PHYSICAL CONSIDERATIONS FOR LAND USE PLANNING OF AN AREA IMMEDIATELY WEST OF MANHATTAN, KANSAS

by

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INTRODUCTION

Purpose of Investigation

The continued increase in demands for land places a burden on the planning process to provide enlightened decisions which will allow the optimum development of limited land resources. In order to plan for optimum development it is necessary to know the physical limitations of the land so that the best use may be made of the land resources. Much information about the physical characteristics of the area immediately west of Manhattan, Kansas, is presently available. The information, however, is scattered throughout many books, reports, and files, and is not totally complete. This report attempts to bring together the scattered information, fill in some of the information gaps, and divide the selected study area into capability units which have similar physical characteristics. The capability units can then be used to plan for the optimum development of the study area.

Scope of Investigation

Discussed in this report is geology, geography, soils, hydrology, earth materials, rock and mineral resources, and special physical considerations. The discussion of the geology of the study area includes stratigraphy, structure, and the earthquake history. Physiography, vegetation, and climate are included in the geography discussion. The engineering properties, location, and clay mineral content of the soils are described. The discussion of the hydrology of the study area includes water resources and flooding. Earth materials are categorized and described. The rock and mineral resources are divided into construction materials and minerals. Under special physical consideration the physical effect of the practice firing at Fort Riley is discussed. The discussion of each topic is limited to the physical effect that should be considered when establishing a general land use plan.

Location of Investigation

Manhattan, Kansas, is a community of approximately 30,000 persons, located at the confluence of the Kansas and Big Blue rivers in northeast Kansas (Fig. 1). Manhattan has grown in area during recent years in a westerly direction (Fig. 2). The area covered by this report is immediately west of the city limits and soon may be urbanized. The eastern half of the study area is within Manhattan's City Planning Zone two (Fig. 3), as outlined by the Manhattan Riley County planning boards (Riley County Planning Board, 1975). Some urban development has occurred along Wildcat Creek which flows through the southern third of the area (Pl. 1).

Previous Investigations

Use of geologic information in planning has attained great importance in the last 15 years. Most geologic writings prior to 1960 used geologic information to solve engineering problems, or emphasized esoteric geologic subjects. Numerous books and articles on the role of geology in planning appeared in the late 1960's and early 1970's. Perhaps the most widely known book of this period is "Design with Nature" by Ian McHarg (1969). McHarg's book introduced to planners and landscape architects the invaluable use of basic geologic information for site selection and planning. He developed an overlay system using increasing density of shading to indicate increasing physical and social costs for a specific use.

During this same period geologists attempted to make geologic information more readily available to non-geologists. Two noteworthy examples are "Environmental Geology" by Peter Flawn (1970), and "Cities and Geology" by Robert Leggett (1973). Flawn's approach introduced geologic processes and applied these to an example situation. Leggett used examples of past and present use and non-use of geologic information.

Recent efforts by geologists have been directed toward those who make planning decisions. Spangle, *et al*. (1974) prepared, for the United States

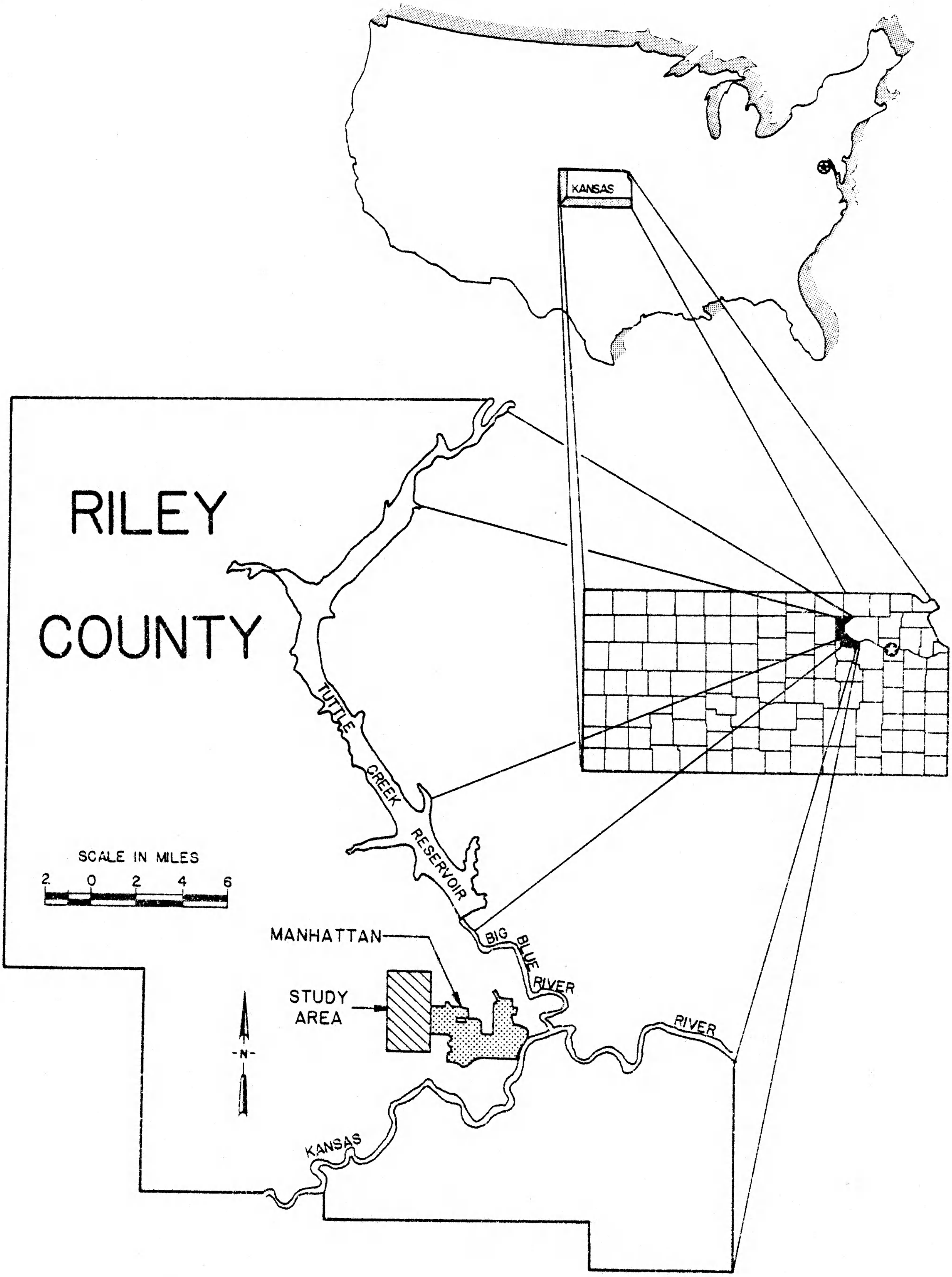


Figure 1. Location of study area in Riley County, Kansas

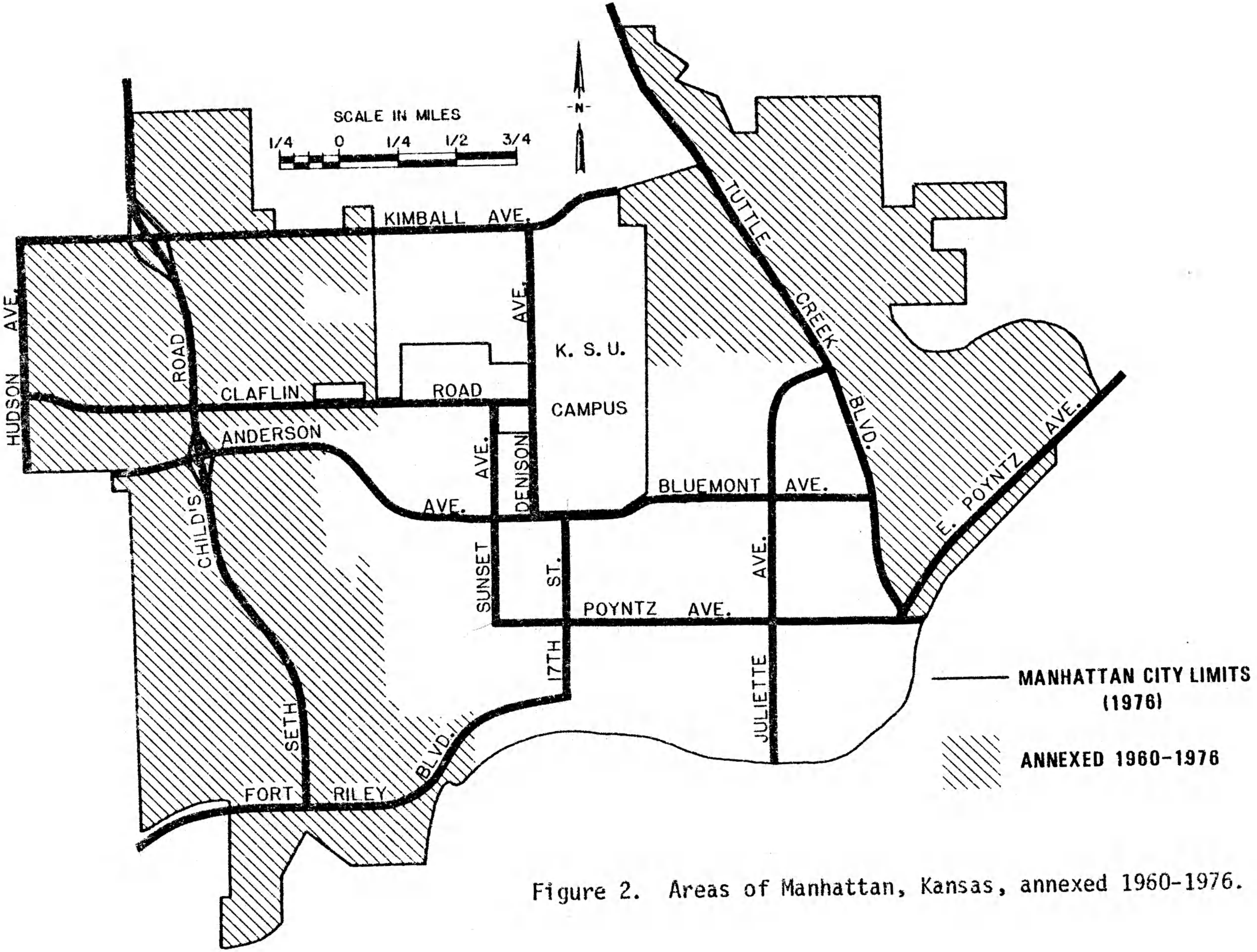


Figure 2. Areas of Manhattan, Kansas, annexed 1960-1976.

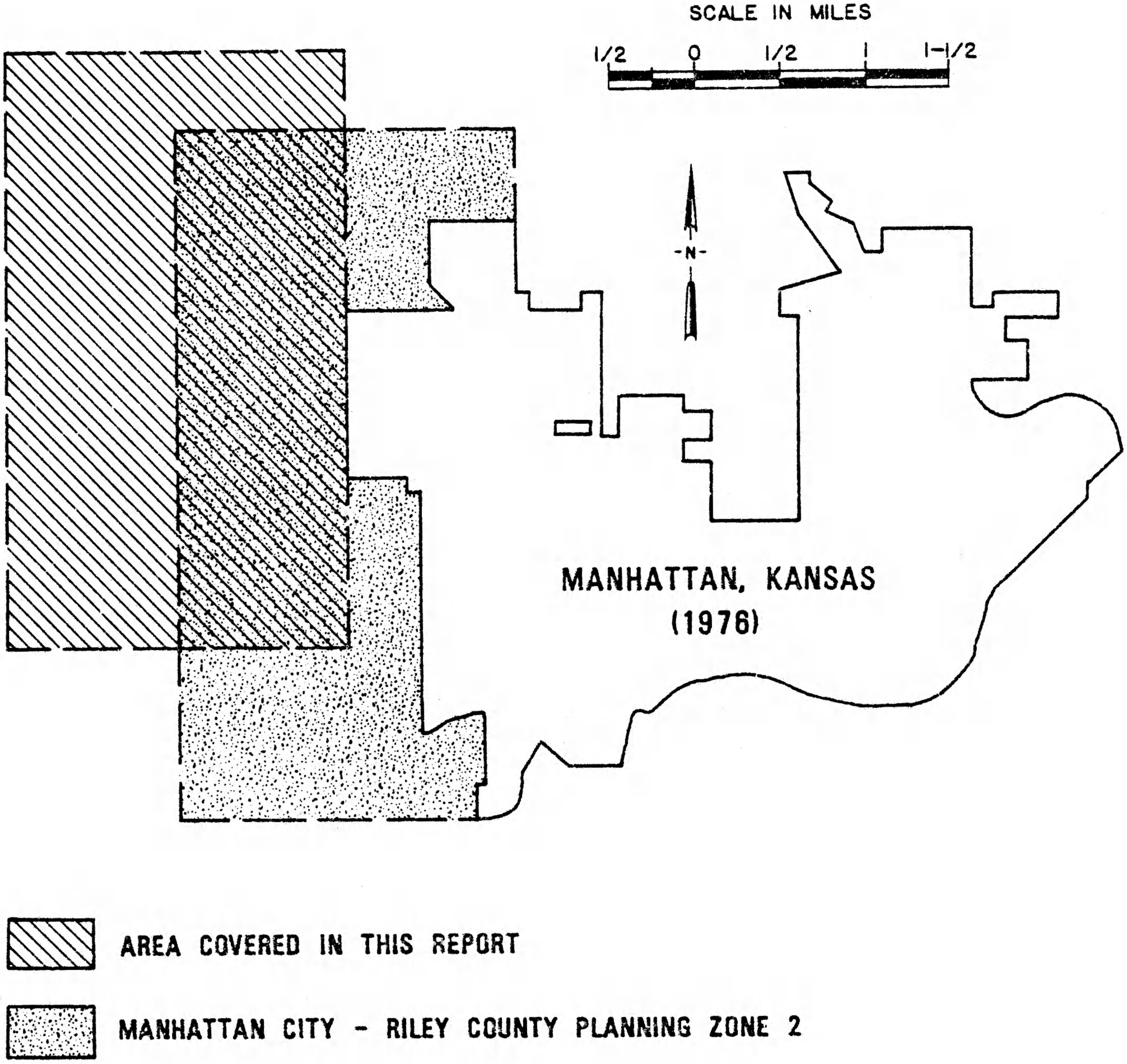
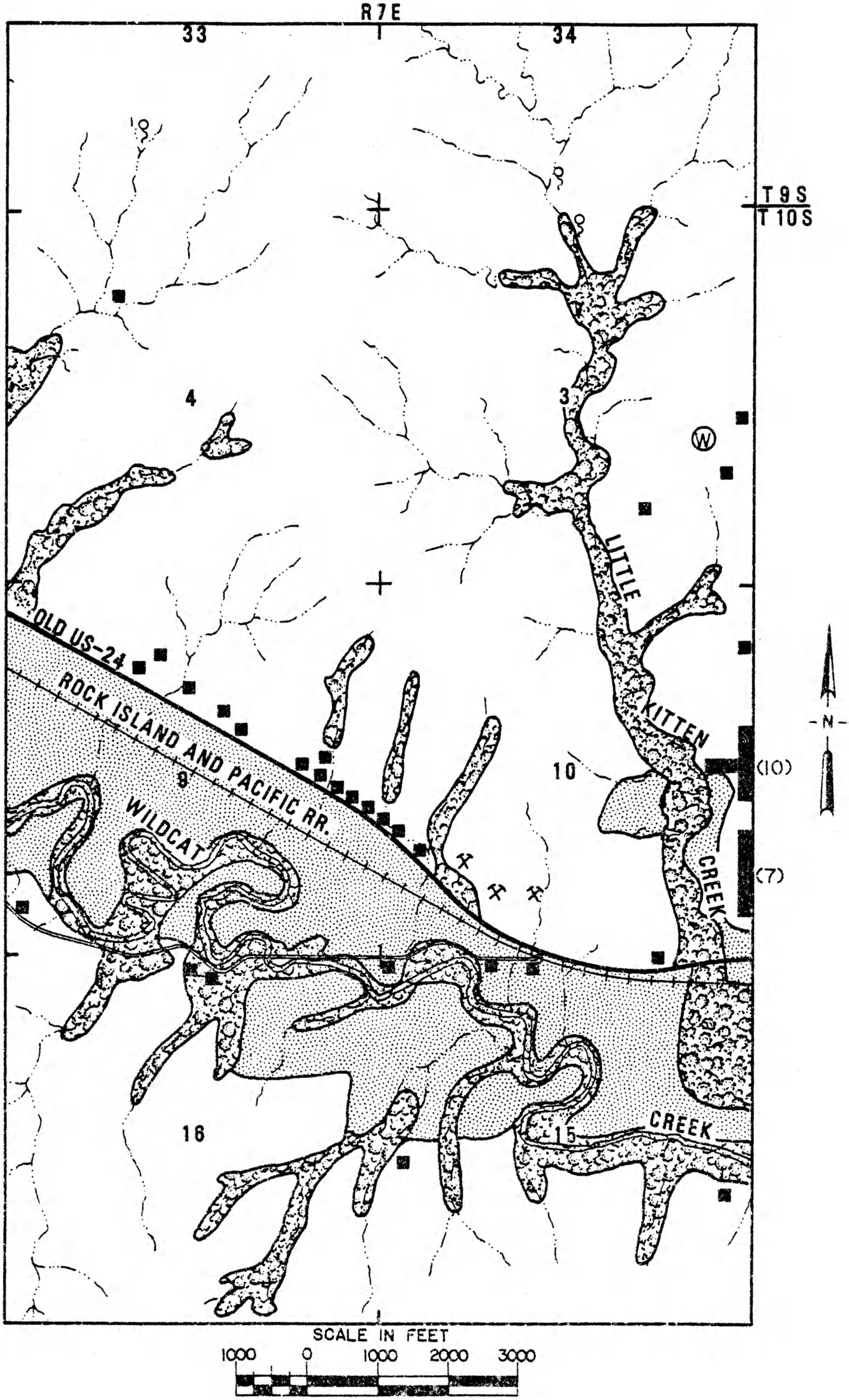


Figure 3. Relationship of study area to Manhattan/Riley County Planning Zone 2.

Plate 1. Generalized land uses within the study area.

▨	WOODLANDS & BRUSHLANDS
□	RANGELAND
▒	CULTIVATED LAND
⚒	ABANDON LIMESTONE QUARRY
■	RESIDENTIAL DWELLING: SINGLE
▮(2)	RESIDENTIAL DWELLING: MORE THAN ONE
Ⓦ	WATER STORAGE TANK CITY OF MANHATTAN
o∼	SPRING


R7E
33
34
T9S
T10S
4
3
W
LITTLE
KITTEN
CREEK
(10)
(7)
N
OLD US-24
ROCK ISLAND AND PACIFIC RR.
9
WILDCAT
10
16
15
CREEK
SCALE IN FEET
1000
0
1000
2000
3000

Geological Survey (USGS), a state-of-the-art review of applying earth-science information to urban land-use planning. Spangle, et al. (1974) was summarized in layman's language in 1976 as USGS Circular 721. Turner and Coffman (1973) summarized several mapping techniques used in compiling earth-science information for land-use planning. They also discussed the future requirements and the role of advanced computer systems in presenting geologic information.

