

KANSAS GEOLOGICAL SURVEY OPEN-FILE REPORT 73-4

APPLICATIONS OF GEOLOGY TO LAND USE PLANNING IN THE CLINTON RESERVOIR SANITATION ZONE, DOUGLAS COUNTY, KANSAS

by

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APPLICATIONS OF GEOLOGY TO LAND USE PLANNING IN THE
CLINTON RESERVOIR SANITATION ZONE, DOUGLAS COUNTY, KANSAS

by

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Instructor in charge

For the Department

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ABSTRACT

This study deals with problems related to geologic conditions met by expanding communities. The Clinton reservoir sanitation zone lies within the "Suburban Growth Area" of the City of Lawrence, Kansas. Environmental planning for the area deals with such community needs and activities as water supply, flood hazard, on site soil absorption systems, solid waste disposal, general excavation, mineral resources, and recreational resources. Geologic data is vital to environmental planning and needs to be used by planners in making plans for local projects.

The presentation of geologic data in this study has proved to be successful so that the probable environmental impact of future land use can be more adequately addressed.

Specific physical data have been gathered in the field and from other sources. Maps have been prepared to show topography, percent slope, bedrock geology, soils, thickness of common excavation material, stream drainage network, and sub-basins. Soil types and bedrock geology have been mapped according to their engineering properties. A suitability map for on site soil absorption systems, the most critical land use for the Clinton reservoir area, also is included.

INTRODUCTION

Purpose of Study

Problems have been encountered with several reservoirs in Kansas that could have been alleviated or avoided if geologic data had been utilized in the planning stages. As examples, John Redman reservoir was polluted by run off from feedlots in the upper reaches in 1967, so that the reservoir had to be closed for three weeks (Stoltenberg, personal communication). The problem was abated by relocation of some feedlots and the building of retention structures around others, but with the right kind of storm it could be polluted again. The Nemaha County State Lake is practically filled with sediment and no longer satisfactory for most recreational activities (Shull, personal communication).

Evaluation of geological factors is a fundamental step in designing land use plans for all man's activities, yet the usual geologic reports are not designed to meet the needs of contemporary society in this realm. This point was well illustrated by the disastrous earth in Anchorage, Alaska in 1964. "Although modern topographic and geologic maps of the area were available prior to the earthquake, and a geological report clearly mentioned the possibility that land slides could be triggered by earthquakes, there was no general

awareness on the part of the public or of responsible officials that such a danger existed. The report had correctly assessed potential hazards in the event of a strong seismic shock but the public did not recognize the warning. Obviously, unless a different approach is adopted there is little need for preparing similar geologic reports because they most likely will go unheeded or unused" (Hilpman and Stewart, 1968).

The construction of the Clinton reservoir dam southwest of Lawrence, Kansas will stimulate development in the surrounding area. It will be more intensely used than nearby Perry reservoir or similar recreational areas. This intense use affords an opportunity to further demonstrate to land use planners the need for and applicability of geologic data to plans developed for local projects, and permits the development of better techniques for data gathering and presentation and to communicate with a society that demands environmental data.

Prior geologic investigations of the area have not been addressed to the kinds of problems that will be met by the expanding community, especially those that result from the development of recreational facilities and the probable increase in pollution. Most studies have been concerned primarily with problems of stratigraphy, sedimentation, structure, and paleontology. Problems concerning slope, soil, depth to

bedrock, and engineering applications have not been studied.

