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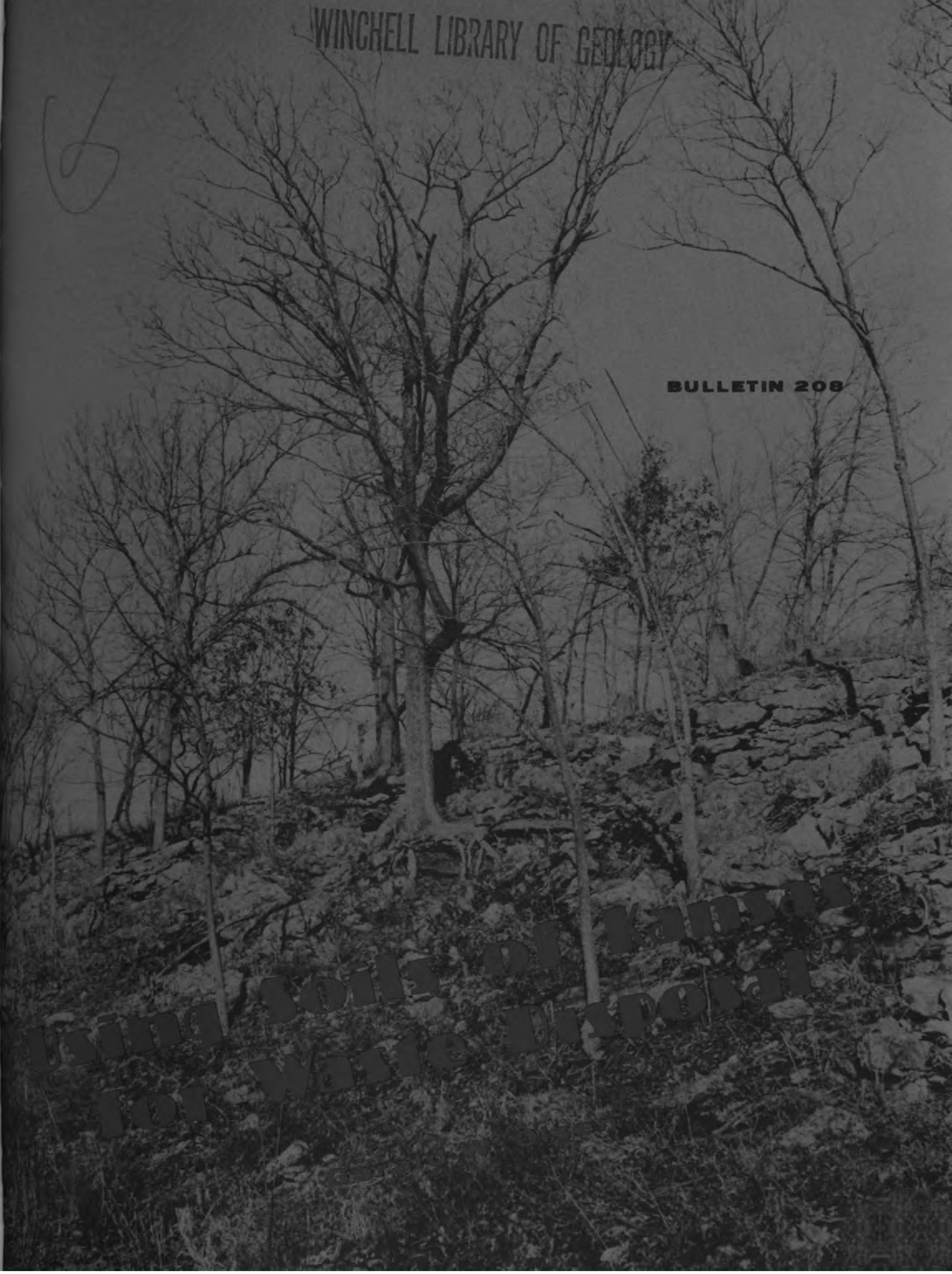
BULLETIN 208

Using Soils of Kansas for Waste Disposal



BULLETIN 208

Using Soils of Kansas For Waste Disposal

A first approximation for solution to the problems and a guide to further interdisciplinary efforts

By

Gerald W. Olson

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GERALD W. OLSON[1]

Using Soils of Kansas For Waste Disposal

A first approximation for solution to the problems and a guide to further interdisciplinary efforts

ABSTRACT

Soils of Kansas have slight, moderate, and severe limitations for waste disposal by septic-tank seepage fields, sewage lagoons, and sanitary landfills. Each soil is rated for each use according to tested standardized criteria, based on the soil properties. Problems and potentials for environment improvement in waste disposal are outlined. Each landscape unit shown on detailed soil maps has an integrity of its own; management of each with respect for that integrity will yield maximum production and environmental efficiency. This bulletin supplements detailed soil maps for improving waste disposal in specific soils. It is intended as a guide for officials, scientists, and citizens. In addition to detailed soil map examples, a general soil map of Kansas is included to give an overall view of the major soils of the state.

INTRODUCTION

Soil information can contribute to the solution of many waste-disposal problems in Kansas, and can effectively be combined with studies relating to geology, engineering, ecology, aquatics, meteorology, and those of other disciplines—to yield integrated approaches to environmental improvement. This publication emphasizes the contribution of soil maps and descriptions. The work was financed by the Kansas Geological Survey, uses mainly soils data provided by the U.S. Department of Agriculture, and has considerable contributions from the Kansas State Department of Health, Kansas Agricultural Experiment Station, and from many other sources. To emphasize the universality of the support, mention should be made of the contribution of Cornell University, which supplied half-salary sabbatical support while the author assembled and organized this information.

Successful waste disposal consists essentially of consideration of the alternatives open for solution of specific problems, in light of the resources available. Thus, with adequate funding, public municipal collection facilities and large sewage treatment plants are generally the best method to handle liquid waste from concentrated houses and urban areas. Where housing is scattered, septic tanks and seepage fields, seepage pits, sewage lagoons, or other engineering designs may solve the waste disposal problems. In most cases the most feasible method of waste disposal is determined ultimately by the economics of the particular situation; the best waste disposal method is generally the cheapest method that will meet local environmental quality standards and safeguard public health.

This publication concentrates mainly on the suitability of soils for disposal of liquid wastes from individual homes through septic tanks and soil seepage systems. Consideration also is given, however, to soil suitability for sewage lagoons and for solid waste burial in sanitary landfill. Soil information provided, such as the depth to bedrock and depth to apparent water table, can also be useful in engineering planning and design related to trench excavations for sewer lines, landscaping after excavations, evaluating trafficability of soils for heavy construction equipment, determining seepage and drainage conditions onto and away from areas, identifying hazards of flooding, and handling other important construction aspects. Soil information is also valuable for solving some industrial waste problems, such as in determining the suitability of areas for spray irrigation from feedlot lagoons and various processing plants. Soil maps are particularly valuable because they enable predictions to be made of performances and problems of different engineering systems in different areas, with reasonable accuracy, even before construction begins. Thus engineering designs can be made that correct the soil limitations (if that is feasible) in the planning stages of the waste disposal facilities.

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This publication was created to provide information to all people interested in solving relevant waste disposal problems, where soil characteristics are contributing factors. Although an informed public is a necessity, this information will probably be most useful to workers in public agencies (e.g. Kansas Geological Survey, Soil Conservation Service, Kansas State Department of Health, Kansas Agricultural Experiment Station). The language of the report is that of current common usage by soil scientists, with the glossary, explanations, and additional information provided for laymen.

Although this publication was designed for use with detailed soil maps, a general soil map of Kansas is included in an envelope inside the back cover; the general soil map will be useful to show the location of counties and the general distribution of some of the soils of major acreages. The map legend includes brief descriptions of some of the major soil characteristics in Kansas. The general soil map inside the back cover was published separately by the Kansas Agricultural Experiment Station, in cooperation with the Soil Conservation Service. Arrangements to include the map in this bulletin were facilitated by Prof. O. W. Bidwell and Dr. F. W. Smith, Director of the Agricultural Experiment Station.

ACKNOWLEDGMENTS

This study results from the encouragement of Dr. Paul L. Hilpman, Chief, Environmental Geology Section, Kansas Geological Survey. Generous provision of information and data review by Mr. Charles W. McBee, State Soil Scientist, and the staff of the Soil Conservation Service of the U.S. Department of Agriculture made the organization of material possible. In the early part of the work, Mr. R. W. Eikleberry and Dr. J. Stiegler of Kansas State University and Agricultural Experiment Station provided orientation to sources of information about soils and soils problems in Kansas. Mr. J. H. Duncan and Mr. M. Gray of the Kansas State Department of Health provided designs and information relating to engineering and related aspects of the problems. Prof. O. W. Bidwell of Kansas State University reviewed the final manuscript, as have the other participants in the effort. A great deal of information was further provided by the author's many other colleagues within and outside of the state of Kansas. Numerous conferences with Mr. H. P. Dickey, Soil Scientist at Lawrence, were especially helpful. Sabbatic support of Cornell University, and administrative support of the Kansas Geological Survey were greatly appreciated.

FIG. 1. View of rock outcrops. Rocky soils with bedrock outcrops are common in many parts of Kansas, as the soil maps indicate. Commonly the areas are not farmed or intensively developed, because the soils are poor for most uses. Although these areas are poor for waste disposal, they can be effectively used for aesthetic and recreational purposes—like hiking trails and picnic areas. Areas like this are common around many of the reservoirs in Kansas; their locations should be carefully considered in overall planning for location of septic tanks, sewer lines, and other types of land development.

SOIL LANDSCAPES

Each *soil** in Kansas occupies a logical and predictable part of the landscape. *Soil maps* locate the local variabilities which the *soil profile* descriptions record. Regionally, within Kansas, landscapes differ as the traveler drives from one part of the state to another part. Photographs (Figures 1 and 2), diagrams, or cross sections are useful in showing some of these soil-landscape positions. In Brown County, for example, some soils are located on hills of *glacial till*, mantled by *loess* from wind deposits, with other soils formed in *colluvium* moved into the low spots and

* Terms included in the glossary are italicized the first time they occur.

FIG. 2. View of alluvial area. Soils in recent alluvium may be frequently, occasionally, or rarely flooded. These places may have severe limitations for waste disposal. In critical areas, like around lakes in Kansas, developments on these soils can be restricted to parks, recreation, and certain other uses which are not damaged as much by flooding as are buildings and some other structures.

valleys by gravity and water. Figure 3 shows a typical soil landscape for this area. Ladoga and Monona soils formed in loess deposited by wind thousands of years ago; these soils are generally *sloping*. Judson soils, however, formed in colluvium moved more recently from the slopes by gravity and water; the Judson soils occupy the footslopes of valley walls. Obviously, Monona and Ladoga soils may have good homesites with aesthetic views of the valley, but Judson soils have a flooding hazard. All the soils have moderate or moderately slow *permeability* for septic tanks. Some places may be suitable for sewage lagoons, but careful investigations are necessary before lagoons are built.

In contrast, some soil landscapes around Topeka in Shawnee County have more complex soil patterns. One of these landscapes is illustrated in Figure 4, taken from the soil survey report (Abmeyer and Campbell, 1970). In these places (Figure 4), Dwight soils occupy the tops of hills mantled by thin loess deposits over bedrock, and Ladysmith soils have developed in thicker loess deposits over bedrock. Obviously, Dwight soils have hazards for *septic-tank seepage fields* due to the proximity of the fissured limestone and shale, but both Dwight and Ladysmith soils have fine *textures*, very slow permeability for sewage *effluent*, and seasonally high apparent *water tables*. Water rises higher than 30 inches from the soil surface within Ladysmith soils during early spring of most years. Labette, Sogn, Vinland, and Martin soils have variable depths to bedrock, occupying the respective slopes shown in Figure 4; excavations in all these places in these soils will probably encounter bedrock at less than 40 inches, except in Martin soils where bedrock is deeper than 40 inches. In the valley bottoms, Kennebec, Reading, and Wabash soils have formed in *alluvial* sediments deposited by floodwaters. Without flood protection, these soils have flooding limitations for all kinds of waste disposal.

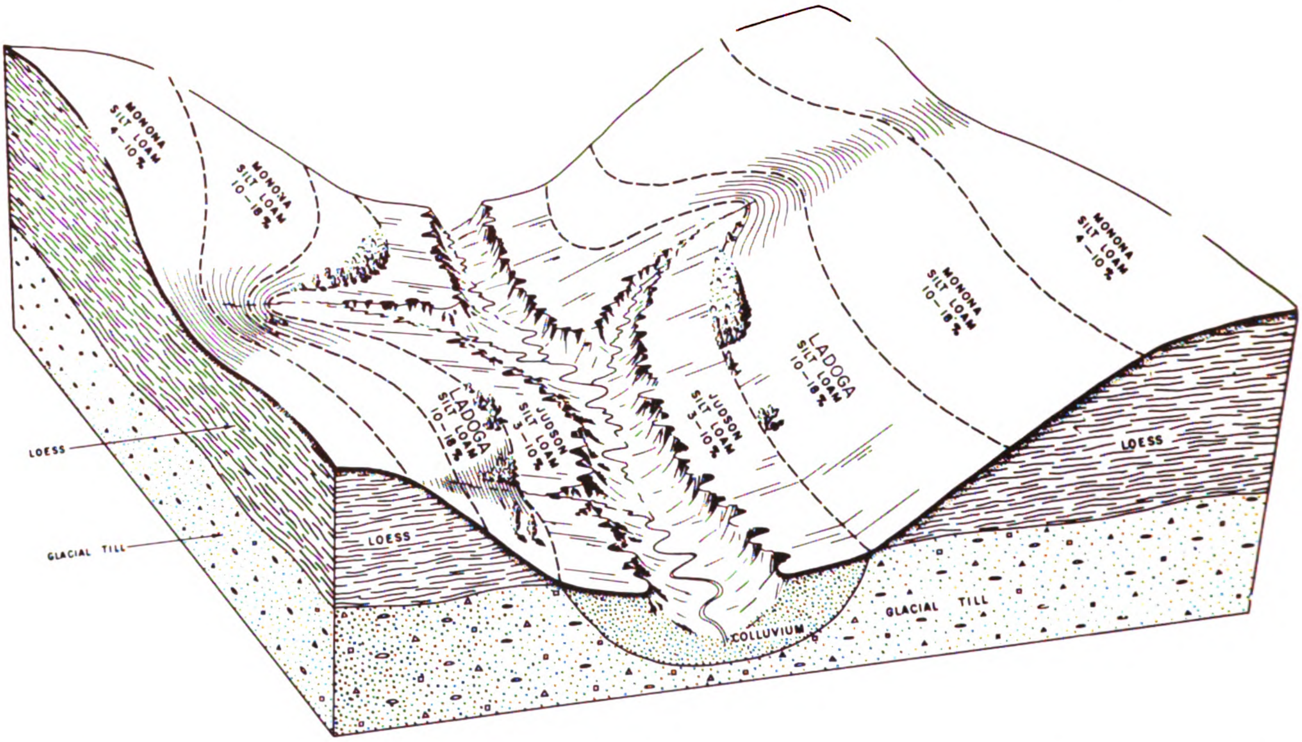

FIG. 3. Typical cross section of soils of the strongly sloping loess hills in Brown County, Kansas (Adapted from Eikleberry, 1960, page 2).

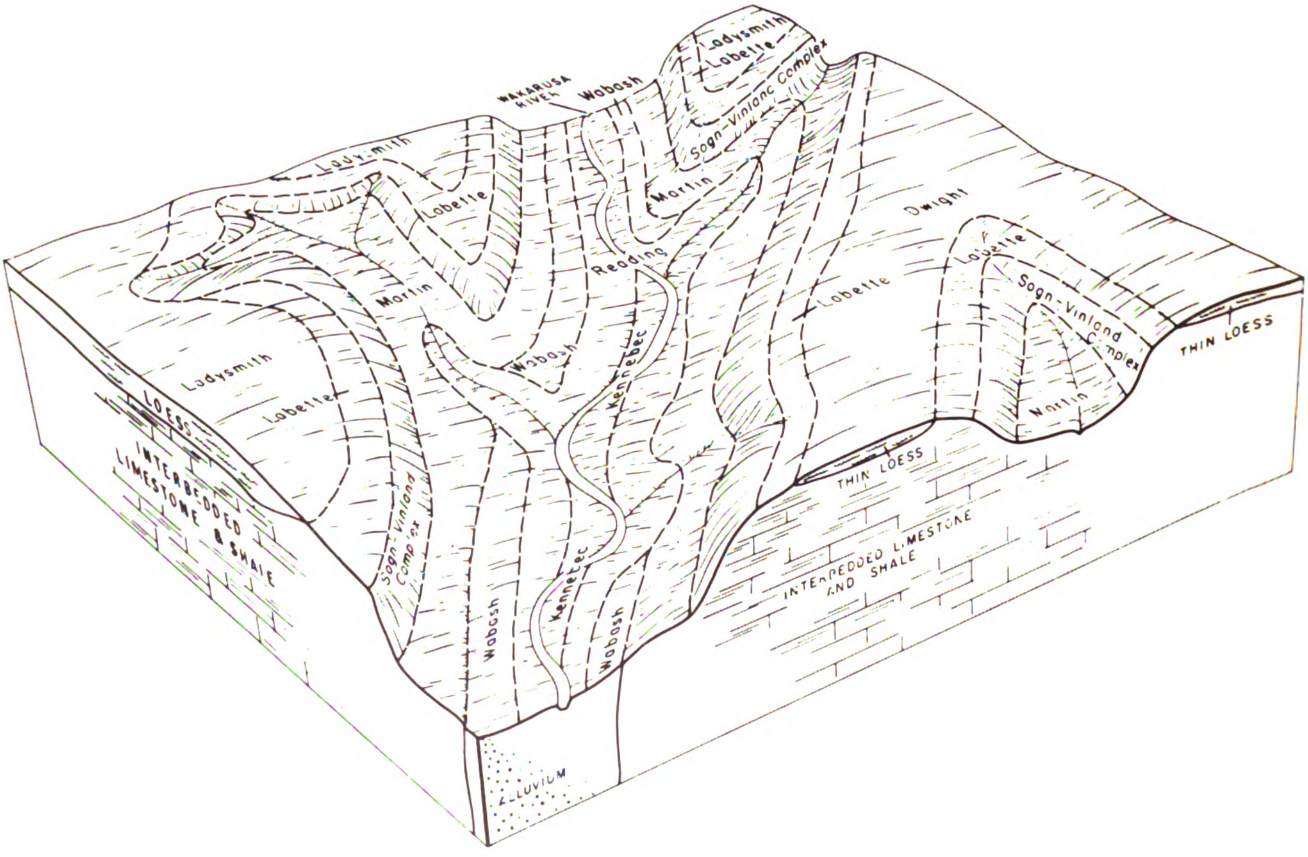

FIG. 4. Soil relationships to surface deposits and bedrock in the southwestern part of Shawnee County, Kansas (Adapted from Abmeyer and Campbell, 1970, page 5).

In Figure 5, another type of soil landscape of Kansas is illustrated. Some of these landscapes in Republic County (Atkinson and Gier, 1967) have Crete soils on variable slopes of the uplands. Crete soils have slow permeability for septic-tank seepage fields and have apparent water tables shallower than 30 inches during early spring in most years. Butler soils occupy the low spots where water tables are even higher; these places may be flooded after heavy rains in some years. Hastings, Crete, and Geary soils occupy slopes likely to be eroded in these landscapes. Hobbs soils are on the bottomlands and generally are not subject to erosion.

Landscapes in western Kansas are different, as Figure 6 illustrates. In Bear Creek valley in the southwestern part of the state, Richfield soils occupy nearly level loess uplands of 0 to 1 percent slopes; these areas are good for most kinds of waste disposal. Richfield soils are well drained, but have fine textures and moderately slow permeability. Ulysses soils are well drained and have moderate permeability on more sloping areas of loess over coarse outwash deposits. Dalhart soils have fine loamy textures and no limitations for any kind of waste disposal; they have excellent characteristics for septic tanks, sanitary landfill, and even sewage lagoons. Manter soils have shale at 40 to 60 inches. Tivoli soils on sand dunes have rapid permeability, but this causes a *ground-water* contamination hazard for waste disposal. Travessilla soils have sandstone at 10 to 20 inches on steep slopes; they are not very suitable for any kind of waste disposal. Valley bottoms have Bridgeport soils in fine silty alluvium; they are well drained and have moderate permeability, but are subject to flooding.

SOIL MAPS

Current soil mapping in Kansas is done on aerial photographs at a scale of four inches to one mile, and published at a scale of 1:20,000 (one unit on the map represents 20,000 units on the soil surface), 1:24,000, or 1:31,680. About half of the state of Kansas has been mapped at the four inch to one mile scale, and about one-fourth of the area of the state has published soil maps available at the 1:20,000 or smaller scales. Published soil maps are available for counties including Brown, Finney, Ford, Geary, Grant, Gray, Greeley, Hamilton, Harper, Haskell, Kearny, Lane, Logan, Morton, Pratt, Reno, Republic, Saline, Scott, Seward, Shawnee, Stanton, Stevens, and Wichita. In 1972, a typical year, about 30 full-time soil scientists were engaged in the field mapping of soils in Kansas. In the

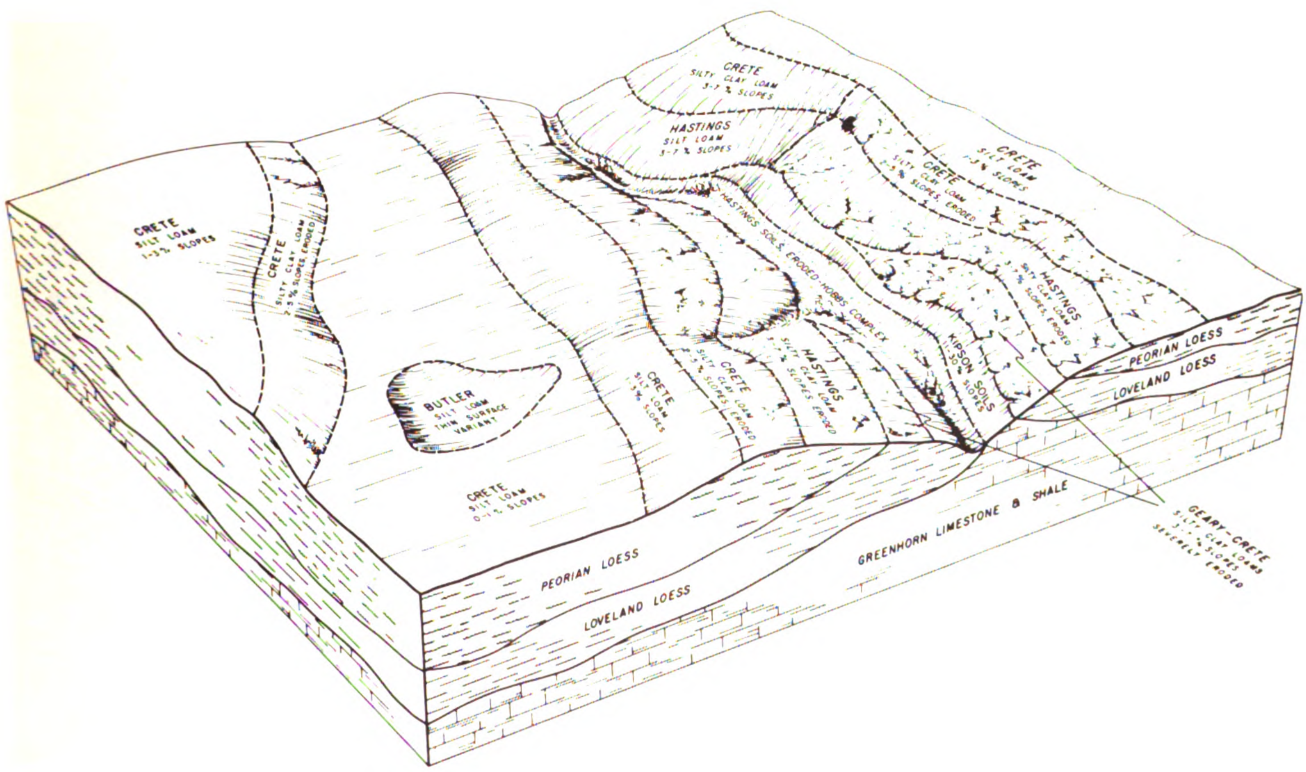

FIG. 5. Soil landscape in loess of different depositions and Greenhorn limestone and shale in Republic County, Kansas (Adapted from Atkinson and Gier, 1967, page 3).

past 20 years, millions of dollars have been invested in Kansas in this resource inventory of soils, one of the most valuable natural resources. Much of the mapping is scattered and unpublished, but the field maps on the aerial photographs can be consulted in district offices of the Soil Conservation Service, one of which is located in most of the counties in Kansas.

In effect, soil maps are an on-site inventory of soil resources, in which the soil scientist has mapped several hundred acres each day. He has dug holes in surface soils and subsoils, measured slopes, observed vegetation, and recorded everything that might affect use of the soils for septic tanks, sewage lagoons, sanitary landfill, and other uses. Holes are dug in every delineated area or soil map unit, and each significant soil variation is shown on the map down to areas as small as an acre or several acres in size. Accuracy of the maps may be considered to be at least 80-90 percent for most uses; the information to be derived from a soil map depends somewhat upon the skill and experience of the user of the map and his knowledge of soils, geomorphology, and other earth sciences. Each soil of an area is described and mapped with respect to:

1. Land form, relief, drainage
2. Parent material of soils, geology
3. The soil profile in vertical section
   a. Color
   b. Texture
   c. *Structure*
   d. Porosity
   e. *Consistence*
   f. Acidity, alkalinity, lime status
   g. Concretions, other special formations
   h. Organic matter, roots
   i. Chemical and *mineralogical* composition
   j. Other characteristics
4. *Stoniness*
5. Erosion
6. Vegetation
7. Land use
8. Other significant factors

Figure 7 gives an example of a soil survey field sheet, taken from a leaflet on planning for proper land use in Kansas (Soil Survey Staff, 1972a). The soil map shows areas that have steep slopes (5D), areas that are flooded (1M41), areas that have high seasonal water tables (1M4 in legend, not labeled on map), areas that have slow permeability (F22C), and areas that have

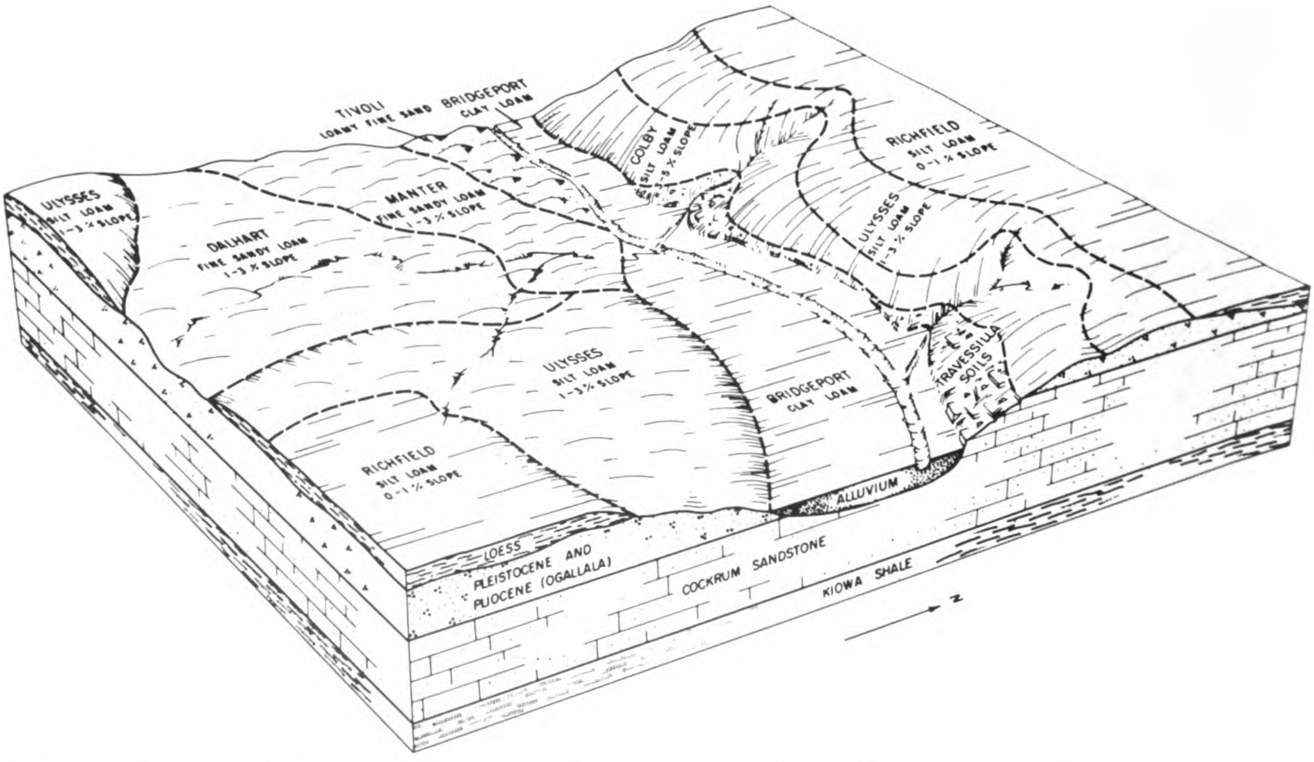

Fig. 6. Landscape of soils in Bear Creek valley in Stanton County, Kansas (Adapted from Fleming *et al.*, 1961, page 2).

few or no significant limitations for waste disposal in septic tanks (M4B). Similarly, all areas of Kansas that have soil maps can be rated for waste disposal and for soil properties that favor or restrict various methods of disposal of liquid and solid wastes.

