Creek, approximately 2000 feet north of State Route 100. The capacity of the pumps at the spring is approximately 72,000 gallons per day, and the storage tank capacity is 100,000 gallons. The spring is connected with the storage tank by a 6 inch line, with some additional 6 inch pipe along State Routes 96 and 100. Treatment of the spring water includes coagulation with soda ash and alum, and chlorination. Treatment at the Harpeth Valley Utility District includes coagulation, sedimentation, filtration, disinfection, liming, and fluoridation (Tennessee State Planning Commission, 1971).

The South Cheatham Utility District can meet a moderate increase in demand for water due to the present excess of pump and storage capacity over demand. Modification of the plant would allow expanded service if necessary. The major environmental limitation is occasional low flow conditions on the Harpeth River that might possibly require additional storage capacity for such a contingency if future demand is greatly increased. The low flow of 12 cfs, recorded September 18, 1939, is, however, equivalent to 7,755,782 gallons per day.

Since the Fairview Water System is now able to supplement its needs through the Harpeth Valley Utility District, future demands can be met with only the limitation of the main connector's capacity.

Soils

Soil associations within the Kingston Springs quadrangle are discussed in terms of their relationships with the topographic and rock units present. The following are descriptions of the major soil series present within the quadrangle, listed by topographic situation. Some modification of standard Soil Conservation Service association groupings is made in order to more closely relate the soils to rock types as outlined in this report. Some overlap of soil types and topographic units must necessarily occur. Most of the recommendations as to the suitability of these soils for various uses are those of the Soil Conservation Service and were suggested to the writer through personal communications and unpublished data tables or were derived from the Williamson County soil report. The recommendations which are included within the descriptions of soil units relate primarily to overall agricultural suitability. Specific data related to the engineering characteristics of soils within this quadrangle are summarized in the form of tables at the end of this section (tables 7 and 8, pages 16 and 18). These are similar to the tables on engineering geology factors. The soils are individually rated for two classes of land-use — intense urban developments, and residential and associated developments.

No soil maps are included in this summary. Published soil maps with detailed descriptions of soils are available for the Williamson County portion of the quadrangle. Maps for the Davidson County portion of the quadrangle are in the process of being published. No detailed soil maps are available for the Cheatham County portion of the quadrangle. Any available maps may be obtained from the U. S. Department of Agriculture, Soil Conservation Service.

UPLANDS (Warsaw and Fort Payne Highland Rim areas), Mountview-Baxter-Bodine Association

This association of soils is present in the south-central, southwestern, and western areas of the quadrangle. They are underlain by deep cherty residuum, saprolith, or siliceous limestones and shales. Such areas correspond to moderately dissected Highland Rim and have extensive rolling to nearly level zones. The most extensive soil in this association is Mountview, which is formed in 20 to 40 inches of loess on the nearly level to gently rolling uplands and ridge crests. It has a silt loam surface and a silty clay loam subsoil.

Baxter and Bodine soils occupy hillsides and range from 2 to 10 feet in depth. They are underlain by siliceous limestone or chert beds. Baxter soils are cherty, red clayey soils formed in residuum from Warsaw Limestone, and the Bodine soils are formed in very cherty residuum from the Fort Payne Formation.

The soils in this association are low in natural fertility; however, the Mountview and Baxter soils respond well to fertilization and liming and may be suited to various agricultural uses. Bodine soils are best left in forest.

DISSECTED UPLANDS (primarily Fort Payne Fm., minor Warsaw Fm.), Bodine-Mountview-Greendale (Cannon) Association

The same characteristics of the Bodine and Mountview soils just outlined apply in this association as well, but the topography differs in that the area underlain by these soils is more dissected. It corresponds essentially to the central and north-central parts of the quadrangle. The Mountview (more silty) soils in this area are more restricted to somewhat narrow ridgetops and make up about 25% of the area. The cherty Bodine soils are on narrow ridgetops and steep side slopes, and overlie Fort Payne saprolith and bedrock. They make up over 50% of this association. Greendale (Cannon) soils are formed in cherty alluvium and colluvium on bottoms in narrow stream valleys.

Practically none of the area within this association is used for agriculture except the Mountview ridge crests.

FORT PAYNE RIDGES, Sulphura-Dellrose-Bodine Association

These soils develop on steep Fort Payne ridges throughout much of the quadrangle but are more typical of the eastern third and also some areas to the north. The soils form on long, steep slopes and in narrow valleys.