Earth-science information for planning has been provided through state agencies because of the widely varied geologic circumstances in the United States. Several states have emerged as leaders in this effort and either have established special agencies or used existing agencies to provide earth-science information for use in planning. Missouri has published a series, Engineering Geology Reports, on the counties in the state, all of which contain a discussion of geologic factors that might influence land use and urban development. The Illinois State Geological Survey publishes a series, Environmental Geology Notes, which is distributed free to anyone who is interested. Illinois outlines specific problems where geologic information would be helpful. Texas has made significant contributions to environmental geology through publications of the Bureau of Economic Geology. Texas, through its Bureau of Economic Geology, has developed a series of publications which are designed to provide a comprehensive atlas of earth-science information areas within the state. An example of application of geologic information to planning in Kansas is provided by Hilpman (1968). Hilpman approached the subject by asking what information was needed by architects, engineers, planners, developers, and local officials, who make planning decisions. Other authors have asked decision makers for their input but, because of varied geographic areas their results are of limited application to Kansas and the area covered in this report.

Information on the area covered by this report comes from diverse sources. The geology of the area was first mapped by Jewett (1941). Byrne, et al. (1949) discussed and described the geologic construction materials resources of the area. Duryee, et al. (1974) discussed the relationship between the soils, geology, and land use of the Manhattan area. Jantz, et al. (1975) has published the soil survey of Riley County which includes the soils found in the area covered by this report. Chelikowsky (1972) discussed the goelogic structures which affect the bedrock underlying the area. The City of Manhattan and Riley County have commissioned several reports dealing with very specific projects in the area covered by this report. Surface water resources have been reviewed by the U.S. Army Corps of Engineers in connection with a report of flooding of portions of Wildcat Creek.

Methods and Procedures

Although some information in this report has been summarized from other investigations, some information represents original investigative work. The surface geology of the study area was mapped using aerial photographs with field checks. Large scale aerial photographs, 1 inch approximately equal to 660 feet, were used as a base and the mapping units were field-checked during the summer of 1976. The mapping method is described in Appendix 1. Three exposures of bedrock were measured and described (Appendix 2).

Dip of the rock units in the study area was measured using the large scale photographs and the U.S. Geological Survey's 7.5 minute Keats quadrangle topographic map of the area. To determine the dip of the rocks within the study area the top of the Cottonwood Limestone was used as a datum because of the ease with which it could be recognized both in the field and on aerial photographs. A determination of the strike was made by identifying two points on the datum within the study area which had the same elevation as given by the topographic map. The dip was then determined by dividing the difference in elevation as given by the topographic map by the perpendicular distance on the topographic map between the line defined by the two points and a third point on the datum within the study area. The distance between all points was kept as large as possible to eliminate the effect of any localized irregularities.

Joints present in the bedrock were measured both in direction and spacing by using a Brunton compass and a steel tape. Analysis of these measurements are given in Table 1. Locations where joints were measured are indicated on Plate 3.

* Physiographic subdivisions within the study area were recognized based upon the slope of the land, type of underlying bedrock, and thickness of the soils.

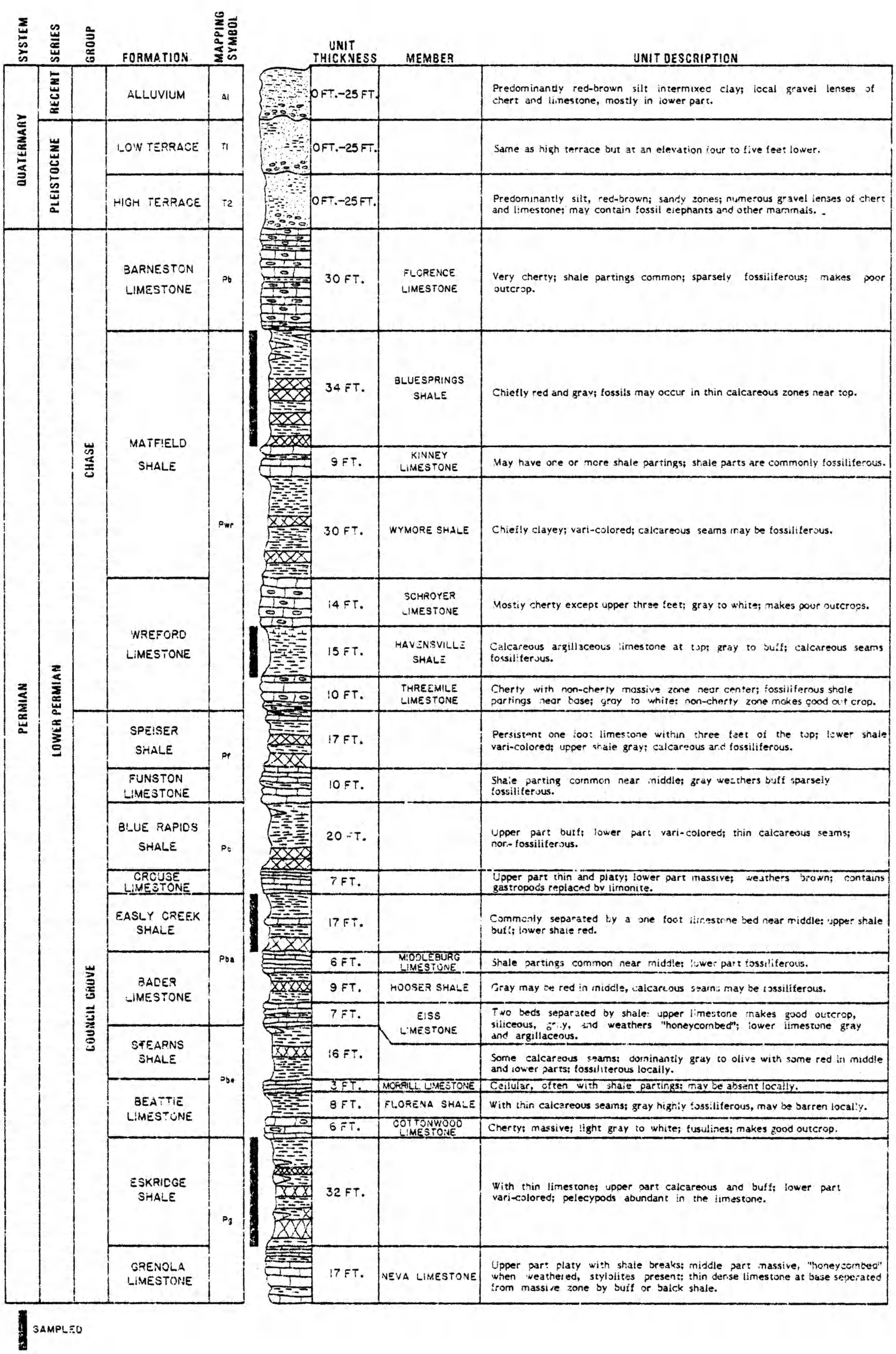
A clay mineral analysis was made of three soil samples, one from each physiographic subdivision (Pl. 4). Each soil sample was divided into two size fractions, less than two microns and greater than two microns. The less than two-micron fraction was analyzed for clay minerals using an X-ray diffractometer. Results of the diffraction analyses are given in Appendix 3. Soil sampling locations are indicated on Plate 4 and the relative quantities and types of clay minerals are given in Table 4.

Slopes within the study area were mapped using the U.S. Geological Survey's 7.5 minute Keats quadrangle topographic map. Slopes were analyzed by dividing the horizontal distance between two contour lines by the contour interval to determine the grade which was then mapped by categories (Pl. 6).

Four bulk shale samples were taken for engineering property tests. Three of the shales were sampled within the study area and the fourth shale was sampled from a road cut exposure a half-mile from the northeast corner of the study area (Pl. 2, Tab. 7). The bulk samples were taken through the full exposure of the shale to try and make the samples representative of the conditions that would occur if the shale were excavated and used for fill material. Bulk samples were then split using a quartering system until a split sample of approximately six pounds was obtained. Specific gravity, grain size and compaction analyses of the split samples were made using procedures described by Lambe (1951, p. 15-21, 32-39, 43-51). The analyses were used to establish a standard condition for the samples prior to testing for swelling. Each sample was compacted by a hydraulic press to a standard 95 percent Proctor density in a sample ring of a consolidometer. Compacted samples were then placed in a consolidometer and held under 500 pounds per square inch pressure while excess water was introduced. The total amount of expansion in inches was divided by the original sample thickness (0.75 inches) to obtain percent of linear expansion (Tab. 7). Results for all of the analyses is given in Appendix 4. The shale samples were also treated with an 18.5-percent hydrocloric acid solution to remove the carbonate and other soluble minerals. Percentage values of non-soluble minerals in the samples are given in Table 7. Clay minerals and quartz are the predominant non-soluble minerals found in the shales of this area. Chaudhuri (1978) indicates that two of the four shale samples show that quartz represents only 35 to 40 percent of the non-soluble residue in these samples.

GEOLOGY

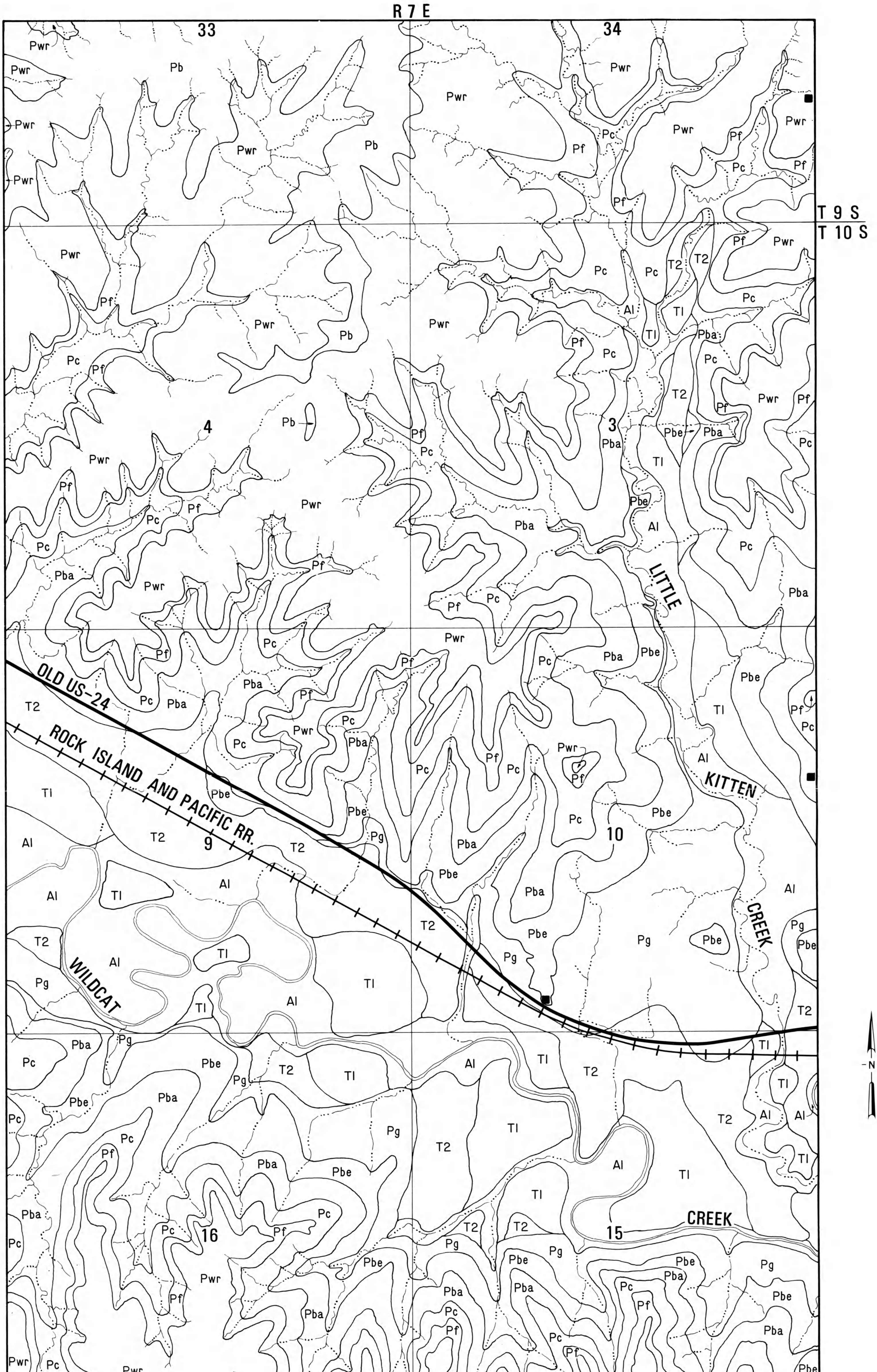
Geologic formations and their structures are the foundation upon which the physical abilities of the land are dependent. Bedrock of any area is altered by weathering processes particular to that area and the physical characteristics of the land are the result. To understand the physical properties it is necessary to start with the foundation upon which they depend. This is best done by first discussing the types and sequence of rocks (petrography and stratigraphy) and then discussing the attitude of the rocks (structure). The surface geology of the study area is mapped in Plate 2. The mapping units consist of a limestone formation and the overlying shale formation. Formations may consist of more than one member of differing type rock (Fig. 4).



SYSTEM	SERIES	GROUP	FORMATION	MAPPING SYMBOL	UNIT THICKNESS	MEMBER	UNIT DESCRIPTION
QUATERNARY	RECENT		ALLUVIUM	Al	0 FT.–25 FT.		Predominantly red-brown silt intermixed clay; local gravel lenses of chert and limestone, mostly in lower part.
	PLEISTOCENE		LOW TERRACE	Tl	0 FT.–25 FT.		Same as high terrace but at an elevation four to five feet lower.
			HIGH TERRACE	T2	0 FT.–25 FT.		Predominantly silt, red-brown; sandy zones; numerous gravel lenses of chert and limestone; may contain fossil elephants and other mammals.
PERMIAN	LOWER PERMIAN	CHASE	BARNESTON LIMESTONE	Pb	30 FT.	FLORENCE LIMESTONE	Very cherty; shale partings common; sparsely fossiliferous; makes poor outcrop.
			MATFIELD SHALE	Pwr	34 FT.	BLUESPRINGS SHALE	Chiefly red and gray; fossils may occur in thin calcareous zones near top.
					9 FT.	KINNEY LIMESTONE	May have one or more shale partings; shale parts are commonly fossiliferous.
					30 FT.	WYMORE SHALE	Chiefly clayey; vari-colored; calcareous seams may be fossiliferous.
			WREFORD LIMESTONE		14 FT.	SCHROYER LIMESTONE	Mostly cherty except upper three feet; gray to white; makes poor outcrops.
					15 FT.	HAVENSVILLE SHALE	Calcareous argillaceous limestone at top; gray to buff; calcareous seams fossiliferous.
					10 FT.	THREEMILE LIMESTONE	Cherty with non-cherty massive zone near center; fossiliferous shale partings near base; gray to white; non-cherty zone makes good out crop.
		COUNCIL GROVE	SPEISER SHALE	Pf	17 FT.		Persistent one foot limestone within three feet of the top; lower shale vari-colored; upper shale gray; calcareous and fossiliferous.
			FUNSTON LIMESTONE		10 FT.		Shale parting common near middle; gray weathers buff sparsely fossiliferous.
			BLUE RAPIDS SHALE	Pc	20 FT.		Upper part buff; lower part vari-colored; thin calcareous seams; non-fossiliferous.
			CROUSE LIMESTONE		7 FT.		Upper part thin and platy; lower part massive; weathers brown; contains gastropods replaced by limonite.
			EASLY CREEK SHALE	Pba	17 FT.		Commonly separated by a one foot limestone bed near middle; upper shale buff; lower shale red.
			BADER LIMESTONE		6 FT.	MIDDLEBURG LIMESTONE	Shale partings common near middle; lower part fossiliferous.
					9 FT.	HOOSER SHALE	Gray may be red in middle, calcareous seams may be fossiliferous.
					7 FT.	EISS LIMESTONE	Two beds separated by shale: upper limestone makes good outcrop, siliceous, gray, and weathers "honeycombed"; lower limestone gray and argillaceous.
			STEARNS SHALE	Pbe	16 FT.		Some calcareous seams; dominantly gray to olive with some red in middle and lower parts; fossiliterous locally.
			BEATTIE LIMESTONE		3 FT.	MORRILL LIMESTONE	Cellular, often with shale partings; may be absent locally.
					8 FT.	FLORENA SHALE	With thin calcareous seams; gray highly fossiliferous, may be barren locally.
					6 FT.	COTTONWOOD LIMESTONE	Cherty; massive; light gray to white; fusulines; makes good outcrop.
			ESKRIDGE SHALE	Pg	32 FT.		With thin limestone; upper part calcareous and buff; lower part vari-colored; pelecypods abundant in the limestone.
			GRENOLA LIMESTONE		17 FT.	NEVA LIMESTONE	Upper part platy with shale breaks; middle part massive, "honeycombed" when weathered, stylolites present; thin dense limestone at base seperated from massive zone by buff or balck shale.

▮ SAMPLED

Figure 4. Generalized stratigraphic section of rock units cropping out within the study area. (after Chelikowsky *et al.*, 1963)


R 7 E
33
34
T 9 S
T 10 S
4
3
9
10
16
15
OLD US-24
ROCK ISLAND AND PACIFIC RR.
LITTLE
KITTEN
CREEK
WILDCAT
CREEK
Pwr
Pb
Pf
Pc
Pba
Pbe
Pg
T2
Tl
Al
N
SCALE IN FEET
1000
0
1000
2000
3000

Stratigraphy

Permian System - Lower Permian Series - Gearyan Stages

Council Grove Group.--The upper part of the Council Grove Group consists of a sequence of alternating limestone and shale beds. In general the limestones of this group are thinner and more thinly bedded than the overlying Chase Group (Zeller, 1968, p. 45).

Grenola Limestone.--Only the Neva Limestone Member of the Grenola Limestone is exposed within the study area. The Neva consists of three limestone beds interbedded with shales. The lower limestone bed and the shale above it are generally covered within the area. The middle limestone is thick-bedded, gray, eight feet thick and forms a prominent hillside bench. Building stone has been quarried from this bed in other areas. Above the massive limestone is a gray to grayish-green fossiliferous shale, one foot thick (Zeller, 1968, p. 46). The top limestone bed of the Neva is two feet thick, gray, and platy.

Eskridge Shale.--The Eskridge Shale is a varicolored shale and about 32 feet thick in the Manhattan area. A persistent limestone bed less than one foot thick occurs in the middle to upper part of the unit.

Beattie Limestone.--The Beattie Limestone consists of two limestone members separated by a shale member (Zeller, 1968, p. 47). The Cottonwood Limestone Member is the lower member that is six feet thick and contains some chert nodules and abundant fusulines (a small wheat-grain shaped fossil) in the upper part. The Cottonwood has been quarried for building stone and some abandoned quarries exist in the southeast part of the study area. Springs may occur at the contact with the underlying Eskridge Shale, and the relatively large amount of water in the Cottonwood encourages a strong growth of brush on the hillsides above where the shale crops out. The Florena Shale Member is the middle unit and immediately overlies the Cottonwood. The Florena is highly fossiliferous, forming a shall bed at places (Byrne, et al., 1949, p. 15). Thickness of the Florena in the area is eight feet. The Morrill Limestone Member is the upper limestone in the Beattie Limestone. The Morrill is three feet thick and massive when unweathered but, when exposed weathers quickly to a cellular or cavernous structure (Byrne, <u>et</u> <u>al</u>., 1949, p. 25). There may be a thin shale parting in the middle of the Morrill.

Stearns Shale.--The Stearns Shale is a 16-foot thick calcareous silt shale, gray to olive in fresh outcrops, and light gray to light brown in weathered portions (Byrne, <u>et</u> <u>al</u>., 1949, p. 24). A few calcareous seams occur in the lower and middle portions.