SOIL-PROFILE DESCRIPTIONS

Soil maps are accompanied by soil-profile descriptions, which are the records of the observations the soil scientist makes when he digs holes in soils and examines the various layers or horizons. A special publication of about 90 pages (Olson, in press) has been prepared to give laymen the criteria for interpreting a soil-profile description. The procedure for making and interpreting a soil profile or *pedon* description consists simply of "comparing various properties of parts of an individual soil profile with descriptive standards that have been established to describe these various properties for all soil profiles." All the information in the special publication on criteria (Olson, in press) is contained also in scattered publications of the U.S. Department of Agriculture in common use by soil scientists throughout the USA.

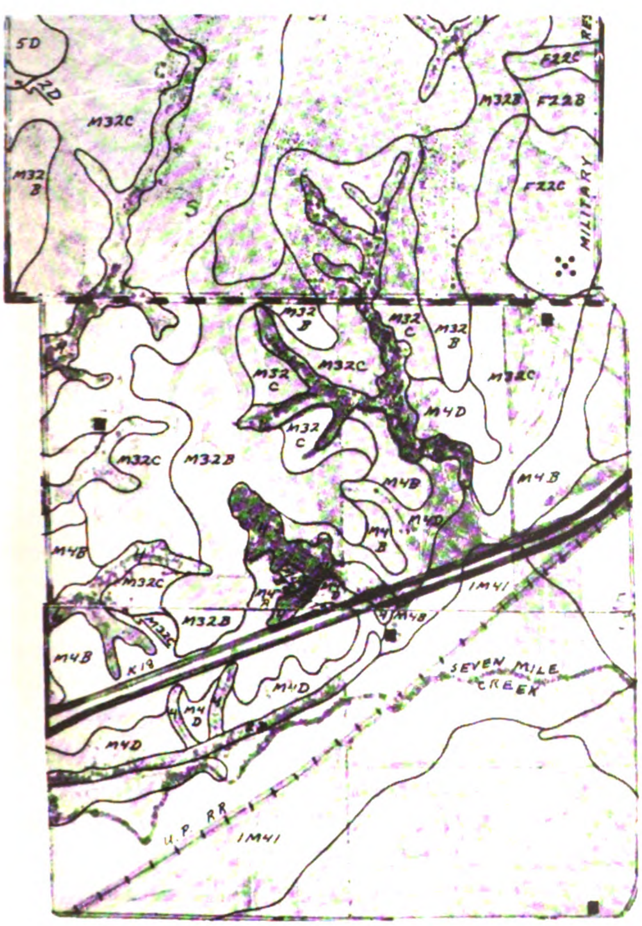

FIG. 7. Reproduction of portion of unpublished soil map from area in Riley County, Kansas (Adapted from Soil Survey Staff, 1972a). Top of map is north.

Each soil-survey area or published soil-survey report has numerous soil-profile descriptions, which give the properties of the soils that are significant for their use. Figure 8 gives a schematic picture of the pit and soil profile that a soil scientist describes for each soil when making a map. In parts of Kansas, for example, Randall clay soils occupy some enclosed depressions often flooded after heavy rains; these places have *severe limitations* for septic-tank seepage fields and pits and severe limitations for sanitary landfill, but the locations may be feasible for sewage lagoons. The clay in Randall soils is high in content of *montmorillonite,* which causes it to shrink with drying, and swell when wet; this shrinking and swelling causes considerable difficulties for some engineering structures. The soil survey of Ford County (Dodge *et al.,* 1965) contains a typical soil-profile description (page 72) of Randall clay from a location about six miles north of Dodge City:

A1—0 to 31 inches, gray (10YR 5/1)* clay, very dark gray (10YR 3/1) when moist; moderate, fine, blocky structure in upper part, moderate, medium, blocky structure in lower part; extremely hard when dry, plastic when wet; noncalcareous; gradual boundary.

AC—31 to 40 inches, grayish-brown (10YR 5/2) clay, dark grayish brown (10YR 4/2) when moist; weak, medium, blocky structure; very hard when dry, plastic when wet; weakly *calcareous;* gradual boundary.

C—40 to 60 inches, light brownish-gray (10YR 6/2) silty clay loam, grayish brown (10YR 5/2) when moist; massive (structureless); *friable* when moist, slightly hard when dry; calcareous.

The gray colors in this soil indicate that the soil is under water for significant periods each year (Figure 9), because reducing conditions (absence of free oxygen) prevail to form gray colors in wet soils. The blocky structure is formed by the shrinking and swelling in the upper part of the profile; the lower part is massive clay and practically impermeable to sewage effluent. The clay of the Randall soil tends to become very hard when dry and is plastic when wet; wheeled vehicles and even crawler-type vehicles often become bogged down in Randall soils.

* These number-and-letter designations are part of a standardized system of soil color notations (Munsell soil color system), outlined in the publication by Olson (in press).

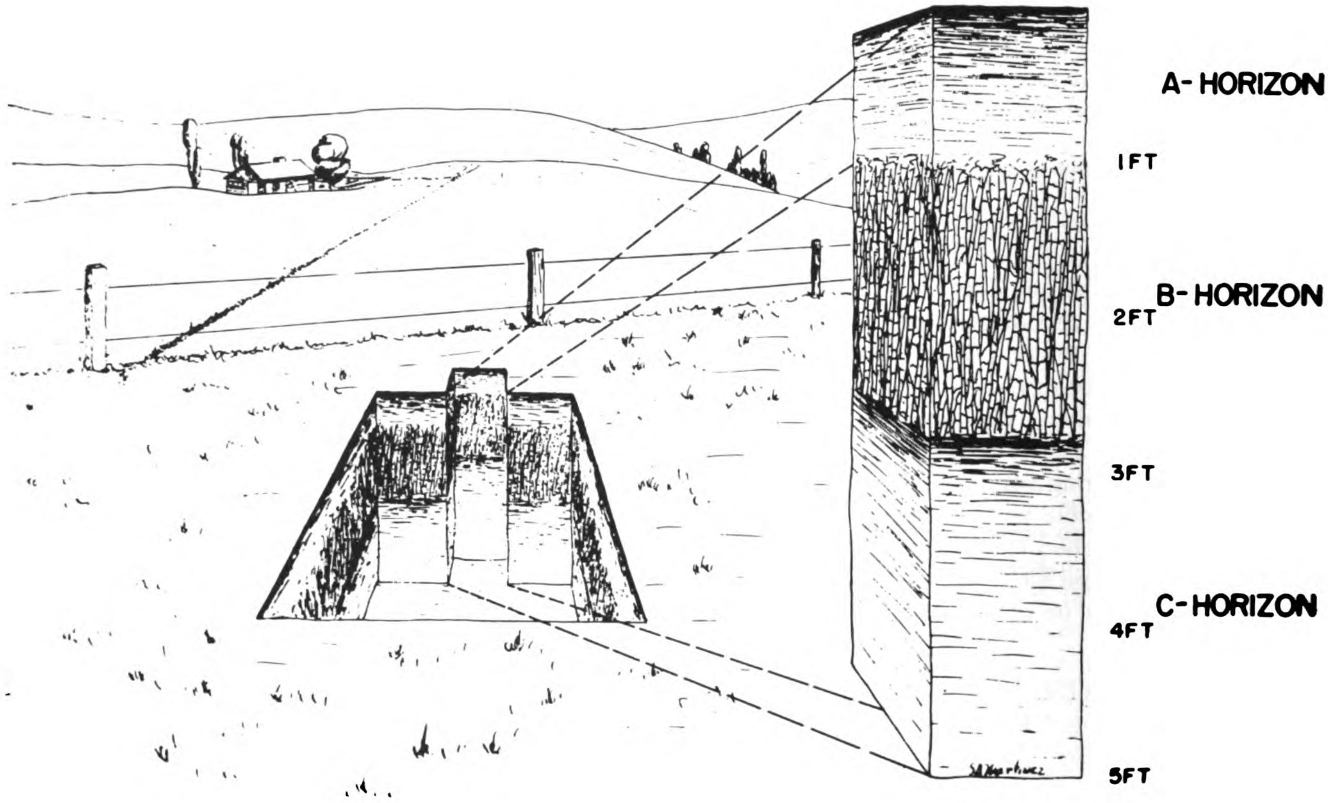

FIG. 8. Schematic drawing of pit and soil profile as described by a soil scientist making a profile description during a soil survey (Adapted from Dunmire and Bidwell, 1960, page 15).

Keith soils are among the better soils in Kansas for waste disposal. The following soil profile description was made during the soil survey of Finney County (Harner *et al.*, 1965, page 73):

Alp—0 to 7 inches, dark grayish-brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) when moist; weak, granular structure in upper part of plow layer and weakly platy in lower part; slightly hard when dry, friable when moist; noncalcareous; abrupt boundary (plow slice).

Al—7 to 10 inches, dark grayish-brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) when moist; moderate, fine, granular structure; slightly hard when dry, friable when moist; worm casts; noncalcareous: clear, smooth boundary.

AB—10 to 15 inches, dark grayish-brown (10YR 4/2) heavy loam, very dark grayish brown (10YR 3/2) when moist; moderate, fine, granular structure; slightly hard when dry, friable when moist; numerous worm casts; noncalcareous; clear, smooth boundary.

B21t—15 to 20 inches, grayish-brown (10YR 5/2) light clay loam, very dark grayish brown (10YR 3/2) when moist; moderate, fine, granular and weak, fine, subangular blocky structure; hard when dry, firm when moist; patchy clay films; pockets of worm casts; noncalcareous; clear, smooth boundary.

B22t—20 to 24 inches, brown (10YR 5/3) light clay loam, dark brown (10YR 3.5/3) when moist; moderate, fine, subangular blocky structure; hard when dry, firm when moist; clay films; noncalcareous; clear, smooth boundary.

Cca—24 to 60 inches, pale-brown (10YR 6/3) silt loam, brown (10YR 5/3) when moist; weak, subangular blocky structure; slightly hard when dry, friable when moist; calcareous; contains numerous concretions and threads of lime.

The brown colors in the Keith soils, without *mottling* (spots) of different colors, indicate a well-drained soil that does not have high water tables for significant periods. The granular and blocky structures provide good aeration and permeability for septic-tank seepage fields and pits, but the loam textures have enough clay so that the soil will hold liquids fairly well in sewage lagoons. Keith soils are easy to excavate in

FIG. 9. View of ponded soil area. Many soils in Kansas, including Randall soils, occupy low spots frequenly wet or flooded. Generally these soils are not well drained, and have mottles (spots of different colors) recorded in their soil-profile descriptions. These places are generally poor for septic-tank seepage fields and sanitary landfill, but may be good sites for sewage lagoons.

sanitary landfill operations and have no bedrock, water table, or flooding limitations. Keith soils, of course, are also good for many other uses; land values are generally higher in these areas due to the competition for intensive uses of the best soils.

Kipson soils are shallow to limestone and shale bedrock. These areas occupy gently sloping hilltops with a thin soil mantle, and, in some parts of Kansas, steep sideslopes with rock outcrops. A typical soil profile of a Kipson soil was described in Republic County (Atkinson and Gier, 1967, pages 53-54):

A1—0 to 10 inches, dark-gray (10YR 4/1) loam, very dark brown (10YR 2/2) when moist; moderate, fine, granular structure; slightly hard when dry, friable when moist; calcareous; numerous small fragments of limestone; gradual, smooth boundary.

C—10 to 20 inches, white (10YR 8/1) shaly loam, pale brown (10YR 6/3) when moist; mass of soil and weathered fragments of limestone and calcareous shale.

R—20 inches +, interbedded limestone and calcareous shale.

Kipson soils are very poor for most methods of waste disposal because of the shallowness to bedrock (Figure 10). Septic-tank seepage fields and pits in Kipson areas are very likely to pollute ground-water supplies for a considerable distance, because solution cracks and joints in the rock do not permit adequate filtration of the sewage effluent. These areas are unsuitable for sewage lagoons because the cracks in the bedrock would let the liquid waste drain out and contaminate ground-water. Use of these soils for sanitary landfill is not recommended due to the shallowness to bedrock; even transporting soil material for cover from deeper soil areas may be too expensive if the distance is great.

Many soils in Kansas have important soil characteristics with seasonal influences; their soil-profile descriptions must be very carefully studied to seek out the subtle criteria which are important for waste dis-

Fig. 10. View of shallow soil. Many soils in Kansas have bedrock at shallow depths; the specific bedrock-influenced soils and bedrock depths are listed in Table 1 and Table 6. If the bedrock is listed as "rippable," it can be dug out with common excavating equipment; if the bedrock is listed as "hard," it cannot be excavated easily. These soils may occupy nearly level or steep places—locations and slopes for each soil are shown on the detailed soil maps.

posal. For example, many soils in Kansas have apparent water tables within 30 inches of the soil surface for significant periods during the late winter and early spring of each year. Although these soils are wet in late winter and early spring, the apparent water table drops in the summer due to transpiration by plants. Indications of wetness (mottles, or spots of different colors) remain in the soil even when the season is dry; the mottles indicate that the apparent water table will rise again when it rains. The Butler series, as described in Republic County (Atkinson and Gier, 1967, page 48), is one of the many soils in Kansas that have free water within 30 inches of the surface during the late winter and early spring:

Ap—0 to 9 inches, dark-gray (10YR 4/1) silt loam, very dark gray (10YR 3/1) when moist; moderate, fine, granular structure and massive; slightly hard when dry, friable when moist; slightly acid; abrupt, smooth boundary.

B21t—9 to 18 inches, dark-gray (10YR 4/1) silty clay, very dark grayish brown (10YR 3/2) when moist; moderate, medium, angular blocky structure; thick, dark-colored clay films; extremely hard when dry, very firm when moist; slightly acid; gradual, smooth boundary.

B22t—18 to 24 inches, gray (2.5Y 5/1) silty clay, dark gray (2.5Y 4/1) when moist; few, distinct, fine mottles of strong brown; moderate, medium, angular blocky structure; thick clay films; extremely hard when dry, very firm when moist; neutral; gradual, smooth boundary.

B3ca—24 to 38 inches, light brownish-gray (2.5Y 6/2) heavy silty clay loam, grayish brown (2.5Y 5/2) when moist; common, distinct, fine mottles of strong brown; moderate, medium and fine, angular blocky structure; moderately thick clay films; very hard when dry, firm when moist; mildly alkaline; numerous concretions of calcium carbonate; gradual, smooth boundary.

Cca—38 to 60 inches, light-gray (5Y 7/2) light silty clay loam, olive gray (5Y 5/2) when moist; common, distinct, medium mottles of strong brown; weak, medium and fine, subangular blocky structure; slightly hard when dry, friable when moist; calcareous; small, hard concretions and soft, white coatings of calcium carbonate.

The mottles described in the B22t, B3ca, and Cca horizons of the Butler series are especially critical, because they indicate periodic wetness. Septic-tank seepage fields and pits in the Butler soils will not function below 30 inches in the late winter and early spring when the apparent water table is above that depth. If artificial water diversion and drainage is provided, of course, the soil is improved over its natural condition for effluent seepage. Seasonal water tables in Butler soils also affect their use for sewage lagoons and sanitary landfill. The soil-profile descriptions of the soils, however, indicate the soils' problems to be encountered for waste disposal and the corrections that might need to be made to overcome them.

RESEARCH ON SOILS FOR WASTE DISPOSAL

Soil scientists and engineers have carried out considerable research on the use of soils for waste disposal. Literature reviews discussing soils' implications for septic-tank effluents (Cain and Beatty, 1965; Keppner, 1972), municipal effluents (Ramsey *et al.*, 1972), and public health and engineering aspects (Olson, 1964) list many references. In addition, many publications (Bender, 1971; Porter and Pettry, 1971) show how soil maps can lead to enhanced environmental quality through good planning.

The percolation test for waste disposal in soils has been subjected to rigorous evaluation on a statistical areal basis (Derr *et al.*, 1969); proposals for improved tests have been made (Bouma, 1971). The percolation test is important because it measures the rates at which water flows through soils and gives an approximation of effluent seepage capacity for design purposes. Morris *et al.* (1962) suggested that detailed soil maps can substitute for percolation tests, probably with better results. Studies also have related *percolation rates* to soil-map units (Persinger and Yahner, 1970), and measured seasonal apparent water-table variations in soils affecting waste disposal (Latshaw and Thompson, 1968; Fritton and Olson, 1972).

Hill (1972) evaluated the waste-water renovation potential of several soils, and found that soil properties affected the results to a considerable extent. Huddleston and Olson (1967) outlined a technique by which seepage-field designs can be specified for areas on detailed soil maps, on the basis of percolation tests related to soil-map units, with accessory studies showing statistical incidence of seepage-field failures in the different soils. By putting all of this information together, percentages of failures of septic-tank seepage fields can be predicted for different soils (Figure 11), and, conversely, engineering systems which will give satisfactory performances over a long period of time can be prescribed for each soil on the map.

Ultimately, most septic-tank failures are due to inadequate investments in the engineering systems for the different soils. Although any soil can be made suitable for any purpose with unlimited funds, most soils with severe limitations require such expensive seepage fields or other structures for adequate effluent treatment that the feasibility of construction may be questionable. Builders of homes with septic tanks should select sites with ***slight limitations*** for effluent

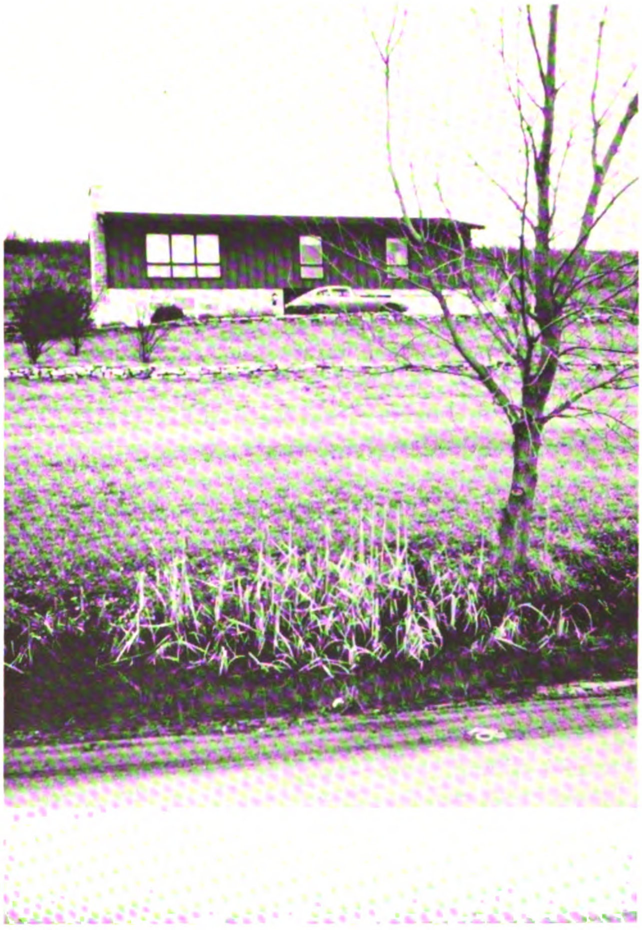

Fig. 11. House on clayey soils with slow permeability and severe limitations for septic-tank seepage fields. Sewage effluent seeps downslope and collects in the ditch shown at the bottom of the photograph. Rank vegetative growth indicates soil seepage, fertilized by nutrients in the sewage effluent. Research on failing septic tanks helps to indicate soil conditions which produce slight, moderate, or severe limitations for seepage fields. Percentages of septic-tank failures, of course, are smaller in the soils with slight limitations that have moderate or rapid permeability.

disposal; soil maps thus can be of great help for environmental improvement, as well as in cutting construction costs. Popkin and Bendixen (1968) have published some cost figures for seepage fields in various soils. Although their calculations appear to be largely theoretical, and their assumptions of percolation rates are not realistic for most soils of Kansas, soils are shown to be a major factor determining costs of on-site sewage disposal—especially if costs of system failures and duration of satisfactory performances can be included in the evaluation. Relative costs for seepage field designs in different soils, for homes with five occupants and three bedrooms, using recommended systems (Popkin and Bendixen, 1968), were:

Good soil with practically no limitations	\$ 515
Fair soil with few limitations	\$ 651
Poor soil with some limitations	\$1,244

These costs, of course, are not adjusted for devaluations or inflations. They do, however, reflect the need for additional investments for adequate disposal in soils with *moderate* to severe *limitations*. Real costs on poor soils, figuring also considerations for health hazards, environmental quality, and system failures, are probably much higher than these data indicate.

Wall and Webber (1970) have published a paper on soil characteristics and subsurface sewage disposal which is relevant for planning around reservoirs in Kansas; their study area had cottages with failing septic tanks on the shore of a *eutrophic* lake that had "become weed-choked within the past five years." Ten out of 14 samples of ground-water associated with tile systems on poorly drained soils had phosphorus in excess of 0.01 to 0.02 *ppm*. Ground-water analyses from 11 sites associated with septic-tank systems had concentrations as high as 4.4 ppm NO_3-N, 2.0 ppm P, and 46,000 coliform bacteria (*MPN*/100 ml). Water quality analyses from five wells used as sources of drinking water in the area had concentrations as high as 0.73 ppm NO_3-N, 0.027 ppm P, and 1,700 coliform bacteria (MPN/100 ml).* On the basis of their observations and data, they proposed a plan for classifying the suitability of soils as a medium for the disposal of septic-tank effluents. Important "soil and site factors" evaluated were depth to bedrock, depth to water table, slope, seepage, stoniness, natural soil drainage, soil texture, and soil structure. The suitability classes of soils which they proposed are similar to those presented in this publication, except that Wall and Webber (1970) suggest five suitability classes of soils instead of three classes.

* When more than two coliform bacteria are present in 100 mls of sample, the water can be suspected of containing sewage or soil bacteria that may be injurious to health.

SOIL CLASSIFICATION

Although soil profile descriptions provide the most detailed information about each soil (Olson, in press), a taxonomic classification (Soil Survey Staff, 1972b) has been made for all the soils of Kansas. This classification groups the soils into families with respect to *particle size* and mineralogy, among other things (Soil Survey Staff, 1972b). The classification is comprehensive and includes all soils in the nomenclature (Soil Survey Staff, 1970). The soil-family classification is particularly valuable for evaluating each soil's probable suitability for waste disposal, because particle size and clay mineralogy are categorized. The particle size groups, given for each soil in Kansas in Table 1 (pages 14-21), describe the general size of mineral particles (the "average" particle size of the several horizons or the particle size when soil layers are mixed up as in excavations) in the control section down to a depth of about one meter or to the top of hard layers or bedrock. For convenience in using Table 1, each type of bedrock is described as being "hard" if it cannot be dug up or ripped out with backhoes or other common excavating equipment. If the bedrock is listed as "rippable," it can be dug out without blasting in most places. Table 1 also lists the predominant clay mineralogy of each soil in Kansas; the soils with montmorillonitic clays have special problems because of shrinking and swelling when they are subjected to wetting and drying conditions. The montmorillonitic soils have special problems for engineering uses and are generally poor for *trafficability* of heavy construction equipment, especially when they are wet.

Particle size categories (Soil Survey Staff, 1970) for soil families in Table 1 are graphically illustrated in Figure 12; these groupings are general and apply to average or mixed soil horizons, not specific horizons as noted in a soil profile description (Olson, in press). Verbal descriptions (Soil Survey Staff, 1970) of the categories are as follows:

Sandy-skeletal soils have 35 percent by volume particles coarser than 2 mm, with enough fine earth to fill *interstices* larger than 1 mm; the fraction finer than 2 mm is defined as sandy.

Loamy-skeletal soils have 35 percent by volume fragments coarser than 2 mm, with enough fine earth to fill interstices larger than 1 mm; the fraction finer than 2 mm is defined as loamy.

Clayey-skeletal soils have 35 percent by volume fragments coarser than 2 mm, with enough fine earth to fill interstices larger than 1 mm; the fraction finer than 2 mm is defined as clayey.

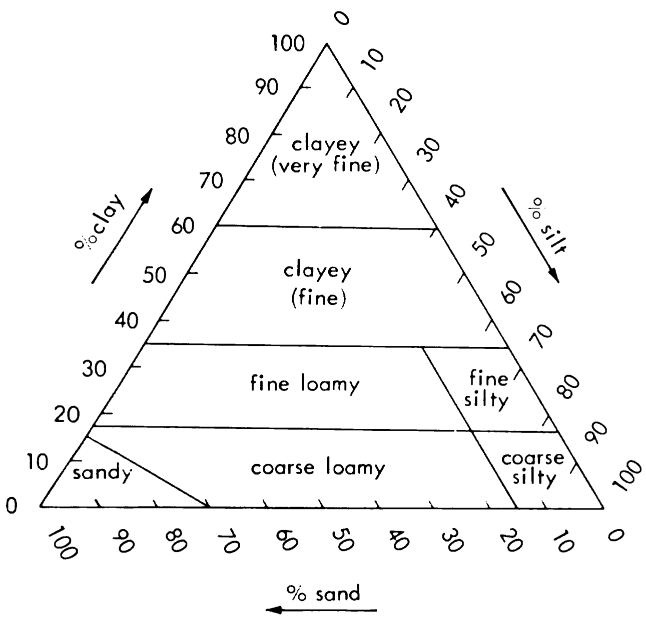

FIG. 12. Weight percentages of sand, silt, and clay for classification in soil families (Adapted from Soil Survey Staff, 1970).

Sandy soils have fine-earth textures, including sands (Olson, in press) and loamy sands, exclusive of loamy very fine sand and very fine sand textures; coarse fragments are less than 35 percent by volume.

Loamy soils have the texture of fine earth which includes loamy very fine sand, very fine sand, and finer textures with less than 35 percent clay; coarse fragments are less than 35 percent by volume. Loamy soils are subdivided into coarse-loamy, fine-loamy, coarse-silty, and fine-silty categories (see Figure 12).

Coarse-loamy soils have a loamy particle size that has 15 percent or more by weight of fine sand (0.25-0.1 mm) or coarser particles, including fragments up to 7.5 cm, and have less than 18 percent clay in the fine earth fraction.

Fine-loamy soils have a loamy particle size that has 15 percent or more by weight of fine sand (0.25-0.1 mm) or coarser particles, including fragments up to 7.5 cm, and has 18 to 35 percent clay in the fine earth fraction.

Coarse-silty soils have a loamy particle size that has less than 15 percent of fine sand (0.25-0.1 mm) or coarser particles, including fragments up to 7.5 cm, and has less than 18 percent clay in the fine earth fraction.

Fine-silty soils have a loamy particle size that has less than 15 percent of fine sand (0.25-0.1 mm) or coarser particles, including fragments up to 7.5 cm, and has between 18 and 35 percent clay in the fine earth fraction.

Clayey soils consist of the fine earth with 35 percent or more clay by weight and coarse fragments are less than 35 percent by volume. Clayey soils are subdivided into fine and very-fine soils (see Figure 12).

Fine soils have a clayey particle size that has 35 to 60 percent clay in the fine earth fraction.

Very-fine soils have a clayey particle size that has 60 percent or more clay in the fine earth fraction.

Notice should be made of those soils listed as carbonatic in Table 1; carbonates of clay size are not considered to be clay in this classification, but are treated as silt. Carbonatic soils have more than 40 percent by weight of carbonates (as $CaCO_3$) and of gypsum, and the carbonates are more than 65 percent of the sum of carbonates and gypsum (Soil Survey Staff, 1970). *Siliceous* soils listed in Table 1 have more than 90 percent by weight of silica minerals (quartz, chalcedony, opal), and other extremely durable minerals that are resistant to weathering. Soils listed as having mixed mineralogy in Table 1 have less than 40 percent of any one mineral other than quartz. Montmorillonitic soils, which present some of the greatest problems for waste disposal (if other soil properties are also poor), have more than half montmorillonite and *nontronite* by weight, or have a mixture of clays with more montmorillonite than any other single clay mineral.

On the basis of soil-profile descriptions, made from pits in all soils in each survey area, soils of Kansas are classified also by *drainage classes* in Table 1. The drainage classes are based on the actual soil characteristics; thus mottles and gray colors in soils not well drained are recorded even during seasons when the soils may be dry. All soils not listed as well drained in Table 1 have mottles (spots of different colors) or gray colors indicating fluctuating or permanent water tables (called apparent water table or free water in soils). Wetter soils generally have mottles at shallower depths in the profile than better-drained soils. In this classification system excessively drained soils are driest (for example, soils of sand dunes), and very poorly drained soils are wettest (for example, soils of seep spots and swamps). This classification is based only on characteristics of the soil profile, so that soils flooded each year for brief periods may be classified as well drained if water does not stand in the profile long enough to produce soil oxygen deficiencies resulting in mottles or gray colors in the soils. Flooding characteristics of well-drained Kansas soils, however, are recorded elsewhere in Table 6 of this publication.

Wetness problems, from the driest soils to the wettest soil profiles, are recorded in the following sequence in Table 1:

Increasing wetness of Kansas soils ↓

- Excessively drained (driest; for example, soils on tops of sand dunes)
- Somewhat excessively drained
- Well drained
- Moderately well drained
- Somewhat poorly drained
- Poorly drained
- Very poorly drained (wettest; for example, some soils in bottoms of swamps)

The soil-profile record of wetness in Table 1 is particularly valuable for waste-disposal planning, because many Kansas soils are wet in the early spring and dry in the late summer and fall. In general, the following soils have apparent water tables (free water) in their profiles at less than 30-inch depths for less than one month during most years, but the water drops below six feet during the dry part of the year: these intermittently wet soils include Butler, Carwile, Chariton, Chase, Cherokee, Crete, Dennis, Detlor, Doxie, Edina, Eram, Grundy, Hepler, Kenoma, Ladysmith, Lagonda, Leanna, Lightning, Martin, Mayberry, McCune, Muldrow, Parsons, Pawnee, Summit, Taloka, Tina, Waurika, and Woodson. Obviously, when the water table is highest in these soils, septic-tank seepage fields will not function below the apparent water table, and effluents emptying into the fluctuating water table are apt to contaminate ground-water supplies. Fluctuating water-table depths are indicated for most of the soils of Kansas in the last column of Table 1.