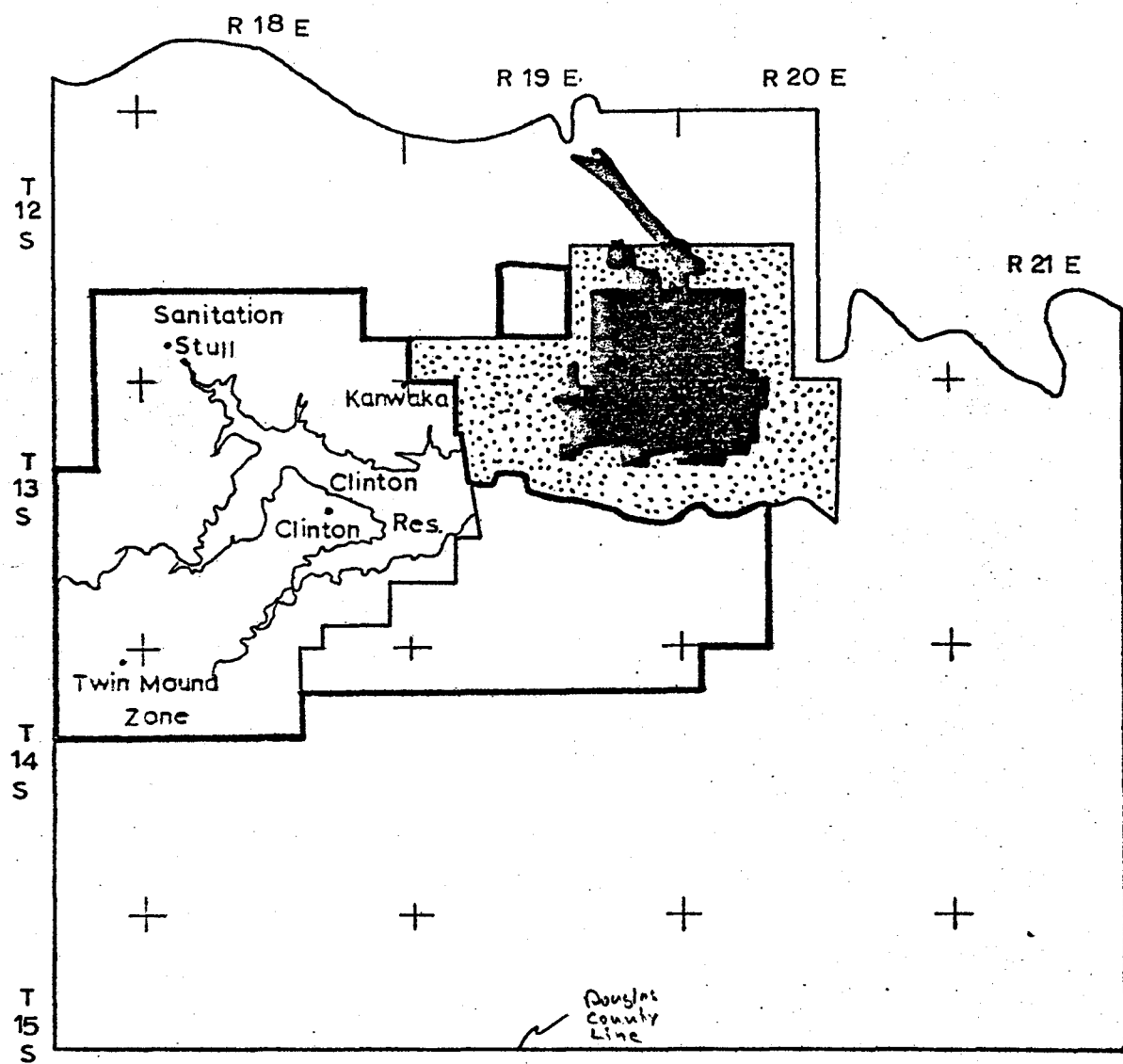
The sequence of rocks in the study area consists of six formations of the Pennsylvanian System (Moore, 1951). Similar shale and limestone units extend over a wide area of the midcontinent and make it possible to apply the same methods of study and conclusions to many populated areas of the state and to similar areas in the midwest.

Location

This study was limited to the area within the boundaries of the Clinton reservoir sanitation zone (Fig. 1), in west central Douglas County in northeastern Kansas. Conditions outside of the zone that are important to conclusions reached about land use within it, however, were taken into account. The Clinton reservoir sanitation zone is within two miles of the present limits of the City of Lawrence. It consists of seventy-four square miles.

Previous Work

The general geology of Douglas County and the surrounding region has been studied by numerous workers over the past seventy years. Stratigraphic descriptions and classifications were made by Haworth (1894a, 1895), Bennett (1896),



Scale:

-  City of Lawrence Corporate Limits
-  Primary Urban Growth Area
-  Suburban Growth Area
-  Small Communities

Fig. 1 Clinton reservoir sanitation zone and projected growth areas of Lawrence, ~~Kansas~~, Douglas County, Kansas

Wing (1921), Moore (1932, 1936, 1949), Rich (1932a, 1932b, 1933), Patterson (1933), Moore, Elias, and Newell (1934), Newell (1935), Hoover (1936), Moore and Landes (1937), Moore, Frye, and Jewett (1944), Frye and Walters (1950), Lins (1950), O'Connor and others (1955), Ball (1957), Laughlin (1957), Sanders (1957), O'Connor (1960), and Johnson and Adkison (1967).

Geomorphic studies were done by Todd (1909, 1911, 1918a, 1918b), Haworth (1894b), Schoewe (1923, 1924, 1930a, 1930b, 1930c, 1949), and Frye and Leonard (1952).

Coal resources were discussed by Haworth (1898), Whitla (1940), Bowsher and Jewett (1943), and Abernathy, Jewett, and Schoewe (1947).

Ground water resource studies have been made by Bailey (1902), Haworth (1913), Moore and others (1940), Lohman (1941), Davis and Carlson (1952), Merriam (1954), Foley, Smrha, and Metzler (1955), Grimes (1957), and Dufford (1958).

The subsurface geology of the general area has been described by McClellan (1930), Ockerman (1935), Lee (1943), Lee and others (1946), and Lee and Merriam (1954). Jewett summarized oil and gas development in eastern Kansas in 1954 and the structural geology in 1951.

Few of the above named workers have effectively addressed the problem of relating the geologic data to the land use in the area. In addition, none of the previous work has been

directed at audiences other than professional geologists, and as such, is not in the most useful form for planners, engineers, and laymen.