Bader Limestone.--The Bader Limestone includes three members from the bottom up, the Eiss limestone, Hooser shale, and Middleburg limestone and has a total thickness of 22 feet. The lower bed of the Eiss is two feet thick, shaly, and thin-bedded, and contains some high-spired gastropod (snail) fossils. The upper limestone bed of the Eiss is three feet thick, contains some chert, and forms a prominent outcrop (Zeller, 1968, p. 47). Separating the two limestones of the Bader Limestone is the Hooser Shale Member, a gray to grayish-green shale, nine feet thick, which has some fossiliferous calcareous seams in places. The upper member of the Bader Limestone is the Middleburg limestone which consists of two limestone beds separated by a dark gray shale. The lower limestone bed is slabby to massive; the upper limestone bed is platy. Total thickness of the Middleburg is six feet.

Easly Creek Shale.--The Easly Creek Shale is varicolored, thin-bedded to blocky, calcareous and silty. One or two thin layers of dense limestone occur near the top of this unit which is 17 feet thick (Byrne, <u>et</u> <u>al</u>., 1949, p. 24).

Crouse Limestone.--This limestone consists of a massive basal limestone bed and an upper sequence of hard, thin limestone beds separated by thin-bedded fossiliferous shales. The upper limestone beds weather to blocks and plates which may be found uphill from the prominent bench formed by the lower massive bed. Total thickness of the Crouse Limestone is seven feet.

Blue Rapids Shale.--The Blue Rapids Shale is a non-fossiliferous, gray to tan, or varicolored red and green, thin-bedded to blocky shale. Total thickness of the Blue Rapids Shale is 20 feet.

Funston Limestone.--The Funston Limestone is composed of limestone beds separated by one or two thin calcareous, light brown silty shale beds, in the middle or lower part (Byrne, _et al._, 1949, p. 23). The limestone beds are massive and weather to blocks or plates. Outcrops may be stained by iron oxide from the overlying Speiser Shale. Total thickness is 10 feet, and a well-defined hillside bench is formed by this unit.

Speiser Shale.--The Speiser Shale is varicolored, thin-bedded to blocky, silty to clayey, and calcareous shale that is 17 feet thick. A persistent massive gray-orange limestone that is one foot thick occurs in the upper three feet of this unit. The part of the shale above the limestone bed is fossiliferous locally.

Chase Group.--Only three formations of the Chase Group crop out in the study area. These formations consist of a series of limestone and shale beds that are, in general, more massive and thick-bedded than those found in the underlying Council Grove Group. The limestone beds in this group generally contain an abundance of chert nodules or chert beds or both, and form prominent hillside benches.

Wreford Limestone.--This formation of the Chase Group consists of two cherty limestone members and an intervening shale member. The lower Threemile Limestone Member is light gray to white, and commonly cherty throughout (Byrne, _et al._, 1949). Total thickness of the Threemile is 10 feet. The Havensville Shale Member overlies the Threemile and is gray, calcareous, may contain several limestone beds, and is 15 feet thick. The Schroyer Limestone Member of the Wreford Limestone is gray, hard, fossiliferous, and contains chert nodules or beds with less chert in upper part of the limestone. Total thickness of the Schroyer is 14 feet. The two limestone members of the Wreford Limestone form hillside benches with the Threemile bench more prominent.

Matfield Shale.--The Matfield Shale consists of two shale members and a middle limestone member. The Wymore shale is the lower member and is blocky to platy, thin-bedded, varicolored, calcareous and 30 feet thick (Byrne, _et al_., 1949, p. 21). Two thin limestone beds are present in the upper part. The Kinney Limestone Member, which is nine feet thick, consists of two gray fossiliferous limestone beds separated by a gray fossiliferous mudstone. The Blue Springs shale is the upper member of the Matfield Shale. The Blue Springs, is 34 feet thick, red, green, and gray with fossiliferous calcareous zones near the top. The slope below the hill-top benches formed by the Florence Limestone Member of the Barneston Limestone is formed on the Blue Springs Shale Member of the Matfield Shale.

Barneston Limestone.--The Florence limestone member of the Barneston Limestone occurs in the study area. The Florence is easily recognized by the abundant chert nodules and chert bands which occur throughout the total thickness of 30 feet. The Florence caps the ridges in the western portion of the area where weathering has left residual chert gravel. The Florence consists of several cherty limestone beds separated by thin shale beds; the shales in the lower part are fossiliferous.

Quaternary System - Pleistocene Series - Wisconsin Stage

Terrace Deposits.--Two levels of terrace deposits occur along Wildcat and Little Kitten creeks. The older upper terrace deposits occur along the lower slopes of the hillsides at an elevation five to ten feet higher than the lower terrace deposits. The lower terrace deposits are located between the upper terrace deposits and the floodplain, and are five to ten feet higher than the floodplain. These terrace deposits consist of gravel, sand, silt, and clay and are somewhat graded. Locally one or both levels of terraces are missing, having been eroded by the stream as it meandered across the valley.

Quaternary System - Pleistocene Series - Recent Stage

Alluvium.--Streams within the study area are eroding sediment from their upper reaches and depositing it at a lower level downstream. These sediments constitute the floodplain and channel deposits. Deposits of alluvium contain predominantly silt and clay with local sandy zones and some chert and limestone gravel. The alluvium is about 50 feet thick along Wildcat Creek and about 25 feet thick in the smaller tributary streams (Byrne, et al., 1949, p. 7).

Structure

Limestone and shale were deposited as soft muds and oozes in the Permian sea which covered most of Kansas. Pressure from the addition of more sediments upon the top of the already deposited oozes and muds, together with the passage of time, caused the soft sediments to be lithified. During deposition sediments are not laid upon perfectly flat surfaces and may not be the same thickness everywhere. This and any folding and bending which occur during lithification give the rocks a general shape which may be described. The rocks within the area maintain a constant thickness and dip approximately 15 feet per mile to the west. Some dip might be the result of upward movement of the Nemaha anticline to the east which is described by Merriam (1963) as being mildly tectonically active.

Regional deformation and folding have affected the structure of the rocks within the area. The axis of the Nemaha Anticline is 10 miles east, and is a major structural feature in Nebraska, Kansas, and Oklahoma. The axis of the Abilene Anticline is 20 miles west, and this fold is another major structural feature in Nebraska and Kansas. The area between the two anticlines is known as the Irving Syncline. The stress which caused movement along the features has fractured the bedrock and created joints in the rocks. Neff (1949) discussed the theory of joints together with the mechanisms which created these joints.

Joints within the study area show an east northeast west southwest and a north northwest south southeast orientation, with the two sets of joints being approximately perpendicular to each other. Both joint sets are approximately perpendicular to the rock bedding. Joints measured in the Barneston Limestone show a minor third set in a north northeast south southwest direction. Joint direction and spacing were measured at two localities, one in the northern part and one in the southern part of the study area. Plate 3 shows direction of joints with the length of individual lines showing the number of joints having that bearing. For clarity only those bearings which had two or more joints are shown.

Neff (1949, p. 6) indicated that spacing, but not direction of jointing is controlled by the type of rock. Measurements of joint spacing (Tab. 1) indicate that less massive cherty limestone shows more closely spaced joints than more massive non-cherty limestone. This closer spacing is probably because of the thinner more brittle beds in cherty limestone. Because of weathering of the shale outcrops, only one series of joint spacing was measured in a shale. The Blue Springs Shale, in which the joint spacing was measured, is located stratigraphically between two limestone units with relatively close joint spacing. The spacing of the joints in the shale follow more closely that of the cherty limestone.

Additional fracturing of bedrock occurs near excavations in which explosives were used. The two sets of joints measured in the Beattie Limestone illustrate this point. The naturally occurring Cottonwood Limestone Member shows few joints with spacing of six to eight feet. The Cottonwood found in a roadcut in which explosives were used shows a much larger number of joints on a 1.5 to 3 foot spacing (Tab. 1). The joints in the roadcut show the same trends as the naturally occurring joints (Pl. 3).

KEY TO GEOLOGY

QUATERNARY SYSTEM

PLEISTOCENE SERIES

RECENT STAGE

Al	ALLUVIUM

WISCONSINAN STAGE

Tl	LOW TERRACE
T2	HIGH TERRACE

■ SHALE SAMPLE LOCATIONS

Plate 2. Geologic map of study area.

PERMIAN SYSTEM

LOWER PERMIAN SERIES

GEARYAN STAGE

CHASE GROUP

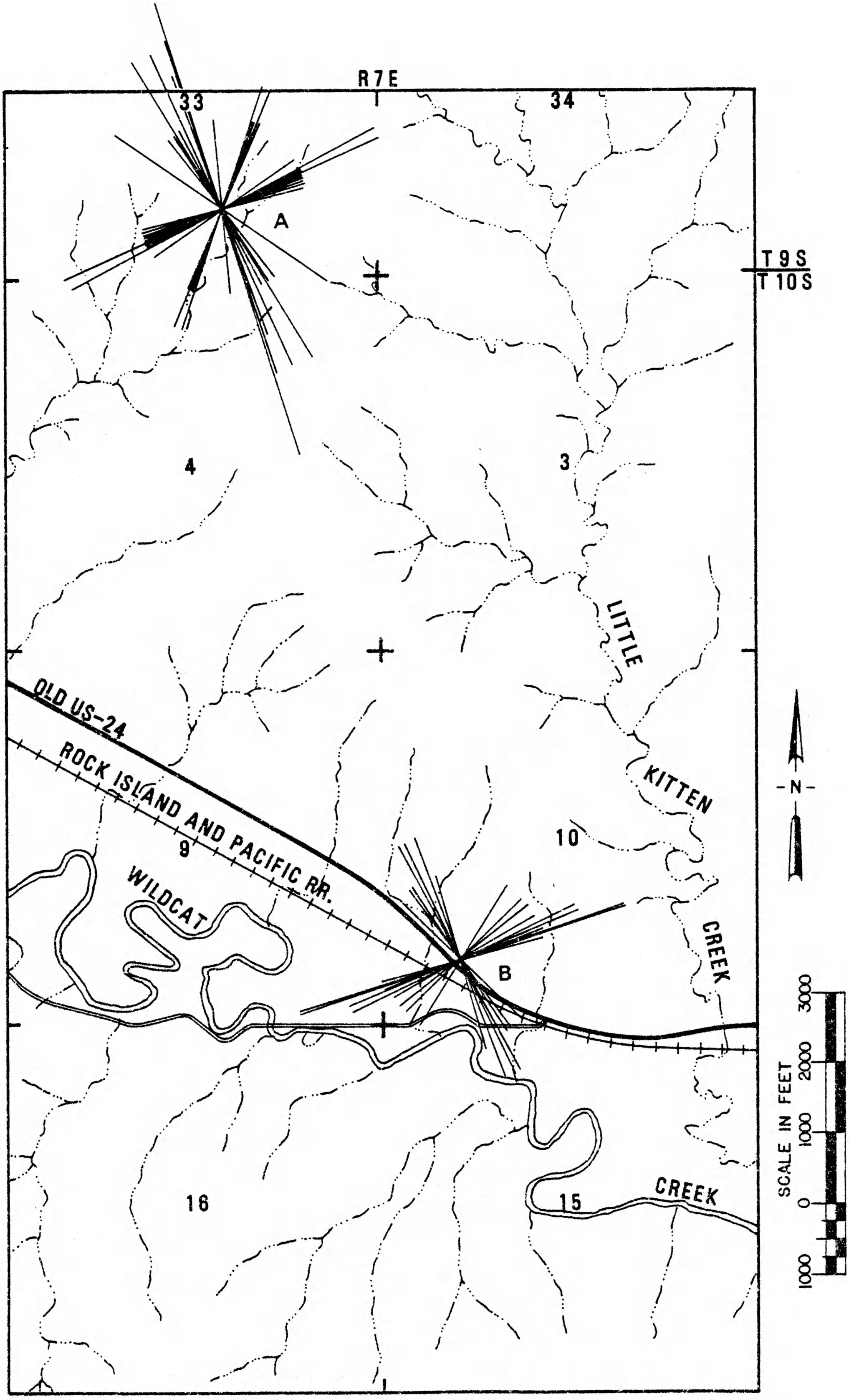
	FORMATIONS	MEMBERS
Pb	BARNESTON LS	FLORENCE LS
Pwr	MATFIELD SH	BLUE SPRINGS SH (SAMPLED) KINNEY LS WYMORE SH
	WREFORD LS	SCHROYER LS HAVENSVILLE SH (SAMPLED) THREEMILE LS

COUNCIL GROVE GROUP

	FORMATIONS	MEMBERS
Pf	SPEISER SH	
	FUNSTON LS	
Pc	BLUE RAPIDS SH	
	CROUSE LS	
Pba	EASLY CREEK SH (SAMPLED)	
	BADER LS	MIDDLEBURG LS HOOSER SH EISS LS
Pbe	STEARNS SH	
	BEATTIE LS	MORRILL LS FLORENA SH COTTONWOOD LS
Pg	ESKRIDGE SH (SAMPLED)	
	GRENOLA LS	NEVA LS

Table 1. - Spacings of joints in Permian bedrock immediately west of Manhattan, Kansas.

SAMPLE LOCATION	TYPE OF ROCK	BED	Average spacing/Number of joints ENE-WSW	NNW-SSE	NNE-SSW
Barneston Limestone Formation					
Florence Limestone Member					
NW¼, NE¼, SE¼, Sec. 33, T. 9 S., R. 7 E. (stream bed)	cherty limestone	limestone	0.9in/20	0.8in/20	0.8in.20
Matfield Shale Formation					
Blue Springs Shale Member					
SW¼, NE¼, SE¼, Sec. 33, T. 9 S., R. 7 E. (stream bank)	shale	shale	0.2in/7	1.8in/7	
Wreford Limestone Formation					
Schroyer Limestone Member					
NE¼, SE¼, SE¼, Sec. 33, T. 9 S., R. 7 E. (stream bed)	cherty limestone	limestone chert	1.8in/14 0.2in/30	2.0in/11 0.2in/30	
Beattie Limestone Formation					
Cottonwood Limestone Member					
NW¼, NE¼, NE¼, Sec. 10, T. 10 S., R. 7 E. (stream bed)	non-cherty limestone	limestone	8.2ft/2	5.8ft/2	
SW¼, SE¼, SW¼, Sec. 10, T. 10 S., R. 7 E. (roadcut)	non-cherty limestone	limestone	1.7ft/13	2.8ft/17	
Grenola Limestone Formation					
Neva Limestone Member					
SW¼, SE¼, SW¼, Sec. 10, T 10 S., R. 7 E. (roadcut)	non-cherty limestone	limestone	1.3ft/34	2.1ft/34	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Earthquake History

Several earthquakes have shaken Kansas in historic time. Of the 41 earthquakes known to have been felt in Kansas, 14 have possibly been felt in Manhattan, 7 of the 14 had epicenters in the Manhattan area (Merriam, 1963). Table 2 lists the earthquakes felt in the Manhattan area and the dates of their occurrence. Although the last earthquake felt in the Manhattan area occurred in 1961, in comparison to the rest of Kansas the Manhattan area has a high incidence of earthquakes (Fig. 5). Based upon past occurrence, size of earthquakes, and geologic structure, the United States has been divided into seismic risk zones (Fig. 6). Manhattan and the area covered in this report have been placed in seismic risk zone 2 (Algermissen, 1969), indicating there is a high probability that if an earthquake should occur it would cause moderate damage with an intensity of VII (Coffman and von Hake, 1973). Intensity VII corresponds to a Richter magnitude of 5.5 to 6.1 (Holmes, 1965, p. 901).

Table 2. - Earthquakes known to have been felt in the Manhattan, Kansas area. (after Merriam, 1963, p. 288-289, and Dubois and Wilson, 1978)

DATE	APPROXIMATE EPICENTER	MAXIMUM INTENSITY MM*
1811, December 16	New Madrid, Missouri	X
1867, April 24	Wamego, Kansas	VII
1875, November 8	Topeka, Kansas	V
1877, November 15	Eastern Nebraska	VII
1895, October 31	Charleston, Missouri	VIII-IX
1906, January 7	Manhattan, Kansas	VII-VIII
1906, January 23	Manhattan, Kansas	II-III
1929, September 23	Manhattan, Kansas	V
1929, October 21	Junction City, Kansas	V
1929, October 23	Junction City, Kansas	II or III?
1929, December 7	Junction City, Kansas	V
1939, November 23	Griggs, Illinois	V
1952, April 9	Oklahoma City, Oklahoma	VII
1961, December 25	Excelsior Springs, Missouri	IV-V

*MM -- Twelve point Modified Mercalli scale of 1956

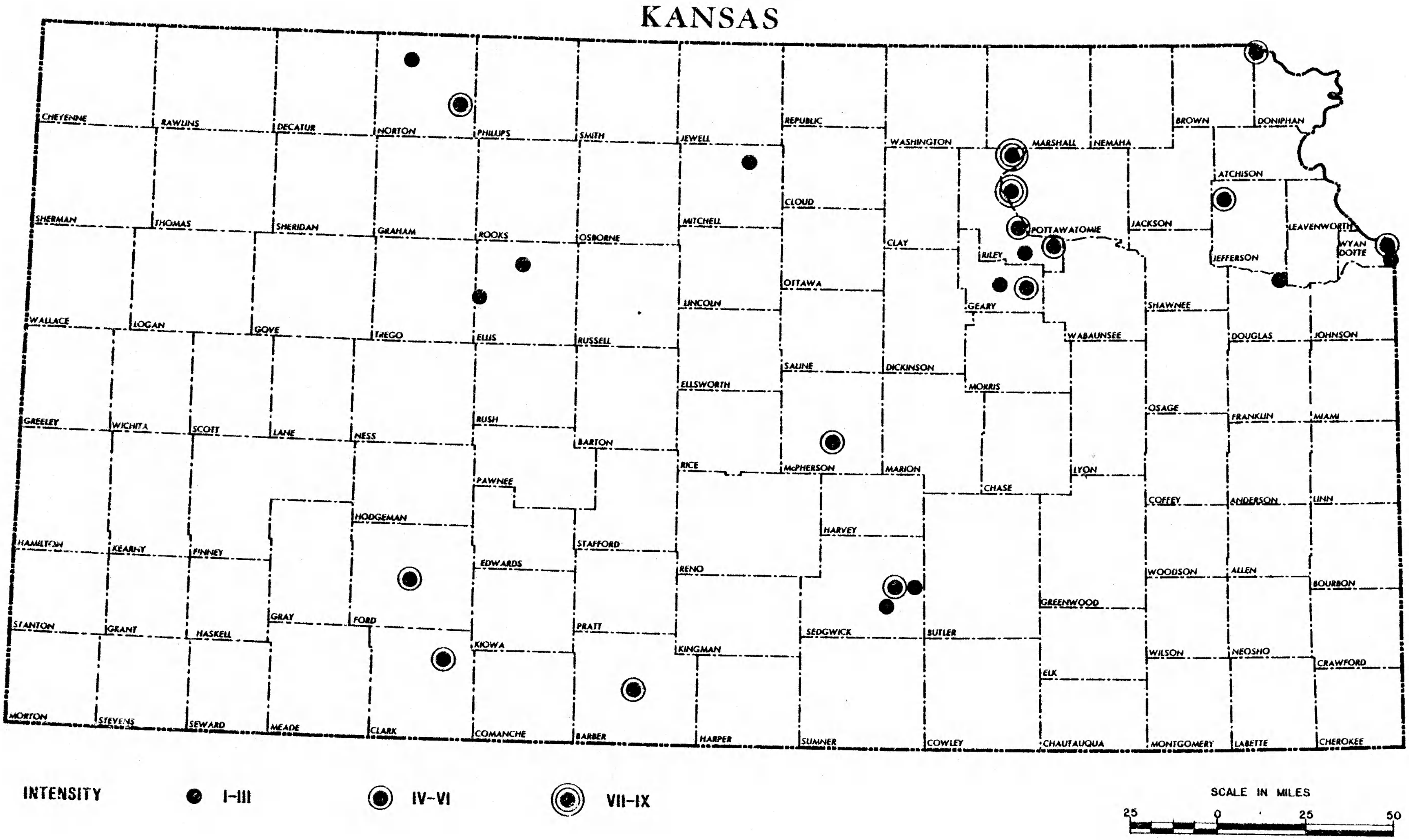


Figure 5. Earthquake epicenters in Kansas (after Merriam, 1963).