Soil permeability is also given in Table 1 for the control section in each soil of Kansas; permeability is that quality of soil that permits it to transmit sewage effluent. The rate is referred to as "saturated hydraulic conductivity" in soil physics, and is measured in the laboratory and field on soil cores under saturated conditions with a low head on water moving downward (Soil Survey Staff, 1971). The permeability, of course, is dependent upon soil characteristics including texture, structure, organic matter, clay mineralogy, and other factors. Where data are not available, permeability classes can be estimated with acceptable precision from the soil-profile descriptions. The permeability classes of soils of Kansas are:

Very slow	< 0.06 in/hr	> 1,000 min/in
Slow	0.06-0.2 in/hr	1,000-300 min/in
Moderately slow	0.2-0.6 in/hr	300-100 min/in
Moderate	0.6-2.0 in/hr	100-30 min/in
Moderately rapid	2.0-6.0 in/hr	30-10 min/in
Rapid	6.0-20 in/hr	10-3 min/in
Very rapid	> 20 in/hr	< 3 min/in

For comparison purposes, permeability rates in inches per hour on cores in soils of Kansas (Table 1) are also compared with percolation rates in minutes for water to drop one inch in presoaked auger holes in the soils. Data collected over many years show that permeability rates measured on soil cores are not absolutely comparable with water drop in auger holes in the same soils. Permeability rates on soil cores are conducted under much more carefully controlled conditions, and are subject to much less variability than are auger hole measurements; generally, measurements on saturated soil cores are slower than measurements in auger holes. Auger holes are also affected by apparent water tables, whereas measurements on soil cores in the laboratory are not affected by seasonal soil phenomena. Most soils in which percolation rates in auger holes are measured as slower than 60 minutes per inch for subsurface sewage disposal have been classified as "unsuitable" in the past; actual measurements in these soils are thus seldom recorded by contractors or public health officials. *Pedologists*, on the other hand, must characterize permeability rates in all soils; consequently they measure and record all rates, however slow they might be. Most soils of Kansas, of course, have permeability or percolation rates slower than 60 minutes per inch, so that special considerations must be given to septic-tank seepage field designs in them.

Table 1. Particle size characteristics and water relationships of soils of Kansas (Adapted from Soil Conservation Service classification of soil series of 1972, published soil survey reports, current official soil series descriptions, and other sources).

Soil series name	Related to swelling of soil when wet: General particle size grouping	Related to swelling of soil when wet: Predominant clay mineralogy	Related to percolation and seasonal free water in soil profile: Soil drainage class	Related to percolation and seasonal free water in soil profile: Permeability and water table
ABILENE	Fine	Mixed	Well drained	Slow to very slow
ALBION	Coarse-loamy	Mixed	Well drained to somewhat excessively drained	Moderately rapid
ALTUS	Fine-loamy	Mixed	Well drained	Moderate, water table at 8′-15′; may be at 2-1/2′ in cool wet period
ANGELUS	Fine-silty	Carbonatic	Well drained	Moderate
ANSELMO	Coarse-loamy	Mixed	Well drained	Moderately rapid

TABLE 1 (continued). Particle size characteristics and water relationships of soils of Kansas (Adapted from Soil Conservation Service classification of soil series of 1972, published soil survey reports, current official soil series descriptions and other sources).

Soil series name	Related to swelling of soil when wet: General particle size grouping	Related to swelling of soil when wet: Predominant clay mineralogy	Related to percolation and seasonal free water in soil profile: Soil drainage class	Related to percolation and seasonal free water in soil profile: Permeability and water table
ARMO	Fine-loamy	Mixed	Well drained	Moderate
ARMSTER	Fine	Montmorillonitic	Moderately well drained to well drained	Moderately slow
ATTICA	Coarse-loamy	Mixed	Well drained	Moderately rapid
BANKARD	Sandy	Mixed	Well drained to somewhat excessively drained	Rapid to very rapid
BARLANE	Fine-loamy over sandy to sandy skeletal	Mixed	Somewhat poorly drained	Slow, water table at 2′-6′ seasonally
BASEHOR	Loamy over hard sandstone at 10″-20″	Siliceous	Well drained	Moderately rapid
BATES	Fine-loamy over rippable sandstone at 20″-40″	Siliceous	Well drained	Moderate
BAXTER	Clayey	Mixed	Well drained	Moderate
BAYARD	Coarse-loamy	Mixed	Well drained	Moderately rapid
BENFIELD	Fine over rippable shale at 20″-40″	Mixed	Well drained	Slow
BETHANY	Fine	Mixed	Well drained	Slow
BIPPUS	Fine-loamy	Mixed	Well drained	Moderate
BODINE	Loamy-skeletal	Siliceous	Well drained to somewhat excessively drained	Rapid to very rapid
BOEL	Sandy	Mixed	Somewhat poorly drained	Moderately rapid to rapid, water table at 2′-6′ seasonally
BOGUE	Very fine over rippable shale at 20″-40″	Montmorillonitic	Moderately well drained	Very slow
BOLIVAR	Fine-loamy over hard sandstone at 20″-40″	Mixed	Well drained	Moderate
BOWDOIN	Very-fine	Montmorillonitic (calcareous)	Well drained to moderately well drained	Very slow
BREWER	Fine	Mixed	Moderately well drained	Slow
BRIDGEPORT	Fine-silty	Mixed	Well drained	Moderate
BROWNELL	Loamy-skeletal over hard limestone at 20″-40″	Carbonatic	Well drained	Moderate
BURCHARD	Fine-loamy	Mixed	Well drained	Moderately slow
BUTLER	Fine	Montmorillonitic	Somewhat poorly drained to poorly drained	Slow, water table at 30″-6′+ seasonally
CAMPUS	Fine-loamy over rippable caliche at 20″-40″	Mixed	Well drained	Moderate
CANADIAN	Coarse-loamy	Mixed	Well drained	Moderately rapid
CANLON	Loamy over hard caliche at 10″-20″	Mixed (calcareous)	Well drained to somewhat excessively drained	Moderate
CANYON	Loamy over rippable sandstone at 10″-20″	Mixed (calcareous)	Well drained	Moderate
CAREY	Fine-silty	Mixed	Well drained	Moderate
CARLSON	Fine	Montmorillonitic	Well drained	Moderately slow
CARR	Coarse-loamy	Mixed (calcareous)	Well drained to moderately well drained	Moderate to rapid, water table at 6′+ except for brief periods
CARUSO	Fine-loamy	Mixed	Moderately well drained to somewhat poorly drained	Moderate to moderately slow, water table at 2′-8′ seasonally
CARWILE	Fine	Mixed	Somewhat poorly drained	Slow, water table at 30″-6′+ seasonally
CASE	Fine-loamy	Mixed	Well drained	Moderate
CASS	Coarse-loamy	Mixed	Well drained	Moderately rapid, water table at 6′-10′+ seasonally
CATOOSA	Fine-silty over hard limestone at 20″-40″	Mixed	Well drained	Moderate
CAWKER	Coarse-silty	Mixed	Well drained	Moderate
CHARITON	Fine	Montmorillonitic	Poorly drained	Slow, water table at 30″-6′+ seasonally
CHASE	Fine	Montmorillonitic	Somewhat poorly drained to moderately well drained	Slow, water table at 30″-6′+ seasonally
CHEROKEE	Fine	Mixed	Somewhat poorly drained	Very slow, water table at 30″-6′+ seasonally
CHURCH	Fine	Mixed	Moderately well drained	Very slow, water table at 5′-10′+ and 2′-3′ in wet season
CLAIREMONT	Fine-silty	Mixed (calcareous)	Well drained	Moderate
CLAREMORE	Loamy over hard limestone at 10″-20″	Mixed	Well drained	Moderate

TABLE 1 (continued). Particle size characteristics and water relationships of soils of Kansas (Adapted from Soil Conservation Service classification of soil series of 1972, published soil survey reports, current official soil series descriptions and other sources).

Soil series name	Related to swelling of soil when wet		Related to percolation and seasonal free water in soil profile	
	General particle size grouping	Predominant clay mineralogy	Soil drainage class	Permeability and water table
CLARESON	Clayey-skeletal over hard limestone at 20″-40″	Mixed	Well drained	Moderate to slow
CLARK	Fine-loamy	Mixed	Well drained	Moderate
CLEORA	Coarse-loamy	Mixed	Well drained	Moderately rapid
CLIME	Fine over rippable shale at 20″-40″	Mixed	Moderately well drained to well drained	Slow to moderately slow
COLBY	Fine-silty	Mixed (calcareous)	Well drained to somewhat excessively drained	Moderate to moderately slow
COLLINSVILLE	Loamy over hard sandstone at 10″-20″	Siliceous	Well drained to somewhat excessively drained	Moderately rapid
COLY	Fine-silty	Mixed (calcareous)	Well drained to somewhat excessively drained	Moderate
CORBIN	Fine-silty	Mixed	Well drained	Moderate to slow
CORINTH	Fine over rippable shale at 20″-40″	Mixed	Well drained	Moderately slow
COZAD	Fine-silty	Mixed	Well drained	Moderate
CRETE	Fine	Montmorillonitic	Moderately well drained to somewhat poorly drained	Slow, water table at 30″-6′+ seasonally
CRISFIELD	Coarse-loamy	Mixed	Well drained	Moderately rapid, water table 6′+ except for brief periods
CROCKER	Fine-loamy	Mixed	Well drained	Moderate to rapid
DALE	Fine-silty	Mixed	Well drained	Moderate
DALHART	Fine-loamy	Mixed	Well drained	Moderate
DARNELL	Loamy over rippable sandstone at 10″-20″	Siliceous	Well drained to somewhat excessively drained	Moderately rapid
DEEPWATER	Fine-silty	Mixed	Moderately well drained	Moderate
DENNIS	Fine	Mixed	Moderately well drained	Slow, water table at 30″-6′+ seasonally
DETLOR	Fine over rippable shale at 20″-40″	Mixed	Well drained to moderately well drained	Slow, water table at 30″-6′+ seasonally
DETROIT	Fine	Montmorillonitic	Well drained to moderately well drained	Slow, water table greater than 8′ usually
DILLWYN	Sandy	Mixed	Somewhat poorly drained	Rapid, water table at 1′-5′ seasonally
DOXIE	Fine	Montmorillonitic	Somewhat poorly drained	Slow, water table at 30″-6′+ seasonally
DRUMMOND	Fine	Mixed	Somewhat poorly drained	Very slow, water table at 2′-10′ seasonally
DWIGHT	Fine over hard cherty limestone at 40″+	Montmorillonitic	Moderately well drained	Very slow
DWYER	Sandy	Mixed	Excessively drained	Very rapid
EDALGO	Fine over rippable shale at 20″-40″	Mixed	Well drained	Very slow
EDINA	Fine	Montmorillonitic	Poorly drained	Very slow, water table at 30″-6′+ seasonally
ELKADER	Fine-silty over rippable shale at 40″+	Carbonatic	Well drained	Moderate
ELMONT	Fine-silty over rippable shale at 40″+	Mixed	Well drained	Moderately slow
ELSMERE	Sandy	Mixed	Somewhat poorly drained	Rapid, water table at 2′-6′ seasonally
ELTREE	Fine-silty	Mixed	Well drained	Moderate
ENGLUND	Fine over rippable shale at 20″-40″	Mixed	Well drained	Moderate to slow
ENTERPRISE	Coarse-silty	Mixed	Well drained	Moderately rapid
ERAM	Fine over rippable shale at 20″-40″	Mixed	Moderately well drained	Slow, water table at 30″-6′+ seasonally
EUDORA	Coarse-silty	Mixed	Well drained	Moderate
FARNUM	Fine-loamy	Mixed	Well drained	Moderately slow
FLORENCE	Clayey-skeletal over hard cherty limestone at 40″+	Montmorillonitic	Well drained	Moderately slow
GARA	Fine-loamy	Mixed	Moderately well drained to well drained	Moderately slow
GEARY	Fine-silty	Mixed	Well drained	Moderate
GERLANE	Coarse-loamy	Mixed	Moderately well drained to well drained	Moderately rapid, water table at 2′-6′ seasonally
GEUDA	Fine over rippable shale at 20″-40″	Mixed	Moderately well drained to well drained	Very slow
GIRARD	Fine over hard limestone at 20″-40″	Mixed	Poorly drained	Slow, water table at surface during wet season

TABLE 1 (continued). Particle size characteristics and water relationships of soils of Kansas (Adapted from Soil Conservation Service classification of soil series of 1972, published soil survey reports, current official soil series descriptions and other sources).

	Related to swelling of soil when wet		Related to percolation and seasonal free water in soil profile	
Soil series name	**General particle size grouping**	**Predominant clay mineralogy**	**Soil drainage class**	**Permeability and water table**
GLENBERG	Coarse-loamy	Mixed (calcareous)	Well drained	Rapid
GOESSEL	Fine	Montmorillonitic	Moderately well drained to well drained	Very slow
GOSHEN	Fine-silty	Mixed	Well drained	Moderate
GOSPORT	Fine over rippable shale at 20"-40"	Illitic	Moderately well drained	Very slow
GRABLE	Coarse-silty over sandy or sandy-skeletal	Mixed	Well drained to somewhat excessively drained	Moderate to rapid, water table at 4'+ usually
GRANT	Fine-silty over rippable sandstone at 40"+	Mixed	Well drained	Moderate
GRIGSTON	Fine-silty	Mixed	Well drained	Moderate
GRUNDY	Fine	Montmorillonitic	Somewhat poorly drained	Slow, water table at 30"-6'+ seasonally
GYMER	Fine	Montmorillonitic	Well drained	Moderately slow
HALL	Fine-silty	Mixed	Well drained	Moderately slow
HARNEY	Fine	Montmorillonitic	Well drained	Moderately slow
HASTINGS	Fine	Montmorillonitic	Moderately well drained to well drained	Moderately slow
HAYNIE	Coarse-silty	Mixed (calcareous)	Well drained to moderately well drained	Moderate
HECTOR	Loamy over hard limestone at 10"-20"	Siliceous	Well drained	Moderately rapid
HEDVILLE	Loamy over hard sandstone at 10"-20"	Mixed	Somewhat excessively drained	Moderate
HEIZER	Loamy-skeletal over hard limestone at 10"-20"	Carbonatic	Well drained to somewhat excessively drained	Moderate
HEPLER	Fine-silty	Mixed	Somewhat poorly drained	Moderately slow, water table at 30"-6'+ seasonally
HOBBS	Fine-silty	Mixed	Well drained to moderately well drained	Moderate
HOLDER	Fine-silty	Mixed	Well drained	Moderate to moderately slow
HOLDREGE	Fine-silty	Mixed	Well drained	Moderate
HORD	Fine-silty	Mixed	Well drained	Moderate, water table at 10'-25' seasonally
HUMBARGER	Fine-loamy	Mixed	Well drained to moderately well drained	Moderate
INAVALE	Sandy	Mixed	Somewhat excessively drained to excessively drained	Rapid, water table at 5'-10'
IRWIN	Fine over hard limestone at 40"+	Mixed	Moderately well drained to well drained	Very slow
IVAN	Fine-silty	Mixed	Well drained to moderately well drained	Moderate, water table 6'+ except for brief periods
JUDSON	Fine-silty	Mixed	Well drained to moderately well drained	Moderate, water table 4'+ usually
KAHOLA	Fine-silty	Mixed	Well drained	Moderate
KANZA	Sandy	Mixed	Poorly drained to somewhat poorly drained	Rapid, water table 1'-3' in cool season and 5'-7' in warm season
KASKI	Fine-loamy	Mixed	Well drained	Moderate
KEITH	Fine-silty	Mixed	Well drained	Moderate
KENESAW	Coarse-silty	Mixed	Well drained	Moderate
KENNEBEC	Fine-silty	Mixed	Moderately well drained	Moderate, water table 3'+ usually
KENOMA	Fine over hard limestone or shale at 40"+	Montmorillonitic	Moderately well drained	Very slow, water table at 30"-6'+ seasonally
KIM	Fine-loamy	Mixed (calcareous)	Well drained	Moderate
KIMO	Clayey over loamy	Montmorillonitic	Somewhat poorly drained	Slow, water table 2'+ usually
KINGFISHER	Fine-silty over rippable redbeds at 20"-40"	Mixed	Well drained	Moderately slow
KINGMAN	Fine-silty	Mixed (calcareous)	Poorly drained to very poorly drained	Very slow, water table at surface to 4' seasonally
KIPSON	Loamy over rippable shale at 10"-20"	Mixed	Somewhat excessively drained	Moderate
KIRKLAND	Fine	Mixed	Well drained	Very slow
KNOX	Fine-silty	Mixed	Well drained	Moderate
KONAWA	Fine-loamy	Mixed	Well drained	Moderate
LABETTE	Fine over hard limestone at 20"-40"	Mixed	Well drained	Slow
LADOGA	Fine	Montmorillonitic	Moderately well drained	Moderately slow

TABLE 1 (continued). Particle size characteristics and water relationships of soils of Kansas (Adapted from Soil Conservation Service classification of soil series of 1972, published soil survey reports, current official soil series descriptions and other sources).

Soil series name	Related to swelling of soil when wet		Related to percolation and seasonal free water in soil profile	
	General particle size grouping	Predominant clay mineralogy	Soil drainage class	Permeability and water table
LADYSMITH	Fine	Montmorillonitic	Moderately well to somewhat poorly drained	Very slow, water table at 30″-6′+ seasonally
LAGONDA	Fine	Montmorillonitic	Somewhat poorly drained	Very slow, water table at 30″-6′+ seasonally
LAMO	Fine-silty	Mixed (calcareous)	Somewhat poorly drained	Moderately slow, water table 2′-5′ seasonally
LANCASTER	Fine-loamy over rippable shale, sandstone, and ironstone at 20″-40″	Mixed	Well drained	Moderate
LAS	Fine-loamy	Mixed (calcareous)	Somewhat poorly drained	Slow, water table at 2′-6′ seasonally
LAS ANIMAS	Coarse-loamy	Mixed (calcareous)	Somewhat poorly drained to poorly drained	Rapid, water table at 3′-4′ seasonally
LEANNA	Fine	Mixed	Poorly drained to somewhat poorly drained	Very slow, water table at 30″-6′+ seasonally
LESHARA	Fine-silty	Mixed	Somewhat poorly drained	Moderate, water table at 3′-6′ seasonally
LESHO	Fine-loamy over sandy or sandy-skeletal	Mixed	Somewhat poorly drained	Moderately slow, water table at 2′-6′ seasonally
LIGHTNING	Fine	Mixed	Poorly drained to somewhat poorly drained	Very slow, water table at 30″-6′+ seasonally
LIKES	Sandy	Mixed	Excessively drained	Moderately rapid
LINCOLN	Sandy	Mixed	Somewhat excessively drained	Rapid, water table 5′-8′ seasonally
LISMAS	Clayey over rippable shale at 5″-20″	Montmorillonitic (calcareous)	Well drained	Slow to very slow
LOCKHARD	Fine	Montmorillonitic	Well drained	Moderate to moderately slow
LOFTON	Fine	Mixed	Moderately well drained	Very slow
LONGFORD	Fine	Montmorillonitic	Well drained	Moderately slow
LUBBOCK	Fine	Mixed	Well drained	Moderately slow
LUCIEN	Loamy over rippable sandstone at 10″-20″	Mixed	Well drained to moderately well drained	Moderately rapid
LULA	Fine-silty over hard limestone at 40″+	Mixed	Well drained	Moderate
MANDEVILLE	Fine-loamy over rippable shale at 20″-60″	Mixed	Well drained to moderately well drained	Moderate
MANGUM	Fine	Mixed (calcareous)	Well drained to moderately well drained	Very slow, water table at 5′+ seasonally
MANSIC	Fine-loamy	Mixed	Well drained	Moderate
MANSKER	Fine-loamy	Carbonatic	Well drained	Moderate
MANTER	Coarse-loamy	Mixed	Well drained to somewhat excessively drained	Rapid
MANVEL	Fine-silty	Mixed (calcareous)	Well drained	Moderate to slow
MARSHALL	Fine-silty	Mixed	Well drained	Moderate
MARTIN	Fine over rippable shale at 40″+	Mixed	Moderately well drained	Slow, water table at 30″-6′+ seasonally
MASON	Fine-silty	Mixed	Well drained	Moderately slow
MATFIELD	Clayey-skeletal over hard cherty limestone at 60″+	Montmorillonitic	Well drained	Moderately rapid to very slow
MAYBERRY	Fine	Montmorillonitic	Moderately well drained	Slow, water table at 30″-6′+ seasonally
McCUNE	Fine-silty	Mixed	Somewhat poorly drained	Slow, water table at 30″-6′+ seasonally
McLAIN	Fine	Mixed	Well drained to moderately well drained	Slow
MENFRO	Fine-silty	Mixed	Well drained	Moderate
MENTO	Fine over rippable chalk at 40″+	Montmorillonitic	Well drained	Slow
MILAN	Fine-loamy	Mixed	Well drained	Moderate
MILLER	Fine	Mixed	Moderately well drained	Very slow
MINCO	Coarse-silty	Mixed	Well drained	Moderate
MINNEQUA	Fine-silty over rippable limestone and shale at 20″-40″	Mixed (calcareous)	Well drained	Moderate
MISSLER	Fine	Mixed	Well drained	Moderately slow
MONONA	Fine-silty	Mixed	Well drained	Moderate
MORRILL	Fine-loamy	Mixed	Well drained	Moderately slow
MUIR	Fine-silty	Mixed	Well drained	Moderate
MULDROW	Fine	Mixed	Somewhat poorly drained	Very slow, water table at 30″-6′+ seasonally

TABLE 1 (continued). Particle size characteristics and water relationships of soils of Kansas (Adapted from Soil Conservation Service classification of soil series of 1972, published soil survey reports, current official soil series descriptions and other sources).

Soil series name	Related to swelling of soil when wet		Related to percolation and seasonal free water in soil profile	
	General particle size grouping	Predominant clay mineralogy	Soil drainage class	Permeability and water table
MUNJOR	Coarse-loamy	Mixed (calcareous)	Well drained	Moderately rapid, water table 6′+ except for brief periods
NARON	Fine-loamy	Mixed	Well drained	Moderate to moderately rapid
NASH	Coarse-silty over rippable sandstone at 20″-40″	Mixed	Well drained	Moderate
NASHVILLE	Fine-silty over rippable sandstone at 20″-40″	Mixed	Well drained	Moderate
NESS	Fine	Montmorillonitic	Poorly drained (ponded)	Very slow, water table at surface seasonally
NEW CAMBRIA	Fine	Montmorillonitic	Moderately well drained	Slow
NEWTONIA	Fine-silty	Mixed	Well drained	Moderate
NIBSON	Loamy over rippable shale at 10″-20″	Carbonatic	Somewhat excessively drained	Moderate
NIOTAZE	Fine over rippable shale at 20″-40″	Montmorillonitic	Somewhat poorly drained	Slow
NODAWAY	Fine-silty	Mixed (nonacid)	Moderately well drained	Moderate
NORGE	Fine-silty	Mixed	Well drained	Moderately slow
NORWOOD	Fine-silty	Mixed (calcareous)	Well drained	Moderate
NUCKOLLS	Fine-silty	Mixed	Well drained to excessively drained	Moderate
OAKWOOD	Fine-silty	Mixed	Somewhat poorly drained	Moderately slow to slow, water table within 3′ in wet season of most years
OKEMAH	Fine	Mixed	Moderately well drained	Slow
OLMITZ	Fine-loamy	Mixed	Well drained to moderately well drained	Moderate to moderately slow
OLPE	Clayey-skeletal	Montmorillonitic	Well drained	Slow to very slow
ONAWA	Clayey over loamy	Montmorillonitic (calcareous)	Somewhat poorly drained to poorly drained	Slow to moderately rapid, water table at 2′-4′ seasonally
ORD	Coarse-loamy	Mixed	Somewhat poorly drained	Moderately rapid, water table at 2′-6′ seasonally
ORTELLO	Coarse-loamy	Mixed	Well drained	Moderately rapid
OSAGE	Fine	Montmorillonitic	Poorly drained	Very slow, water table at or near surface seasonally
OSKA	Fine over hard limestone at 20″-40″	Montmorillonitic	Well drained	Slow
OST	Fine-loamy	Mixed	Well drained	Moderately slow
OTERO	Coarse-loamy	Mixed (calcareous)	Well drained to somewhat excessively drained	Rapid
OWEGO	Fine	Montmorillonitic (calcareous)	Poorly drained to somewhat poorly drained	Very slow, water table at or near surface seasonally
OWENS	Clayey over rippable shale at 10″-20″	Mixed	Well drained	Very slow
PARSONS	Fine	Mixed	Somewhat poorly drained	Very slow, water table at 30″-6′+ seasonally
PAWNEE	Fine	Montmorillonitic	Well drained to moderately well drained	Slow, water table at 30″-6′+ seasonally
PENDEN	Fine-loamy	Mixed	Well drained	Moderate to moderately slow
PENROSE	Loamy over hard limestone at 10″-20″	Mixed (calcareous)	Well drained to somewhat excessively drained	Moderate to slow
PLATTE	Sandy	Mixed	Poorly drained to somewhat poorly drained	Moderate to very rapid, water table at 2′-6′ seasonally
PLEASANT	Fine	Montmorillonitic	Well drained to moderately well drained	Slow to very slow
PLEVNA	Coarse-loamy	Mixed	Poorly drained	Moderately rapid, water table at 1′-4′ seasonally
POND CREEK	Fine-silty	Mixed	Well drained	Moderately slow
PORT	Fine-silty	Mixed	Well drained	Moderate
POTTER	Loamy over rippable caliche at 10″-20″	Carbonatic	Well drained	Moderate
PRATT	Sandy	Mixed	Well drained	Rapid
PROMISE	Very-fine	Montmorillonitic	Well drained	Slow and very slow
QUINLAN	Loamy over sandstone at 10″-20″	Mixed	Well drained	Moderately rapid
RADLEY	Fine-silty	Mixed	Moderately well drained	Moderate, water table 5′+ seasonally
RANDALL	Fine	Montmorillonitic	Somewhat poorly drained (ponded)	Very slow, water table at surface seasonally

TABLE 1 (continued). Particle size characteristics and water relationships of soils of Kansas (Adapted from Soil Conservation Service classification of soil series of 1972, published soil survey reports, current official soil series descriptions and other sources).

Soil series name	Related to swelling of soil when wet: General particle size grouping	Related to swelling of soil when wet: Predominant clay mineralogy	Related to percolation and seasonal free water in soil profile: Soil drainage class	Related to percolation and seasonal free water in soil profile: Permeability and water table
READING	Fine-silty	Mixed	Well drained	Moderately slow
REINACH	Coarse-silty	Mixed	Well drained	Moderate
RENFROW	Fine	Mixed	Well drained	Very slow
RICHFIELD	Fine	Montmorillonitic	Well drained	Moderately slow
RINGO	Fine over rippable shale at 20"-40"	Mixed	Well drained	Very slow
RIVERTON	Loamy-skeletal	Mixed	Well drained	Moderate
ROSEHILL	Fine over rippable shale at 20"-40"	Montmorillonitic	Well drained	Very slow
ROXBURY	Fine-silty	Mixed	Well drained	Moderate, water table at 6'+ except for brief periods
RUELLA	Fine-loamy	Mixed	Well drained	Moderate
RYUS	Fine	Montmorillonitic	Well drained	Slow
SARPY	Sandy	Mixed	Excessively drained	Very rapid
SATANTA	Fine-loamy	Mixed	Well drained	Moderate
SHARPSBURG	Fine	Montmorillonitic	Moderately well drained	Moderately slow
SHELBY	Fine-loamy	Mixed	Moderately well drained	Moderately slow
SHELLABARGER	Fine-loamy	Mixed	Well drained	Moderate
SIBLEYVILLE	Fine-loamy over rippable sandstone at 20"-40"	Mixed	Well drained	Moderate
SMOLAN	Fine	Montmorillonitic	Moderately well drained to well drained	Slow
SOGN	Loamy over hard limestone at 10"-20"	Mixed	Somewhat excessively drained	Moderate
SOLOMON	Fine	Montmorillonitic (calcareous)	Poorly drained	Very slow, water table above 4' in spring
SPEARVILLE	Fine	Montmorillonitic	Well drained to moderately well drained	Slow
STEEDMAN	Fine over rippable shale at 20"-40"	Montmorillonitic	Well drained to moderately well drained	Slow
STEINAUER	Fine-loamy	Mixed (calcareous)	Well drained	Moderate
STEPHENVILLE	Fine-loamy over rippable sandstone at 20"-40"	Siliceous	Well drained	Moderate
SUMMIT	Fine over rippable shale at 40"+	Montmorillonitic	Somewhat poorly drained	Slow, water table at 30"-6'+ seasonally
SUTPHEN	Fine	Montmorillonitic	Moderately well drained to somewhat poorly drained	Very slow
SWEETWATER	Fine-loamy over sandy or sandy skeletal	Mixed (calcareous)	Poorly drained	Moderately slow, water table at 1'-3' seasonally
TABLER	Fine	Montmorillonitic	Moderately well drained	Very slow
TALIHINA	Clayey over rippable shale at 10"-20"	Mixed	Well drained	Slow
TALOKA	Fine	Mixed	Somewhat poorly drained	Very slow, water table at 30"-6'+ seasonally
THURMAN	Sandy	Mixed	Well drained to somewhat excessively drained	Rapid
TIMKEN	Clayey over rippable shale at 10"-20"	Montmorillonitic	Moderately well drained	Very slow
TINA	Fine	Montmorillonitic	Somewhat poorly drained	Slow, water table at 30"-6'+ seasonally
TIPTON	Fine-loamy	Mixed	Well drained	Moderate
TIVOLI	Sandy	Mixed	Excessively drained	Rapid
TOBIN	Fine-silty	Mixed	Well drained to moderately well drained	Moderate, water table 6'+ except for brief periods
TRAVESSILLA	Loamy over hard sandstone at 10"-20"	Mixed (calcareous)	Well drained	Moderate to moderately rapid
TULLY	Fine	Mixed	Well drained	Slow
ULY	Fine-silty	Mixed	Well drained to somewhat excessively drained	Moderate
ULYSSES	Fine-silty	Mixed	Well drained	Moderate
VALENTINE	Sandy	Mixed	Excessively drained	Rapid
VANOSS	Fine-silty	Mixed	Well drained	Moderate
VERDIGRIS	Fine-silty	Mixed	Moderately well drained	Moderate
VERNON	Fine over rippable shale at 20"-40"	Mixed	Well drained	Very slow
VINLAND	Loamy over rippable shale at 10"-20"	Mixed	Somewhat excessively drained	Moderate

TABLE 1 (concluded). Particle size characteristics and water relationships of soils of Kansas (Adapted from Soil Conservation Service classification of soil series of 1972, published soil survey reports, current official soil series descriptions and other sources).