The slopes with Fort Payne cropping out develop Bodine soils which are very cherty and droughty. They are underlain by cherty saprolith or siliceous limestone and shale.

Sulphura soils, about 10 to 20 inches in thickness, form in the outcrop belt of the Chattanooga Shale on steep slopes. They are excessively drained shaly loams, strongly acid, and are unsuited for cultivation.

Dellrose soils are developed in colluvium which has collected below the Bodine-Sulphura belts. This colluvium, which is primarily the result of creep, is loamy and ranges from 2 to 6 feet thick. It is underlain by 3 to 15 feet of clayey material. Chert is quite common throughout the colluvium. Although Dellrose soils usually occur on steep slopes, they are naturally fertile and can be cultivated for various crops if properly managed.

GENTLY SLOPING VALLEY AREAS (above alluvium), Dellrose-Mimosa-Rockland Association

These three soils are the most extensive in this topographic zone. Other soils with moderate areal extent include Hillwood, Lobelville, and Pace series.

This zone corresponds to the outcrop belt of pre-Chattanooga rocks above the alluvial areas, and is present on rolling to steep hills with some areas of bottom land. They are mostly underlain by clayey limestone (limestone, shale, shaley limestone, and mudstone).

As on the steeper ridges, the Dellrose soils in the gently sloping valleys develop in cherty, loamy colluvium that overlies various pre-Chattanooga formations. Mimosa soils are sticky and plastic clayey soils on the slopes below Dellrose soils overlying Silurian and Ordovician limestones. They are fairly productive. Rockland areas have outcrops of limestone over 50% to 90% of the area. Though not extensive individually, such areas are present in much of the eastern third of the quadrangle as well as parts of the northern third within the Harpeth River valley and its northern tributaries (True and others, 1964).

ALLUVIAL AREAS (Pleistocene and Recent flood plains), Lindside (Hamblem)-Armour-Arrington (Huntington) Association

These soils are formed in alluvium on nearly level to gently sloping flood plains (first bottoms or Late Pleistocene and Recent flood plains) and on rolling terraces (second bottoms or Early to Middle Pleistocene flood plains) along the Harpeth and South Harpeth rivers and their larger tributaries. In addition to this association, Cannon (Greendale), Captina, Egam, Newark, and Taft series are alluvial in origin also. Thickness of the alluvial deposits ranges up to 15 feet.

The major soils on the first bottoms along the Harpeth and South Harpeth rivers are the well-drained, naturally fertile, loamy Arrington (Huntington equivalent) soils. Cannon (Greendale) and Hamblen are cherty, loam soils on the flood plains of tributaries in Bodine (Fort Payne) areas. Egam soils are clayey soils in drainageways in areas of Mimosa soils (Silurian and Ordovician limestone). Newark soils are poorly drained soils in overflow channels and in depressions in flood plains.

Armour, Captina, and Taft soils are loamy soils on stream terraces. Armour soils are extensive, nearly level to rolling, deep, well-drained loamy soils that are highly productive. Captina soils are moderately well drained with a fragipan at depths of 24 to 36 inches. Taft soils are poorly drained and occupy slight depressions.

SOIL FACTORS

Intense urban developments

The following is a summary of the methodology used to derive the ratings shown in table 7:

Depth to bedrock.—Many types of excavations in areas of intense urban development—utility ditches, roads, most single level or low-load structures — are facilitated by the presence of deep, easily removed soil. For foundations requiring excavation into bedrock, removal of moderately thick residuum presents no major problem. The ideal condition at a site, therefore, may be assumed to be consistently thick residuum.

Rating	*Basis*
5	Consistently greater than 10 feet of soil throughout excavation area.
3	5 to 10 feet of soil throughout excavation area.
1	Less than 5 feet of soil present throughout most of excavation area.

TABLE 7.—INTENSE URBAN DEVELOPMENT, RATINGS OF SOIL FACTORS

[Highest rating is 5, lowest 1. Methodology for derivation of ratings given in text]