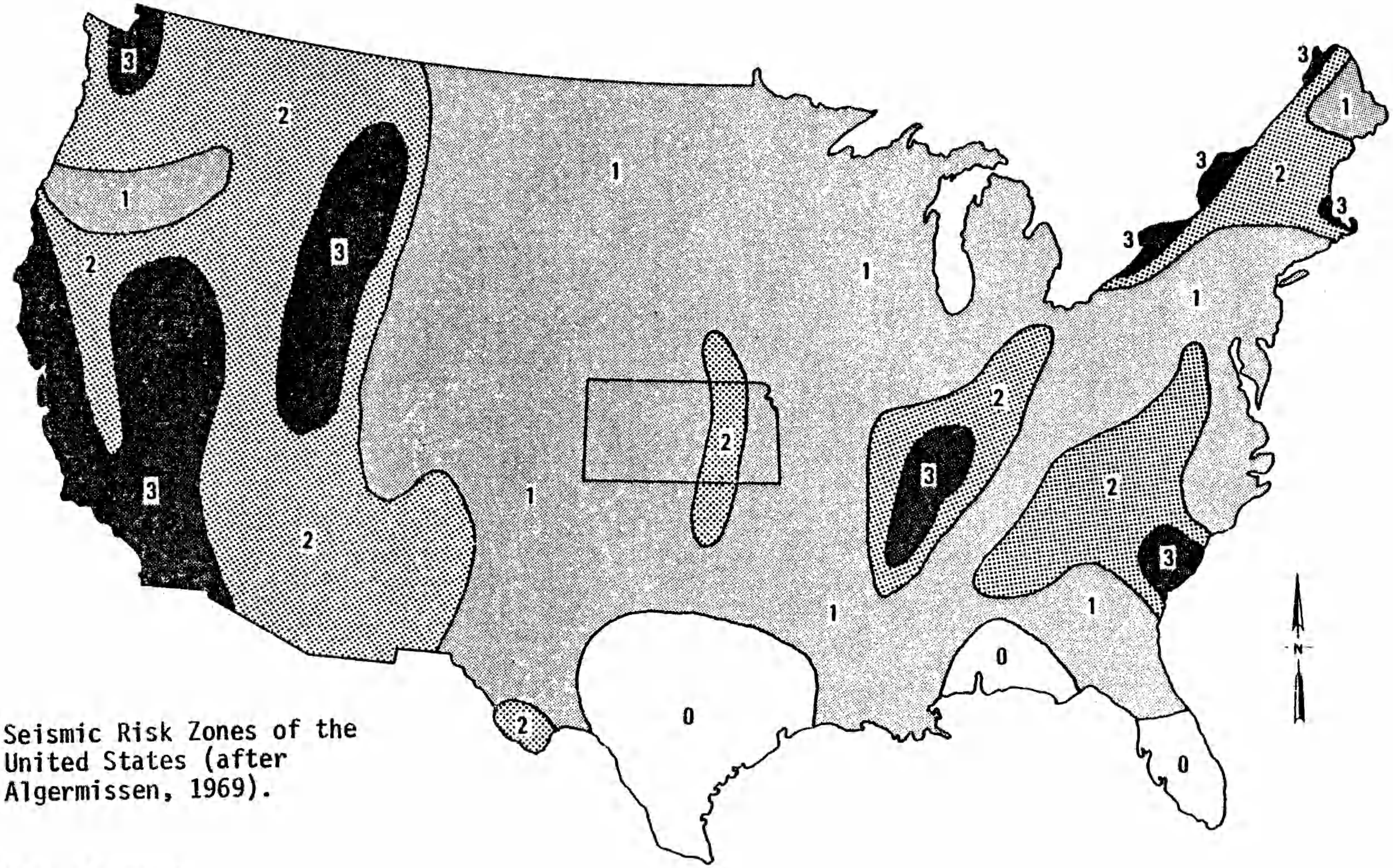


Figure 6. Seismic Risk Zones of the United States (after Algermissen, 1969).

ZONE 0 – NO DAMAGE

ZONE 1 – MINOR DAMAGE: CORRESPONDS TO INTENSITY V AND VI OF THE M.M. °SCALE

ZONE 2 – MODERATE DAMAGE: CORRESPONDS TO INTENSITY VII OF THE M.M. °SCALE

ZONE 3 MAJOR DAMAGE: CORRESPONDS TO INTENSITY VIII AND HIGHER OF THE M. M. °SCALE

° MODIFIED MERCALLI INTENSITY SCALE OF 1931.

The seismic risk map of the United States has been included in the U.S. Uniform Building Code for determining criteria for earthquake-resistant design of critical structures (Dubois and Wilson, 1978, p. 1).

GEOGRAPHY

Physiography

Manhattan and the area surrounding it are in the Flint Hills division (Fig. 7) of the Central Lowland Province of the United States (Socolofsky and Self, 1972, map 3). The Flint Hills are the expression of the cherty-limestone beds which resisted weathering forming flat-topped cuestas. Schoewe (1949, p. 288) indicated that the presences of chert is not solely responsbile for the topographic expression in the Flint Hills, but the chert accentuates the resistence of the hard layers and likewise magnifies the results of erosion. Three physiographic subdivisions may be recognized in the study area: valley bottom, valley wall, and limestone terrace. The physiographic subdivisions may be identified on the basis of slope of the land and type of underlying bedrock (Pl. 4).

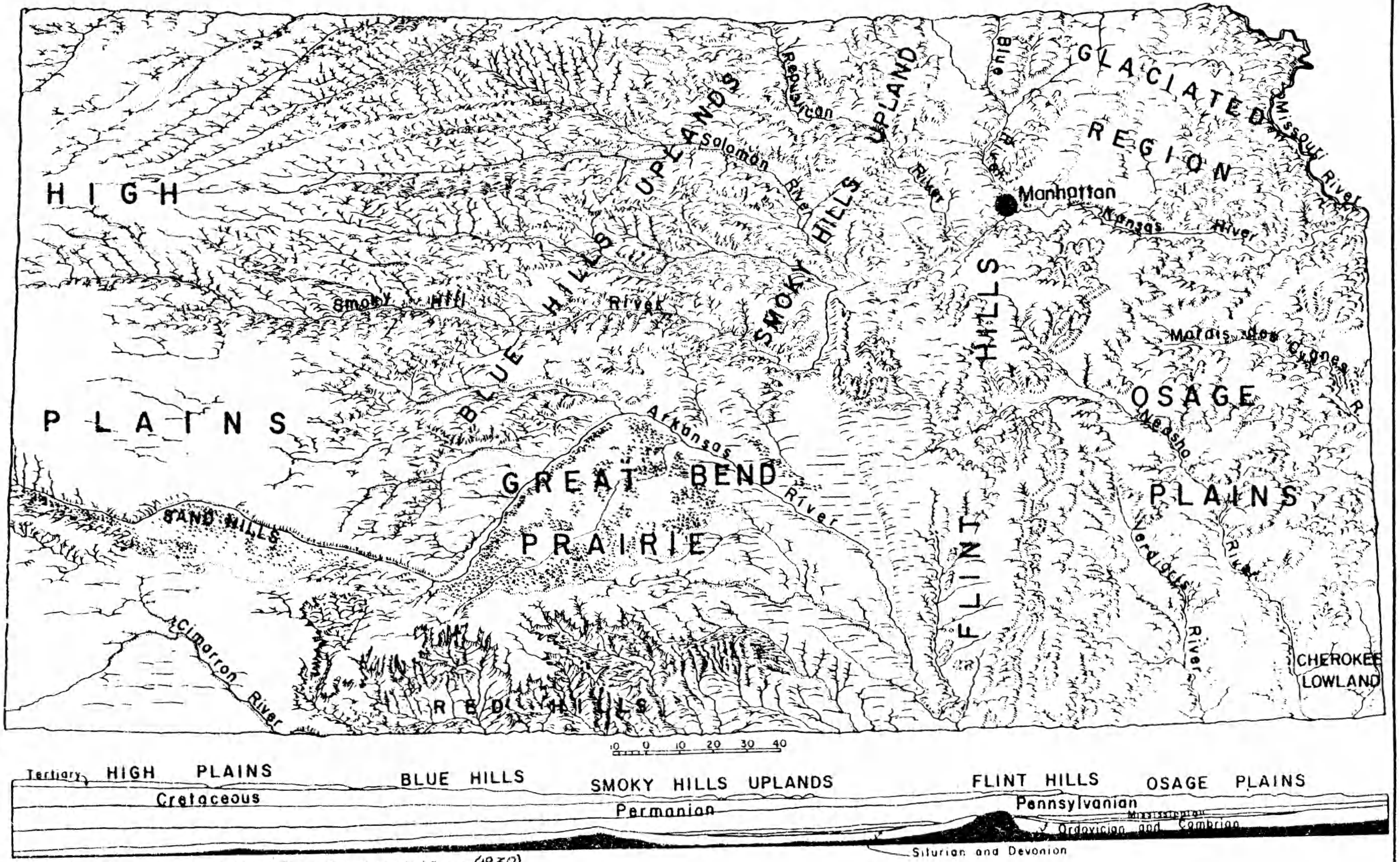
Valley bottom consists of those areas which are mostly stream terraces and floodplains. Most of this subdivision lies along both sides of Wildcat Creek and along Little Kitten Creek. Small portions lie along and form the banks of tributary streams of Wildcat Creek. Slopes in this subdivision range from one to five percent with the areas along the small tributary streams having slopes of 5 to 15 percent. Sediment underlying this physiographic subdivision was transported either by running water (alluvium) or by mass movement (colluvium). Bedrock in this subdivision may be at a depth of 50 feet along Wildcat Creek (Byrne, et al., 1949, p. 7).

Valley walls consist of the severely dissected limestone and shale outcrops, with some colluvial deposits on the lower slopes. Slopes of this subdivision range from 5 to more than 15 percent, with the more gentle slopes on

Plate 3. Joint directions in bedrock of study area.

A. Barneston Limestone - Matfield Shale (natural exposure)

B. Beattie Limestone - Eskridge Shale - Grenola Limestone (roadcut)

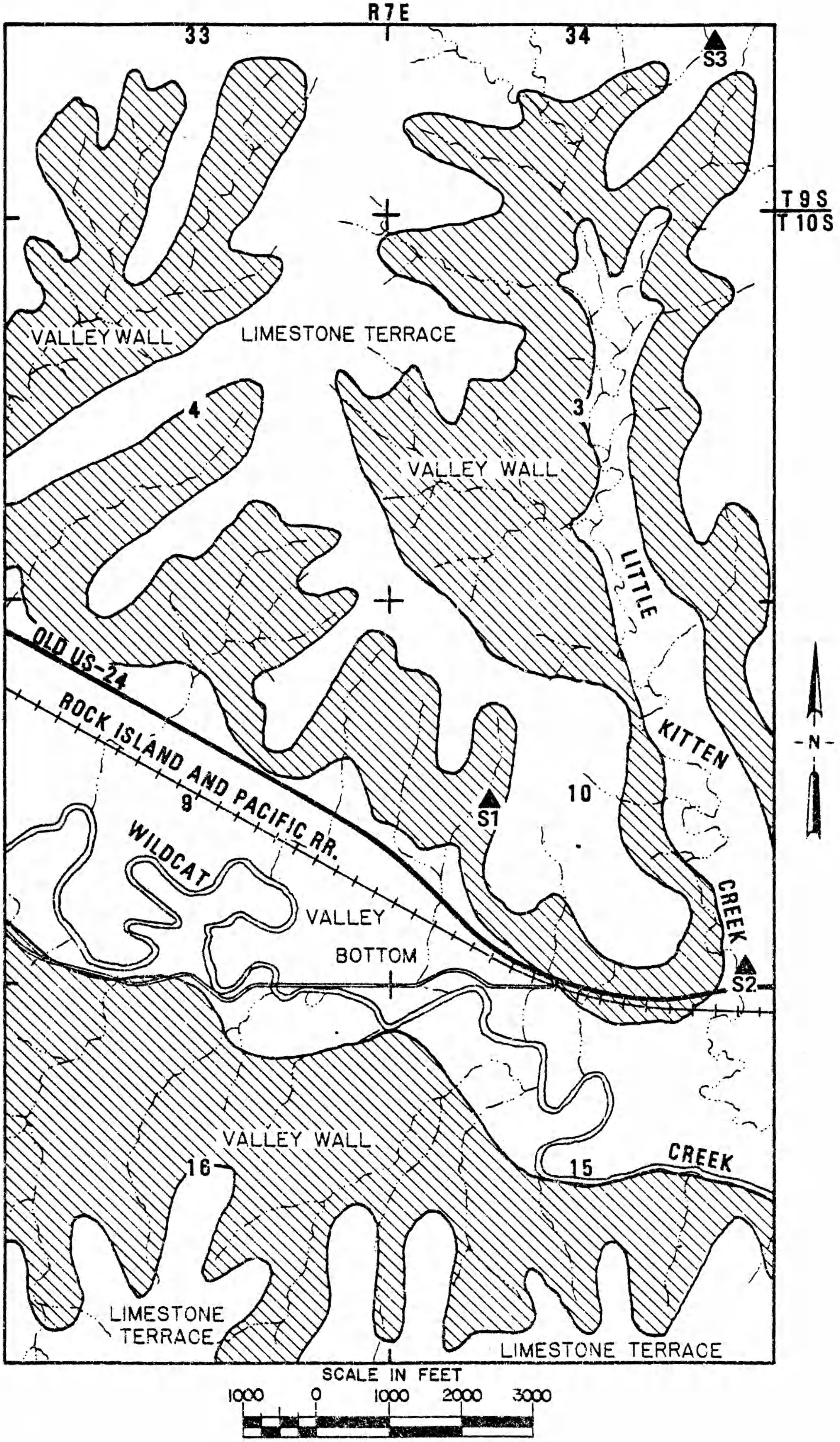


Source: Modified from map by R. C. Moore, Kansas State Geological Survey.(1930)

Figure 7. Surface features of Kansas. (after Socolofsky and Self, 1972)

Plate 4. Physiographic subdivisions in study area.

▲ SOIL SAMPLE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VALLEY
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S2
VALLEY WALL
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LIMESTONE TERRACE
LIMESTONE TERRACE
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the colluvial deposits. Bedrock in this subdivision is at the surface or covered by a thin veneer of soil.

Limestone terraces are primarily on stream divides and are underlain by resistant limestone of either the Schroyer Limestone Member of the Wreford Limestone or the Florence Limestone Member of the Barneston Limestone. Slopes in this subdivision are generally two to five percent. Depth to bedrock ranges from zero to three feet.

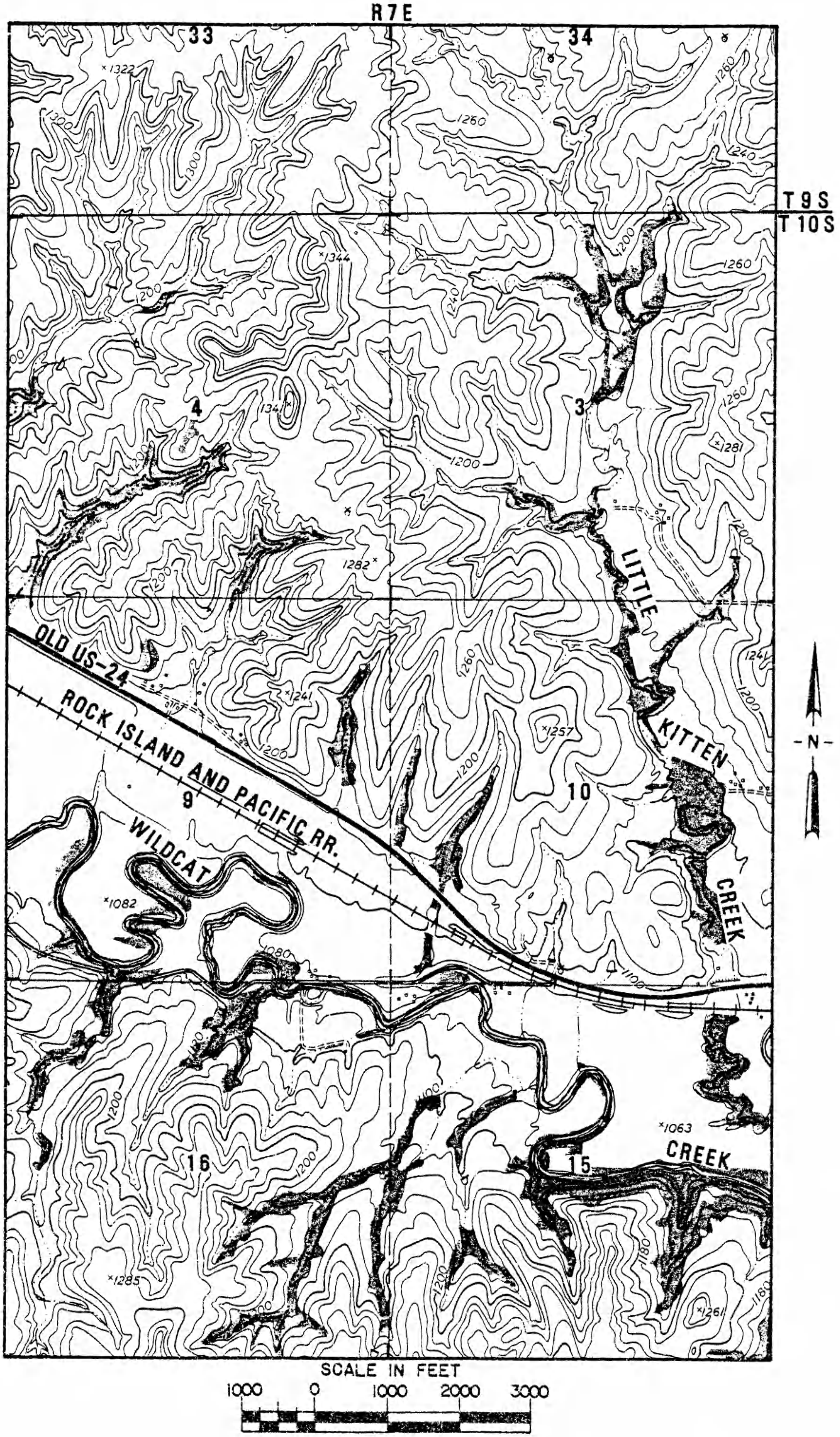
Altitudes within the study area range from 1055 to 1360 feet above mean sea level (Pl. 5). The lowest altitude is along Wildcat Creek at its easternmost point within the study area. The highest altitude is in the southwest corner of the study area. Altitudes decrease from both the southern and northern boundaries toward the Wildcat Creek channel, which itself decreases in elevation from west to east.

General surface slopes range from 1 percent to 100 percent. The gentler slopes, one to five percent, are on the flood plains of Wildcat and Little Kitten creeks. The upper surfaces of the terrace deposits and some hillside limestone benches have a slope between two and five percent. Along the small tributary streams and the hillsides directly above some limestone benches, surface slopes range from 5 to 15 percent. Hillside slopes are generally greater than 15 percent. Figure 8 shows the slope limits for several land uses, and Plate 6 shows the extent of the slope categories mapped.