	Related to swelling of soil when wet		Related to percolation and seasonal free water in soil profile	
Soil series name	**General particle size grouping**	**Predominant clay mineralogy**	**Soil drainage class**	**Permeability and water table**
VONA	Coarse-loamy	Mixed	Well drained to somewhat excessively drained	Rapid
WABASH	Fine	Montmorillonitic	Very poorly drained	Very slow, water table at or near surface seasonally
WAKEEN	Fine-silty over rippable shale or limestone at 20″-40″	Carbonatic	Well drained	Moderate
WALDECK	Coarse-loamy	Mixed	Somewhat poorly drained	Moderately rapid, water table at 2′-8′ seasonally
WANN	Coarse-loamy	Mixed	Somewhat poorly drained to poorly drained	Moderately rapid, water table at 2′-6′ seasonally
WAURIKA	Fine	Montmorillonitic	Somewhat poorly drained	Very slow, water table at 30″-6′+ seasonally
WELDA	Fine	Montmorillonitic	Well drained	Moderately slow
WINDTHORST	Fine over rippable sandstone at 40″+	Mixed	Moderately well drained	Moderately slow
WOODSON	Fine	Mixed	Somewhat poorly drained	Very slow, water table at 30″-6′+ seasonally
WOODWARD	Coarse-silty over rippable sandstone at 20″-40″	Mixed	Well drained	Moderate
WYMORE	Fine	Montmorillonitic	Moderately well drained to well drained	Slow
YAHOLA	Coarse-loamy	Mixed (calcareous)	Well drained	Moderately rapid
ZAAR	Fine over rippable shale at 40″+	Montmorillonitic	Somewhat poorly drained to moderately well drained	Very slow
ZAVALA	Coarse-loamy	Mixed (nonacid)	Well drained	Moderately rapid
ZENDA	Fine-loamy	Mixed	Somewhat poorly drained	Moderate, water table at 2′-6′ seasonally
ZOOK	Fine	Montmorillonitic	Poorly drained	Slow to very slow, water table at 1′-3′ seasonally

SEPTIC-TANK SEEPAGE FIELDS IN SOILS

For more than a decade, soil scientists in the USA have been consulting with public health officials, geologists, engineers, and others to develop guidelines that could assist in using detailed soil maps for waste disposal. Soil-limitation ratings, based on these guidelines, have now been published (Soil Survey Staff, 1971), and all soils of the USA are being rated for their limitations for waste disposal.

Important soil factors to be considered for septic-tank seepage fields for filtering sewage effluent are outlined in Table 2. Soils with slight limitations are good for seepage fields, and only minimal expenditures are required for safe effluent disposal without environmental hazards. Soils with moderate limitations in Table 2 have some undesirable properties; careful planning and design of seepage fields are needed in these areas to compensate for the limitations imposed by the soils (Figure 13). Soils with severe limitations (Table 2) have problems for seepage fields that are difficult to overcome: slow permeability, shallowness to bedrock, wetness, flooding, slope, stoniness, or some other unfavorable soil property. Costs of acceptable seepage fields in soils with severe limitations may be several times greater than costs in soils with slight limitations. In some cases on-site sewage disposal is not feasible in soils with severe limitations because of the high costs and health and environmental hazards.

In Table 2, the most limiting soil property determines the rating for each soil; thus a soil with slopes greater than 15 percent is rated severe even if all the other properties are good for seepage fields. Of course, seepage fields can be put on steep slopes (Figure 14), but costs and hazards are much greater than on gentler slopes. Factors important in determining limitations of soils for seepage fields include: (1) local experience and records of performance for existing seepage fields, (2) permeability of the subsoil and substrata, (3) depth to bedrock and impermeable layers, (4) flooding, (5) seasonal fluctuating and permanent water tables, and (6) slope (Soil Survey Staff, 1971). Failures of seepage fields are indicated by effluent rising to the soil surface, offensive odors, contamination of ground water and well waters, rank plant growth, and, of course, consequent incidence of disease and sickness in the people affected along with the environmental degradation.

Soils of Kansas are rated for permeability in Table 1; Table 2 enables the permeability classes to be evaluated for each soil for septic-tank seepage fields into categories of slight, moderate, and severe limitations. The appropriate category for each soil in Kansas is listed in Table 6, with major limitations also listed for each soil. Soils with moderate to very rapid permeability are rated as having slight limitations (Soil Survey Staff, 1971). Soils with a permeability at the slower end of the moderate range (about 1.0 to 0.6 in/hr, faster than 60 min/in) are rated as having moderate limitations. Soils with a permeability rate of less than 0.6 in/hr or slower than 60 min/in are rated as having severe limitations. In arid or semiarid areas, soils with moderately slow permeability may have a rating of moderate. Although soils with rapid permeability are considered to have slight limitations, contamination hazards exist where the soils are rapidly permeable and water supplies, streams, ponds, lakes, or water courses are nearby and receive seepage from the septic tank.

FIG. 13. Wet soils with slopes and outlets can be considerably improved for subsurface sewage disposal with drainage and good landscape design. Water flowing onto a lot should be intercepted and diverted, and wet soils can be drained for adequate septic-tank seepage field performance. Even if the summer is dry, water in soils may cause problems in cool, wet late winter and early spring. This scene shows a small drainageway on a house lot; landscape design can make this channel an attractive part of the house site.

TABLE 2. Ratings of limitations of soils for waste disposal in septic-tank seepage fields (Adapted from Soil Survey Staff, 1971).

Item affecting use	Soil-limitation rating		
	Slight	Moderate	Severe
Permeability class[1]	Rapid[2], moderately rapid, and upper end of moderate	Lower end of moderate	Moderately slow[3] and slow
Hydraulic-conductivity rate (Uhland core method)	> 1.0 in/hr[2]	1.0-0.6 in/hr	< 0.6 in/hr
Percolation rate (auger hole method; Olson, 1964)	Faster than 45 min/in[2]	45-60 min/in	Slower than 60 min/in
Depth to water table	> 72 in	48-72 in	< 48 in
Flooding	None	Rare	Occasional or frequent
Slope	0-8%	8-15%	> 15%
Depth to hard rock[4], bedrock, or other impervious materials	> 72 in	48-72 in	< 48 in
Stoniness class[5]	0 and 1	2	3, 4, and 5
Rockiness class[5]	0	1	2, 3, 4, and 5

[1] Class limits are the same as those suggested by the Work Planning Conference of the National Cooperative Soil Survey (Soil Survey Staff, 1971). The suitability ratings should be related to the permeability of soil layers at and below the depth of the installed tile lines of the seepage field.
[2] Special considerations should be given to places where pollution is a hazard to water supplies.
[3] In arid or semiarid areas, soils with moderately slow permeability may have a rating of moderate.
[4] These depth ratings are based on the assumption that tile in the seepage field is at a depth of about 2 feet.
[5] Class definitions are given on pages 216-223 of the Soil Survey Manual (Soil Survey Staff, 1951). Larger numbers indicate more stones and rocks.

FIG. 14. Soils at this site have severe limitations for septic-tank seepage fields, due to slopes and slow permeability. Slope limitations have been improved with bulldozer grading, and the tile line for the seepage field has been placed in the looser fill below the house. With good engineering design and proper septic-tank maintenance, this sewage-disposal system could function satisfactorily, but pollution will be a hazard if the volume of soil material is not adequate for filtration.

Field percolation tests made by local health departments generally are conducted under a wide range of soil and environmental conditions; sometimes even homeowners or contractors conduct the tests. Results must be interpreted with caution. Even nearly impermeable soils on which seepage fields have failed can give high percolation test results after periods of drought (Soil Survey Staff, 1971), especially in soils with a high content of montmorillonite (Table 1). In addition to soil properties that influence percolation rates, changes in the microorganisms in the soil may also help or hinder the functioning of the seepage field after it is in operation. Because the methods of measuring percolation and permeability are different, the correlation between the two values is imperfect. The permeability rates listed in Table 1 for soils of Kansas are probably much more reliable than percolation tests in auger holes (see Bouma, 1971).

For septic-tank seepage fields (Table 2), a seasonal water table should be at least four feet below the bottom of the trench at all times for soils with slight limitations; Table 1 lists some of the water-table depths in soils of Kansas. Soils with a water table less than two feet below the bottom of the trench for extended periods have a severe limitation.

Soils that are subject to flooding (Soil Survey Staff, 1971) have severe limitations even if the permeability is satisfactory and the ground-water level is below four feet. Floodwaters interfere with the functioning of the seepage field and carry away unfiltered sewage. Without protection, areas subject to flooding should not be considered for on-site sewage-disposal systems.

Cracked or fractured bedrock without an adequate soil cover permits unfiltered sewage to travel long distances through or into aquifiers, as in deeply creviced limestone areas. At least four feet of moderately coarse or finer textured soil material should be between the bottom of the tile trenches and the bedrock.

Soils (Soil Survey Staff, 1971) with slopes of less than eight percent are the best sites for sewage-dis-

FIG. 15. These soils have slight limitations for septic-tank seepage fields due to slope, but severe limitations due to slow percolation rates. Stoniness and rockiness are not problems, but the soils have severe erosion hazards where lawns are newly-planted and where bare surfaces are exposed during landscape design. Each soil has unique characteristics which should be considered for the most efficient and aesthetic development of the site.

posal systems from the standpoints of construction and successful operation of seepage fields. Mechanical problems of layout and construction increase with steepness of slope (Figure 15). Lateral seepage or down-slope flow of effluent is a problem on sloping soils, especially where bedrock or impermeable layers are within four feet of the surface. Large rocks, boulders, and rock outcrops increase construction costs. On slopes, the tile grade is difficult to maintain if the obstacle cannot be removed. Trench lines can be installed and grade maintained around these obstacles on nearly level soils. On sloping sites, detergents in solution can move through some soils and contaminate ground-water and surface water. Sodium salts from sodium chloride water softeners and other sources tend to disperse the clay in the soil and to reduce the effectiveness of the seepage field.

SEWAGE LAGOONS IN SOILS

An aerobic sewage lagoon (Soil Survey Staff, 1971) or waste-stabilization pond (Kansas State Department of Health, 1971) is a shallow lake (Figure 16) that holds sewage for the time required for bacterial decomposition. Sewage lagoons require considerations of the soils for two functions: (1) as a vessel for the impounded area and (2) as soil material for the enclosing embankment. Enough soil material that is suitable for the structure must be available, and, when the lagoon is properly constructed, it must be capable of holding water with minimum seepage.

Table 3 lists soil properties important for determining limitations for sewage lagoons, formulated after years of consultations and research (Soil Survey Staff, 1971). The most important soil-material classification for construction is the unified soil grouping for engi-

FIG. 16. View of community sewage lagoon. Large sewage lagoons can be easily constructed in soils with slight limitations, where the soils are nearly impermeable, are nearly level, lack coarse fragments, are not flooded, and have a good engineering classification for embankment construction and compaction. In some cases lagoons are the cheapest method of sewage treatment for communities; sewage lagoons can also be used for individual houses where soils are impermeable and where adequate land area is available.

neering; this system is explained for laymen in a publication by Olson (1972a). Soils placed in the *unified soil classification* groups (GC, SC, and SM) are satisfactory for the lagoon bottom; they can be worked easily and have enough fines so that the lagoon bottom will hold liquids. The coarse groups with few fines (GW, GP, SW, and SP) have severe limitations and are poorly suited. The groups consisting of soils high in organic matter (OL, OH, and PT) also have severe limitations and also are poorly suited. Soil material of the other unified classification groups (GM, CL, CH, ML, and MH) are suitable if properly compacted or if used in combination with soil materials classified as GC, SC, and SM. Soil material for sewage lagoons should be free of coarse fragments over 10 inches in diameter that interfere with compaction and earth manipulations.

Soil requirements (Soil Survey Staff, 1971) for basin floors of lagoons are (1) slow rate of seepage, (2) even surface of low gradient and low relief, and (3) little or no organic matter. Official specifications for lagoons state that the depth of liquid should be at least two feet and generally not more than five feet, that the floor should be level or nearly level, and that the materials for the basin floor should be so nearly impervious as to preclude loss of liquid. The relatively impervious soil material should be at least four feet thick; this is especially critical where the local water supply comes from shallow wells that may become contaminated.

Limitation classes for slope and relief (Figure 17; Table 3) are determined by the specifications that the liquid body of a sewage lagoon or waste stabilization pond be no less than two feet or generally no more than five feet deep. Slope must be low enough and soil material thick enough over bedrock to make smoothing practical for uniformity of lagoon depth. Greater slope is allowable if soil material is more than six-feet deep, but generally smoothing is impractical where slope is more than seven percent. If the soil is nearly level and requires little or no smoothing, it need

FIG. 17. View of lagoons on sloping soils. Soils with slopes greater than two percent have moderate limitations for sewage lagoons, because more earth must be moved than on slopes less than two percent. On slopes steeper than seven percent, sewage lagoons may not be feasible. Where large volumes of sewage are to be treated, several lagoons are generally built in series to handle wastes by stages—because certain holding periods are required for waste stabilization and oxidation.

not be more than four to six feet deep. Geological investigations are particularly valuable at lagoon sites to determine, with deep borings, exact depths to bedrock and possible contamination hazards.

If floodwaters overtop embankments (Table 3), they interfere with functioning of the lagoons and carry away polluting sewage before sufficient decomposition has taken place. Ordinarily, therefore, soils susceptible to flooding have a severe limitation for sewage lagoons. If, however, floodwaters are slow flowing and never more than about five-feet deep (not deep enough to overtop lagoon embankments) the limitation rating may not be severe because of susceptibility to flooding. General limitations can be evaluated for each soil, but each site has its own specific peculiarities so that careful, expert evaluations are always necessary before construction starts—if errors are to be minimized.

Depths to water tables are disregarded if the lagoon floor consists of soil material at least two-feet thick that is impermeable or nearly so; depths to water tables, however, are critical if the material is permeable or even slowly permeable. A water table that is below a depth of 60 inches at all times permits a rating of slight. If the water table is seasonally between depths of 40 and 60 inches, it imposes a rating of moderate. If free water in the soil is at a depth of less than 40 inches for extended periods, it imposes a rating of severe. The ratings of Table 3 are based on the requirements that (1) the liquid body of a sewage lagoon must be no less than two-feet or generally no more than five-feet deep, (2) the only water in the lagoon, other than from precipitation, must be that of the sewage; and therefore the water table must never rise high enough to contribute water to the lagoon, and (3) there must be at least four feet of slowly permeable material between the bottom of the lagoon and seasonal water table or the cracked and creviced bedrock.

Soils containing moderate to high amounts of or-

TABLE 3. Ratings of limitations of soils for waste disposal in sewage lagoons (Adapted from Soil Survey Staff, 1971).

Item affecting use	Soil-limitation rating		
	Slight	Moderate	Severe
Depth to permanent or fluctuating water table	> 60 in	40-60 in[1]	< 40 in[1]
Permeability	< 0.6 in/hr	0.6-2.0 in/hr	> 2.0 in/hr
Depth to bedrock	> 60 in	40-60 in	< 40 in
Slope	< 2%	2-7%	> 7%
Coarse fragments < 10 in diameter, % by volume	< 20%	20-50%	> 50%
Percent of soil surface covered by coarse fragments < 10 in diameter	< 3%	3-15%	> 15%
Organic matter	< 2%	2-15%	> 15%
Flooding[2]	None	None	Soils subject to flooding
Unified soil groups[3]	GC, SC, CL, and CH	GM, ML, SM, and MH	GP, GW, SW, SP, OL, OH, and PT

[1] Depth to water table can be disregarded if the floor of the lagoon is to be in nearly impenneable material at least 2 feet thick.
[2] Flooding can be disregarded if the flood water has low velocity and a depth of less than 5 feet, if it is not likely to enter or damage the lagoon embankments.
[3] The unified soil-engineering classification system has been outlined for laymen in a publication by Olson (1972a) available from the Department of Agronomy (Soils) of Cornell University, Ithaca, New York 14850; soil suitability for embankments is also outlined in the publication. The unified soil groups are most relevant in Table 3 to suitability of soil materials for embankments retaining liquids in sewage lagoons.

ganic matter are unsuitable for the basin floor even if the floor is underlain by suitable soil material. The organic matter promotes growth of aquatic plants which are detrimental to proper functioning of the lagoon.

The third column of Table 6 lists limitation classes of soils of Kansas for sewage lagoons; the numbers and letters list some of the major soil-characteristic limitations. Additional relevant characteristics of soils of Kansas for waste disposal are given in Table 1. Soils are grouped into three classes (Soil Survey Staff, 1971) according to their degree of limitation for use as sites of sewage lagoons. The slight-limitation class includes soils that are effective in functioning as sealed-basin floors and that are low in organic matter. Soils in the moderate-limitation class are those that require special practices or treatment to modify limitations to their use as sites for sewage lagoons. Soils placed in the severe-limitation class are those that are very porous, or that are high in organic matter, or that have other limitations that present or make them very difficult to use as sites for sewage lagoons.

SANITARY LANDFILL IN TRENCHES IN SOILS

Sanitary landfill (New York State Department of Health, 1969; Soil Survey Staff, 1971; Kansas State Department of Health, 1972; Figures 18-20) in trenches consists of dug trenches in which refuse is buried and compacted at least daily, and in which the refuse is covered with a layer of soil material at least six-inches thick. The material used in covering the garbage is the soil excavated in digging the trenches. When the trenches are full, a final cover of soil material at least two-feet thick is placed over the landfill.

Soils of Kansas are rated for limitations for trench-type sanitary landfill in Table 6; Table 4 gives the criteria by which the ratings were made. Soil-drainage classes and depths to seasonal water tables in soils of Kansas are given in Table 1; free water in soils is a primary consideration in interpreting these ratings. The degree and duration of soil wetness can so affect earth-moving operations as to make a soil severely limited for sanitary landfill. In addition, the probable contamination of ground water by a landfill is closely related to depth to the seasonal water table.

Permeability of soils is an important consideration in interpreting the limitation ratings for sanitary landfill (Soil Survey Staff, 1971). Soils with slow permeability are most desirable because in them the probability of polluting ground water by vertical or lateral seepage is minimized. If necessary, permeable horizons near the bottom of sanitary landfill trenches can be sealed by compacting (along the sides and bottom of the trench) a blanket of relatively impervious material at least two feet thick—of course, this is very expensive.

Soil slope also (Table 4) is an important consideration in interpreting the limitation ratings. More grading generally is required for the roads that lead to and from landfills located on sloping-to-steep soils than is required for roads leading to and from landfills on nearly level soils. Also, more care is needed on sloping-to-steep soils to provide for the proper disposal of surface water including that from adjacent higher elevations. In landfill operations, the bottom should be kept as nearly level as possible because the bottom tends to serve as a seepage plane; the solid waste layer offers little obstacle to the movement of water. Sloping trench bottoms are likely to cause difficult seepage problems in completed landfills. Trenches for sanitary landfill should be placed on the contour with bottoms level or nearly level.

Soil texture (Table 4) also is important for trenches for sanitary landfill. Textures listed in Table 4 are defined in the Soil Survey Manual (Soil Survey Staff,

FIG. 18. No dumping sign near urban area. Garbage disposal is a problem in practically every county in Kansas. Sanitary landfill can provide a safe, efficient, and aesthetic method of burial and disposal at a site if soil and geologic conditions are favorable. Sites to be avoided include those with rapid permeability and high water tables, areas often subjected to devastating floods, steep slopes, stony soils, and soils with poor workability and trafficability. Good soils for sanitary landfill include the Altus, Clark, Cozad, Dalhart, Hord, Konawa, and Lubbock series (see Table 6).

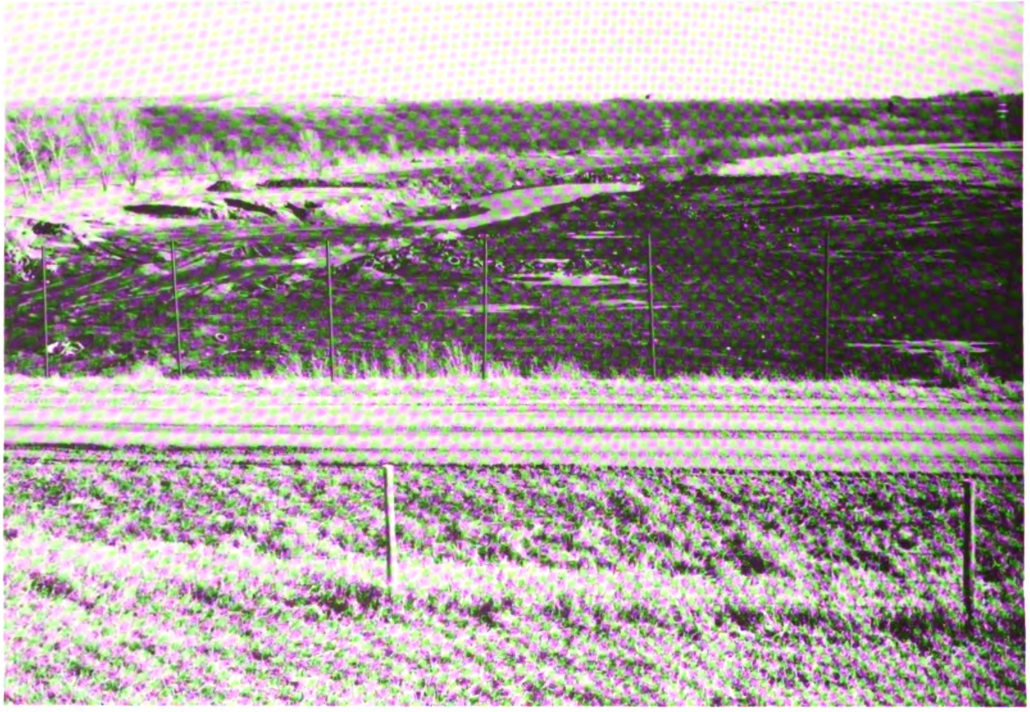

FIG. 19. Sanitary landfill site. Management of sanitary landfill is a critical factor influenced by soil and geologic conditions. At this site garbage is buried each day, but the standing and seeping water indicates a possible pollution hazard. Wells and sampling sites should be established around the landfill sites to monitor contamination movement into aquifers, and to provide additional data for soils and geological interpretation.

TABLE 4. Ratings of limitations of soils for solid-waste disposal in trench-type sanitary landfills[1] (Adapted from Soil Survey Staff, 1971).

Item affecting use	Soil-limitation rating		
	Slight[2]	Moderate[2]	Severe
Depth to seasonal water table	> 72 in	> 72 in	< 72 in
Soil-drainage class	Excessively drained, somewhat excessively drained, well-drained, and some[3] moderately well drained soils	Somewhat poorly drained and some[3] moderately well drained soils	Poorly drained and very poorly drained soils
Flooding	None	Rare	Occasional or frequent
Permeability[4]	Slower than 2.0 in/hr	Slower than 2.0 in/hr	Faster than 2.0 in/hr
Slope	< 15%	15-25%	> 25%
Dominant soil texture[5] to a depth of 60 in	Sandy loam, loam, silt loam, sandy clay loam	Silty clay loam[6], clay loam, sandy clay, loamy sand	Silty clay, clay, muck, peat, gravel, sand
Depth to hard bedrock	> 72 in	> 72 in	< 72 in
Depth to rippable bedrock	> 60 in	< 60 in	< 60 in
Stoniness class[7]	0 and 1	2	3, 4, and 5
Rockiness class[7]	0	0	1, 2, 3, 4, and 5

[1] Ratings based on soil depth of 5-6 feet commonly investigated in soil surveys. Additional geologic and engineering investigations should be made before landfills are established.
[2] If probability is high that the soil material is similar down to a depth of 10-15 feet, this could be indicated by statements like "Probably slight to a depth of 12 feet" or "Probably moderate to a depth of 12 feet" as determined by the soil survey.
[3] Soil drainage classes are related to depth to fluctuating water tables. The overlap of moderately well drained soils into 2 limitation classes allows some of the wetter moderately well drained soils to be given a limitation rating of moderate under certain conditions.
[4] These ratings reflect the ability of a soil to retard movements of effluents leached from landfills. In arid and semiarid areas rapid permeability may not be a severe limitation.
[5] Ratings of soil textures reflect ease of digging in soil, ease of moving soil, and trafficability of vehicles on soils in the immediate area of the trench where hard-surfaced roads are absent.
[6] Soils high in montmorillonitic clays probably need to be given a limitation rating of severe.
[7] Stoniness and rockiness class definitions are given in the Soil Survey Manual on pages 216-223 (Soil Survey Staff, 1951). Large numbers indicate more stones and rocks.

1951). The ease with which the trench is dug and with which a soil can be used as daily and final cover is based largely on texture and consistence of the soil. From knowledge of texture and consistence of a soil, degrees of workability of the soil in both dry and wet conditions can be determined. Soils that are plastic and sticky when wet are difficult to excavate, grade, and compact. To place a uniformly thick cover of wet clayey soil material over a layer of refuse is extremely difficult.

Because trenches (Soil Survey Staff, 1971) as deep as 15 feet or more are used for many landfills, geologic investigation is needed to determine the potential for pollution of ground water as well as to ascertain the design needed. These investigations include examination of stratification, rock formations, and other factors that might lead to the conducting of leachates to aquifers, wells, water courses, and other water sources. Hard nonrippable bedrock, creviced bedrock, and coarse strata in and underlying the proposed trench bottom are undesirable for excavation and hazardous due to the potential pollution of ground water.

The uppermost part of the final cover should be soil material that is favorable for the growth of plants. Surface layers of most soils have the best workability and highest content of organic matter. Thus, in the trench-type landfill operation, it is desirable to stockpile the surface layer for use in final blanketing of the fill.

AREA SANITARY LANDFILL

Because of soil limitations (like shallowness to bedrock), refuse can be placed on the surface of the soil in successive layers in an area-type sanitary landfill (Soil Survey Staff, 1971). Table 5 outlines the criteria for determining limitations for this type of landfill; notice particularly that depth to bedrock is not important because only fill (and not excavation) is made in this area landfill. Information on soil characteristics used in Table 5 are given in Table 1; limitation ratings made from Table 5 are listed in Table 6 for soils of Kansas, along with the major limitations.

In the area-type sanitary landfill, refuse is placed on the surface of the soil in successive layers. The daily and final cover material generally must be imported from other soil areas. A final cover of soil material at least two-feet thick is placed over the fill

TABLE 5. Ratings of limitations of soils for solid-waste disposal in area-type sanitary landfills (Adapted from Soil Survey Staff, 1971).

Item affecting use	Soil-limitation rating		
	Slight	**Moderate**	**Severe**
Depth to seasonal water table[1]	> 60 in	40-60 in	< 60 in
Soil drainage class[1]	Excessively drained, somewhat excessively drained, well-drained, and moderately well drained soils	Somewhat poorly drained soils	Poorly drained and very poorly drained soils
Flooding	None	Rare	Occasional or frequent
Permeability[2]	Slower than 2 in/hr	Slower than 2 in/hr	Faster than 2 in/hr
Slope	< 8%	8-15%	> 15%

[1] Depth to water table and soil-drainage class reflects influence of wetness on operation of heavy-wheeled or crawler equipment.
[2] These ratings reflect the ability of a soil to retard movement of effluents leached from landfills. In arid and semiarid areas rapid permeability may not be a severe limitation.

when it is completed. Although excavations are not made for this type of landfill, soil and geologic materials under the proposed site should be investigated so as to determine the probability that *leachates* from the landfill can penetrate the soil and thereby pollute water supplies.