Soil name (slope range shown in parentheses)	Depth to Bedrock	Soil load-bearing capacity	Soil perm-eability	Depth to seasonably high water table	Shrink-swell potential	Special characteristics
Armour silt loam	3	3	3	5	5	Subject to occasional flooding.
Arrington silt loam (Huntington)	3	3	3	1	5	
Baxter cherty silt loam	5	3	3	5	5	
Bodine cherty silt loam (5% - 20%)	5-3 (3)	5	5	5	5	
Bodine (> 20%)	5-3 (3)	5	5	5	5	These areas are potentially unstable.
Sulphura (> 20%)	5-3 (3)	3	3	5	5	These areas are potentially unstable.
Hillwood cherty silt loam (3% - 12%)	3	5	3	5	5	
Hillwood cherty silt loam (12% - 20%)	3	5	3	5	5	
Cannon cherty silt loam (Greendale)	3	5	5	1	5	Subject to occasional flooding.
Captina silt loam	5-3 (3)	3	1	1	5	Perched water table above fragipan.
Dellrose cherty silt loam	5-3 (3)	1	3	5	5	Subject to slides in cuts.
Egam	5-3 (3)	3-1 (1	1	1	4	Subject to occasional flooding.
Hamblen silt loam	3	3	3	1	5	
Lobelville cherty silt loam	3	5	3	1	5	Subject to occasional flooding.
Mimosa silt loam (2% - 12%)	1	3-1 (1)	1	5	4	
Mimosa silt loam (12% - 25%)	1	3-1 (1)	1	5	4	
Mimosa rock outcrop (5% - 40%)	1	3-1 (1)	1	5	4	
Mountview silt loam	5	3	3	5	5	
Newark silt loam	5-3 (3)	3	1	1	5	Subject to occasional flooding.
Pace cherty silt loam	3-1 (3)	3	5	1	5	Perched water table above fragipan.
Rock outcrop (Barfield)	1	1	1	5	4	
Taft	5	3	1	1	5	Subject to seasonal flooding.

Note : When range is shown, average is given in parentheses.

Soil load-bearing capacity.—Loading of soils is an important consideration in engineering and architectural planning. The American Association of State Highway Officials (AASHO) rates the load-bearing capacity of soils on a scale of A-1 (gravelly soils high in bearing capacity) to A-7 (clay soils which have low bearing capacity when wet). The following generalized ratings are based on a U. S. Soil Conservation Service classification using the AASHO scale as a guide.

Rating	*Basis*
5	Good (A 1-3 AASHO).
3	Fair (A 3-5 AASHO).
1	Poor (A 5-7 AASHO).

Soil permeability.—Permeability of a soil may be defined as that quality which enables it to transfer water. Soils with a high percentage of clay will be, in general, least permeable. Also, the presence of fragipans will greatly impair the downward movement of water. Some of the problems associated with low permeability are excess surface runoff, difficulty in equipment movement, and other difficulties with excavation and construction. Anticipation of such problems is especially important in most types of planning for intense urban development. The following ratings are used to conform with Soil Conservation Service charts that were subsequently used in the compilation of the soil-suitability table. The permeability of individual soils has been accurately measured by the Soil Conservation Service. They are rated on a scale using inches per hour percolation.

Rating	*Basis*
5	High permeability (> 4.0 in /hr)
3	Moderate permeability (.6-4.0 in /hr)
1	Low permeability (< .6 in /hr)

Depth to seasonably high water table.—Most soils in upland areas and on terraces are well drained, whereas those soils in flood plains usually are underlain by a shallow water table. However, in some areas above flood plains, during the rainy season, the main water table or a perched water table (possibly the result of fragipan development or the presence of other impermeable zones) may rise to or near the surface and remain there for long enough periods of time to create problems with existing structures, activities, or especially during excavation. Although those problems due to shallow fragipans may be averted by ditching and diversion of water, other shallow water table problems cannot feasibly be solved. Consequently, such areas of seasonably high ground water should generally be avoided.

Rating	*Basis*
5	Depth to seasonably high water table > 10 feet.
3	Depth to seasonably high water table 5 feet-10 feet.
1	Depth to seasonably high water table < 5 feet.

Shrink-swell potential.—Foundations in residuum or otherwise unconsolidated material may be weakened by excessive shrinking and swelling of the material due to the addition of moisture or to drying. The Soil Conservation Service reports that the presence of montmorillonite in certain soils is especially responsible for this problem. Sands and gravel containing little or no clay fraction have the lowest shrink-swell potential. Ratings of 2 and 1 are omitted, for the assumption is made that proper design and construction can compensate for excessive shrink-swell and use of an area for most large structures is not precluded. Ratings of 4 and 3 are included due to possible additional design considerations necessary in some situations.

Rating	Basis
5	Low shrink-swell potential.
4	Moderate shrink-well potential.
3	High shrink-swell potential.