Vegetation

Plant assemblages and their distribution are controlled in this area primarily by the available water. Limestone terraces have little available water and support only grasses. Dominant native grasses are big bluestem, little bluestem, and forbs such as blacksampson (Jantz, et al., 1975, p. 14). Some areas have been developed as grazing land for cattle, and grasses such as brome and fescue have been introduced. Vegetation on valley walls consists

Plate 5. Topographic map of study area (after U.S. Geological Survey, Keats Quadrangle 1955).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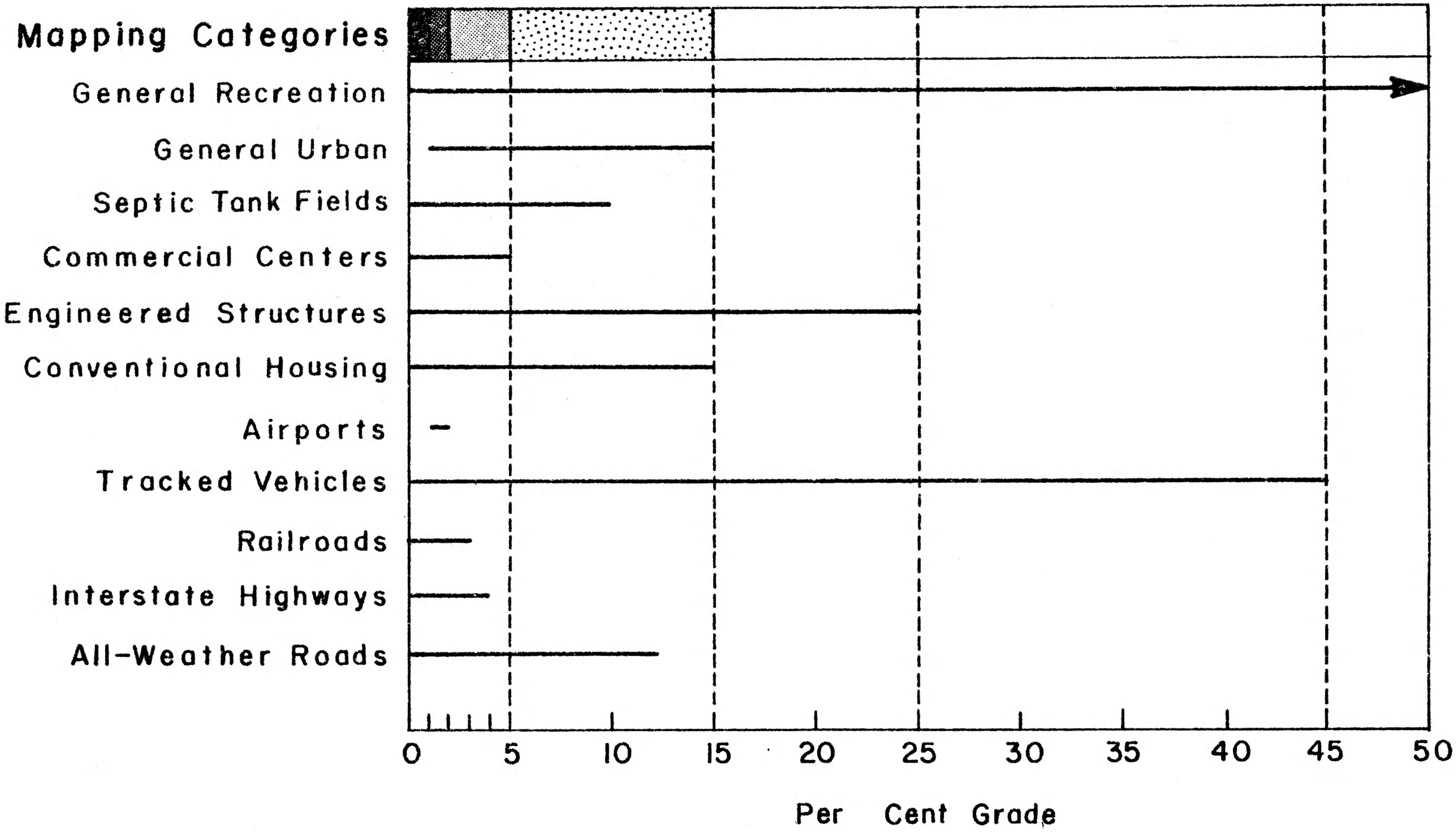
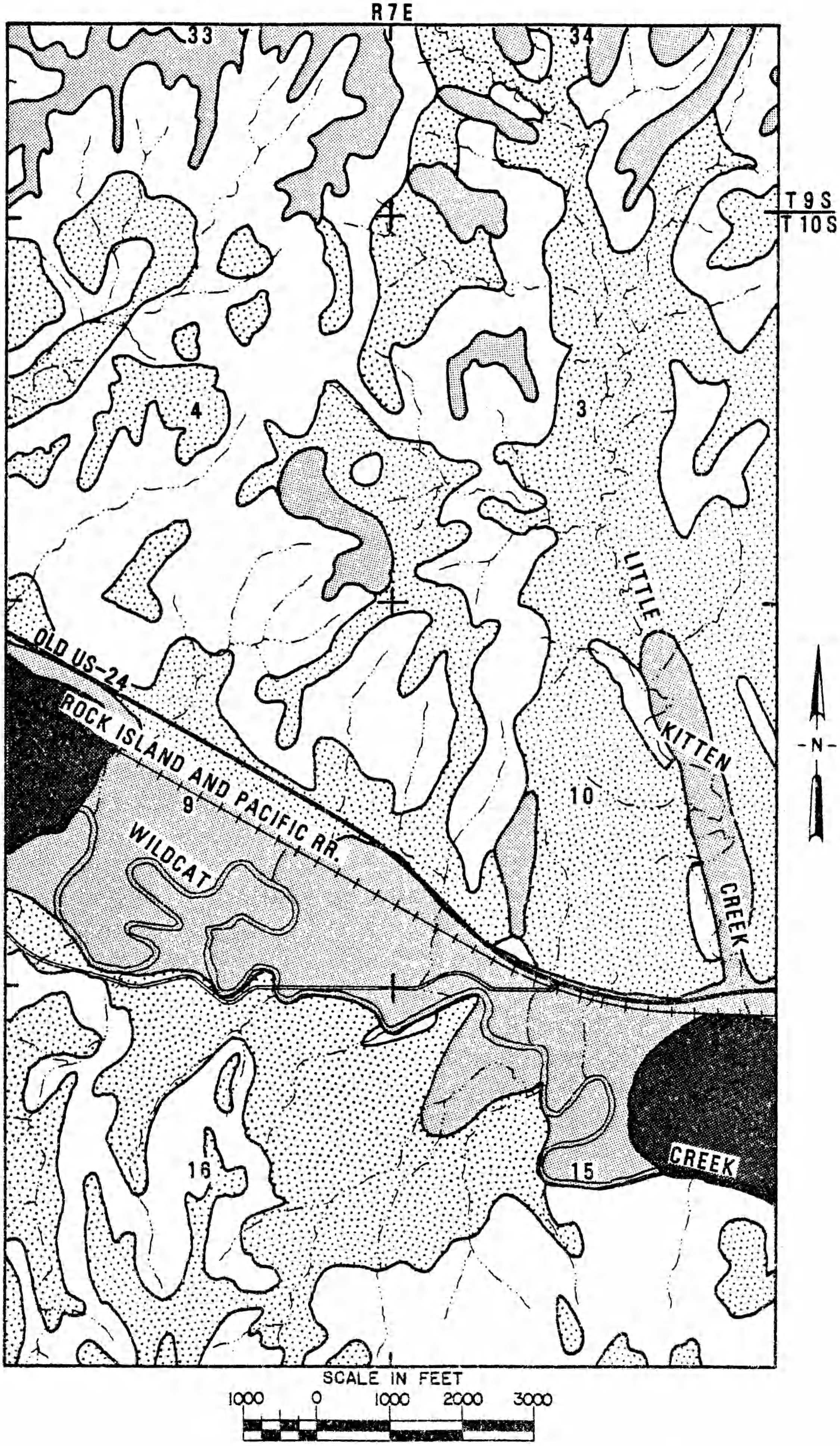


Figure 8. Optimum ranges of slopes (grades) for various urban installations and activities. (after Hilpman, 1968, p. 11)

Plate 6. Slope analysis of study area.

■	1-2 PERCENT GRADE
▒	2-5 PERCENT GRADE
░	5-15 PERCENT GRADE
□	> 15 PERCENT GRADE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of strips of native grasses and strips of brush. Brushy growth occurs at the contact between a shale and an overlying limestone. Limestone beds in this area are fractured and transmit water readily, whereas the shale beds are only slightly permeable and transmit little if any water. Water which infiltrates into the ground on the hilltop flows through the limestone strata horizontally just above the shale beds and forms seeps and springs along the hillsides. Enough water to support low-growing brush is available at these damp places. Brush growth is mostly sumac and honey locust trees. Sumac is a low-growing bush which has characteristic red leaves in the fall. Honey locust trees on the hillsides are stunted and are covered by thorns up to several inches long. Where there is a large supply of water, mostly in small tributary channels, some trees have established small stands. Dominant trees are honey locust, western red cedar, and elm.

Valley bottoms have a more adequate supply of water than the hillsides or limestone terraces and consequently a more luxuriant growth of vegetation. Meadows are prominent in valley bottoms and contain a dense growth of grasses. Predominant grasses in the meadows are bluestem and buffalo grass. Along stream channels and at the base of the valley walls a dense, semi-forest growth occurs. Willow, American elm, Chinese elm, hackberry, and cottonwood are the larger trees, but honey locust and western red cedar are also present along the stream channels. Sumac is in sunny locations; wild grape, wild raspberries, green briar, and poison ivy abound in the damp shady areas of the old stream channels. Much of the valley bottom along Wildcat Creek is in crop production and produces wheat, alfalfa, grain sorghum, and corn.

Climate

Manhattan and the area surrounding, including the area covered in this report, is in the humid continental climatic zone (Socolofsky and Self, 1972, p. 4). Average total precipitation for 62 years at the Manhattan station of the U.S. Weather Bureau is 31.64 inches (Brown, 1975, p. 68). Most moisture occurs during the months of April through September which corresponds to the growing season (Tab. 3). Peak rainfall occurs in June with an average of 4.76 inches and thunderstorms occur on approximately 55 days per year (Brown, 1975, p. 67-68). Temperatures range from an average minimum of 18.0°F in January to an average maximum of 92.6°F in July. Average maximum temperature for the complete year is 67.5°F, with an average yearly minimum of 43.1°F (Brown, 1975, p. 68).

Table 3. - Temperature and precipitation at Manhattan, Kansas (after Brown, 1975, p. 68).

Month	Temperature		Precipitation
	Average daily maximum* (°F.)	Average daily minimum* (°F.)	Average total* (Inches)
January	39.6	18.0	0.80
February	45.4	22.4	1.12
March	55.9	30.9	1.56
April	67.7	42.6	2.73
May	76.5	52.7	4.34
June	86.5	62.8	4.76
July	92.6	67.1	4.38
August	91.5	65.7	3.87
September	83.5	57.1	3.48
October	71.4	45.0	2.30
November	55.9	31.5	1.42
December	42.9	21.6	0.88
Year	67.5	43.1	31.64

*Data for period 1898-1960

Temperatures as low as -32°F and as high as 116°F have been recorded (Brown, 1975, p. 67). The frost free period averages 178 days (Brown, 1975, p. 67), with frost penetration during the winter months between 15 and 20 inches (Spangler and Handy, 1973, p. 319). Sunshine in the Manhattan area occurs completely unobstructed an average of 118 days per year with 100 days per year being partly cloudy and 147 days being cloudy (Robb, 1959). Prevailing surface winds are southerly with strong winds in March and April when the average wind speed is 13 miles per hour (Brown, 1975, p. 67).

SOILS

Soils of the study area are derived directly from the bedrock, except in those areas where streams have covered the bedrock with alluvium. In some smaller areas colluvial and eolian deposits have covered the bedrock and soils have developed from these parent materials. Most soils are silty clay loam to silty clay. In those areas where the soil is derived directly from the bedrock, the thickness is usually less than 36 inches. Soils developed on deposits other than bedrock have a deeper profile; some alluvial soils exceed 64 inches in thickness (Jantz, et al., 1975).

Stream divides have cherty clay and silty clay soils, resulting from weathering of cherty limestones and thin beds of shale. Hillsides have developed soils of silty clay loam and stony steep land (Jantz, et al., 1975, p. 30). The lower slopes of hillsides have silty clay loam and silt loam soils developed from colluvial and eolian deposits. Valley floor soils are silt loam and silty clay loam derived from sediments washed off the higher slopes by streams.

Thickness of valley floor soils is directly influenced by the size and distance from the stream flowing through the valley. Using the information given by Jantz, et al. (1975) it can be derived that the soils in the Wildcat Creek valley are thicker than 64 inches and well developed along the bottom of the hillside slopes where they have developed on stream terraces, but not so well developed closer to the stream because of the periodic flooding. Soils along the smaller tributary streams are much thinner than along Wildcat Creek but the same general trend of thickness and development exist.

Engineering properties of the soils are relatively uniform throughout the area. Permeability of the soils ranges from 0.06 to 2.00 inches per hours, with most of the soils ranging between 0.20 and 0.60 inches per hour (Jantz, et al., 1975, p. 52-55). The higher permeabilities are found in the soils of the valley floors where the soil developed on alluvial deposits. Soils derived from the shale and limestome of the hillsides and hilltops show a lower permeability. Hydrogen ion concentration (pH) averages slightly basic with most soils ranging between 5.6 and 8.4 pH (Jantz, et al., 1975, p. 52-55). Alkalinity of the soils results from calcareous material in the parent material of all the soils in this area. Shrink-swell of the soils is moderate to high because of the high proportion of expandable clays. X-ray diffraction of soil from each of the three physiographic subdivisions indicates that an expandable mix-layered clay mineral is abundant (Tab. 4). Jantz, et al. (1975) contains a detailed description of the soils and their physical properties as summarized below and a map of the soils is provided herein as Plate 7.

HYDROLOGY

Water Resources

Bedrock and alluvial aquifers are both present in the study area. The bedrock aquifer creates springs and seeps where fractured limestone overlies a shale. Some springs have perennial flow but most are intermittent. The smaller perennial springs may cease to flow during periods of extended drought. Springs have been and are presently being used to supply household and livestock water. Most notable of the limestone units at which springs occur are the Cottonwood, Threemile, Schroyer, and Florence limestones. Estimated flows of 30 gallons per minute were noted from these limestones during June and July of 1976. The bedrock aquifers have been tapped by windmills, some of which still stand. The windmills have been used for livestock watering and other wells have been used by residents to supply their household water needs.

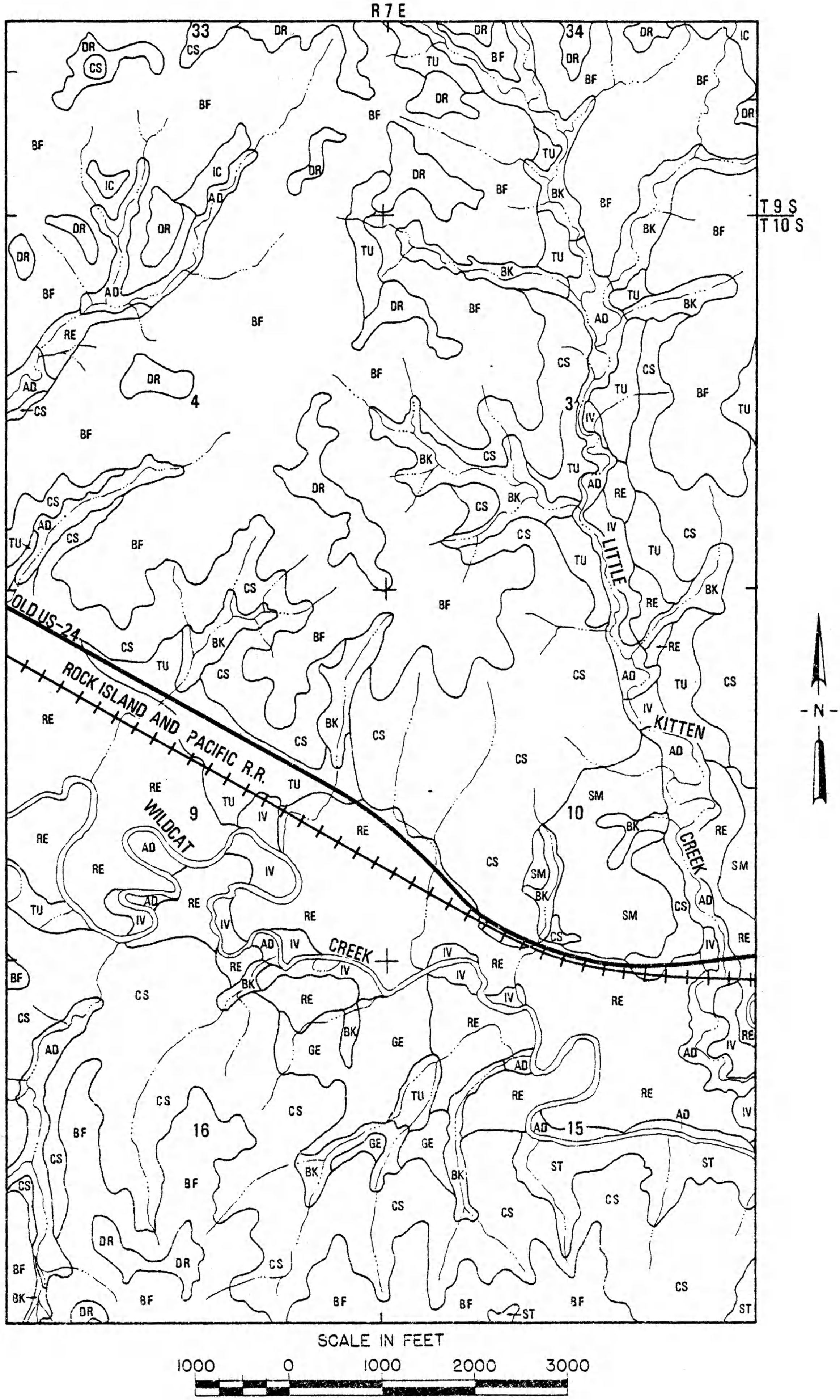
The alluvial aquifer occurs in the larger stream valleys and produces quantities of water sufficient for domestic uses. Wells in the alluvial deposits along Wildcat Creek show water-table depths of approximately 15 feet. Many residents along the stream valleys presently use groundwater from the

Table 4. - Clay minerals in soils of physiographic subdivisions.

		Clay Mineral				
Sample No.	Physiographic subdivision (sample location)	Illite	Expandable Mix-layer	Chlorite	Kaolinite	Percent Quartz in less than 2 micron fraction
S1	Valley wall (SE¼, NW¼, SW¼, Sec. 10, T. 10 S., R. 7 E.)	Major	Abundant	Minor	Trace	65
S2	Valley bottom (SW¼, SE¼, SE¼, Sec. 10, T. 10 S., R. 7 E.)	Major	Abundant	-	Minor	55
S3	Limestone terrace (NE¼, NE¼, SE¼, Sec. 34, T. 9 S., R. 7 E.)	Major	Abundant	-	Minor	30

Plate 7. Soils within the study area (after Jantz, *et al.*, 1975).