For cover material (Soil Survey Staff, 1971), soils with very friable and friable consistence are good (classes of consistence and other soil properties can be obtained from the soil profile descriptions; Olson, in press). Soils with loose and firm consistence are fair; soils with very firm and extremely firm consistence are

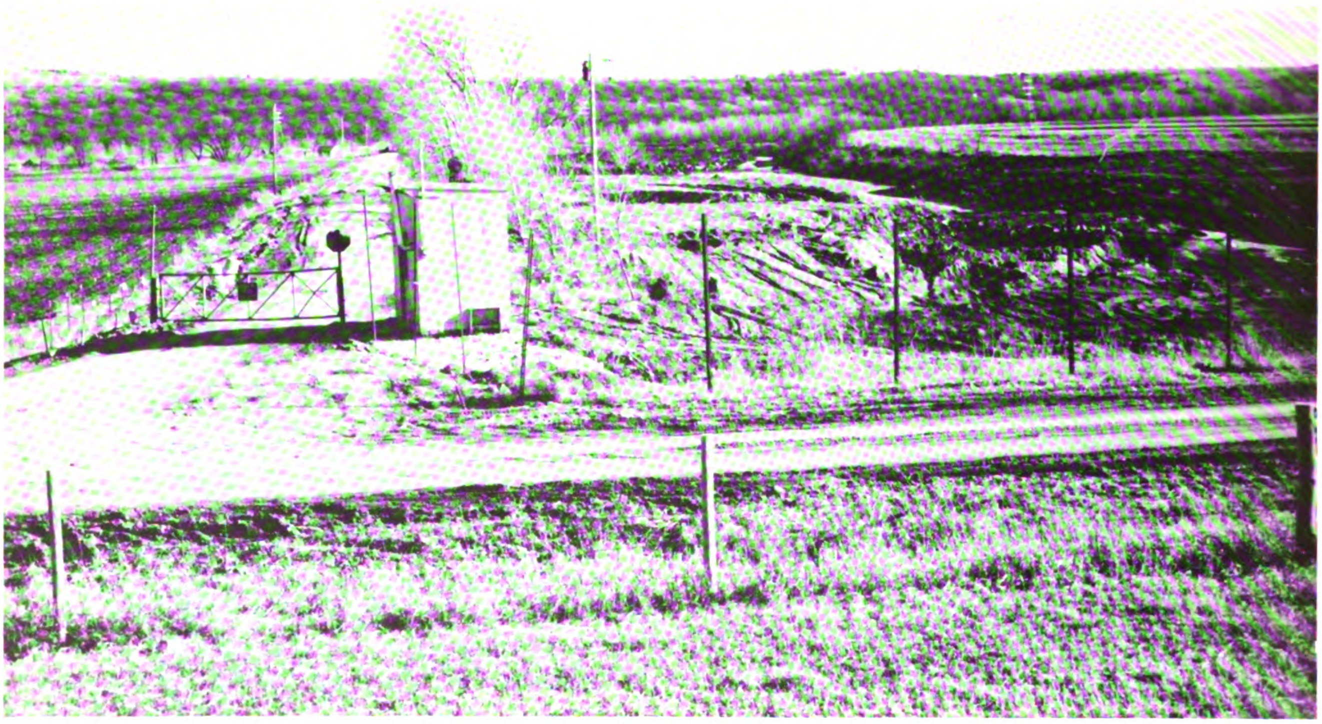

FIG. 20. This photograph of a gate at a sanitary landfill site illustrates the importance of control and operation at the disposal area. Equipment must move soil every day in burial operations, whether the weather is wet or dry, hot or cold. Silty clay, clay, gravel, sand, and organic soils have severe limitations for sanitary landfill; sandy loam, loam, and sandy clay loam soil textures have slight limitations if other soil and geologic characteristics are also good (see Table 4). Dikes and other water-control structures can improve some sites for landfill operations.

poor for cover material. Good soil textures include sandy loam, loam, silt loam, and sandy clay loam; fair textures include silty clay loam, clay loam, sandy clay, and loamy sand; poor textures include silty clay, clay, muck, peat, and sand. Thicker soil material, of course, is more desirable if excavation and hauling is to take place. Soils with gentler slopes, without coarse fragments, and with good drainage are better as a source of cover for sanitary landfill than are steep soils with stones or than soils in wet areas.

DESIGNS OF SEPTIC-TANK SEEPAGE FIELDS IN SOILS

Many excellent engineering designs have been developed for septic-tank seepage fields in different soils and in problem situations. Most of these designs have been tested through many years of engineering experience. The Manual of Septic-Tank Practice (Public Health Service, 1969) outlines standard proven practices which are used, with modifications, throughout most of the USA. Excellent texts (Salvato, 1972; Goldstein and Moberg, 1973) are also available to assist in solution of septic-tank problems and other related problems of environmental sanitation as well. In addition, experiences in other states with the same soils and similar soils can benefit Kansas residents in helping solve disposal problems (Colorado Department of Health, 1970; Texas State Department of Health, 1971).

In Kansas, different regulations exist in different counties, cities, and sanitation districts governing waste disposal. Thus, laws and zoning ordinances are complex and not standardized, although guidelines for waste disposal are developed for the State of Kansas by the Kansas State Department of Health in Topeka. Different lot size regulations and other criteria also have considerable effect upon the pattern of land use in Kansas.

In this discussion, only proven designs will be outlined in a general manner in line with the recommendations of the Kansas State Department of Health. Detailed specifications, of course, are to be obtained from the Department of Health in each county and from professional engineers. Soil maps and descriptions can be used to give information about soil capabilities for waste disposal, soil problems to be encountered, and probable designs that should be employed for adequate disposal in the different soils.

In general, soils with slight limitations for septic-tank seepage fields in Kansas (Table 6) are acceptable for standard tile lines with lengths and areas outlined by standard manuals (Public Health Service, 1969; Kansas State Department of Health, 1971). Figure 21

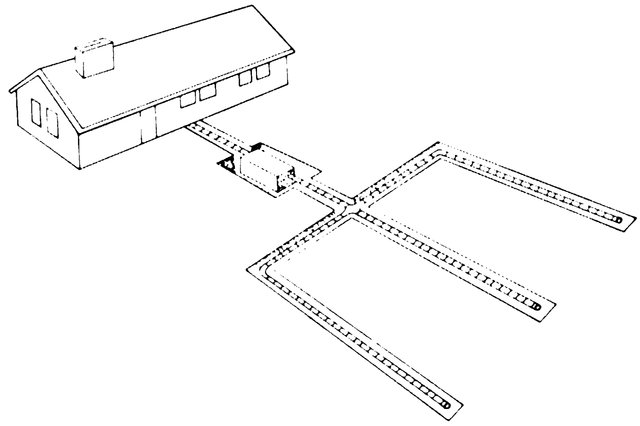

FIG. 21. One tile arrangement for a septic-tank seepage field in soils with slight limitations (Table 6; Adapted from Bender, 1971, page 3).

pictorially shows one arrangement of the tile lines; many variations are possible. For soils with slower percolation rates, the area occupied by tile lines in gravel can be expanded; for sloping soils, tile lines can be run (on specified grade) along the contours of the soil surface (Figure 22). Each soil site, of course, is somewhat unique and should be examined and approved by officials of each local public health department. The soil map should, in each case, serve as a guide to outline the problems and potentials of each soil. The septic-tank seepage field outlined in Figure 21 is generally the simplest and cheapest on-site disposal technique for the best soils of Kansas with only slight limitations (Table 6).

The moderate limitations for septic-tank seepage fields in soils of Kansas are due to retarded permeability, seasonal or permanent high water table, flooding, slope, bedrock, stoniness, or rockiness. Modifications in the design outlined in Figure 21 can overcome some of the lesser moderate limitations by:

1. Increasing area of tile lines in seepage field in soils with slower permeability.
2. Raising tile lines above water table with permeable fill material.
3. Raising tile lines above flood levels with permeable fill material.
4. Laying tile lines (on grade) along the contour on sloping soils (Figure 22).
5. Providing sufficient thickness above bedrock with tile lines in permeable fill.
6. Removing stones from soils with coarse fragments.
7. Moving tile lines out of rocky soils.

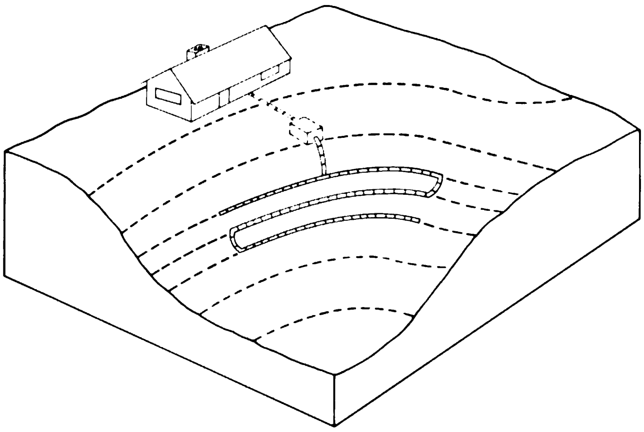

FIG. 22. Adaptation of tile arrangement along the contour (with specified grade) for soils with moderate limitations (Table 6; Adapted from Bender, 1971, page 8).

All of the seven possible tile line seepage field modifications are expensive, of course, and all involve hazards of pollution if adequate control is not maintained over the quality of the installations. For example, if a grade of about 1/16-inch drop per foot of tile line is not properly maintained, effluent will not run adequately through the tile lines for proper filtration. Tile lines in fill (Figure 23) will have problems due to settling if adequate compacting is not done before installation. Any design modification to overcome moderate limitations of soils is expensive, but it is necessary in order to accomplish adequate effluent filtration at the particular site.

Soils of Kansas with severe limitations (Table 6) have serious hazards so that construction may not be feasible at many of these sites. Some people living in places with limited space on deep, permeable well-drained soils might be able to dispose of effluent in a deep seepage pit (see local health department for design and approval). Some sites with almost impermeable soils can have sand filters (Figure 24); these are extremely expensive to construct properly. Sand filters must have extensive site preparation, water diversion, specified sand of large quantity, and discharge to an approved drainageway outside of an inhabited area. People living in places with wet impermeable soils with no other alternative for waste disposal might resort to a sewage lagoon or waste-stabilization pond (Kansas State Department of Health, 1971), but these require extensive grading (dike seven feet above bottom), expensive fencing, drainage diversion, and are subject to considerable odor and aesthetic problems if they fail. Soils on very steep slopes, soils in swamps, soils often flooded, soils shallow to hard and fissured bedrock, very stony and very rocky soils, and soils with some other serious severe limitations are probably not feasible for septic-tank seepage fields. Soils of Kansas with severe limitations are listed in Table 6; detailed soil maps locate the soil areas with severe limitations.

Research has shown that seepage-field design can be improved. Resting periods are beneficial; alternate dosing of two smaller seepage fields will enable better filtration than continual soaking of one larger field of the same size. Distribution boxes are probably not necessary in most tile junctions from the septic tank. Absorption beds (Texas State Department of Health, 1971) and aboveground disposal systems (Colorado Department of Health, 1970) will function where the soil is nearly impermeable. New materials, like lightweight septic tanks and improved tile, offer possibilities for reducing equipment costs. Generally, however, there is no substitute for good engineering expertise in seepage field design, installation, and maintenance. It is a simple fact of life that adequate subsurface sewage disposal and maintenance will be more expensive in soils with moderate and severe limitations than in those soils with slight limitations. If adequate designs for seepage fields are not used in different soils, soil maps can be used to predict percentages of failures of waste disposal in the various areas (Huddleston and Olson, 1967).

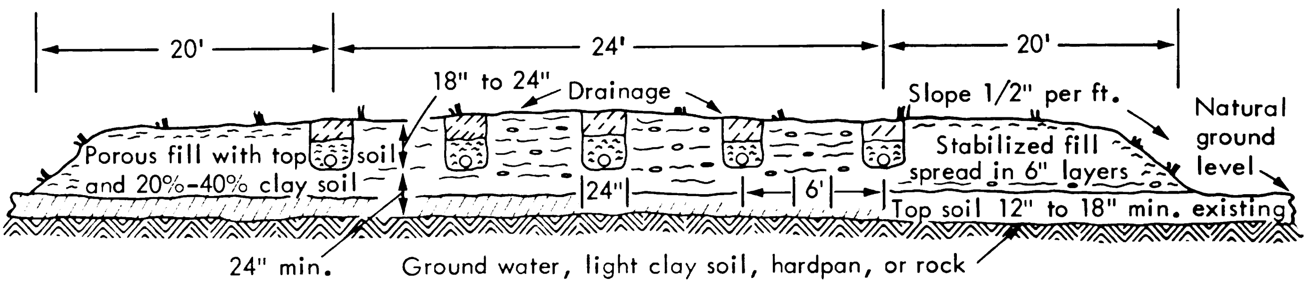

FIG. 23. Placement of tile lines in specified permeable fill to overcome moderate soil limitations due to shallowness to bedrock, apparent water table, impermeable soil horizons, or flood levels (Table 6; Adapted from Salvato, 1972, page 305).

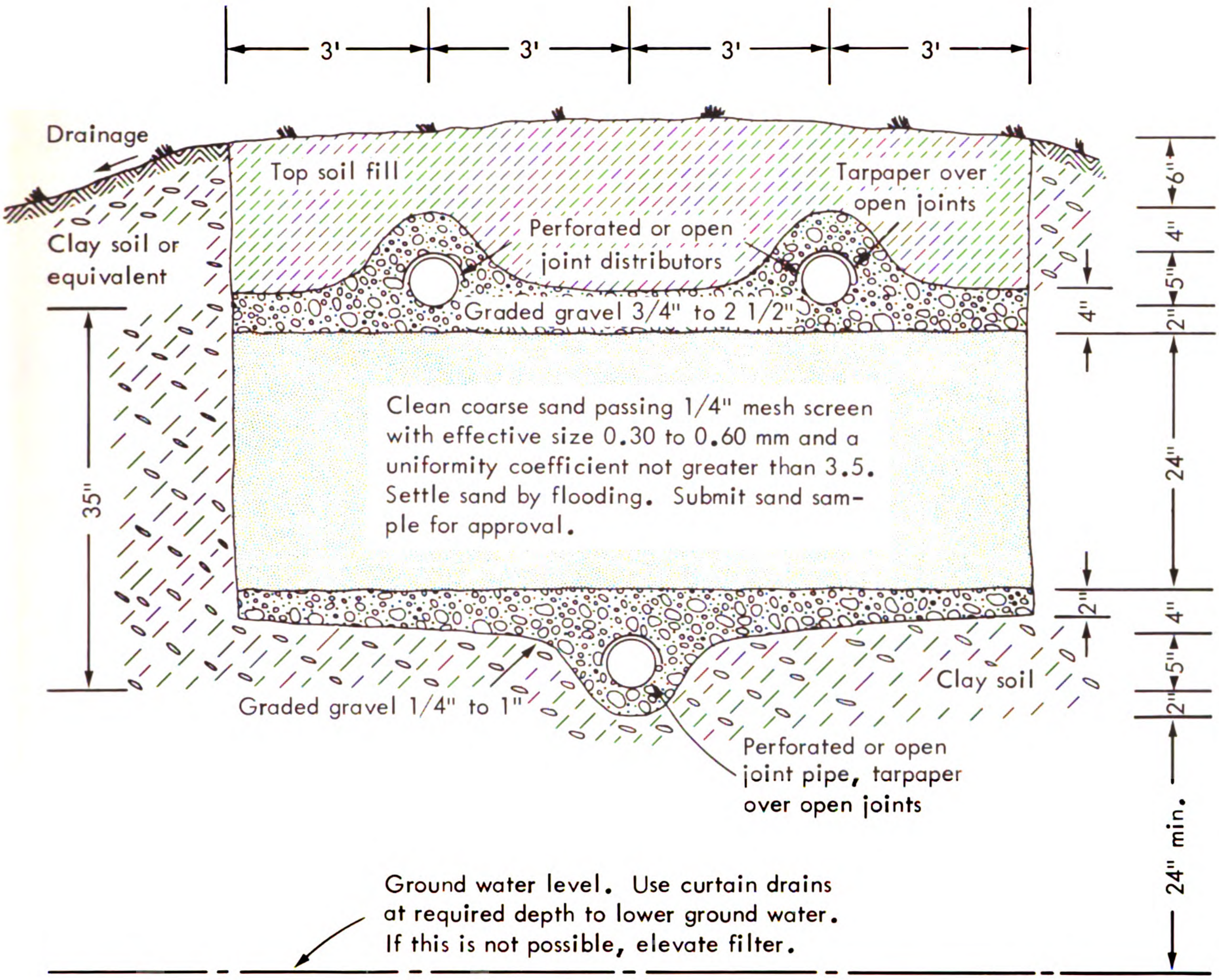

FIG. 24. Sand filter acceptable for some effluent filtration in impermeable soils with severe limitations (Table 6; Adapted from Salvato, 1972, page 310).

HOW TO USE SOIL INFORMATION FOR WASTE DISPOSAL

If you are contemplating using soils for waste disposal (Figure 25), you should first obtain a detailed soil map of the area in which you are interested. If you are a county or regional planner, you may be interested in the soils of an entire county or larger area; if you are a homeowner, you may be interested only in a specific lot and in the surrounding area that affects the drainage and aesthetic qualities of your lot. Published soil maps are available from a variety of sources; unpublished soil maps are available in the district offices of the Soil Conservation Service in nearly every county in Kansas, and in some offices of cooperating agencies. Some places, of course, have not been soil-mapped.

After you have your soil map, you should identify the soil names in the legend that accompanies the map. These names are usually place names where the soils were identified and described. Legends and map numbering systems vary, but the soil names are standardized throughout Kansas and the USA. The soil-profile descriptions, available from the SCS offices and other sources, give the most detailed information about the soils located on the map. Table 1 in this publication lists some of the important characteristics of soils of Kansas for waste disposal.

You should test the soil map by digging some holes yourself. If you find drainage mottles (color spots), apparent water tables, bedrock at shallow depth, or see steep slopes or flood debris in places, you will know these soils are not ideal for waste disposal. If

FIG. 25. Drainage from a farm feedlot. Soil maps and soil information can be useful in helping solve many kinds of waste disposal problems. Table 2 and Table 6, for example, show limitations of soils for septic-tank seepage fields for homes. Feedlot runoff can also be a problem, especially where farms are near reservoirs and close to urban areas. Below feedlots, sewage lagoons can be particularly valuable to reduce pollution (Table 3). Where feedlot effluent is irrigated by sprinklers from lagoons, soil-permeability data from Table 1, Table 2, and Table 6 can be useful in locating areas on soil maps where soils can absorb quantities of liquid wastes without undue hazards.

you dig up loose sand or tight clay, you will know problems of pollution hazards or slow permeability will have to be overcome for adequate disposal.

When you have looked at the soil map and soil conditions, you should then consult your local health department. Local health officials also have soil maps, and are familiar with waste-disposal problems, zoning ordinances, and sanitation districts in the area. They have engineering designs developed to handle difficult soil conditions, and can specify what kind of materials or engineering assistance is needed. Limited assistance from soil scientists is sometimes available for consultations and site evaluations.

Tables 2-6 indicate what soil properties are important for septic-tank seepage fields, sewage lagoons, and sanitary landfill in specific soils of Kansas. If the area you are interested in has soils with slight limitations, you will have few problems for waste disposal and costs will be minimal. If the area has soils with moderate limitations, more costs and hazards are involved. If the soils have severe limitations, then steep slopes, flooding, free water, bedrock, stones, or undesirable permeability are serious problems—these sites may not be feasible for safe waste disposal under existing economic conditions. In many cases it is helpful to shade or color soil maps to show the different limitations of the different soils (Figure 26); in this way a planner or developer can see immediately what is the magnitude of the soil problems in the different places. Other single factor maps can be made to show the locations of the most important soil properties, including slopes, bedrock, water table, stones, flooding, and so on.

Much can be learned by study of the soil maps. Figure 27, for example, shows the soil pattern northeast of Liberal, Kansas. Soil areas marked "Ra" consist of Randall clay; a description of that soil is given in this publication in the section on soil-profile descriptions. Randall soils are very poor for waste dis-

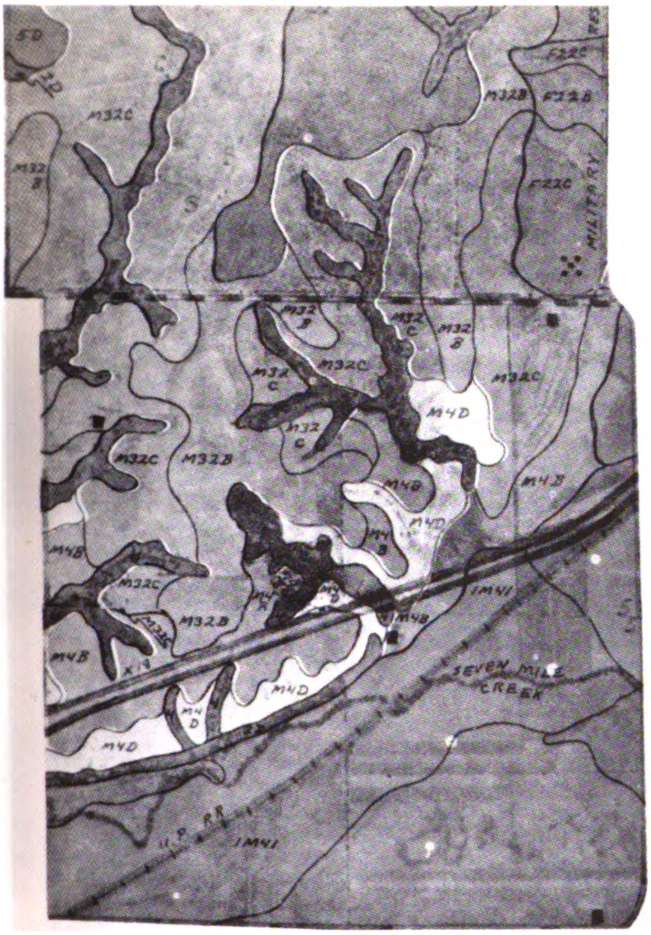

Fig. 26. Soil groupings into slight, moderate (lightest shading), and severe (darkest shading) limitation categories for septic-tank seepage fields on an unpublished soil map from an area in Riley County, Kansas (Adapted from Soil Survey Staff, 1972b; this map was made from the soil map also shown in Figure 1 of this publication). Top of map is north; scale is approximately 3 inches = 1 mile.

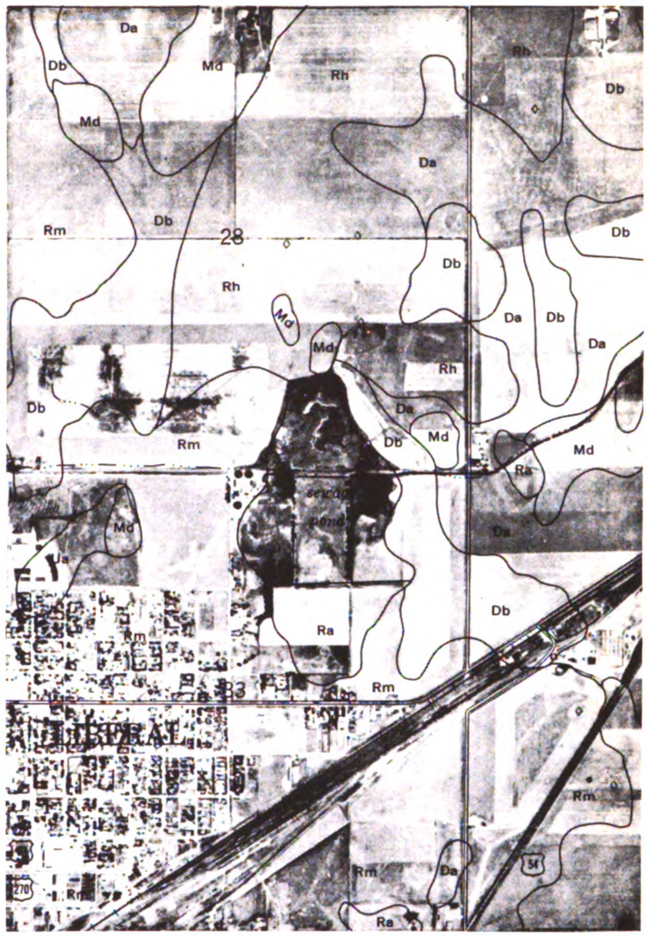

Fig. 27. Soil pattern northeast of Liberal, Kansas (Adapted from Dickey *et al.*, 1965, soil map sheet 45). Top of map is north; scale is reduced from 1:20,000 to approximately 2-1/2 inches = 1 mile.

posal (Table 6), but can be made suitable for sewage lagoons with careful engineering designs. From the aerial photograph (Figure 27), it appears that sewage from Liberal is being diverted into the large Randall soil area northeast of the town. In contrast, "Rm" and "Rh" soil areas (Figure 27) consist of Richfield silt loam soils; they are good for most kinds of waste disposal (Table 6). The Dalhart fine sandy loam soils (Da, Db), on different slopes, are also good for most kinds of waste disposal.

The best solution of most waste-disposal problems is not a simple matter, but involves complex and interrelated planning procedures. One of the best descriptions of a thorough planning process to create an environment for people to grow in has been given by Hoppenfeld for the new city of Columbia, Maryland (1967); almost everyone who has visited or lived in the new city of Columbia is convinced that it represents a creative attempt to build a better city at feasible cost. Similar concepts could be applied to rural and urban planning in Kansas, and soil maps can help in the total planning process. Examples of special soil studies for environmental planning are available (Olson and Marshall, 1968; Olson, 1969, 1972b). Detailed and comprehensive planning using soil maps is particularly relevant in parts of Kansas with more complex soil patterns.

Figure 28 shows the soil pattern east of Wakarusa, Kansas. The Wabash silty clay soils (Wb) have severe limitations for most kinds of waste disposal; the Reading silty clay loam soils (Re) are more suitable for waste disposal in some places, but both soils are subjected to flooding on broad flats. The "Br" drainageways have steep sideslopes and narrow floodplains. Martin silty clay loam soils (Me, Mb) have some potential for sanitary landfill, but severe limitations for

FIG. 28. Soil pattern east of Wakarusa, Kansas (Adapted from Abmeyer and Campbell, 1970, soil map sheet 43). Top of map is north; scale is 1:20,000, or approximately 3-1/2 inches = 1 mile.

septic-tank seepage fields. Pawnee clay loam soils (Pc, Pe) have different limitations for waste disposal on different slopes. Areas marked "Sw" are stony steep land. If these areas are uncleared, it is probably wisest to let them remain that way. As Figure 28 shows, most soils in this area have limitations for waste disposal, but the soil limitations are different and can be turned to an advantage for planning. Thus the very poor stony steep soils (Sw) and stream channels (Br) have unique forest vegetation already, which can be put to good use as green belts and "open" space; floodplains (Wb, Re) can be preserved for farming; uplands (Me, Mb, Pc, Pe) could have cluster housing developments with municipal sewer systems. The topographic variability of the soils gives the area great aesthetic potential, so that it could be enhanced considerably as

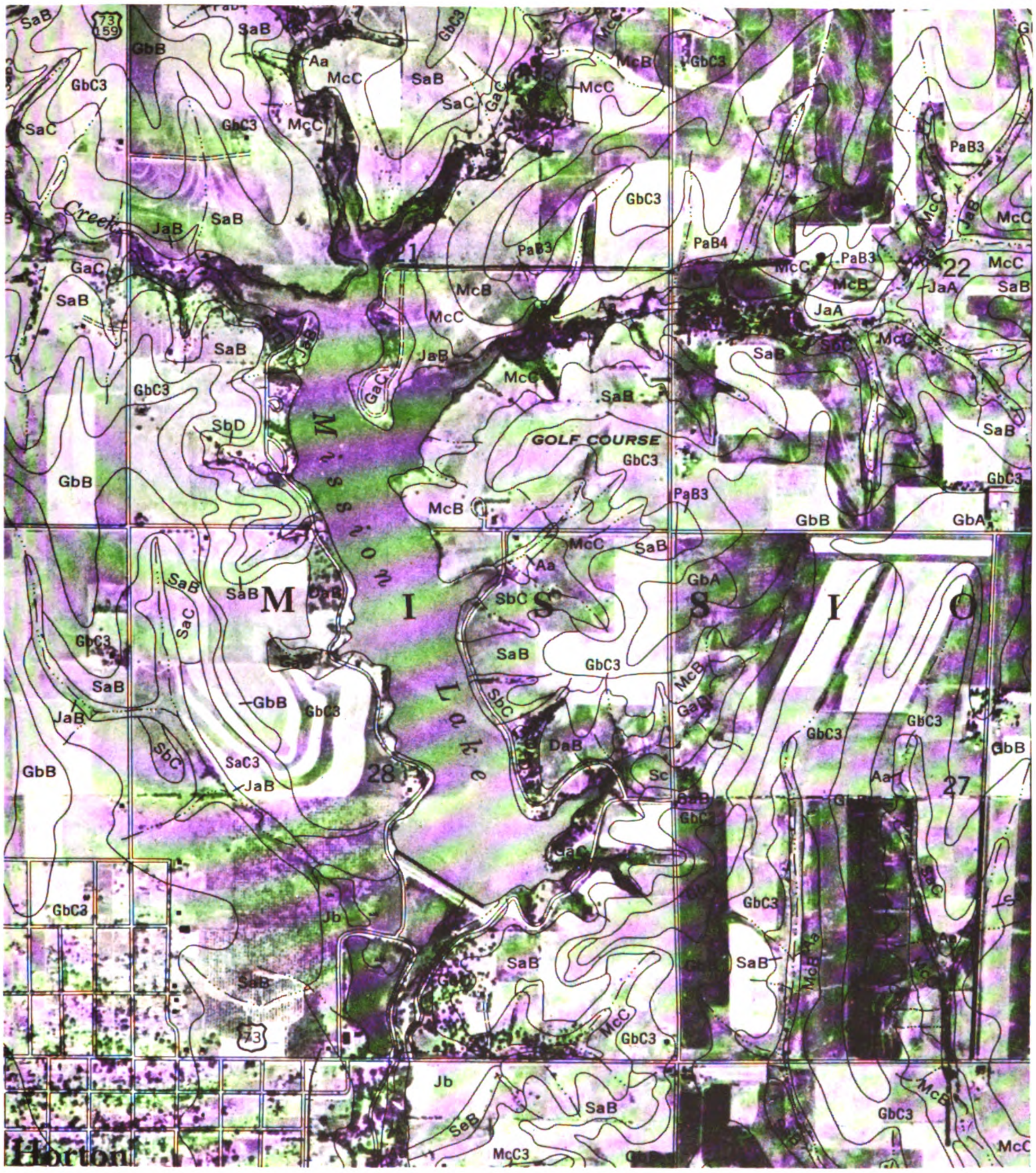

FIG. 29. Soil pattern around Mission Lake northeast of Horton, Kansas (Adapted from Eikleberry, 1960, soil map sheet 24). Top of map is north; scale is 1:20,000, or approximately 3-1/2 inches = 1 mile.

a planned community for people to live in and enjoy.