The Clinton reservoir dam site geology was described by Adams (1961). Various U.S. Army Corps of Engineers reports also deal with the dam site geology (U.S. Army Corps of Engineers, open file reports). The soils have been mapped by the U.S.D.A. Soil Conservation Service (U.S.D.A., 1972). The Wakarusa drainage basin has been discussed in Wakarusa watershed reports (U.S.D.A., 1966).

Applications of geology to land use planning for an eight square mile area near the Clinton reservoir have been studied by Hilpman and Stewart (1968). This type of study has been done also for Bloomington, Indiana (Gates, 1962); Hennepin, Illinois (McComas, 1968); Saskatoon, Canada (Christiansen, 1970); and Waco, Texas (Font, Williamson, and others, 1970). Many state geological surveys are presently involved with such projects. The U.S. Geological Survey has recently completed a similar study for the San Francisco Bay area (U.S.G.S., 1971).

Methods of Study

Some key factors that were studied included bedrock geology, soil ~~types~~ (based on engineering properties), slope,

thickness of regolith (depth to bedrock) ~~or depth to bedrock~~, surface water drainage patterns, sub-drainage basins within the drainage basin defined, and locations of potential mineral resources such as limestone for building, rip-rap, road ballast, and sand and gravel for construction purposes. Other factors considered included climate, ground water availability, faulting, fracturing, bedrock hardness and rippability, and present land use.

Preliminary investigations included the study of aerial photographs and geologic, soil survey, and topographic maps. Soils, drainage courses, slopes, and present land use were plotted on topographic maps and studied in the field. Faults, joints, and bedding planes (rock defects to the engineer) were noted in terms of abundance, character, and orientation. Regrouping of soil types for mapping on the basis of engineering properties was based on laboratory soil tests and existing data. Rock units were mapped in the field according to traditional stratigraphic divisions. They were then regrouped according to their land use applications for presentation in this study. This was done so that units with similar properties were mapped as the same unit and units that have specific application to land use could be mapped separately. Sub-surface investigation included study of data of existing bore holes and excavations.

Field and laboratory data were plotted on factor maps. Different factor maps may be used in combination to provide suitability maps for specific land uses.

Acknowledgments

The investigation was undertaken at the suggestion of Dr. Paul L. Hilpman who has counseled, encouraged, and critically reviewed the manuscript. Drs. William M. Merrill and Ernest E. Angino reviewed the manuscript. Dr. Roger L. Kaesler provided guidance during the formative stages of this investigation. Harold Dickey of the Soil Conservation Service made preliminary soil maps and data available. Ivan Shull and Jerry Stoltenberg of the Kansas Department of Health and L. G. Wright of the U.S.D.A. Farmer's Home Administration provided valuable information. The U.S. Army Corps of Engineers, Kansas City District Office provided information and suggestions. Jean Ann Dick reviewed the manuscript from a layman's point of view and offered suggestions for clarity. The work could not have been accomplished without a grant from Dr. R. Glenn Elliott.

GENERAL DESCRIPTION OF THE AREA

Boundaries of the Sanitation Zone

The boundaries of the Clinton reservoir sanitation zone were established as shown on the official map approved by the Kansas State Board of Health (Fig. 1). The term "sanitation zone" is defined as the land within the designated area, no portion of which is farther than three miles from the water line of the conservation pool, but not including any area within any incorporated city, or any area downstream from the dam site (K.S.A. 65-185a).

Dam and Reservoir

The site of the Clinton reservoir dam is on the Wakarusa River just above its junction with Rock Creek about two miles southwest of the corporate limits of the City of Lawrence. The dam is to be 9,250 feet long and 85 feet high, and planned elevation at the top of the dam is 925 feet. The elevations of the conservation and flood control pools will be 875.5 and 903.4 feet respectively. Run off from approximately 367 square miles of drainage area will be controlled by the dam. The capacities of the sediment, conservation, and flood control pools will be 28,500, 110,400, and 258,000 acre-feet respectively. Total capacity for the reservoir will

be 397,200 acre-feet. The lake will cover 7,000 acres at the top of the conservation pool and 12,800 acres at the top of the flood control pool. There will be 72 miles of shoreline at the top of the conservation pool. The conservation and flood control pools are shown on Map Plate 6.

Estimated rate of sedimentation to be expected which has been used in the design of the reservoir is 1.1 acre-feet per square mile per year. This agrees favorably with the average measured rate of 1.1 of the three stations in the area as reported by Holland (1971).

Topography of the Sanitation Zone

The northern part of the Clinton reservoir sanitation zone is in the Dissected Till Plains section and the southern part is in the Osage Plains section of the Central Lowland physiographic province. The major topographic features are the Wakarusa River valley and its tributaries flowing in an easterly direction and the uplands comprised of low rounded hills with sharp breaks and rock outcrops in some parts near streams. The uplands make up about 85 percent of the acreage in the area and bottomlands make up about 15 percent. The highest point in the area is at 1,107 feet in the southwest at Twin Mounds. The lowest point is 820 feet in the east just before confluence of Rock Creek and the Wakarusa River.