AD	ALLUVIAL LAND
BF	BENFIELD–FLORENCE COMPLEX
BK	BREAKS–ALLUVIAL LAND
CS	CLIME–SOGN COMPLEX
DR	DWIGHT–IRWIN COMPLEX
GE	GEARY SILT LOAM
IC	IRWIN SILTY CLAY LOAM
IV	IVAN & KENNEBEC SILT LOAM
RE	READING SILT LOAM
SM	SMOLAN SILT LOAM
ST	STONY STEEP LAND
TU	TULLY SILTY CLAY LOAM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alluvial aquifer for household purposes.

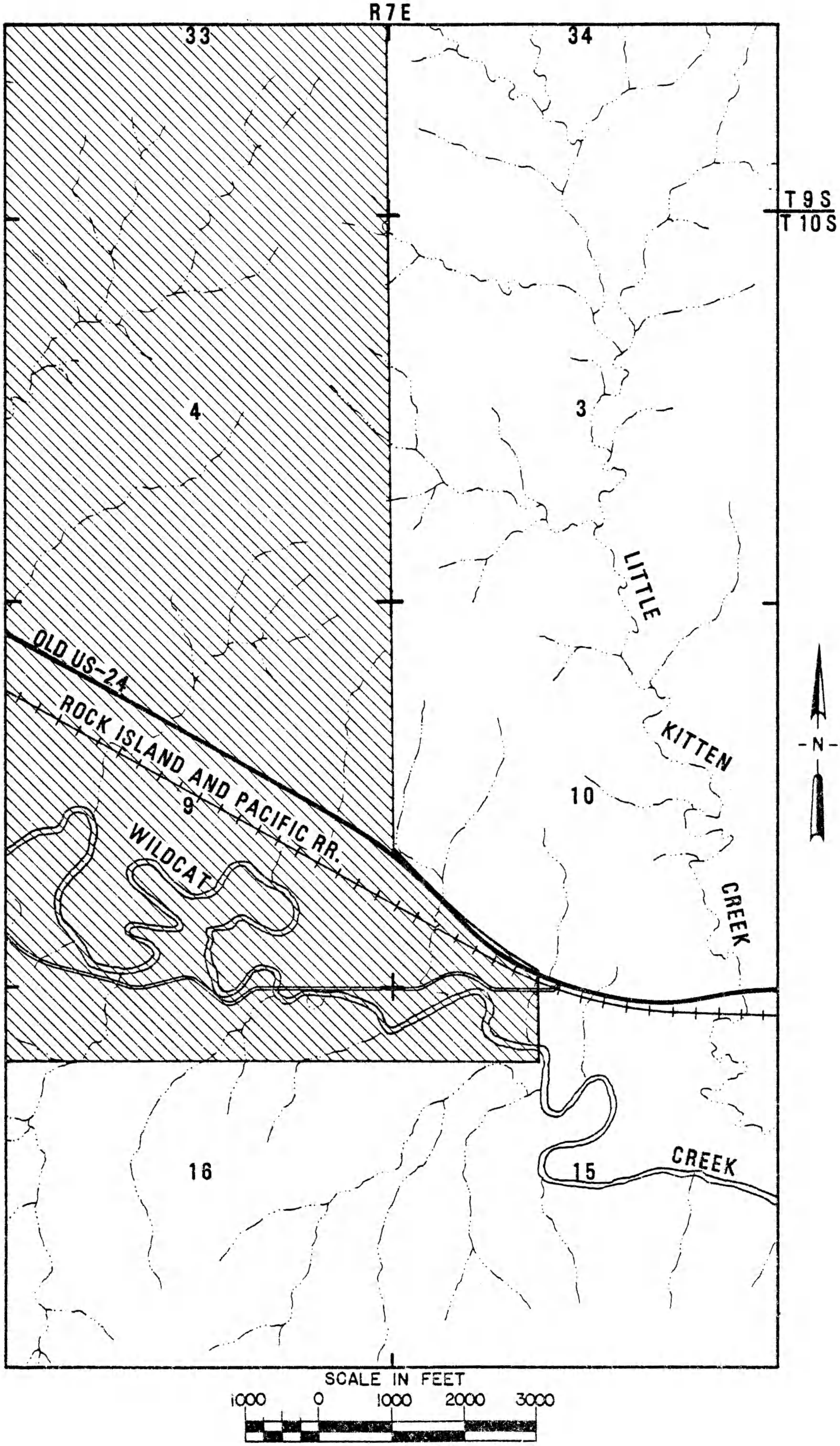
Development of the groundwater resources within the study area, with continued urban development, will be limited to minor uses such as irrigating lawns and gardens, watering livestock, and standby household supplies. A portion of the study area is presently within the boundaries of the Riley County Rural Water District Number 1 (Pl. 8). The rural water district will provide water within its boundaries to households that are presently using wells and springs as primary sources of water. Present plans of the rural water district indicate that the water needed for its operation will come from wells located south of the study area in the alluvial aquifer associated with the Kansas River (Division of Water Resources, 1978). The proximity of the study area to Manhattan's city water system further constrains the development of the groundwater resources within the study area for urban uses. Extension of Manhattan's municipal system appears to be the most likely source of water for urban purposes in the study area. The City of Manhattan has one of its storage tanks within the study area (Pl. 1). Manhattan obtains its water from wells located in the Bug Blue River floodplain east of the city.

The majority of the study area lies within the drainage basin of Wildcat Creek. The Wildcat Creek drainage basin includes 88 square miles and is oriented northwest to southeast (Fig. 9). Wildcat Creek enters the Kansas River immediately south of Manhattan outside the study area. Many small streams drain the limestone-shale upland, with the largest stream being Little Kitten Creek. Most of Little Kitten Creek drainage basin is within the eastern portion of the study area (Pl. 9). Wildcat Creek and the lower portion of Little Kitten Creek are the only perennial streams in the study area.

Development of the surface water resources will be limited. Under most urban developments the small ponds are filled or drained to facilitate more complete development, and the smaller intermittent streams are modified so as to carry the additional runoff which results from urban development. Develop-

Plate 8. Portion of study area within boundaries of Riley County Rural Water District No. 1 (after Division of Water Resources, 1978).

▨ RILEY COUNTY RURAL WATER DISTRICT NO. 1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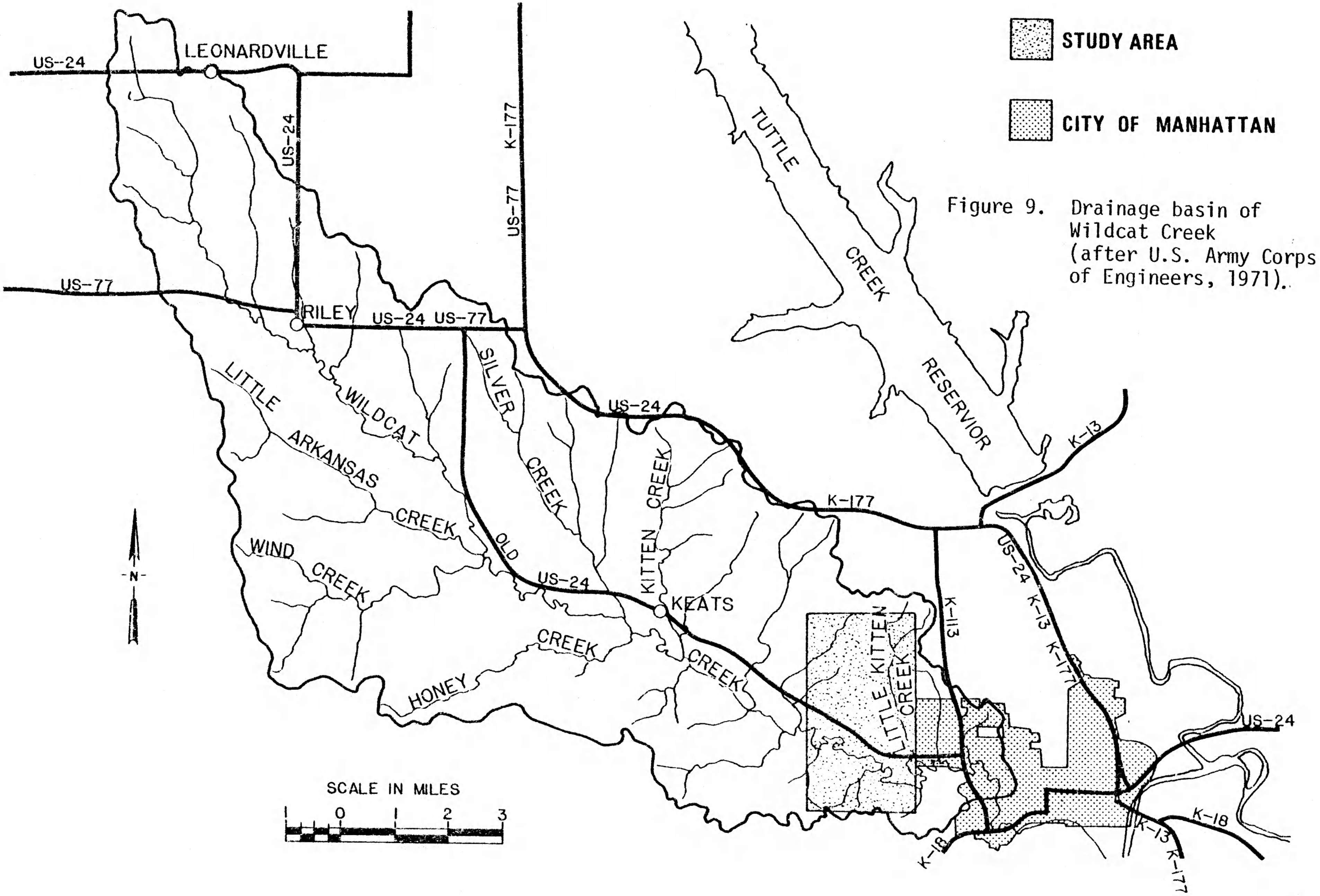
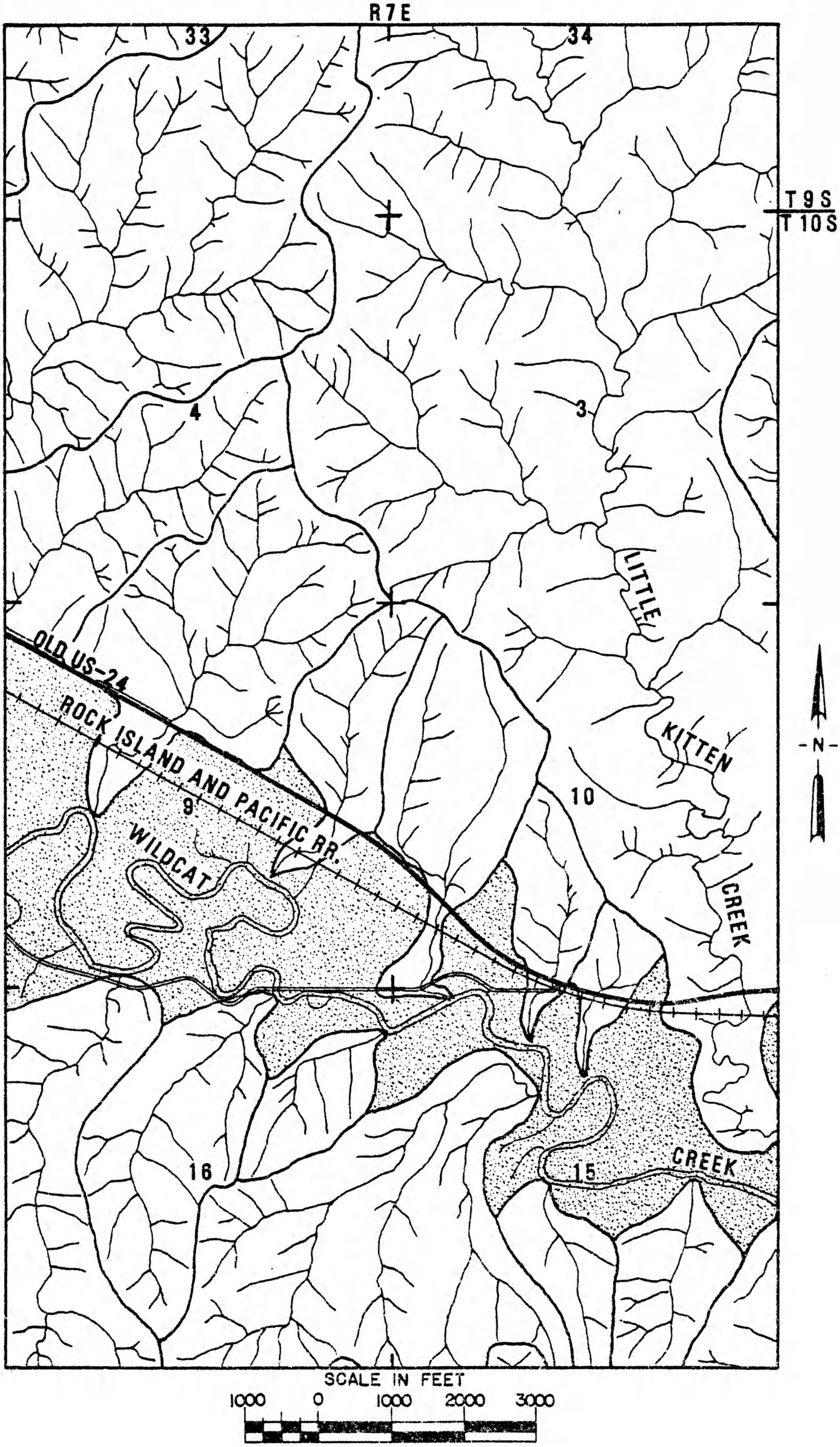


Figure 9. Drainage basin of Wildcat Creek (after U.S. Army Corps of Engineers, 1971).

Plate 9. Drainage basins within study area.

▨	AREAS OF PREDOMINANT SHEET FLOW
—<	DRAINAGE DIVIDE
—<	DRAINAGE CHANNEL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ment of the perennial streams may consist of parks or other low intensity uses. The closeness of the Kansas River, Tuttle Creek Reservoir, and the Big Blue River to the study area eliminates the major development of any surface water resources.

Flooding

Flooding has occurred along Wildcat Creek and the lower portions of Little Kitten Creek. The U.S. Army Corps of Engineers (1971) made a study of Wildcat Creek and outlined an area that would be covered by water should a rain having a 100-year frequency (sometimes referred to as the 100-year flood) occur. The maximum known flood was also mapped in that report. Flooding on the tributaries of Wildcat Creek may be a hazard to increasing the intensity of use of this area. Byers (1976), in looking at Little Kitten Creek, concluded that with total urban development of the watershed a rain having a 25-year frequency would not produce a major flood hazard. Some areas covered by this report have been designated as "Flood Hazard Areas" by the Federal Insurance Administration (1974) (Pl. 10).

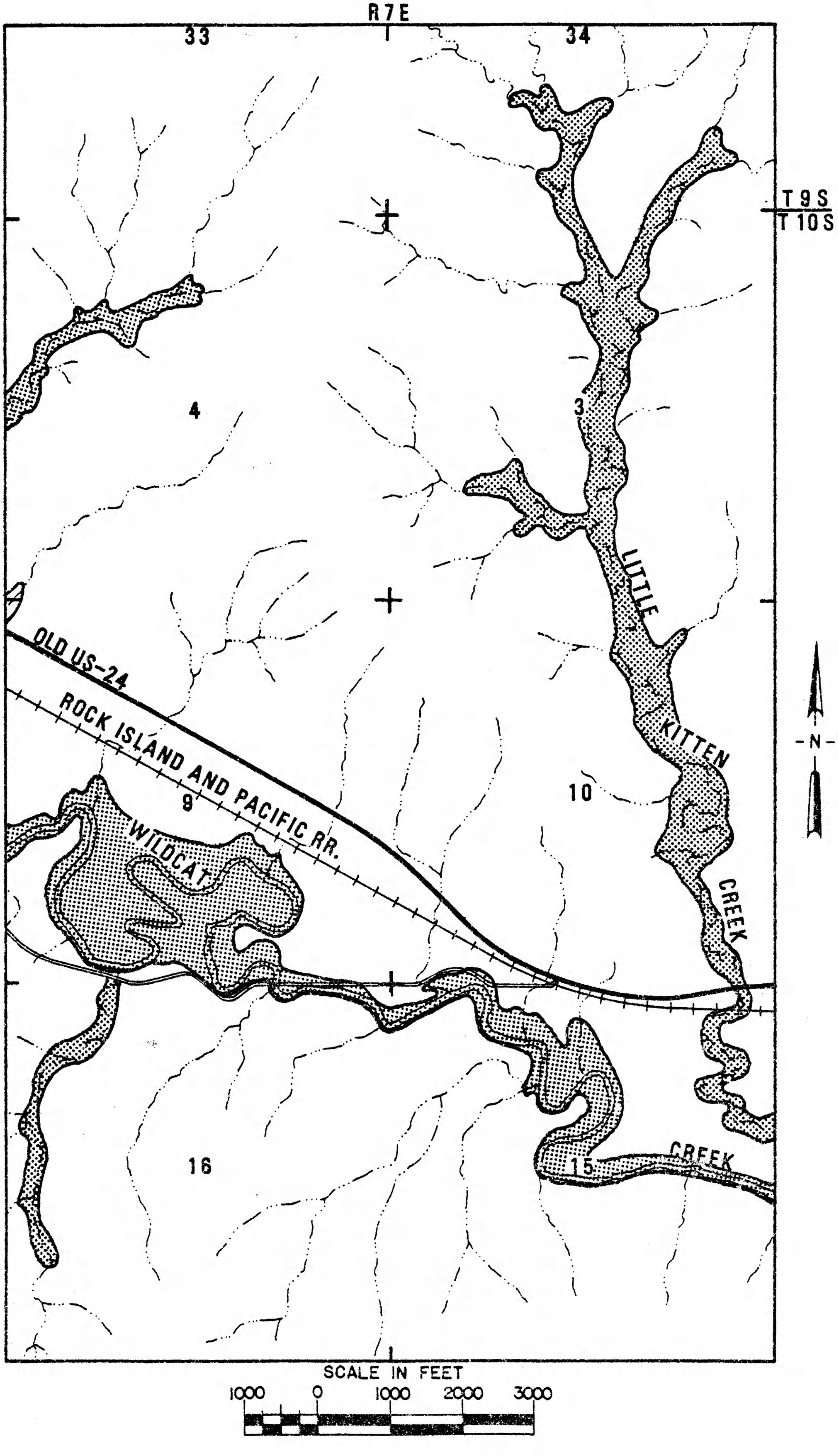
Some hazards not yet recognized may exist because of the errors inherent in any estimate of flooding hazard after actual development. Leopold (1972) showed that the lot size in residential areas affects the percentage of area made impervious which, along with the percentage of the area served by storm sewers, affects the amount of runoff and the lag time within a drainage basin. Caution should be exercised when interpreting any prediction of flooding hazard in an area yet to be urbanized and allowances made for safety. Flood-prone areas should be limited to uses requiring only limited investments in permanent structures.

None of the study area is protected by flood-control structures. Several small farm ponds are located on the small intermittent streams, and these contain some runoff during peak rainfall. As urban development occurs these

Plate 10. Flood Hazard Areas within study area (after Federal Insurance Administration, 1974).

▨ **FLOOD HAZARD AREA**
ZONE A*

*Zone A is defined as the area that would be inundated by a flood that has 1 chance in 100 of occurring in any single year.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ponds, whose primary purpose is the watering of livestock, will be filled or drained in order to facilitate more complete development.

EARTH MATERIALS

Physical Properties

Physical properties which are used to describe and characterize earth materials include excavation difficulty, shrink-swell potential, drainage, and slope stability. Evaluation of the physical properties is based upon laboratory tests, field tests, and field observations.