Residential and associated developments

The following is a summary of the methodology used to derive the ratings shown in table 8:

Depth to bedrock.—The presence of deep, easily excavated overburden is considered an ideal condition in most residential and associated developments. Consistency of thickness is important also

Rating	*Basis*
5	Consistently > 10 feet of soil throughout excavation area.
3	5 to 10 feet of soil throughout excavation area.
1	< 5 feet of soil present throughout most of excavation area.

Soil load-bearing capacity.—Design of road systems and various structures associated with residential developments require consideration of the variable load-bearing qualities of soils. The same rating system used in intense urban developments is applied here.

Rating	*Basis*
5	Good (A 1-3 AASHO).
3	Fair (A 3-5 AASHO).
1	Poor (A 5-7 AASHO).

Soil permeability (suitability to septic percolation).—Although the permeability of soils is important from the standpoint of proper drainage in this category of land-use, its relation to proper septic field percolation is most important, for many individual dwellings or small apartments depend on septic tanks and fields for disposal of sewage. The following ratings are based on a 1 to 5 rating of soils by the Soil Conservation Service in Davidson County for septic tank fields.

TABLE 8.—RESIDENTIAL AND ASSOCIATED DEVELOPMENTS, RATINGS OF SOIL FACTORS

[Highest rating is 5, lowest 1. Methodology for derivation of ratings given in text]

Soil name (slope range shown in parentheses)	*Depth to Bedrock*	*Soil load-bearing capacity*	*Septic percolation*	*Depth to seasonably high water table*	*Shrink-swell potential*	*Special characteristics*
Armour silt loam	3	3	5	5	5	Subject to occasional flooding.
Arrington silt loam (Huntington)	3	3	1	1	5	
Baxter cherty silt loam	3	3	4-2 (3)	5	5	
Bodine cherty silt loam (5% - 20%)	5-3 (3)	5	3-2 (2)	5	5	
Bodine (> 20%)	5-3 (3)	5-3 (4)	1	5	5	These areas are potentially unstable
Sulphura (> 20%)	5-3 (3)	5-3 (4)	1	5	5	These areas are potentially unstable.
Hillwood cherty silt loam (3% - 12%)	3	5	3	5	5	
Hillwood cherty silt loam (12% - 20%)	3	5	3	5	5	
Cannon cherty silt loam (Greendale)	3	5	1	1	5	Subject to occasional flooding.
Captina silt loam	5-3 (3)	3	2	1	5	Perched water table above fragipan.
Dellrose cherty silt loam	5-3 (3)	1	3-2 (2)	5	5	Subject to slides in cuts.
Egam	5-3 (3)	3-1 (1)	1	1	3	Subject to occasional flooding.
Hamblen silt loam (Lindside)	3	3	1	1	5	Subject to occasional flooding.
Lobelville cherty silt loam	3	5	1	1	5	Subject to occasional flooding.
Mimosa silt loam (2% - 12%)	1	3-1 (1)	2	5	3	
Mimosa silt loam (12% - 25%)	1	3-1 (1)	2	5	3	
Mimosa rock outcrop (5% - 40%)	1	3-1 (1)	1	5	3	
Mountivew silt loam	5	3	5	5	5	
Newark silt loam	5-3 (3)	3	1	1	5	Subject to occasional flooding.
Pace cherty silt loam	3-1 (3)	5	2	1	5	Perched water table above fragipan.
Rock outcrop (Barfield)	1	3-1 (1)	1	5	3	
Taft	5	3	1	1	5	Subject to occasional flooding.

Note : When range is shown, average is given in parentheses.

Rating	*Basis*
5	Excellent septic percolation.
4	Good septic percolation.
3	Fair septic percolation.
2	Poor septic percolation.
1	Unsuited septic percolation.

Depth to seasonably high water table.— Dwelling and other building foundations may be weakened by seasonably high ground water and construction may be difficult under such conditions. The presence of excess moisture may also become a nuisance and a health hazard as well. Septic percolation and proper sewage drainage can be impaired by excess shallow ground water. It is important, therefore, to determine the potential presence of seasonably high ground water in this type of planning. The following ratings are the same as those used in intense urban developments.

Rating	*Basis*
5	Depth to seasonably high water table > 10 feet.
3	Depth to seasonably high water table 5 feet-10 feet.
1	Depth to seasonably high water table < 5 feet.