Special critical areas in Kansas which can benefit from use of soil maps include areas around reservoirs. Mission Lake, northeast of Horton, Kansas, is one small lake that can be used as an example. Figure 29 shows the soil pattern around the lake. The variable soil slopes, indicated by B, C, and D letters in the last part of the soil symbols, indicate considerable com-

FIG. 30. View of Mission Lake in Brown County, from the east shore. Although most of the soils around Mission Lake have severe limitations for waste disposal, soil maps show the various magnitudes of the limiting characteristics, and delineate slopes and other criteria which are vital for landscape design. Many reservoir lakeshores should probably be preserved for recreational and aesthetic use; this also reduces the pollution of the lake and prevents property damage when floods come.

plexities for aesthetic planning of vistas and plantings for landscape design. Most of the soils around the lake have clayey textures, so that they are poor for subsurface sewage disposal in septic-tank seepage fields. Cluster developments built along the west shore of the lake could have sewer lines and a central sewage-treatment plant; the rest of the lakeshore could be kept open for golf courses and other recreational activities (Figure 30). The upper part of the reservoir area, which is more subject to flooding and sedimentation, can be used for wildlife and conservation education projects. Watershed management of all soil areas (Kling, 1973) draining into the lake, of course, is essential if the life and desirable qualities of the lake are to be maximized. Thus, soil maps should be used not only to assist in waste disposal, but in all other aspects of land-area management as well.

Soil maps, of course, will not by themselves solve all of the problems of waste disposal, and their accuracy is not 100 percent for all areas. Soil maps are probably at least 80-90 percent accurate for most uses, but they should be continually tested in the field. Soil maps should be considered to be a first approximation for solution to land use problems, as the title page of this publication indicates. For complex projects, soil maps are most useful when combined with deeper geologic investigations, well-log data, water-table fluctuation measurements, sedimentation studies, pollution monitorings, and other careful planning, engineering, and geologic studies. If our environment is to be substantially improved, most of the waste-disposal problems of the future will likely be complex, unique, and individualistic problems involving many interdisciplinary efforts (Stevens, 1971)—with laymen taking an active role in project implementation along with the professional scientists and environmentalists.

(continued on page 46)

TABLE 6. Major limiting soil characteristics and ratings of limitations[*] for waste disposal in soils of Kansas (Adapted from soil interpretation sheets for soil series; Soil Survey Staff, 1971; and other sources). Numbers indicate specific limitations of each soil for each use—1 Slow permeability rates, 2 Rapid permeability rates, 3 Too clayey (workability), 4 Too sandy (workability), 5 Slopes, 6a Occasional and frequent flooding, 6b Rare flooding, 7 Water table, 8 Possible pollution hazard, 9 Drainage, 10a Hard bedrock at 10″-20″, 10b Hard bedrock at 20″-40″, 10c Hard bedrock at 40″-60″, 11a Rippable bedrock at 10″-20″, 11b Rippable bedrock at 20″-40″, 11c Rippable bedrock at 40″-60″, 12 Coarse fragments.

Soil series name	Septic-tank seepage fields	Sewage lagoons	Sanitary landfills: Trench types	Sanitary landfills: Area types
ABILENE	Severe—1	Slight	Severe—3	Slight
ALBION	Slight < 8% Moderate > 8%—5	Severe—2	Severe—2	Severe—2
ALTUS	Slight	Moderate—2	Slight	Slight
ANGELUS	Severe—6a	Severe—6a	Severe—6a	Severe—6a
ANSELMO	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Severe—2	Severe—2	Severe—2
ARMO	Slight < 8% Moderate > 8%—5	Moderate < 7%—2 Severe > 7%—5	Slight	Slight < 8% Moderate > 8%—5
ARMSTER	Severe—1	Moderate < 7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
ATTICA	Slight	Severe—2	Severe—2	Severe—2
BANKARD	Slight < 8% Severe > 8%—8	Severe—2	Severe—2	Severe—2
BARLANE	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
BASEHOR	Severe—10a	Severe—2, 10a	Severe—2, 10a,	Severe—2
BATES	Severe—11b	Severe—11b	Moderate—11b	Slight
BAXTER	Moderate < 15%—1 Severe > 15%—5	Moderate < 7%—1 Severe > 7%—5	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
BAYARD	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Severe—2	Severe—2	Severe—2
BENFIELD	Severe—11b	Severe—11b	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
BETHANY	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Slight
BIPPUS	Slight	Moderate—2	Moderate—3	Slight
BODINE	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Severe—2	Severe—2	Severe—2
BOEL	Severe—6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7
BOGUE	Severe—11b	Severe—11b	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
BOLIVAR	Severe—10b	Severe—10b	Severe—10b	Slight < 8% Moderate > 8%—5
BOWDOIN	Severe—1, 6a	Severe—6a	Severe—3, 6a	Severe—6a
BREWER	Severe—1	Slight	Moderate—3	Slight Moderate—6b
BRIDGEPORT	Severe—6a	Severe—6a	Severe—6a	Severe—6a
BROWNELL	Severe—10b	Severe—10b	Severe—10b	Slight < 8% Moderate > 8%—5
BURCHARD	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
BUTLER	Severe—1	Slight	Severe—3, 9	Severe—9
CAMPUS	Severe—11b	Severe—11b	Moderate—3	Slight < 8% Moderate > 8%—5
CANADIAN	Moderate—6b	Severe—2	Severe—2	Severe—2
CANLON	Severe—11a	Severe—11a	Severe—11a	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
CANYON	Severe—10a	Severe—10a	Moderate < 25%—3, 10a Severe > 25%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5

[*] Limitations of some series are subject to change pending final correlations and acquisition of more data about the soils and the various disposal systems.

Table 6 (Cont.)

Soil series name	Septic-tank seepage fields	Sewage lagoons	Sanitary landfills: Trench types	Sanitary landfills: Area types
CAREY	Slight	Moderate—2	Moderate—3	Slight
CARLSON	Severe—1	Slight < 2% Moderate > 2%—5	Moderate—3	Slight
CARR	Severe—6a	Severe—6a	Severe—6a	Severe—6a
CARUSO	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
CARWILE	Severe—1	Slight	Severe—3	Moderate—9
CASE	Slight	Moderate < 7%—2 Severe > 7%—5	Moderate—3	Slight
CASS	Moderate—6b Severe—8	Severe—2	Severe—2	Severe—2
CATOOSA	Severe—10b	Severe—10b	Severe—10b	Slight
CAWKER	Moderate—6b	Moderate—2	Moderate—6b	Moderate—6b
CHARITON	Severe—1	Slight	Severe—3, 9	Severe—9
CHASE	Severe—1	Moderate—6b	Severe—3	Moderate—6b, 9
CHEROKEE	Severe—1	Slight	Severe—3	Moderate—9
CHURCH	Severe—1, 7	Severe—7	Severe—3, 7	Severe—7
CLAIREMONT	Severe—6a	Severe—6a	Severe—6a	Severe—6a
CLAREMORE	Severe—10a	Severe—10a	Severe—10a	Slight
CLARESON	Severe—10a	Severe—10a	Severe—10a	Slight
CLARK	Slight	Moderate—2	Slight	Slight
CLEORA	Severe—6a	Severe—2, 6a	Severe—2, 6a	Severe—2, 6a
CLIME	Severe—11b	Severe—11b	Severe—3	Slight < 8% Moderate > 8%—5
COLBY	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Moderate < 7%—2 Severe > 7%—5	Slight < 15% Moderate 15-25%—5 Severe > 25%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
COLLINSVILLE	Severe—10a	Severe—10a	Severe—10a	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
COLY	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Moderate < 7%—2 Severe > 7%—5	Slight < 15% Moderate 15-25%—5 Severe > 25%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
CORBIN	Severe—1	Moderate—2	Moderate—3	Slight
CORINTH	Severe—11b	Severe—11b	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
COZAD	Slight	Moderate—2	Slight	Slight
CRETE	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Moderate—9
CRISFIELD	Moderate—6b	Severe—2	Severe—2	Severe—2
CROCKER	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Severe—2	Severe—2	Severe—2
DALE	Moderate—6b	Severe—6b	Moderate—6b	Moderate—6b
DALHART	Slight	Moderate—2	Slight	Slight
DARNELL	Severe—11b	Severe—2, 11b	Severe—2	Severe—2
DEEPWATER	Moderate—1	Moderate—2	Moderate—3	Slight < 8% Moderate > 8%—5
DENNIS	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Slight
DETLOR	Severe—1, 11b	Severe—11b	Severe—3	Slight < 8% Moderate > 8%—5
DETROIT	Severe—1	Slight	Severe—3	Moderate—6b
DILLWYN	Severe—7, 8	Severe—2, 7	Severe—2, 7	Severe—2, 7
DOXIE	Severe—1	Slight	Severe—3	Moderate—6b
DRUMMOND	Severe—1, 7	Slight	Severe—3, 7	Severe—7
DWIGHT	Severe—1	Moderate—10c	Severe—10c, 3	Slight
DWYER	Slight < 8% Moderate 8-15%—5 Severe > 15%—5, 8	Severe—2	Severe—2	Severe—2
EDALGO	Severe—11b	Severe—11b	Severe—3	Slight < 8% Moderate > 8%—5

Table 6 (Cont.)

Soil series name	Septic-tank seepage fields	Sewage lagoons	Sanitary landfills: Trench types	Sanitary landfills: Area types
EDINA	Severe—1	Slight	Severe—3, 9	Severe—9
ELKADER	Moderate—11c	Moderate < 7%—11c Severe > 7%—5	Moderate—3, 11c	Slight < 8% Moderate > 8%—5
ELMONT	Severe—1	Moderate < 7%—11c Severe > 7%—5	Moderate—3, 11c	Slight < 8% Moderate > 8%—5
ELSMERE	Severe—7, 8	Severe—2, 7	Severe—2, 7	Severe—2, 7
ELTREE	Slight < 8% Moderate > 8%—5	Moderate < 7%—2 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8%—5
ENGLUND	Severe—11b	Severe—11b	Severe—3	Slight
ENTERPRISE	Slight < 8% Moderate > 8%—5	Severe—2	Severe—2	Severe—2
ERAM	Severe—1, 11b	Severe—11b	Severe—3	Slight
EUDORA	Severe—6a	Severe—6a	Severe—6a	Severe—6a
FARNUM	Severe—1	Slight < 2% Moderate > 2%—5	Moderate—3	Slight
FLORENCE	Severe—1	Severe—12	Severe—12	Slight < 8% Moderate > 8%—5
GARA	Severe—1	Moderate < 7%—5 Severe > 7%—5	Moderate < 25%—3 Severe > 25%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
GEARY	Slight < 8% Moderate > 8%—5	Moderate < 7%—2 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8%—5
GERLANE	Severe—6a, 7, 8	Severe—2, 6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7
GEUDA	Severe—11b	Severe—11b	Severe—3	Slight
GIRARD	Severe—1, 6a, 7, 10b	Severe—6a, 7, 10b	Severe—3, 6a, 7, 10b	Severe—6a, 7
GLENBERG	Severe—6a	Severe—2, 6a	Severe—2, 6a	Severe—2, 6a
GOESSEL	Severe—1	Slight	Severe—3	Slight
GOSHEN	Moderate—6b	Moderate—2	Moderate—6b	Moderate—6b
GOSPORT	Severe—11b	Severe—11b	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
GRABLE	Moderate—7	Severe—2	Severe—2	Severe—2
GRANT	Moderate < 15%—11c Severe > 15%—5	Moderate < 7%—11c Severe > 7%—5	Moderate—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
GRIGSTON	Moderate—6b	Moderate—2	Moderate—6b	Moderate—6b
GRUNDY	Severe—1	Slight < 2% Moderate 2-7%—5 Severe> 7%—5	Severe—3	Moderate < 8%—9 Severe > 8%—5
GYMER	Severe—1	Moderate < 7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8%—5
HALL	Severe—1	Slight < 2% Moderate > 2%—5	Moderate—3	Slight
HARNEY	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8%—5
HASTINGS	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8%—5
HAYNIE	Moderate—6b	Moderate—2	Moderate—6b	Moderate—6b
HECTOR	Severe—10a	Severe—2, 10a	Severe—2, 10a	Severe—2
HEDVILLE	Severe—10a	Severe—10a	Severe—10a	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
HEIZER	Severe—10a	Severe—10a	Severe—10a	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
HEPLER	Severe—1, 6a	Severe—6a	Severe—6a	Severe—6a
HOBBS	Severe—6a	Severe—6a	Severe—6a	Severe—6a
HOLDER	Moderate—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8%—5
HOLDREGE	Slight	Moderate—2	Moderate—3	Slight < 8% Moderate > 8%—5
HORD	Slight	Moderate—2	Slight	Slight

Table 6 (Cont.)

Soil series name	Septic-tank seepage fields	Sewage lagoons	Sanitary landfills: Trench types	Sanitary landfills: Area types
HUMBARGER	Severe—6a	Severe—6a	Severe—6a	Severe—6a
INAVALE	Severe—6a, 8	Severe—2, 6a	Severe—2, 6a	Severe—2, 6a
IRWIN	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Severe—3	Slight
IVAN	Severe—6a	Severe—6a	Severe—6a	Severe—6a
JUDSON	Moderate—6b	Severe—6b	Moderate—6b	Moderate—6b
KAHOLA	Severe—6a	Severe—6a	Severe—6a	Severe—6a
KANZA	Severe—6a, 7, 8	Severe—2, 6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7
KASKI	Severe—6a	Severe—6a	Severe—6a	Severe—6a
KEITH	Slight < 8% Moderate > 8%—5	Moderate < 7%—2 Severe > 7%—5	Slight < 8 Moderate > 8%—5	Slight < 8% Moderate > 8%—5
KENESAW	Slight < 8% Moderate > 8%—5	Moderate < 7%—2 Severe > 7%—5	Slight < 8% Moderate > 8%—5	Slight < 8% Moderate > 8%—5
KENNEBEC	Severe—6a	Severe—6a	Severe—6a	Severe—6a
KENOMA	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Slight
KIM	Slight < 8% Moderate > 8%—5	Moderate < 7%—2 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8—5%
KIMO	Severe—1, 7, 8	Severe—6b, 7	Severe—7	Severe—7
KINGFISHER	Severe—1, 11c	Severe—11c	Moderate—3, 11c	Slight < 8% Moderate > 8%—5
KINGMAN	Severe—1, 6a, 7	Severe—6a, 7	Severe—6a, 7, 9	Severe—6a, 7, 9
KIPSON	Severe—11a	Severe—11a	Moderate—11a	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
KIRKLAND	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Slight
KNOX	Slight < 8% Moderate 8-15%—5 Severe < 15%—5	Moderate < 7%—2 Severe > 7%—5	Slight < 15% Moderate 15-25%—5 Severe > 25%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
KONAWA	Slight	Moderate < 7%—2 Severe > 7%—5	Slight	Slight
LABETTE	Severe—1, 10b	Severe—10b	Severe—10b	Slight
LADOGA	Severe—1	Moderate < 7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
LADYSMITH	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Moderate—9
LAGONDA	Severe—1	Moderate < 7%—5 Severe > 7%—5	Moderate—3, 9	Moderate—9
LAMO	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
LANCASTER	Severe—11b	Severe—11b	Moderate—3, 11b	Slight < 8% Moderate > 8%—5
LAS	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
LAS ANIMAS	Severe—6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7, 9	Severe—2, 6a, 7, 9
LEANNA	Severe—1, 6a	Severe—6a	Severe—6a, 9	Severe—6a, 9
LESHARA	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
LESHO	Severe—1, 6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
LIGHTNING	Severe—1, 6a	Severe—6a	Severe—3, 6a, 9	Severe—6a, 9
LIKES	Slight	Severe—2	Severe—2, 4	Severe—2
LINCOLN	Severe—6a	Severe—2, 6a	Severe—2, 4, 6a	Severe—2, 6a
LISMAS	Severe—11a	Severe—11a	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
LOCKHARD	Severe—1	Slight	Severe—3	Slight
LOFTON	Severe—1	Slight	Severe—3	Slight
LONGFORD	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8%—5
LUBBOCK	Severe—1	Slight	Slight	Slight
LUCIEN	Severe—11a	Severe—2a, 11a	Severe—2	Severe—2
LULA	Moderate—10c	Moderate—10c	Severe—10c	Slight

Table 6 (Cont.)

Soil series name	Septic-tank seepage fields	Sewage lagoons	Sanitary landfills	
			Trench types	Area types
MANDEVILLE	Severe—11b	Severe—11b	Moderate—11b	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
MANGUM	Severe—1, 6a	Severe—6a	Severe—3, 6a	Severe—6a
MANSIC	Moderate—1	Moderate < 7%—2 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8%—5
MANSKER	Slight	Moderate < 7%—2 Severe > 7%—5	Moderate—3	Slight
MANTER	Slight	Severe—2	Severe—2	Severe—2
MANVEL	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Slight	Slight < 8% Moderate > 8%—5
MARSHALL	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Moderate < 7%—2 Severe > 7%—5	Moderate—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
MARTIN	Severe—1	Moderate < 7%—11c Severe > 7%—5	Severe—3	Slight < 8% Moderate > 8%—5
MASON	Severe—1	Slight < 2% Moderate 2-7%—2 Severe > 7%—6b	Moderate—3, 6b	Slight < 8% Moderate > 8%—5, 6b
MATFIELD	Severe—1	Severe—12	Severe—12	Slight
MAYBERRY	Severe—1	Moderate < 7%—5 Severe > 7%—5	Severe—3	Slight < 8% Moderate > 8%—5
McCUNE	Severe—1, 6a	Severe—6a	Severe—6a	Severe—6a
McLAIN	Severe—1	Slight	Moderate—3, 6b	Moderate—6b
MENFRO	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Moderate < 7%—2, 5 Severe > 7%—5	Moderate < 25%—3 Severe > 25%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
MENTO	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—3	Slight
MILAN	Moderate—1	Moderate < 7%—2 Severe > 7%—5	Moderate—3	Slight
MILLER	Severe—1, 6a	Severe—6a	Severe—6a	Severe—6a
MINCO	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Moderate < 7%—2 Severe > 7%—5	Slight < 15% Moderate 15-25%—5 Severe > 25%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
MINNEQUA	Severe—11b	Severe—11b	Moderate—11b	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
MISSLER	Severe—1	Slight < 2% Moderate > 2%—5	Moderate—3	Slight
MONONA	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Moderate < 7%—2 Severe > 7%—5	Slight < 15% Moderate 15-25%—5 Severe > 25%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
MORRILL	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Slight < 15% Moderate > 15%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
MUIR	Moderate—6b	Moderate—2	Moderate—6b	Moderate—6b
MULDROW	Severe—1	Slight	Severe—3	Moderate—6b
MUNJOR	Severe—6a	Severe—2, 6a	Severe—2, 6a	Severe—2, 6a
NARON	Slight	Moderate to Severe—2	Slight to Severe—2	Slight to Severe—2
NASH	Severe—11b	Severe—11b	Moderate—11b	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
NASHVILLE	Severe—11b	Severe—11b	Moderate—11b	Slight < 8% Moderate > 8%—5
NESS	Severe—1	Slight	Severe—3, 6a	Severe—6a
NEW CAMBRIA	Severe—1	Slight	Severe—3	Moderate—6b
NEWTONIA	Slight	Moderate—2	Severe—3	Slight
NIBSON	Severe—11a	Severe—11a	Moderate—11a	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
NIOTAZE	Severe—1, 11b	Severe—11b	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5

Table 6 (Cont.)

Soil series name	Septic-tank seepage fields	Sewage lagoons	Sanitary landfills: Trench types	Sanitary landfills: Area types
NODAWAY	Severe—6a	Severe—6a	Severe—6a	Severe—6a
NORGE	Severe—1	Slight < 2% Moderate > 2%—5	Moderate—3	Slight
NORWOOD	Severe—6a	Severe—6a	Severe—6a	Severe—6a
NUCKOLLS	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Moderate < 7%—2 Severe > 7%—5	Slight < 15% Moderate > 15%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
OAKWOOD	Severe—1, 6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
OKEMAH	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Slight
OLMITZ	Moderate—1	Moderate—2	Moderate—3	Slight < 8% Moderate > 8%—5
OLPE	Severe—1	Severe—12	Severe—3	Slight < 8% Moderate > 8%—5
ONAWA	Severe—1, 6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
ORD	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
ORTELLO	Slight < 8% Moderate > 8%—5	Severe—2	Severe—2	Severe—2
OSAGE	Severe—1, 6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
OSKA	Severe—1, 10b	Severe—10b	Severe—10b	Slight
OST	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—3	Slight
OTERO	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Severe—2	Severe—2	Severe—2
OWEGO	Severe—1, 6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
OWENS	Severe—1, 11a	Severe—11a	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
PARSONS	Severe—1	Slight < 2% Moderate > 2%—2	Severe—3	Moderate—9
PAWNEE	Severe—1	Moderate < 7%—5 Severe > 7%—5	Severe—3	Slight < 8% Moderate > 8%—5
PENDEN	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8%—5
PENROSE	Severe—10a	Severe—10a	Severe—10a	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
PLATTE	Severe—6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7
PLEASANT	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Slight
PLEVNA	Severe—6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7
POND CREEK	Severe—1	Slight < 2% Moderate > 2%—5	Moderate—3	Slight
PORT	Moderate—1, 6b	Moderate—2	Moderate—3, 6b	Moderate—6b
POTTER	Severe—11a	Severe—11a	Moderate < 25%—11a Severe > 25%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
PRATT	Slight < 8% Moderate > 8%—5	Severe—2	Severe—2	Severe—2
PROMISE	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
QUINLAN	Severe—11a	Severe—2, 11a	Severe—2	Severe—2
RADLEY	Severe—6a	Severe—6a	Severe—6a	Severe—6a
RANDALL	Severe—1	Slight	Severe—3, 6a	Severe—6a
READING	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—6b	Moderate—6b
REINACH	Moderate—6b	Moderate—2	Moderate—6b	Moderate—6b
RENFROW	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Slight

Table 6 (Cont.)

Soil series name	Septic-tank seepage fields	Sewage lagoons	Sanitary landfills	
			Trench types	**Area types**
RICHFIELD	Moderate—1	Slight < 2% Moderate > 2%—5	Moderate—3	Slight
RINGO	Severe—1, 11b	Severe—11b	Severe—3	Slight < 8% Moderate > 8%—5
RIVERTON	Moderate—1	Moderate—2, 12	Moderate—3, 12	Slight
ROSEHILL	Severe—1, 11b	Severe—11b	Severe—3	Slight
ROXBURY	Moderate to Severe—6a, 6b	Severe—6a, 6b	Moderate to Severe—6a, 6b	Moderate to Severe—6a, 6b
RUELLA	Slight < 8% Moderate > 8%—5	Moderate < 7%—2 Severe > 7%—5	Slight	Slight < 8% Moderate > 8%—5
RYUS	Severe—1	Slight	Moderate—3, 6b	Moderate—6b
SARPY	Severe—6a, 8	Severe—2, 6a	Severe—2, 4, 6a	Severe—2, 6a
SATANTA	Slight < 8% Moderate > 8%—5	Moderate < 7%—2 Severe > 7%—5	Slight	Slight < 8% Moderate > 8%—5
SHARPSBURG	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8%—5
SHELBY	Severe—1	Moderate < 7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
SHELLABARGER	Slight < 8% Moderate > 8%—5	Moderate < 7%—2 Severe > 7%—5	Slight	Slight < 8% Moderate > 8%—5
SIBLEYVILLE	Moderate—11b	Severe—11b	Moderate—11b	Slight < 8% Moderate > 8%—5
SMOLAN	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—3	Slight < 8% Moderate > 8%—5
SOGN	Severe—10a	Severe—10a	Severe—10a	Slight < 8% Moderate > 8%—5
SOLOMON	Severe—1, 6a, 7	Severe—6a, 7	Severe—3, 6a, 7	Severe—6a, 7
SPEARVILLE	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Slight
STEEDMAN	Severe—11b	Severe—11b	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
STEINAUER	Moderate < 15%—1 Severe > 15%—5	Moderate < 7%—2 Severe > 7%—5	Moderate < 25%—3 Severe > 25%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
STEPHENVILLE	Severe—11b	Severe—11b	Moderate—11b	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
SUMMIT	Severe—1	Moderate < 7%—11c Severe > 7%—5	Severe—3	Slight < 8% Moderate > 8%—5
SUTPHEN	Severe—1, 6a	Severe—6a	Severe—3, 6a	Severe—6a
SWEETWATER	Severe—1, 6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
TABLER	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Slight
TALIHINA	Severe—11a	Severe—11a	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
TALOKA	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Moderate—9
THURMAN	Slight < 8% Moderate 8-15%—5 Severe > 15%—8	Severe—2	Severe—2	Severe—2
TIMKEN	Severe—1, 11a	Severe—11a	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
TINA	Severe—1	Slight	Severe—3	Moderate—6b
TIPTON	Slight	Moderate—2	Slight	Slight
TIVOLI	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Severe—2	Severe—2, 4	Severe—2
TOBIN	Severe—6a	Severe—6a	Severe—6a	Severe—6a
TRAVESSILLA	Severe—11a	Severe—11a	Severe—11a	Slight < 8% Moderate 8-15%—5 Severe > 15%—5

Table 6 (Concluded)

Soil series name	Septic-tank seepage fields	Sewage lagoons	Sanitary landfills: Trench types	Sanitary landfills: Area types
TULLY	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Severe—3	Slight < 8% Moderate > 8%—5
ULY	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Moderate < 7%—2 Severe > 7%—5	Slight < 15% Moderate > 15%—5	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
ULYSSES	Slight < 8% Moderate > 8%—5	Moderate < 7%—2 Severe > 7%—5	Slight	Slight < 8% Moderate > 8%—5
VALENTINE	Slight < 8% Moderate 8-15%—5 Severe > 15%—5	Severe—2	Severe—2, 4	Severe—2
VANOSS	Slight	Moderate—2	Moderate—3	Slight
VERDIGRIS	Moderate to Severe—6a, 6b	Severe—6a	Moderate to Severe—6a, 6b	Moderate to Severe—6a, 6b
VERNON	Severe—1, 11b	Severe—11b	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
VINLAND	Severe—11a	Severe—11a	Moderate—3	Slight < 8% Moderate > 8%—5
VONA	Slight < 8% Moderate > 8%—5	Severe—2	Severe—2	Severe—2
WABASH	Severe—1, 6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
WAKEEN	Severe—11b	Severe—11b	Moderate—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
WALDECK	Severe—6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7
WANN	Severe—6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7	Severe—2, 6a, 7
WAURIKA	Severe—1	Slight	Severe—3	Moderate—9
WELDA	Severe—1	Moderate < 7%—5 Severe > 7%—5	Severe—3	Slight < 8% Moderate > 8%—5
WINDTHORST	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Moderate—3	Slight
WOODSON	Severe—1	Slight < 2% Moderate > 2%—5	Severe—3	Moderate—9
WOODWARD	Severe—11b	Severe—11b	Moderate—11b	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
WYMORE	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Severe—3	Slight < 8% Moderate > 8%—5
YAHOLA	Moderate to Severe—6a, 6b	Severe—2	Severe—2	Severe—2
ZAAR	Severe—1	Slight < 2% Moderate 2-7%—5 Severe > 7%—5	Severe—3	Slight < 8% Moderate 8-15%—5 Severe > 15%—5
ZAVALA	Severe—6a Moderate—6b	Severe—2	Severe—2	Severe—2
ZENDA	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7	Severe—6a, 7
ZOOK	Severe—1, 6a, 7	Severe—6a, 7	Severe—6a, 7, 9	Severe—6a, 7, 9

SUMMARY

This publication encourages the use of detailed soil maps in solving waste-disposal problems in Kansas, in conjunction with other studies. Soil landscapes, soil maps, and soil-profile descriptions of parts of Kansas are briefly explained. Relevant research and soil classification is summarized in narrative and tabular form. Criteria for rating Kansas soils as having slight, moderate, or severe limitations for septic-tank seepage fields, sewage lagoons, and trench-type and area-type sanitary landfills are given, and ratings are made for each of the 300 or so soil series of Kansas. Use of detailed soil information is explained, and references and terms are given for further consultations. Soil maps should be considered to be a first approximation to solution of land use problems; they are most useful when combined with deeper geologic investigations and other complimentary studies.

GLOSSARY

These definitions are for laymen—including geologists, planners, public health officials, and engineers—who may be unfamiliar with some of the terms of soil science. A 27-page glossary of soil science terms, published in 1970, is available from the Soil Science Society of America, 677 South Segoe Road, Madison, Wisconsin 53711, for those who want a more complete listing. A publication (Olson, in press) in the reference list is specially designed to explain exact criteria for interpreting the terms of a soil-profile description. Interpretation of soil-profile descriptions will become increasingly important as more people use soil maps and soil descriptions for waste disposal and many other purposes.

Aerobic—Aerobic conditions of an environment are those with plenty of oxygen or air for respiration and oxidation. Open sewage lagoons are aerobic systems, especially if the water is aerated (mixed). Anaerobic conditions, as in closed septic tanks, are those where oxygen content is deficient. Different sets of organisms decompose materials in the contrasting environments.

Alluvium—Alluvium is soil material deposited by floodwaters. It is stratified in places, and occupies floodplains of Kansas like those illustrated in Figures 4 and 6.

Calcareous—Calcareous soil contains sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1N hydrochloric acid. Kansas soils listed as carbonatic in Table 1 have more than 40 percent by weight carbonates (expressed as $CaCO_3$) plus gypsum, and the carbonates are greater than 65 percent of the sum of carbonates and gypsum.

Colluvium—Colluvium is a deposit of soil material accumulated at the base of steep slopes as a result of gravitational action. Figure 3 shows the relative landscape position of colluvium in Brown County.