Excavation Difficulty.--Excavation difficulty refers to the ease with which an earth material may be removed for subsurface installations. Degree of consolidation and composition primarily determine excavation difficulty. Because the removal cost of material is based upon its classification as common or rock excavation, this fact should be considered whenever removal of a natural material is necessary.

Defining the difference between common and rock excavation is somewhat arbitrary. The Kansas Department of Transportation classifies common excavation material as material which can be penetrated by a manually operated auger; all other material is classified as rock excavation (Kotoynantx, 1976). There are some exceptions: a thin limestone, less than one foot thick, that is fractured may be considered common excavation if it can be removed by a backhoe in a reasonable amount of time. More generally, any material which might be removed without first using explosives is considered common excavation. In this report the excavation difficulty of the material is based upon field tests with a hand auger and field observations.

A material is considered to have high excavation difficulty if it is obvious that explosives would be necessary for its removal. Low excavation difficulty materials are easily penetrated by a hand auger. Moderate excavation difficulty materials are those materials which will be partly rock and partly common excavation. Materials rated as moderate excavation difficulty should be investigated on a site by site basis.

Shrink-Swell Potential.--Moisture is in most materials and affects the shrink-swell potential. If more water is introduced to materials there is a tendency for some to swell upon absorption of the additional water. Conversely, upon removal of moisture from materials they shrink. Part of the shrinking and swelling is caused by moisture being absorbed and removed from between the individual grains of the material and part of it is due to the swelling and shrinking of the grains themselves. Whereas the shrinking and swelling due to water between particles may be controlled by selecting materials with different particle sizes, the shrinking and swelling of the particles themselves is not so easily controlled or identified. In fact, the inter-particle shrinking and swelling is much less than the intra-particle shrinking and swelling. The shrink-swell potential of a material is a function of the type of clay minerals which are contained by the material. Montmorillonite clay upon addition of water may increase in volume as much as 258 percent under no pressure. This corresponds to a linear percent swell of 53 percent (Attewell and Farmer, 1976). Confinement of montmorillonite to a fixed volume with wetting has created pressures of 47.9 pounds per square inch (Post and Janke, 1974). Montmorillonite is the most expansive of the clay minerals but studies of illite, a relatively nonexpansive clay mineral, show a linear expansion of six percent (Attewell and Farmer, 1976) and show pressures of 1.7 pounds per square inch (Post and Janke, 1974). The amount of shrink-swell depends upon:

> "(1) nature and quantity of clay minerals present; (2) presence and type, or absence, of matrix cement; (3) exchangable ions of the clay minerals; (4) electrolyte content of the water phase; (5) particle size and void size distribution and the extent of the absorbing surface; (6) internal structural arrangement of the material skeleton; (7) actual moisture content; (8) applied pressure." (Attewell and Farmer, 1976, p. 163)

A 10 percent linear expansion from dry to saturated conditions would classify a material as having a high shrink-swell potential. A 2 to 10 percent linear expansion would indicate a moderate shrink-swell potential and less than two percent would be low shrink-swell potential.

Drainage.--Drainage of a material refers to its ability to absorb and transmit fluids. Drainage is related to the porosity (ratio of void volume to total volume) and the permeability (interconnection of the pore spaces). Both of these properties may be measured in the laboratory but relative values needed for drainage classification may be estimated from field observations. Materials with good drainage will absorb and transmit water readily and would have permeabilities greater than six inches per hour. Materials with moderate drainage will absorb moisture and transmit it except during moist periods when the material will be saturated, and would have permeabilities between 6 and 0.2 inches per hour. Poor drainage materials do not readily absorb or transmit water and have permeabilities less than 0.2 inches per hour.

Slope Stability.--Slope stability is commonly used to refer to the resistance of a material to mass movements or landslides. Mass movements are caused by gravity overcoming the resistant forces which normally hold the material in place. There resistant forces are caused by friction between the particles of the material. Mass movements occur when energy is introduced to the material and the resistant forces are overcome, or when the resistant forces are lessened. Energy may be introduced into a material by several means: earthquake, explosion, the rumble of traffic, freezing and thawing, water pressure, or an increase in the weight or load the material is supporting. Resistant forces may be lessened by removing the bottom or toe of a slope which serves as an anchor, or by the introduction of water which lubricates the particles (Flawn, 1970, p. 39) as well as by increasing the weight and water pressure in the material. Any event which causes a movement is said to trigger the movement. Some events trigger very rapid movements; others cause a slow progressive downward movement referred to as creep. The speed of a mass movement depends upon the amount of energy introduced in excess of the resistant forces. The difference between the triggering energy and the resistant forces is dependent upon the internal frictional forces of the mass, slopes of the surface on which the mass is moving, and the length of time over which the triggering energy is spread.

Rockfalls also should be considered under slope stability. Rockfalls are a sudden movement of rock usually down a vertical surface. Rockfalls may occur as large masses or just a few pieces. In this area rockfalls are more of a nuisance than danger because of the small quantities involved. Proper design of roadcuts, with a bench and terrace (berm) slope rather than a smooth sloping surface, will allow the slope to remain stable without filling the ditches below.

Materials with a high slope stability are those materials which will maintain steep slopes, one-half:one or greater (horizontal distance:vertical distance), without any mass movement. Occurrence of rockfalls does not lower the slope stability, but caution in design should be exercised when dealing with materials subject to rockfalls. Moderate slope stability materials will maintain intermediate slopes of three:one to one-half:one. Materials with low slope stability should have the most gentle slopes, less than three:one and subject to stringent use restrictions. Slope stability is best estimated from field observations.

Categories of Earth Materials

Earth materials identified in the study area may be grouped into three general categories: alluvium, limestone, and shale. Table 5 shows the geologic units which can be identified and how they are grouped in the three categories. A generalized stratigraphic section is shown as Figure 4.

Limestone.--Limestones of the study area are light gray to yellow-brown and range from less than 1 foot to 30 feet thick. Terraces on hillsides are formed by the limestone units.

Table 5. - Grouping of geologic units into earth material categories.

Geologic Unit	Earth Material Categories			
		Limestone		
	Alluvium	Cherty	Non-cherty	Shale
Alluvial deposits	X			
Low terrace deposits	X			
High terrace deposits	X			
Florence Limestone		X		
Blue Springs Shale				X
Kinney Limestone			X	
Wymore Shale				X
Schroyer Limestone		X		
Havensville Shale				X
Threemile Limestone		X		
Speiser Shale				X
Funston Limestone			X	
Blue Rapids Shale				X
Crouse Limestone			X	
Easly Creek Shale				X
Middleburg Limestone			X	
Hooser Shale				X
Eiss Limestone			X	
Stearns Shale				X
Morrill Limestone			X	
Florena Shale				X
Cottonwood Limestone			X	
Eskridge Shale				X
Neva Limestone			X	

Limestone may be divided into cherty and non-cherty varieties. Chert occurs in the limestone as layers of "nodules" or discrete beds. Cherty limestone occurs on all the hilltops underlying the residual cherty soil. Chert also occurs as beds less than one foot thick between limestone beds with the limestone beds being thicker than the chert beds. Cherty limestone is very difficult to remove by mechanical means and is classed as rock excavation except where outcrops are weathered to chert gravel. There it would be common excavation. Shrink-swell potential of cherty limestone is very low, even in weathered areas, because of the low quantities of clay in proportion to the quantities of chert. Drainage of cherty limestone is good because of fractures which affect these as well as all limestone in the area. Good drainage of these units is indicated by the springs and seeps which occur on many of the hillsides just below exposures of limestone. Slope stability of the limestone is high, but rockfalls will occur if cuts are vertical.

Non-cherty limestone beds in this area are usually much thinner, one to three feet, than the cherty limestone units, but the non-cherty limestone occurs as thick layers of six or more feet. These non-cherty limestone units are usually composed of several individual beds which are seldom over 12 inches thick and most commonly less than six inches. The beds of non-cherty limestone are bound together sufficiently to class them as rock excavation. Weathered portions of these limestone strata are more easily removed than unweathered portions and may be common excavation. Two limestone units which are significant exceptions are the Cottonwood and Neva limestones. These are found as thick beds. The Cottonwood in the area characteristically is six feet thick. Any excavation that must be done in the Cottonwood will be rock excavation. The Neva consists of three limestone sections separated by shale, and the center section is quite massive. Any excavations into the Neva will be rock excavation, except where it is weathered at the surface. Some parts of the Cottonwood which are weathered may be moved as blocks because of the fractures which cut this unit at right angles to each other. Shrink-swell potential of non-cherty limestone is very low because of the internal structure of the rock which does not allow penetration of moisture. Drainage of these limestone beds is very good because of the fractures. Many springs may be found where the bottom of these limestone beds crop out on the hillsides. Slope stability of the non-cherty limestone is high for mass movement, but rockfalls do occur in vertical cuts.

Shale.--Most of the shales occurring in the area of this study could more technically be described as mudstones because they lack the thin bedding of true shales; however, shale is used commonly to refer to both. For discussion, the mudstone and shale are grouped together because their physical properties are similar. Clay-size particles form a large portion of the bulk of the shale beds but silty and sand-size particles occur locally. Grain-size analysis of four shale samples indicate that the quantity of clay-size particles ranges from 38 to 51 percent. Minerals in the clay-size particles are illite, chlorite, and mix layer clay minerals together with small quantities of kaolinite, montmorillonite, and vermiculite (Wingard, 1964). Table 6 gives the relative abundances of the clay minerals in the shale units of this area.

Physical properties of shale are varied but there are some general characteristics. Excavation of these materials depends upon the amount of weathering which has affected them. In unweathered areas rock excavation will be the rule, but weathered portions will be common excavation. If a shale is overlain by two or more feet of weathered limestone then it will likely be rock excavation. Only site-by-site investigations will give relative proportions; therefore, shale beds are classified as having moderate excavation difficulty. Shrink-swell potential of shale is dependent upon the type and quantity of clay minerals which are present.

Clay minerals which provide the expansion are montmorillonite, mix-layered clay minerals such as vermiculite-chlorite, and chlorite in its poorly crystalline form. The four shale samples tested for swelling gave a linear expansion ranging from 3.8 to 6.8 percent (Tab. 7). Since expansion of a shale is dependent upon the proportion of clay minerals to non-clay minerals the relative proportion was tested. No significant correlation can be seen between the expansion and the quantity of insoluble residue in the four shales (Tab. 7). None of the shale beds in this area have sufficient quantities of expandable clay to be rated as having a high shrink-swell potential, but sufficient quantities do exist for a moderate shrink-swell potential rating. Drainage in shale is very poor because of low permeability produced by the fine grain sizes. Slope stability of shale is high when unweathered, but weathering quickly

Table 6. - Clay minerals in selected Permian shales (after Wingard, 1964).

Shale Unit	Illite-Montmorillonite	Illite	Chlorite	Kaolinite	Chlorite-Illite	Chlorite-Vermiculite	Vermiculite-Chlorite	Montmorillonite	Montmorillonite-Illite	Montmorillonite-Chlorite	Montmorillonite/Chlorite**	Chlorite-Montmorillonite	Montmorillonite-Chlorite-Illite
Blue Springs	P	Mj	Abu-Mj	-	P	P/4	P/4	P?	-		-		-
Wymore	P	Mj	My	-	P	P/3	P/1	-	-		-		-
Havensville	-	Mj	Mn-Tr	-	-	-	P/3	-	P		P		-
Speiser	P	Mj	Tr-Mn	?	P	P/3	P/1	P?	-		-		-
Blue Springs	-	Mj	P	-	-	-	-	-	P		P		P
Easly Creek	-	Mj	Mn	?	P	P/3	P/3	-	P		-		-
Hooser	P?	Mj	Abu	?	P	P/3	P/3	-	P		-		-
Stearns	P?	Mj	Abu	-	P	P/3	P/3	-	-		-		-
Florena	P	Mj	Abu	-	P	P/3	-	-	-		-		-
Eskridge	-	Mj	P	-	-	P	-	P	P	P/5		P/8	P

P	-Present	P/2	-Present in two samples
Mj	-Major	P?	-Presence questionable
Abu	-Abundant	?	-May be present
Tr	-Trace	Mn	-Minor

**relative proportion undefined

reduces the slope stability to moderate.

Table 7. - Expansion of clay minerals of four selected shales.

Shales (sample location)	Percent Linear Expansion	Percent Insoluable Residue in 18.5% HCl by Weight
Big Springs Shale (roadcut, NW¼, SE¼, NW¼, Sec. 35, T. 9 S., R. 7 E.)	3.9	31.8
Havensville Shale (road ditch, SE¼, NE¼, SE¼, Sec. 34, T. 9 S., R. 7 E.)	5.8	42.6
Easly Creek Shale (road ditch, NE¼, SE¼, SE¼, Sec. 10, T. 10 S., R. 7 E.)	5.8	28.9
Eskridge Shale (roadcut, SW¼, SE¼, SW¼, Sec. 10, T. 10 S., R. 7 E.)	6.8	37.6

Alluvium.--Alluvium consists of a mixture of clay, silt, and sand which was deposited by flowing water in the stream-channels and floodplains. Excavation difficulty of alluvium is low; alluvium is rated as common excavation. Shrink-swell potential of alluvium is low for the sand, moderate to high for the clays, and moderate for silt and mixtures of clay and sand. Drainage of the sands is good to excellent, but the clays have poor drainage. Silt has poor to moderate drainage. Slope stability of alluvium is moderate to low depending upon moisture content, size and sorting of particles, and slope of cuts. Some small slumps were observed in the upper reaches of the small tributary streams where the streams had over-steepened slopes in previously deposited alluvium.

ROCK AND MINERAL RESOURCES

Preservation of rock and mineral resources is a necessary part of planning for any area. Urban development of any area precludes the development of some subsurface resources.

Construction Materials

Materials suitable for construction are grouped into three types of materials: aggregate, stone products, and road metal. Aggregate materials are incorporated with a cementing agent of either portland cement or asphalt base for roadway and structural construction. Stone products are used as a construction medium and as dimension stone for aesthetic effect and protective covering. Road metal is used to improve the performance characteristics of a roadway surface.

Aggregates must be clean and free of any coating which would interfere with the bonding of the cementing agent. Maximum diameter is approximately two inches, and none of the particles should contain a mineral which would react with the cementing agent. Earth materials which provide suitable aggregate are: gravel and sand of alluvial deposits, and the limestones which would require crushing of the rock to the proper size. Chert reacts with portland cement and thus cherty limestone is eliminated as a source of aggregate to be used with portland cement.

Stone products are subdivided into two groups: structural stone and dimension stone. Structural stone is used for the supporting walls of structure and must be free from defects, hard, dense, resistant to weathering, and of sufficient proportions to allow the cutting of desired sized of stone. The Cottonwood Limestone and the Neva Limestone have been used extensively in the past for the production of structural stone. Dimension stone is a "catchall" category for other uses of rock; this category includes rip-rap and decorative stone. Stone for rip-rap should be of sufficient size to resist removal by flowing water and of sufficient soundness to resist weathering. The Cottonwood, Neva, and Threemile limestones are suitable for this use. Aesthetic uses are numerous and difficult to generalize. The exact requirements a material must have for aesthetic uses, such as color, texture, hardness, and strength, must first be determined and then the appropriate materials selected.

Road metal is any material which by itself is used to increase the life of a road surface. All materials suitable for aggregate are suitable road metals. Chert gravel and cherty limestone are suitable for road metals and can be incorporated effectively with bituminous material to provide a hard durable surface.

Because of the large amount of undeveloped land within Riley and surrounding counties that is underlain by rock suitable for the production of construction materials, the development of these resources within the study area will be very limited.

Minerals

Some mineral resources can be produced without adversely affecting the use of the land as residential home sites. Production of petroleum products has occurred within the confines of an urban setting through careful design and camouflage of the pump. Other minerals require an excavation from which the mineral or its ore is taken.

Brick clay is the only mineral within the area which might be economically feasible to produce. Brick clay is clay which may be plasticised, molded, and then fired into the desired shape without cracking or breaking. Shale in the area is the only material containing a large enough quantity of clay minerals for economical production. The variability within any shale of the clay mineral species which determine suitability for use as brick clay precludes the discussion of individual source. Generally the shale does not produce high-quality brick clay but does produce clay suited to the making of lower-grade products such as drainage tile and flowerpots. The economic production of such low-grade products is not feasible because of the availability of brick clay in other areas.

SPECIAL PHYSICAL CONSIDERATIONS

Existing uses of adjacent areas may affect the uses which may occur in an area. Two miles west of the study area is the Fort Riley Military Reservation. Explosions which occur as the result of the practice firings of tanks and artillery on the military reservation have been blamed for cracks in walls and foundations in the Manhattan area. These accusations cannot be substantiated by facts. Hall (1977) indicated that the size of the explosions which occur at Fort Riley are approximately equal to 100 pounds of explosive, and the explosions occur in the air or at the ground surface. Cook (1958, p. 353) indicates that for surface and air explosions direct ground shocks are not generated, but air concussion shocks do result from these types of explosions. Air concussion shocks that result from surface or air explosions will not damage properly installed window glass beyond one mile from the point of detonation of 100 pounds of explosive (Cook, 1958, p. 353). Some sound from the explosions will occur beyond one mile if an atmospheric temperature inversion exists (Cook, 1958, p. 356). Operations at Fort Riley should not physically impair any use which might be established within the study area.

PHYSICAL LIMITATIONS OF LAND-USES

Planning for development of an area must consider the possible physical limitations of uses which may be made of the land and unique features of the area which may affect some land uses. Five general categories of land use may serve to describe most urban uses: light construction, heavy construction, waste disposal, subsurface installation, and roadway. Each category has optimum physical requirements which allow the most economical development.

Light construction includes housing and other small buildings which do not require special engineering for their foundations. Excavation difficulty of earth material does not limit most light construction. Areas underlain by materials with high excavation difficulty would preclude the construction of basements at any but the highest costs. Shrink-swell potential of materials underlying light construction should be low to moderate, and precautions should be taken in areas of moderate shrink-swell potential to insure that foundation loads are sufficient to resist the expansion of the material. Materials with moderate drainage are suitable for light construction so long as moisture does not collect beneath foundations. Slope stability of the material underlying light construction should be high. Deeper and more expensive foundations are required in moderate slope stability materials.

Heavy construction uses are those which require specially engineered foundations to support large or differential loads. High excavation difficulty would suggest that the materials could support higher loads, as would high slope stability. Low excavation difficulty suggests that lighter loads or special foundations would be required to support the heavier weights. Shrink-swell potential of materials for heavy construction should be moderate to low. High shrink-swell potential materials may be subject to differential swelling and could put unwanted stress on foundations. High drainage is most suitable for heavy construction. Materials with moderate to low drainage do not specifically limit heavy construction uses so long as provisions are made to prevent collection of moisture in undesirable locations.

Waste disposal takes two forms: solid and liquid. Solid waste includes those wastes which can be disposed safely in sanitary landfills. Liquid wastes are wastes which can be disposed effectively and safely in septic tank systems or sewage lagoons. Areas of high to moderate excavation difficulty would increase the cost of excavation of trenches for solid waste disposal and installation of septic tank systems, but would not limit lagoon waste disposal.

Shrink-swell potential does not limit waste disposal. Moderate to high drainage is desirable for septic tank systems, but liquid sewage lagoons and solid waste disposal require low drainage to prevent contamination of soil and groundwater. Slope stability is not a limiting factor in either type of waste disposal. It is possible to use this report in combination with the Soil Survey Report of Riley County (Jantz, et al., 1975) to be more site specific than is the intention of this report.