Shrink-swell potential.—The foundations of dwellings, apartments, and other associated small structures are particularly susceptible to weakening by excessive shrinking and swelling of the surrounding material. Such foundations normally do not have the structural integrity to withstand such severe conditions. The rating criteria here are modified from those in intense urban development to a 5-3-1 basis on the assumption that high shrink-well potential might preclude some uses without considerable modification of standard construction techniques.

Rating	*Basis*
5	Low shrink-well potential.
3	Moderate shrink-swell potential.
1	High shrink-well potential.

Topography

Past development within the Kingston Springs area has been controlled to a high degree by topography, specifically the limiting factors of steep terrain and potentially unstable slopes, and it will continue to influence man's use of the land. Regionally, the quadrangle lies within the dissected zone of the Western Highland Rim's eastern edge and, with the exception of the extreme northeast corner, it is within the Harpeth River drainage basin. Elevations range from slightly under 460 feet at the point where the Harpeth River leaves the quadrangle to slightly more than 900 feet on Sullivan Ridge in the northeast corner of the quadrangle. Figure 5 relates the quadrangle to major physiographic units present in Tennessee.

The physiographic features present within the quadrangle are: (1) flood plains, (2) gently sloping lowlands, (3) steep slopes, (4) uplands, and (5) karst areas.

FLOOD PLAINS

The Harpeth and South Harpeth rivers both have moderately wide flood plains. That of the Harpeth is as wide as 1700 feet and the South Harpeth's flood plain is as much as 1800 feet wide. The present flood plains of both of these rivers are defined by the flood projection map that shows the limits of the floods of record for each stream (pl. III). Older flood plains are defined in part by the extent of Quaternary alluvium shown on the geologic map. The higher areas covered by this material are mostly in abandoned meander loops of the Harpeth River. Most of the community of Pegram lies within one of these old meanders.

Land-use of present flood plains is restricted essentially to agricultural activities, although some areas remain in forest, particularly along the stream banks. The higher level alluvial areas, representing the older flood plains, have been modified by erosion and solutional sapping of underlying limestones and have developed a gently rolling terrain. They extend to elevations above 600 feet and are ideally suited to various land uses. These zones, which have low slopes and are above present flood levels, develop fertile soils and are easy to excavate. Other than restricted areal extent, their major limitations to development are the presence of sinkholes in some areas and a water table that may rise to near the land surface.

GENTLY SLOPING LOWLANDS

The valley areas above present and Pleistocene flood plains in the eastern and northern parts of the quadrangle are essentially equivalent to the outcrop areas of pre-Chattanooga limestone. The relative ease with which these predominantly limestone units are weathered and eroded has resulted in an equilibrium profile consisting of slopes ranging from 0 to 20%, and locally steeper, but averaging about 10%. In the western part of the quadrangle, the lower Fort Payne locally forms low slopes in some of the valley areas, but it characteristically forms much steeper slopes.

Most of the gently sloping lowland areas are cultivated and most people within the quadrangle live in these valleys. Accessability, adequate water for agriculture and domestic use, and soil fertility are factors that make these areas desirable.

STEEP SLOPES

The resistant nature of the rocks of the Fort Payne Formation has resulted in the steeply sloping terrain of the dissected Highland Rim area of the Kingston