The average gradient of the Wakarusa River is about 2.25 feet per mile. A topographic map of the sanitation zone may be found in the map pocket (Map Plate 1).

Climate

The Eastern Kansas area has a typical continental climate. The winters are cold and the summers are warm to hot. Three-fourths of the annual precipitation falls during the warm season, April through September. The surface winds are moderate and the weather changes frequently from day to day. Table 2, in the Appendix, contains weather statistics summarizing: (1) average monthly rainfall; (2) average total days of rain per month; (3) number of 24-hour periods of specified amounts of rainfall per month; (4) average daily minimum temperature; and (5) average number of days with minimum and maximum temperatures 32°F. or less.

Surface Water

Runoff from precipitation follows a surface network of streams and creeks. Storm and sanitary sewers that follow this natural drainage pattern are simpler and more economical to construct. To aid planners a map has been prepared showing the surface water drainage pattern, the sub-drainage basins, and areas where sheetwash predominates (Map Plate 6). Farm

ponds have been included on this map. Even though they may be destroyed through development of the area, their locations are important to planning since their affect upon soils often present engineering problems.

Most of the small streams in the study area are intermittent. Locally a few streams are fed by small springs. The perennial streams are fed by ground water and receive the flow of the intermittent streams in wet weather. The perennial streams in the study area, Deer, Coon, and Dry Creeks in the north and Elk and Rock Creeks in the south, flow in an easterly direction into the Wakarusa River. The conservation pool of the reservoir will fill these stream beds and cover most of their flood plains. Elk Creek will be inundated only at flood stage.

Wakarusa River Drainage Basin

The axis of the Clinton reservoir dam divides the drainage basin of the Wakarusa River into an upper and lower watershed. The Clinton reservoir drainage basin is comprised of 234,944 acres or 367 square miles. It is about 40 miles long and generally increases in width from 1.5 miles at the upper end to a maximum of 16 miles near the lower end (Fig. 2).

The Wakarusa River drainage originates in the Flint Hills of Wabaunsee County and flows in an easterly direction