Costs of subsurface installations would increase with an increase in excavation difficulty. Subsurface installations such as pipelines might become misaligned in areas of high shrink-swell potential but would not be particularly affected by moderate or low shrink-swell potential if properly constructed. Low drainage could have an adverse effect on some subsurface installations designed to distribute waste water, such as in a septic tank absorption field, or it could serve a beneficial function such as helping to seal a sanitary sewer line to prevent soil and groundwater pollution. Slope stability does not affect subsurface installations, except where the subsurface installations are to be located near embankments. Moderate slope stability offers the best compromise between excavation cost and probably damage near embankments.

Roadway use includes all categories of streets and highways. Excavation difficulty of itself is not a limiting factor, but the increase in cost for rock excavation must be considered when designing roadways. Areas having a moderate shrink-swell potential do not limit the construction of raodways as long as the subgrade has sufficient compaction to resist the imposed stresses. Areas which have a high shrink-swell potential should be avoided for roadway construction. Materials with low drainage under roadways are not limited to this use as long as under-drains are provided in areas where water may seep into the subgrade. Under-drains should be provided wherever there may be a difficulty with subgrade moisture seepage. Slope stability of materials over which roadways are built should be high; even the "flexible" pavements do not provide for the amount of movement associated with moderate slope stability materials without a great increase in the quantity of maintenance.

CONCLUSION

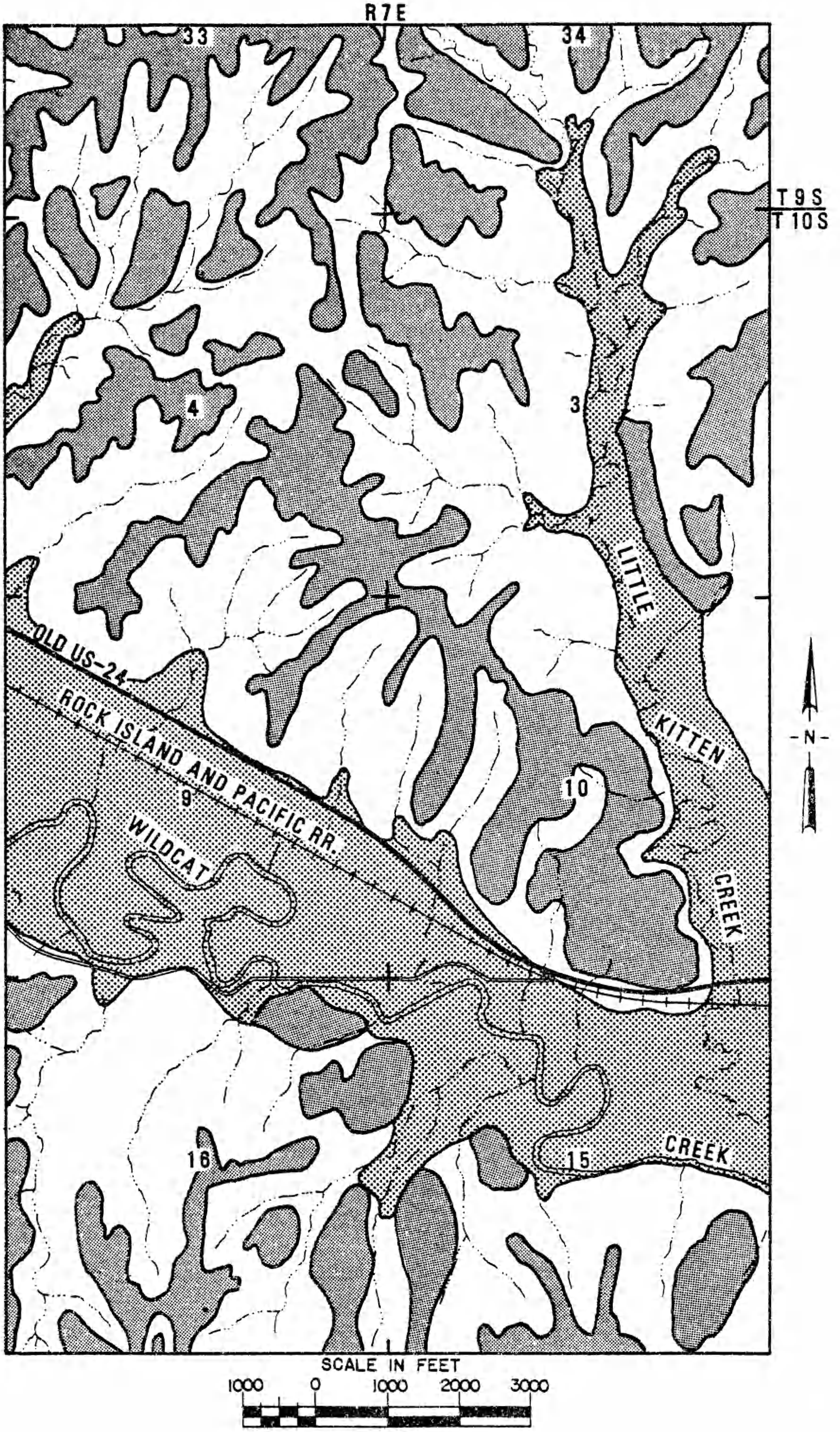
Grouping of areas into capability units allows for the discussion of those areas which have similar physical characteristics and which would react in similar manner to different land uses. Designation of the three capability units, lowland, sloping land, and upland, is done on the basis of the physical properties discussed above. Capability units are mapped in Plate 11 and are discussed as to the suitability for development of homesites, heavy construction, waste disposal, subsurface installations, and roadways.

Lowland

The lowland capability unit comprises the floors of the stream valleys and some of the lower slopes of the hillsides. Underlying the unit are the alluvial deposits of the floodplains and stream terraces with some colluvium and loess. Suitability for homesites is good, but flooding of the areas closest to the streams may be a limiting factor. Heavy construction suitability is limited by the flooding factor and the depth to bedrock which would require special foundation design for heavy structures. Solid-waste disposal in this unit should be limited to the terrace deposits where the water table is below the bottom of waste trenches. Liquid-waste disposal via septic tank systems may be hindered by low permeability of the soil. Sewage lagoon disposal of liquid wastes should be limited to the terrace deposits because of the severe flooding hazard which exists close to the streams. Installations in the subsurface will be easy to construct with no rock excavation in cuts less than 15 feet deep. Excellent roadways may be built across this unit with precautions taken to prevent flooding. Flooding along the streams, expecially Wildcat and Little Kitten creeks, makes development there of other than low intensity uses hazardous.

Plate 11. Capability units identified within study area.

▩	**LOWLAND**
☐	**SLOPING LAND**
▒	**UPLAND**


R7E
33
34
T9S
T10S
4
3
LITTLE
KITTEN
CREEK
OLD US-24
ROCK ISLAND AND PACIFIC RR.
9
10
WILDCAT
CREEK
16
15
N
SCALE IN FEET
1000
0
1000
2000
3000

Sloping Land

Sloping land is characterized by 15 percent and greater slopes and bedrock at the surface or less than three feet deep. Homesite suitability for this capability unit is poor. Shallow depth to bedrock hinders construction of basements, and moisture seeping from the limestone may be diverted into basements and foundations. Steep slopes in this unit require care in placing cuts and fills for homes so as to maintain a stable slope. Heavy construction would require specialized design to overcome the problem of steep slopes, making this unit unsuitable for this use. Solid-waste disposal in this unit could take place in the flow channels and some old quarries; however, special care would have to be taken to provide for the containment of leachate. Liquid-waste disposal by either septic tank systems or sewage lagoons is severely limited by existing steep slopes. Septic tank systems would require a specially designed absorption field much larger than in other capability units. Subsurface installations in this unit would require rock excavation for anything greater than a six inch depth. Roads through this unit would require cutting and filling to obtain the slopes required for safe sight distances, and most of the cutting would have to be rock excavation.

Upland

Homesites in the upland capability unit would have very good vistas, but depth to bedrock would limit the use of basements and burried utilities. Heavy construction should find adequate foundation strength without piling or deep footings. Waste disposal would be severely limited by the depth to bedrock. Subsurface installations would suffer from the shallow depth to bedrock, usually less than three feet, making suitability for this use very limited. Uplands offer adequate foundation for support of the roadway wearing surface but may require under-drains in some localities.

Recommendations

Information used to delineate the land capability units makes it possible to recommend some restrictions that should be placed on urban development in each of the three capability units.

The lowland unit should have restrictions placed on those areas that are flood hazard areas. In flood hazard areas construction of residential, commercial or industrial buildings should be prohibited, unless they are of a flood-proof design; disposal of wastes via landfills and septic tank absorbtion field should be prohibited; and low intensity uses such as parks should be encouraged.

Restrictions in the sloping land unit are needed because of the instable shale slopes and the shale soils. In the sloping land unit cut and fill construction, where part of a slope is cut to provide down slope fill for a building site, should be severely limited; foundation drains should be required except where the foundation is setting directly on a limestone bed; and septic tank absorbtion fields should have longer required laterals that follow the land surface contours.

Use of the upland unit needs little restriction except to allow for the shallow depth to bedrock and possible soil creep along the top of slopes. Foundations along the perimeters of the upland unit should be of a design to resist down hill creep; and subsurface installations such as basements and utilities should be limited because of the shallow depth to bedrock.

These physical restrictions should be recognized in any future development of the study area. However, each individual development site may be examined in detail to overcome these general recommendations.

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APPENDICES

Appendix 1.--Geologic Mapping Procedures

The geology within the study area was mapped using large-scale (one inch = 660 feet) aerial photographs obtained from the Agricultural Stabilization and Conservation Service (ASCS), U. S. Department of Agriculture. The photos were flown on September 27, 1969 and the following numbers were used at this scale: ZA - 3KK - 171, 173, 200, 202, 241, and 243. These photographs are about 24 inches square and impractical to use for stereoscopic study. Contact prints of the same photos at the scale of 1:20,000 were used for stereoscopic study of areas where it was difficult to ascertain the contacts on the larger photographs.

Frosted mylar was used as an overlay on the large scale photographs and the contacts between the selected geologic units were traced directly on the mylar. The photographs were field checked to identify the mapped units and to interpret those areas where the geologic units could not be recognized on the photographs. Each photograph was mapped individually and the separate mylar tracings were collated. Where contacts were distorted because of parallax along the margins of the tracings, they were visually adjusted by halving the error. The final geologic map was then constructed using the six corrected mylar overlays.

Stereoscopic examination of the small-scale (1:20,000) photographs aided in the location of contacts in the distorted area of the photographs. Mapping on photographs of this scale would be more difficult because of the thickness of formations and the width of outcrops formed by many of the limestone units which are only 6 to 10 feet thick. As a rule, a limestone and shale formation were grouped into one map unit for this study as was used by Byrne, *et al.* (1949).

Appendix 2.--Measured Sections

Section from Florence Limestone Member of the Barneston Limestone down into the Wymore Shale Member of the Matfield Shale in a roadcut in the NE¼, SE¼, NW¼ of Sec. 35, T. 7 S., R. 7 E., Riley County, Kansas.

	Thickness (feet)
Barneston Limestone	
Florence Limestone Member	
Gravel, chert, gray to white	1.5
Limestone and chert beds, alternating, limestone beds, brownish yellow 0.5 to 0.6 feet thick, chert beds, gray with white "rinds," 0.2 to 0.4 feet thick.	3.0
Limestone, brownish yellow	2.0
Limestone and chert beds, alternating limestone beds, brownish yellow, 0.6 to 0.8 feet thick, chert beds, gray with white "rinds," some beds show more discrete chert nodules, 0.4 to 0.6 feet thick, lower 3.5 feet have red stain in joints	8.5
Mudstone, greenish gray.	0.6
Limestone, brownish yellow, joints stained red	1.0
Limestone, yellowish brown, platy.	2.8
	19.4
Matfield Shale	
Blue Springs Shale Member	
Mudstone, gray green, granular	3.7
Mudstone, maroon with green zones.	10.0
Mudstone, green, calcareous.	0.5
Limestone, brownish yellow, joints stained red, some solution along joints, water seeping from joints.	1.1
Mudstone, green with black zones, some poorly defined bedding, water seeping 1 foot below top	5.0
Mudstone, black, very soft, water seeping from joints.	3.5
Mudstone, black hard, water seeping from joints, 0.5 feet diameter saucer-shaped concretions present	6.6
Kinney Limestone Member	
Limestone, reddish yellow, macro-crystalline, platy, fossiliferous	0.8
Limestone, yellow with gray mottles, blocky, highly fractured, arenaceous	1.3
Limestone, whitish yellow, block	6.7
Wymore Shale Member	
Mudstone, tan to yellowish brown, bottom covered	10.0
	49.2

Section from Schroyer Limestone Member of the Wreford Limestone down into the Speiser Shale in roadcut in the SE¼, SE¼, SW¼, Sec. 35, T. 9 S., R. 7 E., Riley County, Kansas.

	Thickness (feet)
Wreford Limestone	
Schroyer Limestone Member	
Limestone beds and chert beds, alternating, limestone beds gray to yellow, 0.6 to 1.0 feet thick, chert beds gray to white, 0.8 to 1.0 feet thick, highly fractured throughout.	5.0
Havensville Shale Member	
Mudstone, tan, abundant calcite concretions less than 0.04 feet in diameter, fossiliferous	7.5
Mudstone, tan changing to black at bottom.	9.3
Limestone, reddish brown, macro-crystalline.	0.6
Mudstone, black to gray.	2.4
Threemile Limestone Member	
Limestone, gray to tan, upper part platy, weathers to honeycomb structure, cherty in lower part.	7.0
Mudstone, tan, mostly covered.	2.0
Limestone, tan, blocky	1.0
	34.8
Speiser Shale	
Mudstone, vari-colored maroon, green, and tan, lower part covered.	15.0
	15.0

Section from Threemile Limestone Member of the Wreford Limestone down into Cottonwood Limestone Member of the Beattie Limestone in a road ditch along Hudson Avenue, in the E½ of the NE¼, Sec. 10, T. 10 S., R. 7 E., Riley County, Kansas.

	Thickness (feet)
Wreford Limestone	
Threemile Limestone Member	
Limestone, gray to tan, cherty	9.0
	9.0
Covered.	14.0
	14.0
Funston Limestone	
Limestone, gray, shale parting in middle, upper part forms strong bench and weathers blocky with honeycomb lower part forms weaker bench, weathers to rounded blocks .	9.0
	9.0

Blue Rapids Shale	
Mudstone, vari-colored calcareous.	10.0
Limestone, gray, weathers very light, gray, platy.	5.0
	15.0
Covered.	10.0
	10.0
Crouse Limestone	
Limestone, two beds with shale parting, upper bed platy, weathers to smooth reddish brown plates, contains large brachiopods, lower bed blocky weathers gray, contains gastropods	6.5
	6.5
Easly Creek Shale	
Mudstone, mostly covered	10.0
	10.0
Bader Limestone	
Middleburg Limestone Member	
Limestone, weathers gray, contains brachiopods, forms strong bench.	5.0
Hooser Shale Member	
Mudstone, mostly covered	5.0
Eiss Limestone Member	
Limestone, mostly covered forms strong bench	6.0
Mudstone, mostly covered	2.0
Limestone, mostly covered forms weak bench	4.5
	22.5
Covered.	21.5
	21.5
Beattie Limestone	
Cottonwood Limestone Member	
Limestone, massive, brown to tan, abundant fusulines, chert nodules, forms strong bench	6.0
	6.0

Appendix 3.--X-ray diffraction analyses of soil samples (for locations see Table 4, page 35)

Sample: S1-Valley Wall

Type of Clay Mineral	d-spacing (in Å)		
	Untreated	Treated with Ethylene Glycol	Heated to 450°C
Mixed Layer	15.42	19.80	
Chlorite (001)	14.40	15.66	
Mixed Layer	11.52		
Illite (001)	9.93	9.82	9.95
Chlorite (002)	7.16	7.70	
Kaolinite (001)	7.03	7.07	
Chlorite (003)?		5.06	
Illite (002)	4.95	4.97	4.96

Sample: S2-Valley Bottom

Type of Clay Mineral	d-spacing (in Å)		
	Untreated	Treated with Ethylene Glycol	Heated to 450°C
Mixed Layer	15.77	19.71	
Illite (001)	9.95	9.84	9.84
Kaolinite (001)	7.71	7.09	
Illite (002)	4.96	4.97	4.96
Kaolinite (002)	3.56	3.54	

Sample: S3-Limestone Terrace

Type of Clay Mineral	d-spacing (in Å)		
	Untreated	Treated with Ethylene Glycol	Heated to 450°C
Mixed Layer	16.29	18.39	
?	14.52	14.24	
Illite (001)	9.91	9.91	9.95
Kaolinite (001)	7.06	7.11	
Illite (002)	4.96	4.97	4.96
?	4.23	4.24	4.23
Kaolinite (002)	3.55	3.55	

Appendix 4.--Engineering tests on shale samples (for locations see Table 7, page 51)

Specific Gravity -

Eskridge Shale	2.76
Easly Creek Shale	2.67
Havensville Shale	2.76
Blue Springs Shale	2.79

Grain Size Analysis, Pulverized sample -

	Percent less than	
	0.1 mm	0.01 mm
Eskridge Shale	79.0	50.5
Easly Creek Shale	87.6	38.0
Havensville Shale	80.5	49.8
Blue Springs Shale	79.1	38.8

Proctor Density -

	Optimum Moisture (%)	Density at Optimum Mositure (lb/cu.ft.)
Eskridge Shale	18.5	107
Easly Creek Shale	21.4	106
Havensville Shale	19.0	111
Blue Springs Shale	19.0	112

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PHYSICAL CONSIDERATIONS FOR LAND USE PLANNING OF AN AREA IMMEDIATELY WEST OF MANHATTAN, KANSAS

by

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AN ABSTRACT OF A MASTER'S THESIS

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The area covered by urban land uses in Manhattan, Kansas, area has increased rapidly westward in the last 15 years. It is necessary to identify physical problems of the area soon to be developed so that planning may allow the growth to continue at a high quality.

Bedrock which crops out immediately west of Manhattan consists of relatively flat-lying alternating beds of limestone and shale which prove to be a major controlling factor affecting urban development. Bedrock includes units in ascending order from the Neva Limestone Member of the Grenola Limestone to the Florence Limestone Member of the Barneston Limestone, of Permian age. Two levels of Pleistocene terrace deposits and a Recent alluvial deposit affect the use of areas along Wildcat Creek and its tributaries. A seismic risk zone 2 has been given to the Manhattan area which will affect the design of major structures in the area. Physiographically, the area consists of low, steep-sided, flat-topped hills with altitudes of 1055 to 1360 feet above sea level. Vegetation consists of grassy, brushy, and wooded area with the taller, heavier growths along the stream channels and the grassy areas on the ridge tops.

Climate is moderate with the area being in the humid continental climatic zone. Average temperatures vary from a low of 18.0^{o}F. in January to a high of 92.6^{o}F. in July, and precipitation averages 31.64 inches annually with the heaviest rainfall occurring between April and September. Soils tend to be better developed on the lower slopes, but engineering properties of soils are relatively uniform.

Surface water resources are limited to the perennial Wildcat and the lower portion of Little Kitten creeks; these streams and others may flood during heavy precipitation periods. Groundwater is readily available in the alluvial deposits and may be found in the fractured limestones where springs and seeps are present.

Rock and mineral resources are sand and gravel with some low quality clay production possible; however, the low economic value precludes the development of these. Three categories of earth materials can be recognized in the area: alluvium, limestone, and shale. These materials can be described using four physical properties: excavation difficulty, shrink-swell potential, drainage, and slope stability. The description of the earth materials together with the other information gathered about the area allows the recognition of three capability units (lowland, sloping land, and upland), each of which have unique physical characteristics and could serve as planning units.