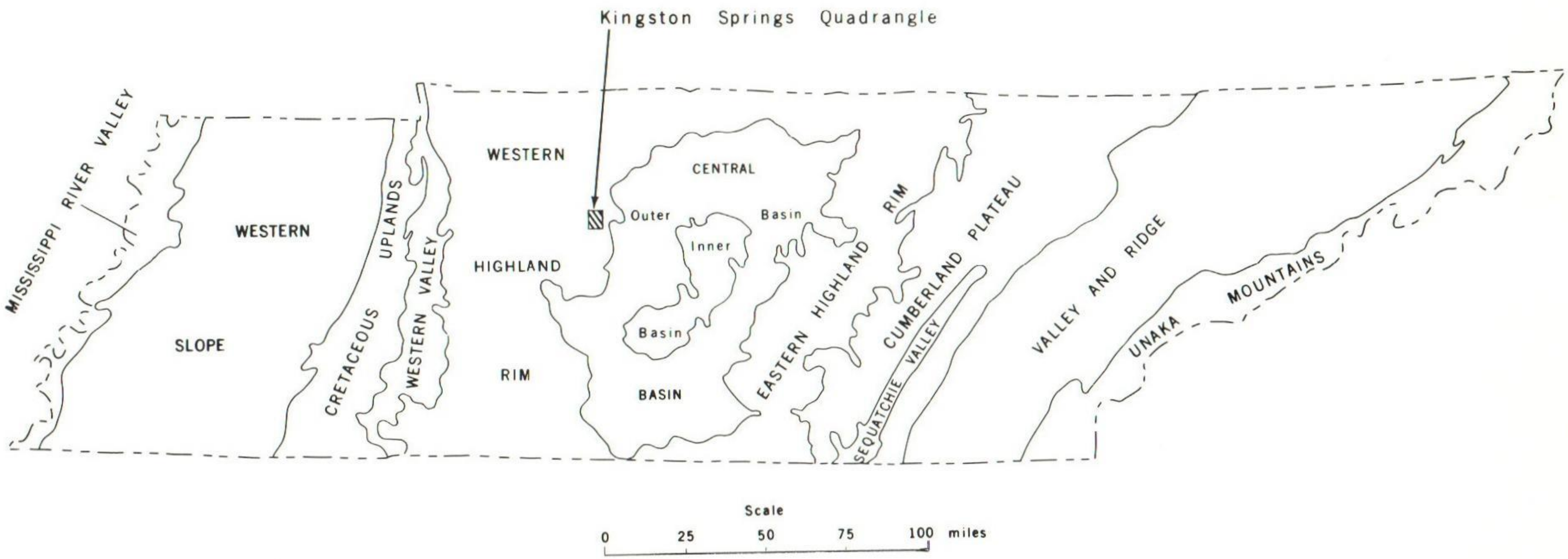

Figure 5. Physiographic map of Tennessee showing the location of the Kingston Springs quadrangle.

Springs quadrangle. These slopes are usually greater than 20%, and are essentially equivalent to the areas outlined on the map showing slopes that are potentially unstable. These slopes are also in a condition of equilibrium, for the abundant large chert fragments which persist in the residuum cannot efficiently be removed by erosion or by gravity movements on lower slopes. This critical angle of the Fort Payne slopes is directly related to slope stability problems inherent in the formation in this area. If the deep residuum is undercut, and the hillside consequently steepened beyond the critical slope, slump will likely occur in order to re-establish the proper (natural) slope angle previously achieved. The type of movement which occurs is slump (slope failure) in which the unit of material moves down and out with initial plastic deformation often followed by some flowage in the toe of the slide. Aiding in the movement in some cases, as well as increasing its dimensions, is the presence of joints in the saprolith. Large blocks of this semi-weathered material, breaking away along joint planes, may also move down-slope once undercutting occurs (Eilender, 1973). These steep Fort Payne areas are almost completely undeveloped in this quadrangle, most remaining in natural vegetation.

UPLANDS

Areas within the quadrangle which are underlain by Warsaw residuum occur on the uplands. They are gently rolling to nearly level and have been cleared in many cases for cultivation and habitation. These areas are confined to the west, southwest, and northeast parts of the quadrangle with elevations of approximatley 800 feet or more.

Some Fort Payne ridge tops in the quadrangle are gently rolling to only moderately steep, but are very limited in use due to their inaccessability and because their soils are shallow, cherty, and rapidly drained. Most are left in natural vegetation.

KARST FEATURES

Karst features are uncommon in this quadrangle. A few sinkholes are developed in pre-Chattanooga limestone overlain by alluvium along the Harpeth and South Harpeth rivers. One such sinkhole on the west side of the community of Pegram, just south of U. S. Highway 70, has a maximum length of almost 2000 feet although it is only 20 feet deep. It remains well drained, indicating solution openings still exist.

Consideration of these sinkholes is important for the planner, for they are most prevalent in the areas of higher alluvium of the abandoned flood plain which is suitable for various land uses. These sinkholes are probably the result of concentrated ground-water movement beneath the porous alluvial material, where underlying cave roofs have collapsed or settled.

Only two caves in the Kingston Springs quadrangle have been systematically explored and described. The following is a brief summary of data on each.

Parachute Cave

Location: 2.6 miles east of Pegram, on the north side of the Harpeth River.

Latitude: 36°05'45'' N.; *Longitude:* 87°00'15'' W.

Elevation: 580 feet

Geologic Horizon: Wayne Group

(Barr, 1959, p. 150)

Cave Springs Cave

Location: 600 feet southeast of Cave Springs School, on the east side of Turner Creek, and at the base of a hill.

Latitude: 36°06'02'' N.; *Longitude:* 87°02'36'' W.

Elevation: 570 feet

Geologic Horizon: Wayne Group

(Matthews, 1969, p. 35)

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