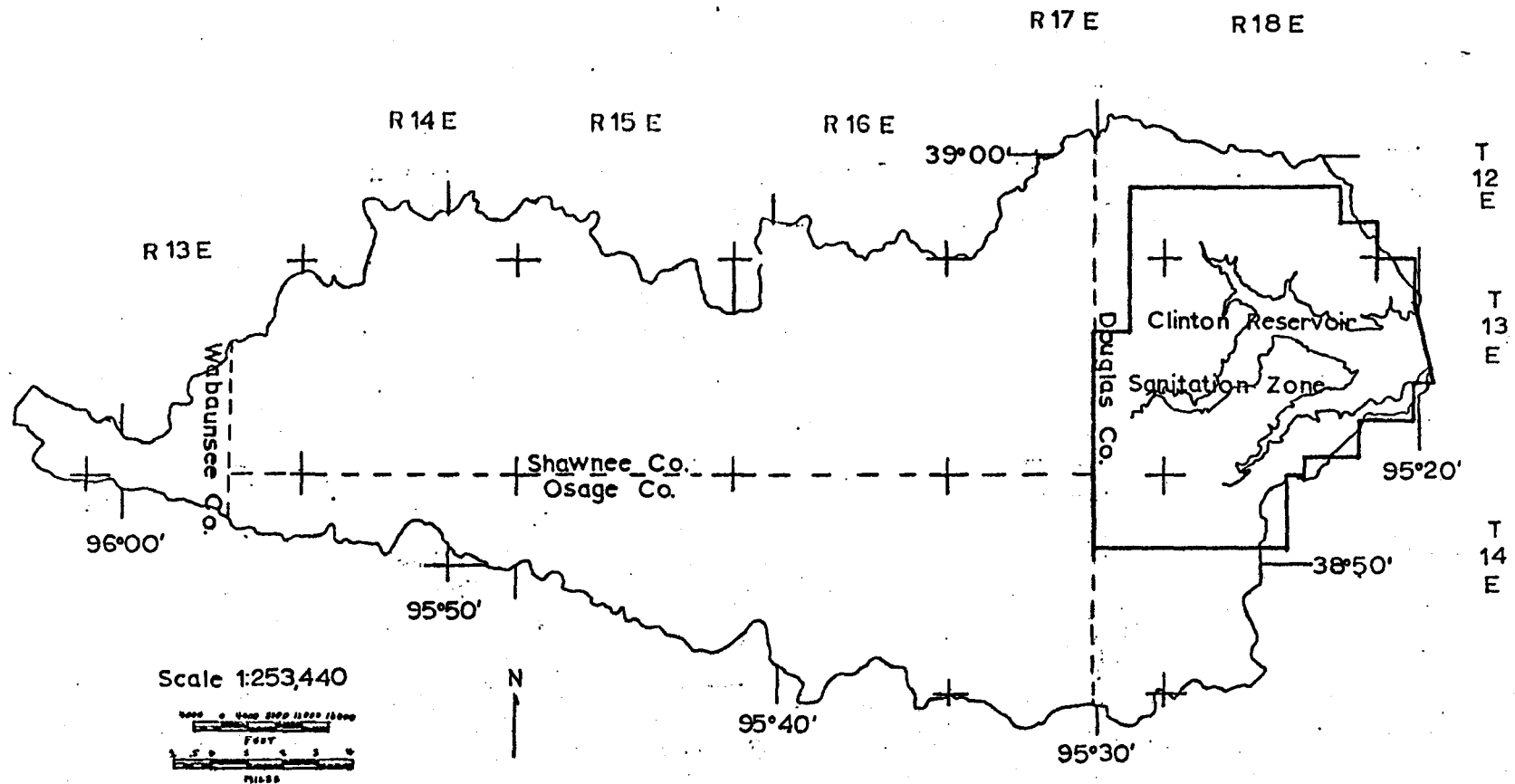


Fig. 2 Clinton reservoir drainage basin

through the Clinton drainage basin. Below the dam it continues its easterly course and enters the Kansas River near Eudora, Kansas.

Elevations range from 1,350 feet in the uplands of the drainage basin to 810 feet at the lower end, giving a total fall of 540 feet; one-half of which occurs in the upper 10 miles of the valley.

The sub-basins within the study area are shown on Map Plate 6. The limits of a sub-basin determine the area that can be served by an integration of storm sewers and natural drainage. The size of the sub-basin is used to determine the quantity of run off from a given rainfall so that capacities of pipes can be planned to adequately handle the run off. It is necessary, however, to keep the entire drainage basin in mind because activities influencing the run off above the reservoir will ultimately affect the water quality of the reservoir.

Groundwater Availability

There are no good aquifers in the sanitation zone. A small amount of groundwater, about 50 gallons per minute, or less, may be obtained from the Newman and Buck Creek Terrace deposits or the Tonganoxie sandstone member of the Stranger formation. The water quality from the river terrace deposits

is satisfactory except for hardness and iron content. The Tonganoxie water quality ranges from soft to moderately hard in sodium chloride.

Population

According to the 1970 census, the population of Douglas County is 57,932 and is ranked fifth among the counties of Kansas. Lawrence, the county seat and largest city, had a population of 45,698. The approximate population of the Clinton reservoir sanitation zone was about 1,000. The small communities located within the sanitation zone are Clinton, Stull, Kanwaka, and Twin Mound (Fig. 1).

Lawrence is a university town with students at the University of Kansas and Haskell Indian Junior College accounting for more than one-third of the population. More than one-fourth of the total labor force is employed at these institutions.

The Lawrence-Douglas County Planning Commission recently adopted subdivision and development regulations for the city and county. The Clinton reservoir sanitation zone has been completely included within the "Suburban Growth Area" of the City of Lawrence (Fig. 1).