Consistence—Soil consistence is the resistance to deformation or rupture and the degree of cohesion or adhesion of the soil mass. Terms used for describing consistence at various soil moisture contents are: nonsticky, slightly sticky, sticky, very sticky, nonplastic, slightly plastic, plastic, very plastic (wet soil); loose, very friable, friable, firm, very firm, extremely firm (moist soil); loose, soft, slightly hard, hard, very hard, extremely hard (dry soil). Exact definitions of these terms are given in the publication by Olson (in press).

Effluent—Effluent is the liquid portion of sewage, especially that handled in septic-tank seepage fields. Limitations of soils of Kansas for disposing of effluent in septic-tank seepage fields are given in Table 2 and Table 6.

Eutrophic—Eutrophic conditions are environmental conditions where concentrations of nutrients are optimal or nearly so for plant or animal growth. Eutrophic conditions in lakes and reservoirs cause growth of weeds and algae, especially when sewage or waste leachates and effluents empty into bodies of water. Good waste management in soils of Kansas can help to avoid or reduce eutrophication of lakes and reservoirs, by preventing excessive nutrient enrichment of the waters.

Friable—See definition of consistence.

Glacial Till—Glacial till is unstratified glacial deposits left by the icemass and consisting of clay, sand, gravel, and boulders intermingled in variable proportions. Only the northeast corner of Kansas has soils formed in glacial till.

Ground Water—Ground water is that portion of the total precipitation which at any particular time is either passing through or standing in the soil and the underlying strata and is free to move under the influence of gravity. Depths to fluctuating ground water or apparent water table in soils of Kansas are given in Table 1.

Interstices—Interstices are the spaces between soil particles, also called pore spaces. Generally they are filled with water or air, and are the scene of most of the biological and chemical activities which are important to ultimate waste disposal and treatment in septic-tank seepage fields and sanitary landfills. The size and shape of interstices in soils are largely determined by particle size (Table 1) and other characteristics of the soil profile (Olson, in press).

Leachate—Leachate is the liquid material sometimes lost from a sanitary landfill, particularly when the landfill is improperly maintained in soils with severe limitations. Liquid material in a septic-tank seepage field is generally called effluent. Both leachates and effluents in soils with slight limitations for waste disposal (Table 6) are generally adequately filtered before reaching the water table, if the waste disposal system is properly maintained.

Loess—Loess is soil material transported and deposited by wind; it consists predominantly of silt-sized particles. Many soils in Kansas have formed in loess deposits (see Figures 3-6).

Mineralogy—Soil mineralogy is the study and characterization of natural inorganic compounds with definite physical, chemical, and crystalline properties (within the limits of isomorphism), that occur in the soil. The mineralogy of soils of Kansas is listed for each specific soil in Table 1.

Moderate Limitations—Moderate limitations are the ratings given to soils that have properties moderately favorable for waste disposal. Moderate limitations can be overcome or modified by special planning, design, or maintenance. During some part of the year moderate soils are less desirable for waste disposal than soils rated slight. Some soils rated moderate for waste disposal require special drainage, extended tile lines, extra excavation, or some other modification. Criteria for moderate limitations for soils for waste disposal are given in Tables 2, 3, 4, and 5; specific soils of Kansas with moderate limitations for waste disposal are listed in Table 6.

Montmorillonite—Montmorillonite is an aluminosilicate clay mineral with a 2:1 expanding crystal structure (with two silicon tetrahedral layers enclosing an aluminum octahedral layer). Considerable expansion may be caused along the C axis by water moving between silica layers of contiguous units. Kansas soils with high content of montmorillonite clays are listed in Table 1; these soils shrink appreciably when dry and swell when wet. This shrinking and swelling has great implications for waste disposal, affecting permeability, tile lines, trafficability, and many other aspects of soil behavior.

Mottles—Soil mottles are spots or blotches of different color or shades of color, indicating wet conditions in Kansas soils. The pattern of mottling and the size, abundance, and color contrast of the mottles varies considerably in different soils and is specified in soil-profile descriptions. Significance of soil mottling to waste disposal in Kansas is discussed in the section on soil-profile descriptions for the Butler soils.

MPN—Most probable number (MPN) is a measurement of numbers of microorganisms in water or some other media. Often the microorganisms are too numerous and too small to be counted, so that a "most probable number" is estimated instead. For coliform bacteria (see discussion of research on soils for waste disposal) a culture medium is generally inoculated with a small amount of soil or water. After incubation, a count of the number of colonies formed on the culture medium enables a "most probable number" to be estimated to give an approximation of the number of organisms present in the original sample.

Nontronite—Nontronite is a clay mineral of montmorillonitic type with a relatively high content of iron (see definition of montmorillonite).

Particle Size—Particle size refers to the grain-size distribution of the whole soil down to a depth of about one meter or to a hard layer or bedrock. The term is a marriage between engineering and pedologic (soil science) classifications. Particle size groups of Kansas soils are given in Table 1 and Figure 12, and are discussed in the section on soil classification. Particle size groups include soils that are sandy-skeletal, loamy-skeletal, clayey-skeletal, sandy, loamy (coarse-loamy, fine-loamy, coarse-silty, fine-silty), and clayey (fine, very-fine).

Ped—A ped is a unit of soil structure such as an aggregate, crumb, prism, block, or granule, formed by natural processes. A pedologist is a person who studies peds and whole soils in their natural state.

Pedologist—See definition of ped.

Percolation Rate—Percolation rate is the rate of downward movement of water through soil. For septic-tank seepage field design it is measured commonly in auger holes in soils with minutes for the water level to drop one inch the unit of measure, indicating the downward flow of water in nearly saturated soil at hydraulic gradients of the order of 1.0 or less. Some of the variabilities of auger hole percolation tests in soils are discussed in the section on soil classification.

Permeability—Permeability is that quality of soil that permits it to transmit gases, liquids, and sewage effluent. Permeability classes (slow, moderate, rapid) are defined in the section on soil classification, and are specified for soils of Kansas in Table 1. Permeability rates (in/hr) are also compared with percolation rates (min/in) in the discussion on soil classification.

ppm—Parts per million (ppm) is a unit of measurement, generally expressed in weight of an element, nutrient, or contaminant as compared with the weight of the media or mass in which it occurs.

Rockiness—Rockiness refers to the relative proportion of bedrock exposures, either rock outcrops or patches of soil very thin over bedrock, in a soil area. The word rocky is used arbitrarily for soils having fixed rock (bedrock). In contrast, the word stony is used for soils having loose detached fragments of rock. Specific classes of rockiness are defined in the publication by Olson (in press). Rockiness classes 0 to 5 in Table 2 and Table 4 indicate increasing proportion of rock in the map units as the numbers increase.

Septic-Tank Seepage Field—A septic-tank seepage field is a system enabling filtration and oxidation of sewage liquids in soils. After sewage digestion in a septic tank, effluent seeps through the soil and is purified over time in the seepage field. Eventually, the water becomes free of health hazards and returns to the ground water for reuse. Figures 21 and 22 are examples of the many kinds of septic-tank seepage fields.

Severe Limitations—Severe limitations are the ratings given to soils that have one or more properties unfavorable for waste disposal, such as steep slopes, bedrock near the surface, flooding hazard, high shrink-swell potential, or unfavorable permeability. This degree of limitation generally requires major soil reclamation, special design, or intensive maintenance. Some soils can be improved by reducing or removing the soil feature that limits use, but most are difficult and costly to alter for waste disposal. Criteria for severe limitations for soils for waste disposal are given in Tables 2, 3, 4, and 5; specific soils of Kansas with severe limitations for waste disposal are listed in Table 6.

Siliceous—Siliceous soils have more than 90 percent by weight of silica minerals (quartz, chalcedony, or opal) and other extremely durable minerals that are resistant to weathering. Kansas soils which are siliceous are listed in Table 1.

Slight Limitations—Slight limitations are the ratings given to soils that have properties favorable for waste disposal. The degree of limitation is minor and can be overcome easily. Good performance and low maintenance can be expected. Criteria for slight limitations for waste disposal are given in Tables 2, 3, 4, and 5; specific soils of Kansas with slight limitations for waste disposal are listed in Table 6.

Slope—Slope is soil surface deviation from the level horizontal plane, measured in percentage (units vertical drop per 100 horizontal units). Thus a slope of 15 percent has 15 feet of vertical drop for each 100 feet of horizontal distance. Slope complexities are also described in the soil survey, where soil map units have undulations or other variations from a simple slope.

Soil—Soil is unconsolidated material several feet thick formed by environmental factors acting on geologic materials over time, conditioned by relief, to produce a sequence of layers or horizons which occupy predictable and mappable parts of landscapes. Soil, as used in this Bulletin, refers to delineations on soil maps and descriptions of those soil map units with depth in the landscapes of Kansas. Soils in landscapes are illustrated in Figures 3-6.

Soil-Drainage Class—Soil-drainage class is determined by mottles and patterns of color in soils, indicating duration and extent of wet conditions. Drainage classes include excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained. The classes are briefly discussed in the section on soil classification, are specified for Kansas soils in Table 1, and are more completely defined in the Soil Survey Manual (Soil Survey Staff, 1951).

Soil Map—A soil map is a map showing the distribution of different soil map units in relation to the prominent physical and cultural features in the geography of Kansas. Examples of soil maps are given in Figures 27-29.

Soil Profile—A soil profile is an exposed section of soil commonly described for each soil map unit in a soil survey. Figure 8 is an illustration of a soil profile.

Soil Series—Soil series is the basic unit of soil classification consisting of soils which are essentially alike in all major characteristics except the texture of the surface horizon. Soil series are generally named for the places where they were first identified; Table 1 and Table 6 list the soil series mapped in Kansas.

Stoniness—Stoniness refers to the number and kinds of loose coarse fragments in or on soils. Specific classes of stoniness are defined in the publication by Olson (in press). Stoniness classes 0 to 5 in Table 2 and Table 4 indicate increasing stoniness as the numbers increase.

Structure—Soil structure is the combination or arrangement of primary soil particles into secondary particles, units, or peds. These secondary units may be arranged in the profile in a distinctive characteristic pattern. The secondary units are characterized and classified on the basis of size, shape, and degree of distinctness into classes, types, and grades. Classes (size) include fine, medium, and thick; types (shape) include plates, prisms, blocks, and granules; grades (degree of distinctness) include weak, moderate, strong, and structureless. Structure examples are given in the section on soil profile descriptions for some soils of Kansas; exact definitions of the terms are in the publication by Olson (in press).

Texture—Soil texture is the relative proportion of sand (0.05-2.0 mm diameter), silt (0.002-0.05 mm diameter), and clay (less than 0.002 mm diameter) in a soil sample. Soil textures include sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. Soil textures are precisely defined in the publication by Olson (in press).

Trafficability—Trafficability of soils is the relative ease or difficulty with which wheeled or crawler-type vehicles can move over the soils. Trafficability is a general term, dependent upon type of soil materials (see definition of unified soil classification), depth to water table, soil moisture content, slope, and many other factors. Trafficability of soils is especially critical for heavy equipment during installation of septic-tank seepage fields, construction of sewage lagoons, and covering of sanitary landfill in Kansas soils. Wet clayey soils (Figure 9) with high content of montmorillonite (listed in Table 1) generally have poor trafficability; well-drained soils with loamy textures (Table 1) on level or gentle slopes generally have good trafficability. Soil consistence (see definition of consistence) is another good indicator of soil trafficability.

Unified Soil Classification—The unified soil classification is a system of categorization of soil materials, particularly relevant for excavations and embankments of sewage lagoons as listed in Table 3. The classification is outlined for laymen in a publication by Olson (1972a), available from the Department of Agronomy (Soils), Cornell University, Ithaca, New York 14850. Briefly, the unified soil groups listed in Table 3 are:

- GW—Well-graded gravel, gravel and sand mixtures, little or no fines
- GP—Poorly graded gravel, gravel and sand mixtures, little or no fines
- GM—Silty gravel, gravel and sand and silt mixtures
- GC—Clayey gravel, gravel and sand and clay mixtures
- SW—Well-graded sands, gravelly sands, little or no fines
- SP—Poorly graded sands, gravelly sands, little or no fines
- SM—Silty sands, sand and silt mixtures
- SC—Clayey sands, sand and clay mixtures
- ML—Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity
- CL—Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, lean clays
- OL—Organic silts and organic silty clays of low plasticity
- MH—Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
- CH—Inorganic clays of high plasticity, fat clays
- OH—Organic clays of medium to high plasticity, organic silts
- Pt—Peat and other highly organic soils

Water Table—Water table is the upper surface of ground water or that level below which the soil is saturated with water. Apparent water table is the level to which the water level rises when holes are dug in soils. Obviously, waste disposal is difficult when apparent water tables are high in soils. Table 1 lists the seasonal depths to apparent water table in Kansas soils.

ENGLISH-METRIC CONVERSION TABLE

Linear Measure
1 inch = 2.54 centimeters (cm)
1 foot = 30.48 cm = 0.3048 (m)
1 mile = 1.609 kilometers (km)
1 centimeter = 0.39 inches
1 meter = 3.281 ft = 39.37 in
1 kilometer = 0.621 miles

Square Measure
1 square foot = 0.093 m^2
1 square mile = 259 hectares (ha)
1 acre = 0.405 ha
1 hectare = 0.01 km^2 = 2.471 acres
1 square kilometer = 0.386 $mile^2$

Cubic Measure
1 cubic foot = 0.028 m^3
1 cubic meter = 35.3 ft^3

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Map compiled by O. W. Bidwell, Kansas Agricultural Experiment Station, and C. W. McBee, Soil Conservation Service, Salina, Kansas

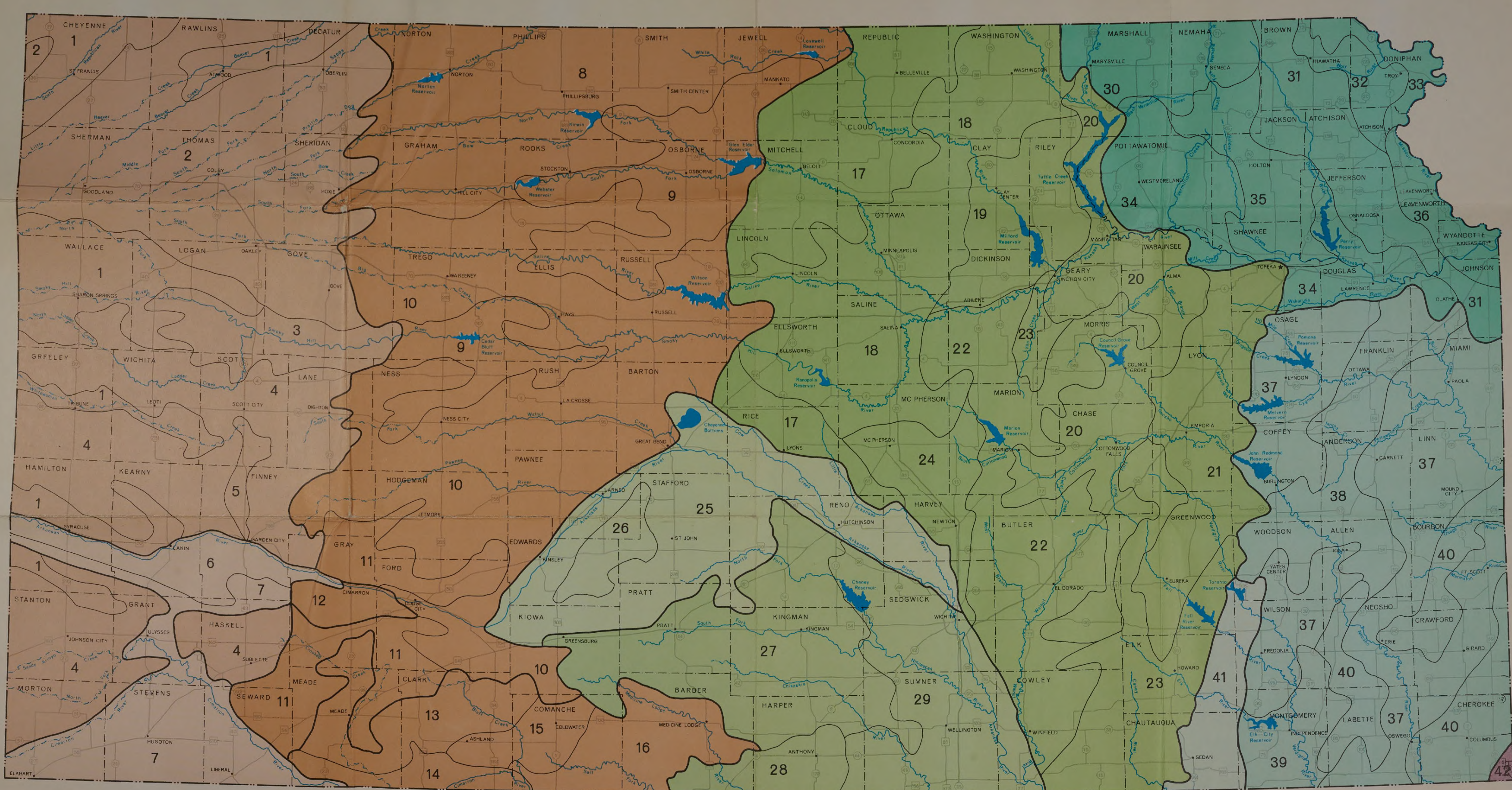
Mary Clawson, Cartographer

SOILS OF KANSAS

1973

KAES Department of Agronomy Contribution No. 1359

Published by the Kansas Agricultural Experiment Station, Floyd Smith, Director, Kansas State University, Manhattan, in cooperation with the Soil Conservation Service, Lee T. Morgan, State Conservationist, U. S. Department of Agriculture, Salina



SOIL LEGEND

Numbered areas represent soil associations composed of major soils, listed in order of extent. Named soils occur in distinctive proportional patterns on the landscape. A soil of one association may occur in a different proportional pattern in another association.

Names of soil groups and soil series are those adopted by the National Cooperative Soil Survey.

MILES 10 0 10 20 30 40

KILOMETERS 10 0 10 20 30 40 50

ARIDIC USTOLLS

Ustolls, Orthents, and Ustalfs
Deep, grayish-brown and dark grayish-brown silt loams; depth to secondary carbonates, less than 36 inches; average annual temperature at 20 inches, less than 59°

1 Ulysses, Colby
2 Keith, Ulysses
3 Elkader, Ulysses
4 Richfield, Ulysses
5 Ulysses, Drummond

Ustalfs, Psamments, Ustolls, and Argids
Deep, grayish-brown silt loams and sandy loams, and pale-brown loamy fine sands and fine sands; depth to secondary carbonates, from less than 36 inches to greater than 60 inches in the Psamments and Ustalfs; average annual temperature at 20 inches, less than 59°

6 Tivoli, Vona
7 Dalhart, Richfield, Vona

TYPIC USTOLLS

Ustolls and Usterts
Deep and moderately deep, dark grayish-brown silt loams and moderately deep, gray clays; depth to secondary carbonates, less than 36 inches; average annual temperature at 20 inches, less than 59°

8 Holdrege, Uly
9 Harney, Bogue
10 Harney, Uly, Wakeen
11 Harney, Spearville

Ochrepts, Ustolls, Ustalfs, and Psamments
Moderately deep and shallow, reddish-brown loams and clays, and deep, grayish-brown silt loams and clay loams and pale-brown loamy fine sands and fine sands; depth to secondary carbonates, from less than 36 inches to more than 60 inches in the Psamments and Ustalfs; average annual temperature at 20 inches, greater than 59°

12 Manter, Pratt
13 Mansic, Mansker
14 Tivoli, Pratt
15 Woodward, Carey
16 Vernon, Woodward, Quinlan

UDIC USTOLLS

Ustolls, Usterts, and Udolls
Deep, moderately deep, and shallow, dark grayish-brown and very dark grayish-brown silt loams, silty clay loams, and silty clays; depth to secondary carbonates, more than 36 inches; average annual temperature at 20 inches, less than 59°

17 Crete, Hastings, Kipson
18 Lancaster, Smolan, Hedville
19 Wymore, Irwin, Clime
20 Florence, Irwin, Sogn
21 Ladysmith, Labette, Tully
22 Irwin, Ladysmith
23 Clime, Tully, Sogn
24 Ladysmith, Goessel

Ustalfs, Ustolls, and Aquolls
Deep, dark grayish-brown loams and fine sandy loams and pale-brown loamy fine sands; depth to secondary carbonates, more than 36 inches; average annual temperature at 20 inches, greater than 59°

25 Pratt, Carwile
26 Naron, Carwile

Ustolls
Deep, dark grayish-brown and brown fine sandy loams, loams, and silt loams; depth to secondary carbonates, more than 36 inches; average annual temperature at 20 inches, greater than 59°

27 Farnum, Shellabarger
28 Pond Creek, Grant
29 Bethany, Tabler

TYPIC UDOLLS

Udolls, Udalfs, and Ustolls
Deep and shallow, black and very dark-brown silt loams, clay loams, and silty clay loams; depth to secondary carbonates, more than 60 inches; average annual temperature at 20 inches, less than 59°

30 Wymore, Pawnee
31 Grundy, Pawnee
32 Sharpsburg, Marshall
33 Monona, Marshall
34 Martin, Pawnee, Sogn
35 Pawnee, Shelby
36 Sharpsburg, Ladoga, Knox

Udolls, Aquolls, and Aqualfs
Deep and moderately deep, very dark grayish-brown and black silt loams, clay loams, and silty clay loams; depth to secondary carbonates, more than 60 inches; average annual temperature at 20 inches, greater than 59°

37 Summit, Lula, Woodson
38 Woodson, Kenoma
39 Eram, Dennis, Bates
40 Parsons, Dennis

Ochrepts, Udolls, and Ustalfs
Moderately deep, very dark grayish-brown clay loams, and shallow and moderately deep, dark-brown fine sandy loams and cobbly fine sandy loams; depth to secondary carbonates, more than 60 inches; average annual temperature at 20 inches, greater than 59°

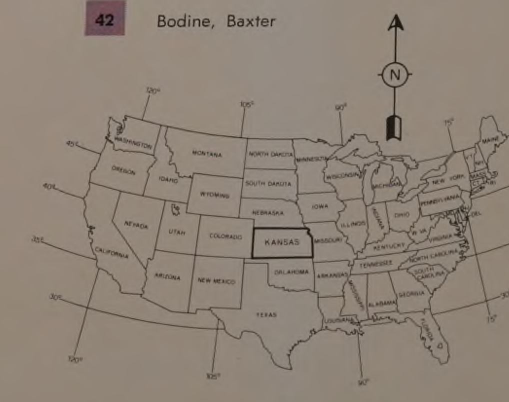
41 Darnell, Niotaze, Eram

TYPIC UDULTS

Udults
Deep, brown cherty silt loams; depth to secondary carbonates, more than 60 inches; average annual temperature at 20 inches, greater than 59°

42 Bodine, Baxter

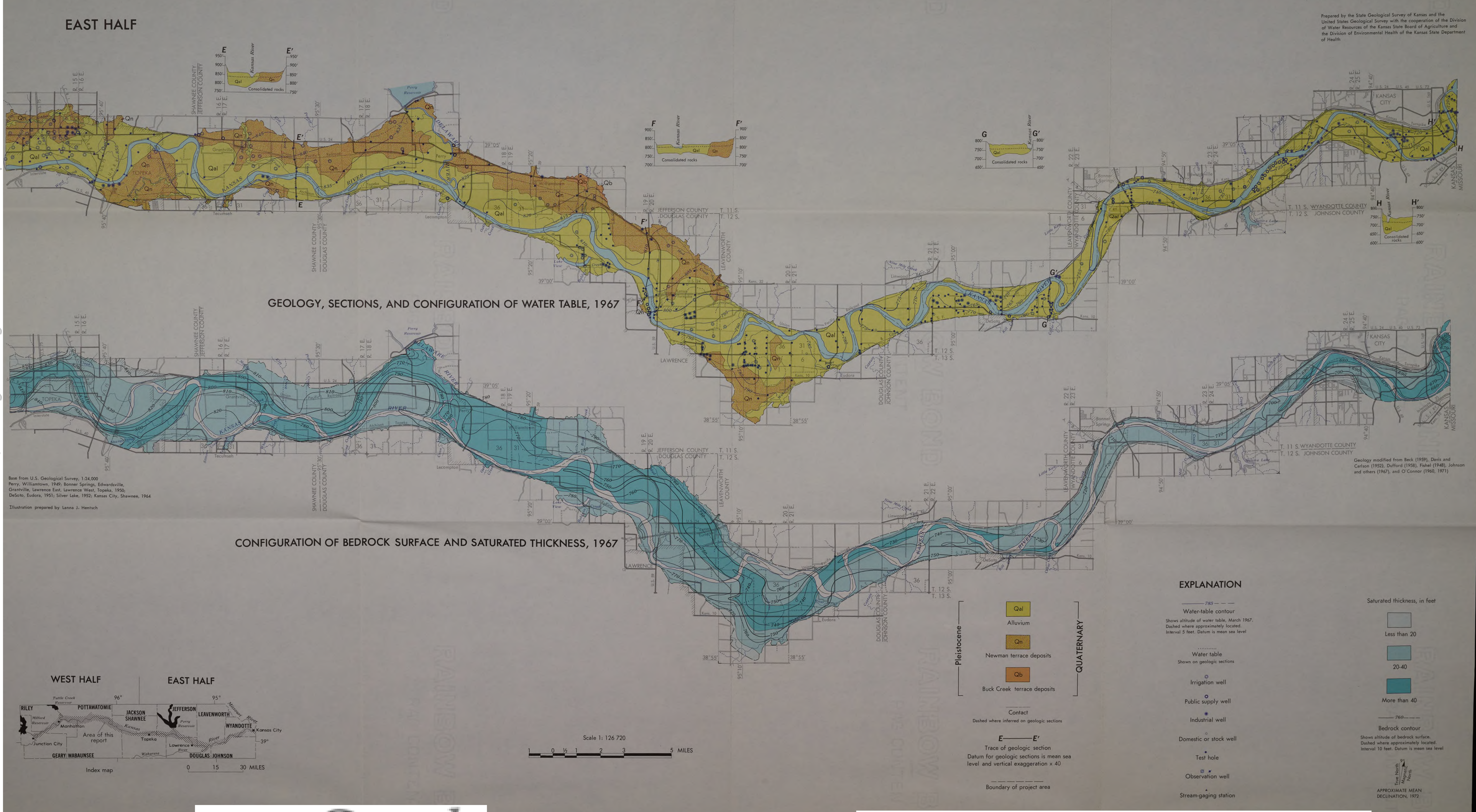
Scale 1:1,125,000   1 inch = 17.5 miles
Lambert Conformal Conic Projection



State Geological Survey of Kansas

GEOHYDROLOGY IN KANSAS RIVER VALLEY, JUNCTION CITY TO KANSAS CITY, KANSAS

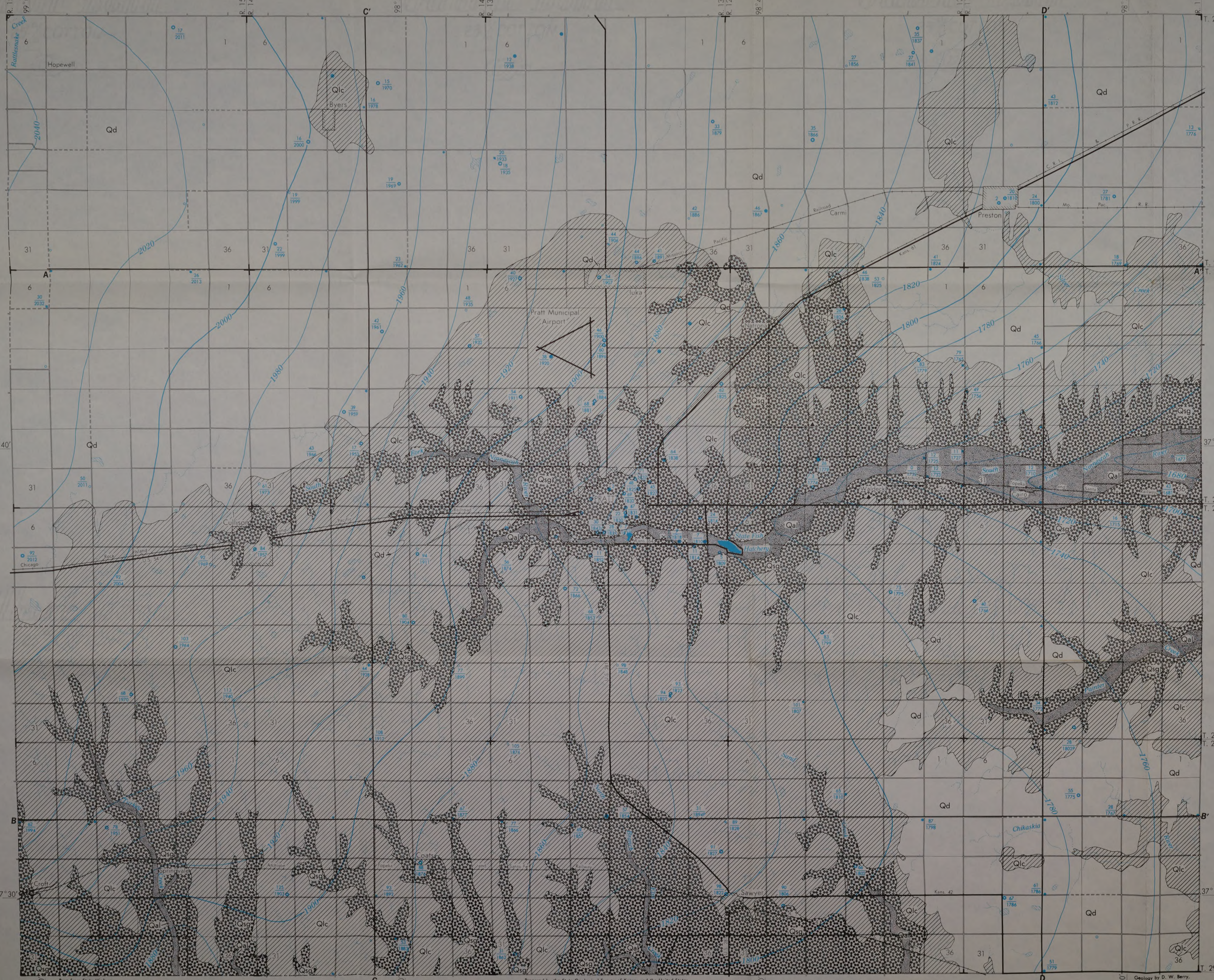
Bulletin 206
Part 2
Plate 2



State Geological Survey
of Kansas

GEOHYDROLOGIC MAP OF PRATT COUNTY, KANSAS

Bulletin 205
Plate 1



Base from State Highway Commission of Kansas, 1962, and U.S. Geological Survey, 1959

Prepared by the State Geological Survey of Kansas and the United States Geological Survey, with the cooperation of the Division of Water Resources of the Kansas State Board of Agriculture and the Division of Environmental Health of the Kansas State Department of Health

Geology by D. W. Berry, 1951, and D. W. Layton, 1964. Potentiometric contours by D. W. Layton, 1964.

EXPLANATION

QUATERNARY SYSTEM — Pleistocene Series

Wisconsinan to Recent

Qal — **Alluvium and terrace deposits**
Silt, sand, and gravel with minor amounts of clay in or near channels of major streams. Yields small to medium quantities of water to wells.

Qd — **Dune sand**
Fine sand and silt with minor amounts of clay in upland areas. Generally lies above potentiometric surface.

Illinoisan

Qlc — **Loveland and Crete Formations**
Sand and gravel in lower part; sand and silt in upper. Contains clay lenses and caliche locally. Yields small to medium quantities of water to wells.

Kansan

Qsg — **Sappa and Grand Island Formations**
Sand and gravel with minor amounts of silt and clay lenses in lower part. Sand, silt, and minor amounts of gravel, clay, and caliche in upper part. Locally contains a lens of Pearlette volcanic ash near top. Yields large quantities of water to wells.

Contact
Approximately located

A —— A′
Geologic section
Sections shown on plate 2

Gravel pit

Ash deposit

—1800—
Potentiometric contour
Shows altitude at which water level would have stood in tightly cased wells in Quaternary deposits, 1964. Contour interval 20 feet. Datum is mean sea level

28 / 1802P
Upper number is depth to water, in feet below land surface. Lower number is altitude of potentiometric surface, in feet above mean sea level. P indicates perched water table

Domestic, stock, or unused well

Municipal or public supply well

Industrial supply well

Irrigation well

Test hole

Observation well

Numeral indicates number of wells at same location

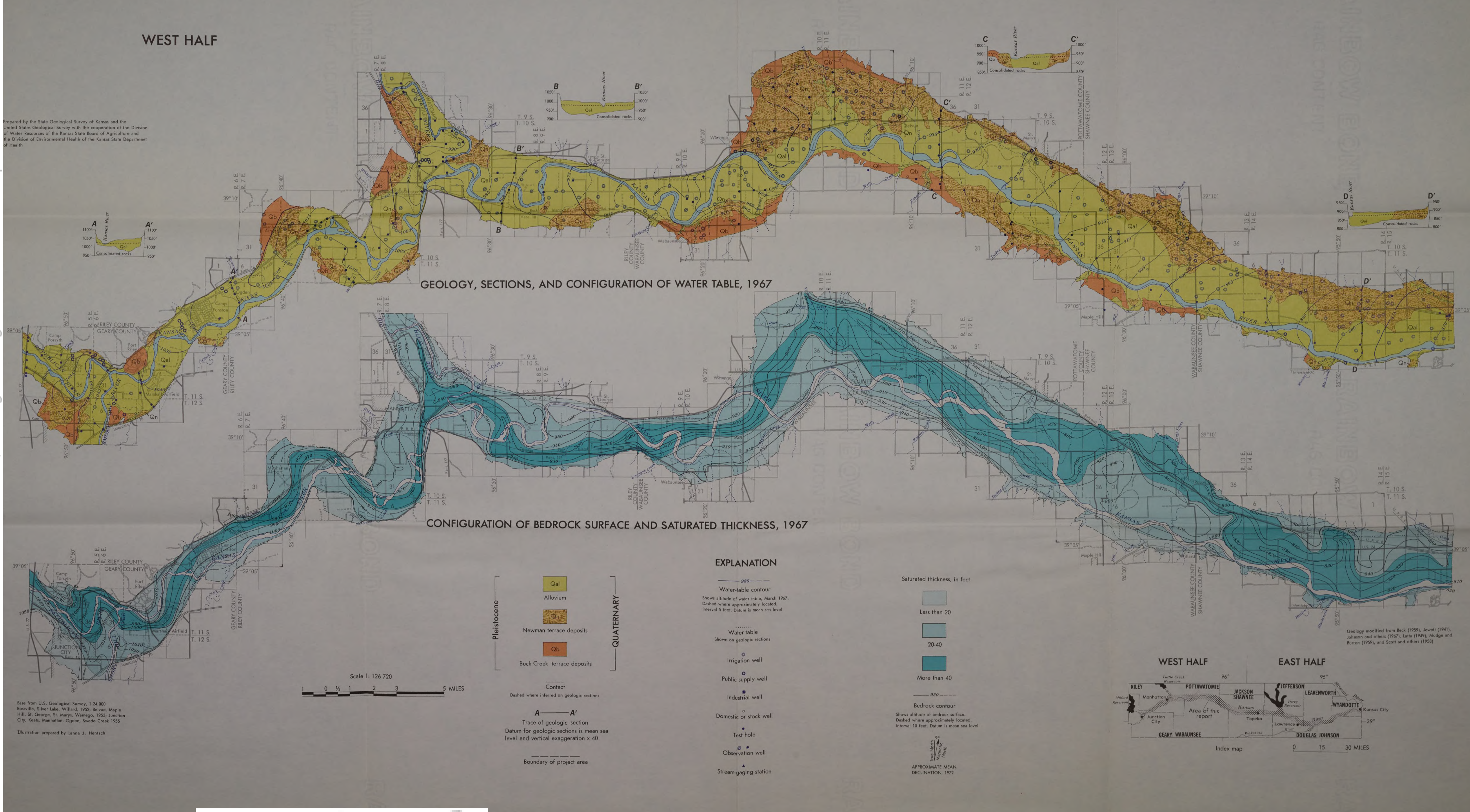
True North / Magnetic North 10°
APPROXIMATE MEAN DECLINATION, 1972

Scale 1: 84 480
0 ½ 0 1 2 3 MILES

State Geological Survey
of Kansas

GEOHYDROLOGY IN KANSAS RIVER VALLEY, JUNCTION CITY TO KANSAS CITY, KANSAS

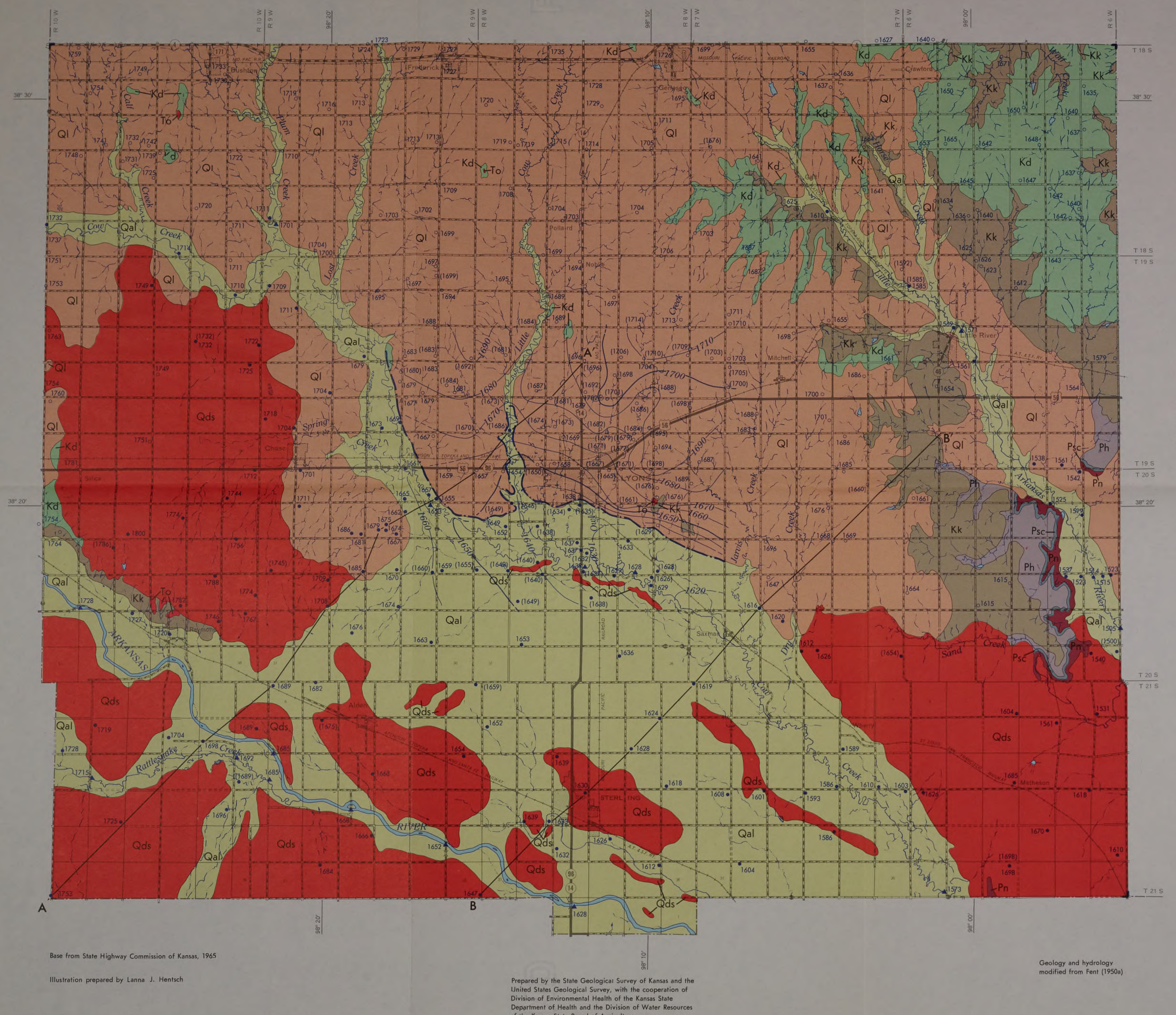
Bulletin 206
Part 2
Plate 1



State Geological Survey
of Kansas

GEOHYDROLOGIC MAP OF RICE COUNTY, CENTRAL KANSAS

Bulletin 206
Part 3
Plate 1



Base from State Highway Commission of Kansas, 1965

Illustration prepared by Lanna J. Hentsch

Prepared by the State Geological Survey of Kansas and the United States Geological Survey, with the cooperation of Division of Environmental Health of the Kansas State Department of Health and the Division of Water Resources of the Kansas State Board of Agriculture.

Geology and hydrology modified from Fent (1950a)

EXPLANATION

QUATERNARY SYSTEM — Pleistocene Series

Qal — Alluvium and terrace deposits

Alluvium (Recent) consists of silt, sand, and gravel in the Arkansas Valley; yields brackish water to a few domestic and stock wells. Terrace deposits (Wisconsinan) consist of gravel, sand, and some silt in tributary valleys to the north. In Arkansas Valley yields large quantities of moderately hard water.

Qds — Dune sand

Medium sand, some fine sand and silt. Generally above the water table, but yields water to a few wells in the large dune tracts. Locally overlies fluvial deposits, which yield moderate to large quantities of water.

Ql — Loess

Silt, mostly eolian. Principally loess of Loveland Formation (Illinoisan) and Peoria Formation (Wisconsinan), but may contain some loess of Bignell Formation (Wisconsinan). Locally present in thin deposits in upland areas and overlies fluvial deposits in abandoned-channel areas. Yields small quantities of water to wells locally.

TERTIARY SYSTEM — Pliocene Series

To — Ogallala Formation

Soil caliche with distinctive pink banding occurring as thin deposits marking topography at end of Pliocene Epoch. Yields no water to wells.

CRETACEOUS SYSTEM — Lower Cretaceous Series

Kd — Dakota Formation

Clay, silt, shale, sandstone, and siltstone, locally cemented with hematite and limonite. Contains lignite and locally beds of quartzitic sandstone. Colors are white, red, gray, brown, and tan. Yields small to moderate quantities of water to wells from sandstone beds.

Kk — Kiowa Formation

Shale, fissile, light-gray, dark-gray, and black. Contains thin sandstone bodies throughout and a persistent thick light-colored sandstone at top. Beds of cone-in-cone, quartzitic sandstone, siltstone, and thin limestone are common. A marine molluscan fauna occurs in the limestone. Yields small to moderate quantities of water to wells from the sandstone.

PERMIAN SYSTEM — Lower Permian Series

Ph — Harper Sandstone

Red siltstone and fine-grained silty sandstone. Yields little or no water to wells in Rice County.

Psc — Stone Corral Formation

White and light-gray limestone and dolomite. Yields small quantities of mineralized water to wells in Rice County.

Pn — Ninnescah Shale

Shale, siltstone, and very fine grained silty sandstone. Yields little or no water to wells in Rice County.

Contact

A——A′ Trace of section

Boundary between Pleistocene and Cretaceous aquifers

Well or test hole in Pleistocene aquifer

Well or test hole in Cretaceous aquifer

Stream water-level-measurement site

(1704) 1700

Numbers are altitudes of water levels above mean sea level, in feet. Number in parentheses is 1970 measurement; number without parentheses is 1946 measurement

1640

Potentiometric contour

Shows altitude at which water level would have stood in tightly cased wells in Pleistocene and Cretaceous aquifers, 1970. Dashed where approximately located. Contour interval 10 feet. Datum is mean sea level

In this report small quantities refers to yields generally less than 10 gpm, moderate quantities 10-100 gpm, and large quantities 100-2,000 gpm

9°
True North
Magnetic North

APPROXIMATE MEAN DECLINATION, 1973

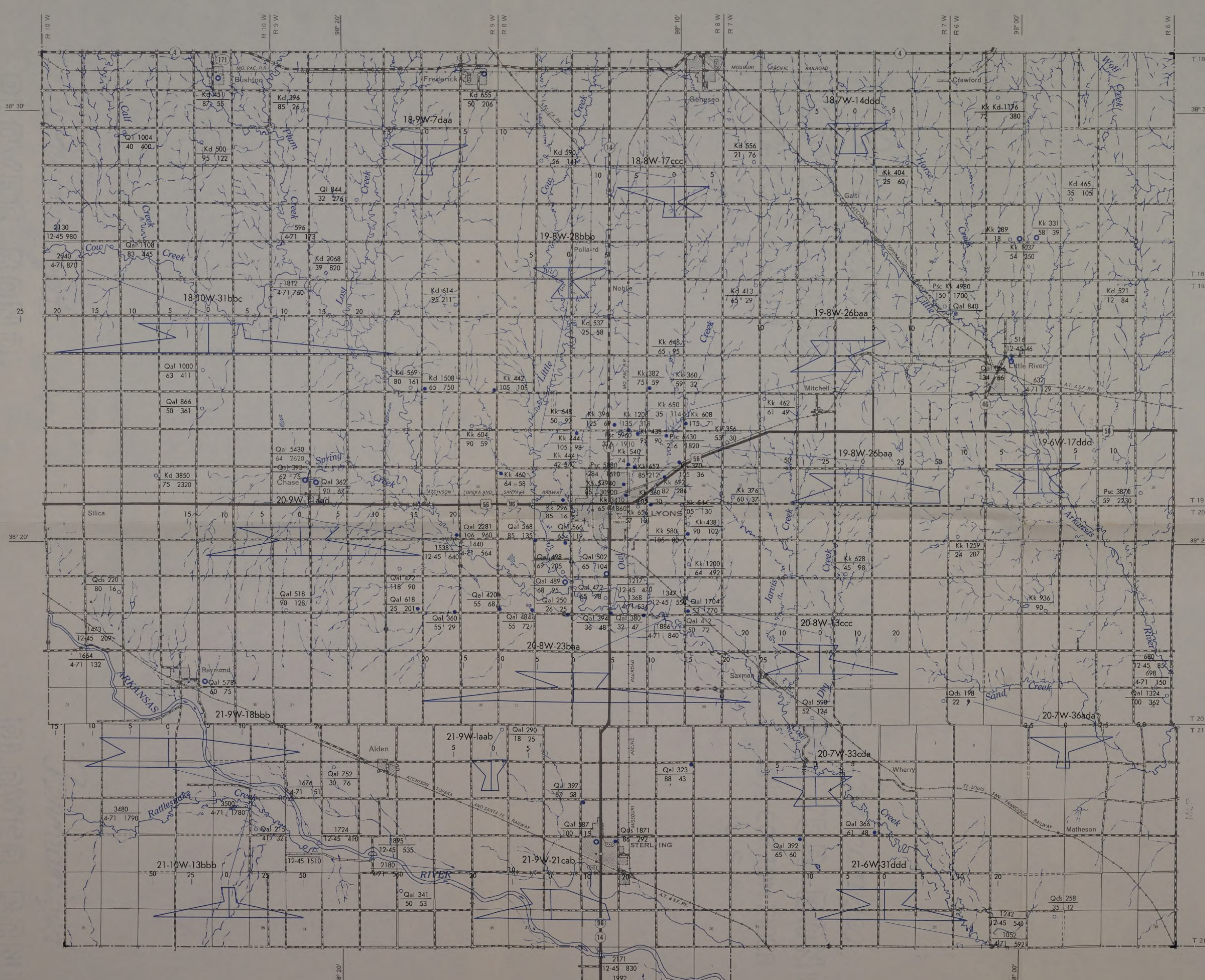
Scale 1:126 720

1 0 ½ 1 2 3 MILES

State Geological Survey
of Kansas

MAP SHOWING WATER QUALITY IN RICE COUNTY, CENTRAL KANSAS

Bulletin 206
Part 3
Plate 2



EXPLANATION

GROUND WATER

Test hole

Domestic or stock well

Municipal well

Qal 323
88 43

Upper left symbol is aquifer (see list below); upper right number is concentration of dissolved solids, in milligrams per liter. Lower left number is depth of well or test hole below land surface, in feet; second number is concentration of chloride, in milligrams per liter

- Qal — Alluvium and terrace deposits
- Qds — Dune sand
- Ql — Loess
- Kd — Dakota Formation
- Kk — Kiowa Formation
- Psc — Stone Corral Formation

SURFACE WATER

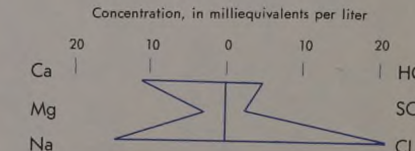
Stream sampling site

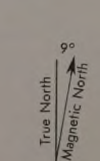
1242
12-45 540

Upper number is concentration of dissolved solids, in milligrams per liter. Lower left number is month and year sample was collected; second number is concentration of chloride, in milligrams per liter

WATER QUALITY

Sample pattern diagram and well number





APPROXIMATE MEAN DECLINATION, 1973

Scale 1:126 720

1 0 ½ 1 2 3 MILES

Base from State Highway Commission of Kansas, 1965

Illustration prepared by Lanna J. Hentsch

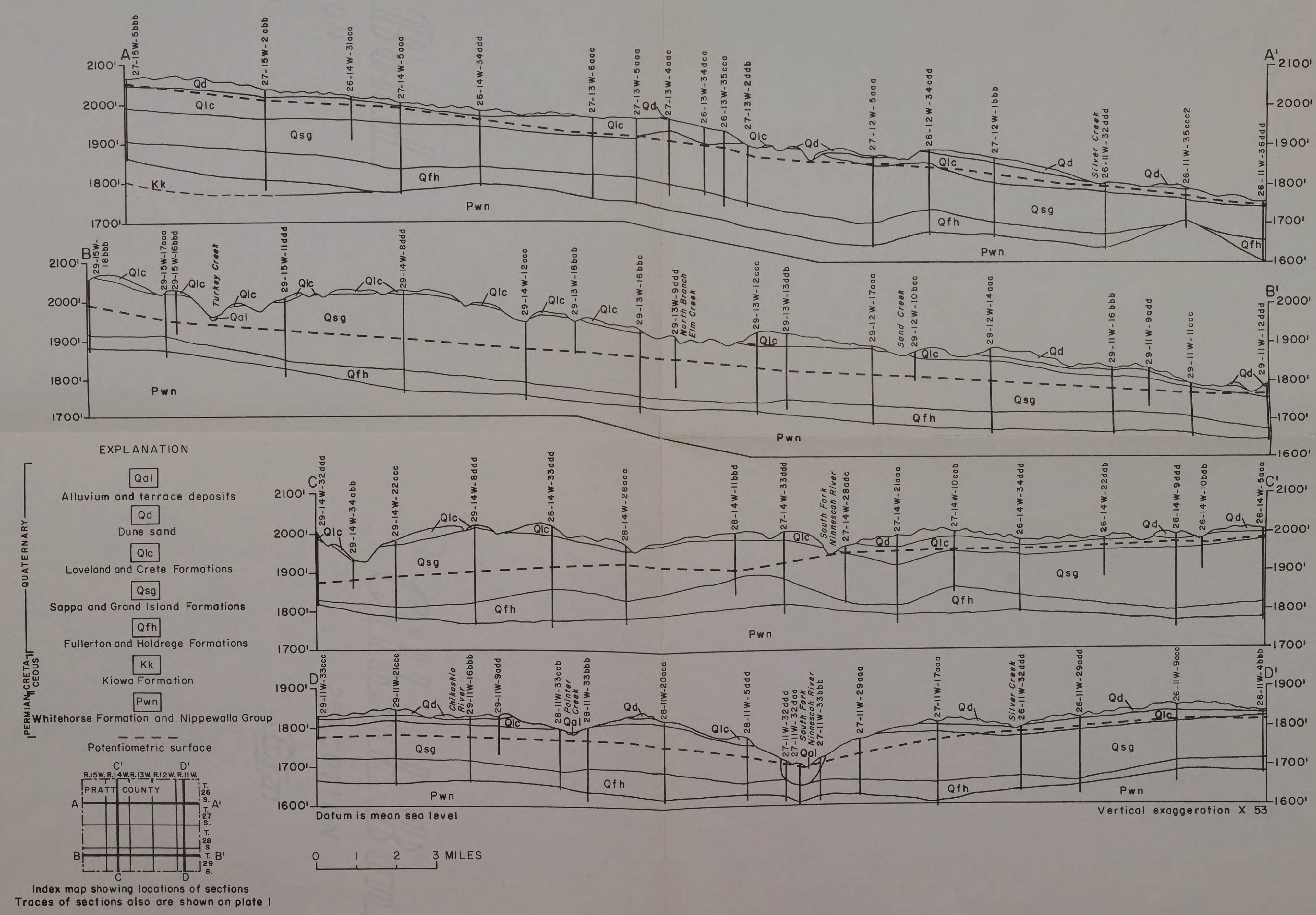
Prepared by the State Geological Survey of Kansas and the United States Geological Survey, with the cooperation of Division of Environmental Health of the Kansas State Department of Health and the Division of Water Resources of the Kansas State Board of Agriculture.

Data in part from Fent (1950a)

State Geological Survey
of Kansas

Bulletin 205
Plate 2

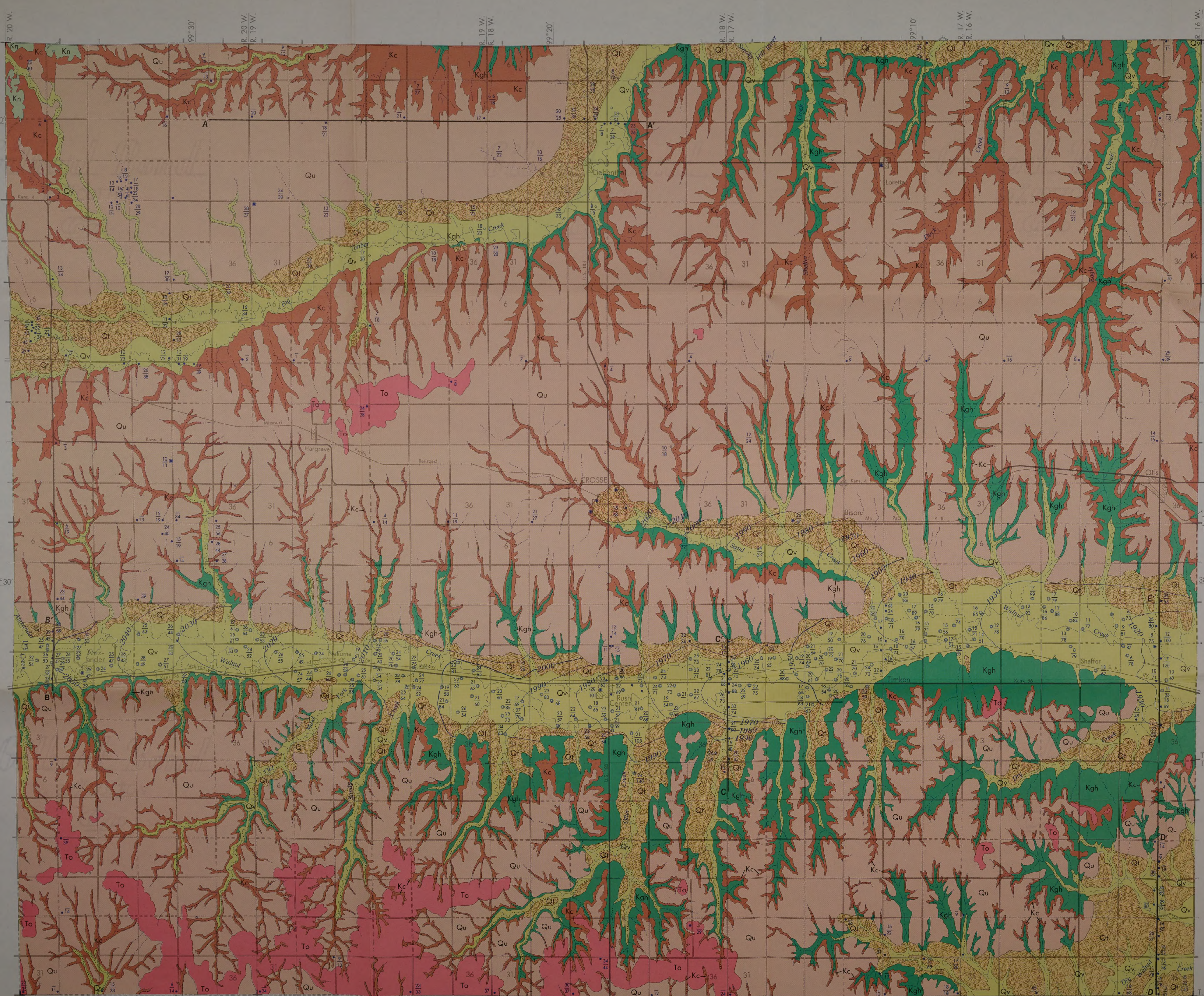
GEOLOGIC SECTIONS IN PRATT COUNTY, KANSAS



State Geological Survey
of Kansas

GEOHYDROLOGIC MAP OF RUSH COUNTY, KANSAS

Bulletin 207
Plate 1



Base from maps by U.S. Soil Conservation Service (1947) and State Highway Commission of Kansas (1968)

Prepared by the State Geological Survey of Kansas and the United States Geological Survey, with the cooperation of the Division of Environmental Health of the Kansas State Department of Health and the Division of Water Resources of the Kansas State Board of Agriculture

Geohydrology by Jesse M. McNellis, 1960

EXPLANATION

QUATERNARY — Pleistocene

Qu — Undifferentiated deposits

Eolian, fluvial, and colluvial deposits of mostly silt, which may overlie sand and some gravel. May yield small to moderate quantities of water to wells.

Qv — Valley-fill deposits

Fluvial and eolian deposits of gravel, sand, silt, and clay. May yield moderate to large quantities of water to wells in Walnut Creek valley and small to moderate quantities of water to wells in other stream valleys.

Qt — Terrace deposits

Fluvial and eolian deposits of gravel, sand, silt, and clay in terrace position to stream courses. May yield small to moderate quantities of water to wells.

TERTIARY — Pliocene

To — Ogallala Formation

Fluvial deposits of gravel, sand, silt, and clay; soil caliche (referred to as "algal limestone"); and quartzitic-appearing green conglomerate with an opaline matrix. Occurs on divide areas. Not known to yield water to wells.

CRETACEOUS — Upper Cretaceous

Kn — Fort Hays Limestone Member of the Niobrara Chalk

Marine deposits of massive chalky limestone. Only lowest part present. Yields no water to wells.

Kc — Carlile Shale

Marine deposits of chalky limestone, noncalcareous to chalky shale containing large concretions and thin bentonite beds, and friable silty sandstone. Not known to yield water to wells.

Kgh — Greenhorn Limestone

Marine deposits of alternating chalky limestone and chalky shale containing thin bentonite beds. Not known to yield water to wells.

Contact

A —— A′
Trace of geologic section
Sections shown on figure 6

—— 1940 – – –
Water-table contour
Shows altitude of water-table, 1960. Dashed where approximately located. Contour interval 10 feet. Datum is mean sea level

Domestic or stock well

Public supply well

Irrigation well

Test hole

Observation well

34/56
Upper number is depth to water and lower number is depth to bedrock, if known, or depth of well, in feet below land surface

10°
True North
Magnetic North
APPROXIMATE MEAN DECLINATION, 1972

Scale 1: 84 480

1 ½ 0 1 2 3 MILES