Land Use

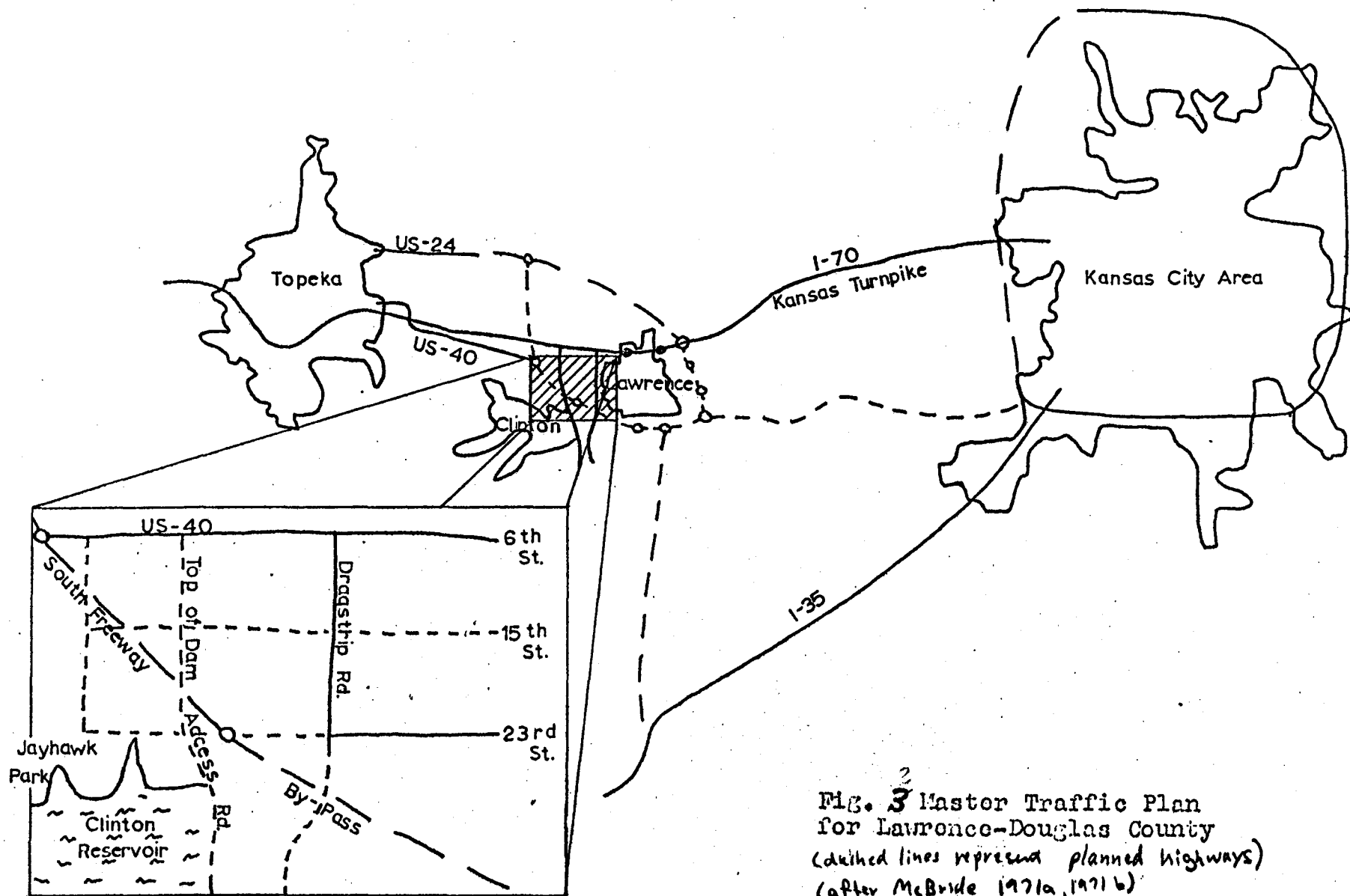
Land use within the sanitation zone consists of 70 percent cropland, 16 percent woodland, 10 percent grassland, and the remainder in miscellaneous uses, including roads and buildings. With the exception of one limestone quarry near the top of the flood control pool southeast of Stull, there is no commercial mineral production in the lake area.

Transportation

Douglas County is served by the main lines of the Atchison, Topeka, and Sante Fe Railway system; the Chicago, Rock Island, and Pacific Railroad; the Union Pacific Railroad; and Amtrak. Lawrence is linked to nearby major cities by a turnpike and four major highways.

The Clinton reservoir area is currently served by county and township blacktop and rock surfaced roads generally following the pattern formed by section lines. The projected street plan for the year 2000 in the Lawrence-Douglas County area indicates that there will be a major access road running across the top of the dam north to US 40; 23rd Street and 15th Street will be extended westward; another road will run south from US 40 to Jayhawk Park; and Dragstrip Road will be extended to the south. The master traffic plan also proposes

a major artery that would encircle the Clinton reservoir
(Fig. 3).



BEDROCK AND SURFICIAL GEOLOGY

Stratigraphic Description

The outcropping rocks in the Clinton area (Fig. 4) consist of alternating beds of limestone and shale. Glacial drift deposits cover many hills while unconsolidated river terrace deposits fill the valleys. The bedrock sequence may be described as: (1) a thick unit of shale and siltstone; (2) overlain by ten feet of massive limestone; (3) followed by a sequence of shale within which there is a single bed of limestone two feet thick; (4) above which there are ten to twenty feet of wavy bedded and massive limestone. This cycle repeats itself three times as one goes up to the geologic column in the study area. The geologic units are listed below with brief descriptions. For more detailed stratigraphic descriptions, see Moore and others (1951).

Lawrence Shale

The Lawrence Shale, a thick sequence of beds of shale and siltstone, is the lowermost unit in the study area. Only the upper fourth of the unit, or about 40 feet, crops out in the area.

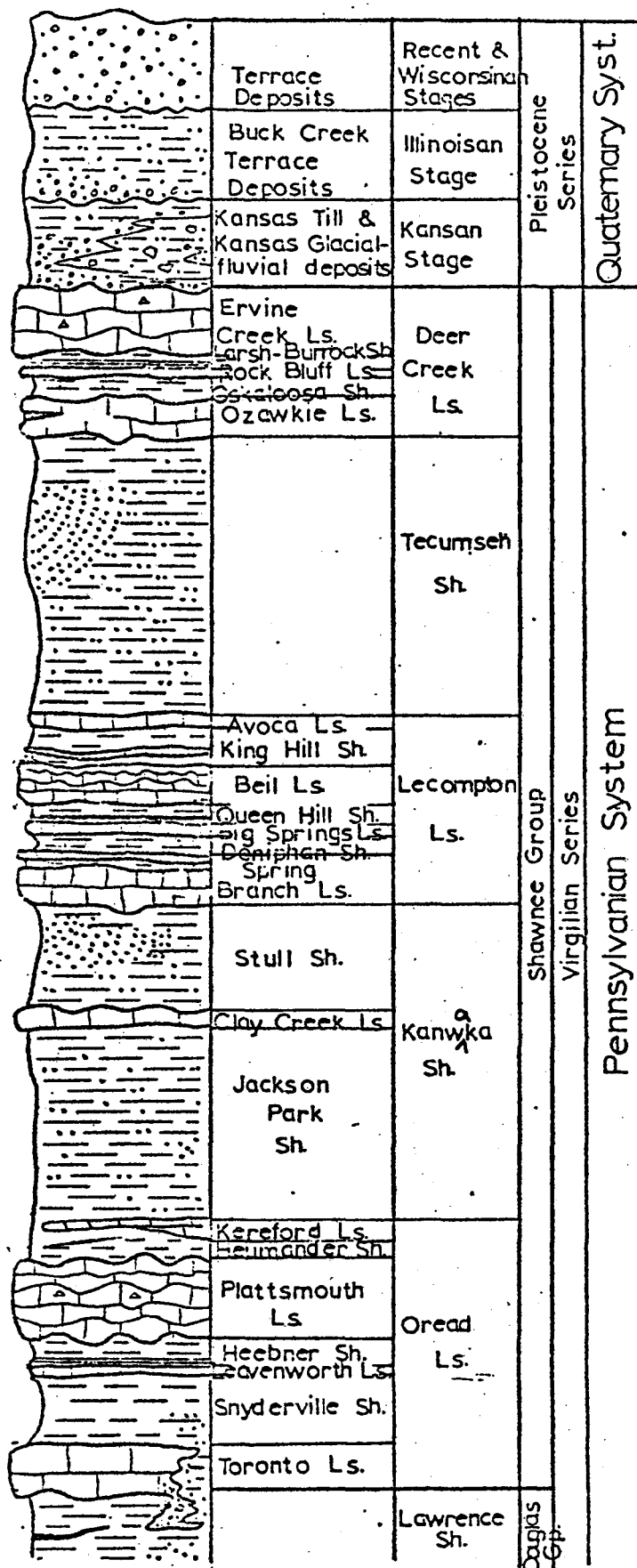


Fig. 4. Graphic Geologic Column
(after O'Connor, 1960)

Oread Limestone

The average thickness of the Oread Limestone is about 60 feet. It is made up of four limestone and three shale members.

Toronto Limestone member.--The Toronto Limestone member is massive with at least two thin shaly partings in the bed.

Snyderville Shale member.--The Snyderville Shale member is made up of shale, claystone, and siltstone about 10 to 15 feet thick.

Leavenworth Limestone member.--The Leavenworth Limestone member consists of a single massive bed of limestone 1 to 2 feet thick with prominent vertical joints.

Heebner Shale member.--The Heebner Shale member is composed of 5 to 8 feet of thinly bedded shale.

Plattsmouth Limestone member.--The Plattsmouth Limestone member is an 18 foot thick wavy-bedded limestone with scattered chert nodules near the middle of the unit.

Henmander Shale member.--A thin shale, 2 to 4 feet thick is named the Henmander Shale member.

Kereford Limestone member.--The Kereford Limestone member is a thin, nonresistive limestone unit 2.5 to 9 feet thick.

Kanwaka Shale

The Kanwaka Shale ranges from 54 to 86 feet in thickness and consists of two thick shale units with a limestone unit between them.

Jackson Park Shale member.--The Jackson Park Shale member is the lowermost unit 33 to 52 feet thick made up of shale and siltstone.

Clay Creek Limestone member.--One-third of the way down from the top of the Kanwaka Shale is the Clay Creek Limestone member which is 3 to 6 feet thick. The bottom two-thirds of the member is massive and the upper part consists of shale and fragmental limestone.

Stull Shale member.--The Stull Shale member is 18 to 28 feet thick and is made up of shale and siltstone.

Lecompton Limestone

The Lecompton Limestone ranges from 40 to 57 feet thick and is made up of four limestone and three shale members.

Spring Branch Limestone member.--The lowermost unit in the Lecompton Limestone is the Spring Branch Shale member. It is 8 to 14 feet thick and consists of a lower massive, resistant limestone 5 feet thick overlain by 3 to 8 feet of shaly limestone, shale, and limestone. In position and character it is analogous to the Toronto Limestone member of the Oread Limestone.

Doniphan Shale member.--A clay shale 2 to 5 feet thick comprises the Doniphan Shale member.

Big Springs Limestone member.--The Big Springs Limestone member is a single bed of dense limestone 2 to 3 feet thick with well developed verticle joints.

Queen Hill Shale member.--A thin bedded shale 2 to 5 feet thick makes up the Queen Hill Shale member.

Beil Limestone member.--The Beil Limestone member is 9 to 10 feet thick. Its lower half is massive and irregularly bedded. Its upper half is made up of limestone, shaly limestone, and very calcareous shale.

King Hill Shale member.--The King Hill Shale member is made up of 8 feet of shale with one or more impure limestones in the middle and lower parts.

Avoca Limestone member.--The Avoca Limestone member consists of 3 to 4.5 feet of dense, massive limestone.

Tecumseh Shale

The Tecumseh Shale is 62 feet of shale and siltstone with up to 10 feet of sandstone locally.

Deer Creek Limestone

The Deer Creek Limestone about 34 feet thick is made up of three limestone and two shale members.

Ozawkie Limestone member.--The Ozawkie Limestone member consists of 5 to 11 feet of massive limestone.

Oskaloosa Shale member.--The Oskaloosa Shale member is 3 to 5 feet thick and is made up of thin-bedded shale and blocky clay.

Rock Bluff Limestone member.--The Rock Bluff Limestone member is made up of a single bed of dense limestone 2 feet thick with prominent vertical joints.

Larsh-Burroak Shale member.--The Larsh-Burroak Shale member is a thin-bedded shale 2.5 to 5 feet thick.

Ervine Creek Limestone member.--The Ervine Creek Limestone member is the uppermost unit in the area. It averages 15 feet thick and consists of a wavy-bedded, dense limestone with several thin shale partings.

Joints

All of the rock units discussed are cut by joints. The limestone beds contain two prominent sets of joints that trend northeastward and northwestward. Joints are more abundant and more clean cut in the limestone beds than in the shale beds.

Glacial Drift Deposits

Glacial till in the area is dominantly unstratified and unsorted consisting chiefly of clay. Kansan Glaciofluvial deposits of Kansan age are poorly sorted sand and gravel ranging in thickness from about 2 to 30 feet. The deposits are leached and consist mainly of chert, quartz, and igneous and metamorphic rocks from the north. Glacial drift deposits are found in the uplands covering many hilltops.

River Terrace Deposits

The Buck Creek Terrace deposits are dissected alluvial fill. The coarse basal part is made up of sand

and gravel generally less than 10 feet thick. The finer grained upper part is chiefly silt, sandy silt, and clay. It constitutes most of the terrace and is locally at least 62 feet thick (O'Connor, 1960).

Erosion deepened the bedrock floor of the Wakarusa River valley 20 to 50 feet below the basal Buck Creek Terrace deposits. The Newman Terrace deposits were laid down on this valley floor. They are generally 30 to 40 feet below the Buck Creek Terrace deposits. The basal part is not exposed in the Wakarusa River valley. They are generally less than 10 feet thick and composed chiefly of gravel (O'Connor, 1960). The valley fill consists mainly of silt and clay.

Grouping of the Units

The geologic units of the Clinton reservoir study area have been mapped in the field using traditional stratigraphic division shown in Figure 3. For purposes of this study they were then grouped into four general categories (Fig. 4):

Glacial Drift.--Glacial Drift consists of unconsolidated, moderate to well-drained material. It may be readily removed with a shovel, however, occasionally large boulders may be encountered that may require the

use of hammers or dynamite in order to break them down to a size more easily handled.

River Terrace.--River Terrace includes the unconsolidated, poorly drained material known as the Newman and Buck Creek Terrace deposits. They are readily removable with a shovel.

Shales (including rippable limestone).--Shales consist of all bedrock units that can be ripped or plucked out with a tractor when removal is desired. The shale units are rippable and relatively thin beds of limestones can usually be plucked out in large block due to their well developed joints. This group of rippable bedrock is generally impervious to water except where joints are well developed and where weathering has been extensive.

Limestones (massive, requiring blasting).--Limestones that are thick and massive require blasting in order to be removed. Small springs are usually associated with these units.

An on site survey may be necessary to determine whether or not a specific unit at that locality can be ripped or require blasting for excavation. It is beyond

the scope of this study to give an on site analysis of the bedrock character. A graphic geologic column (Fig. 5) includes the traditional stratigraphic divisions as well as the regrouped divisions discussed here, with symbols for the latter taken from Map Plate 2.

Structure

The study area lies within the Forest City Basin which is a major sedimentary basin east of the Nemaha anticline in northeastern Kansas and neighboring states (Jewett, 1951, p. 135-6). The Prairie Plains Monocline is the dominant regional structure affecting eastern Kansas (Jewett, 1951, p. 152). The monocline imposes a gentle dip of 20 feet per mile to the west and northwest. It is chiefly post-Permian in age (Jewett, 1951, p. 152). Many smaller synclinal and anticlinal structures are superimposed on the regional structure with the amount of structural deformation increasing with depth from the surface rocks into older Pennsylvanian and Mississippian rocks (O'Connor, 1960).

The dip of the beds is so slight that they may be regarded as being essentially horizontal. All the rock units in the study area are cut by joints.

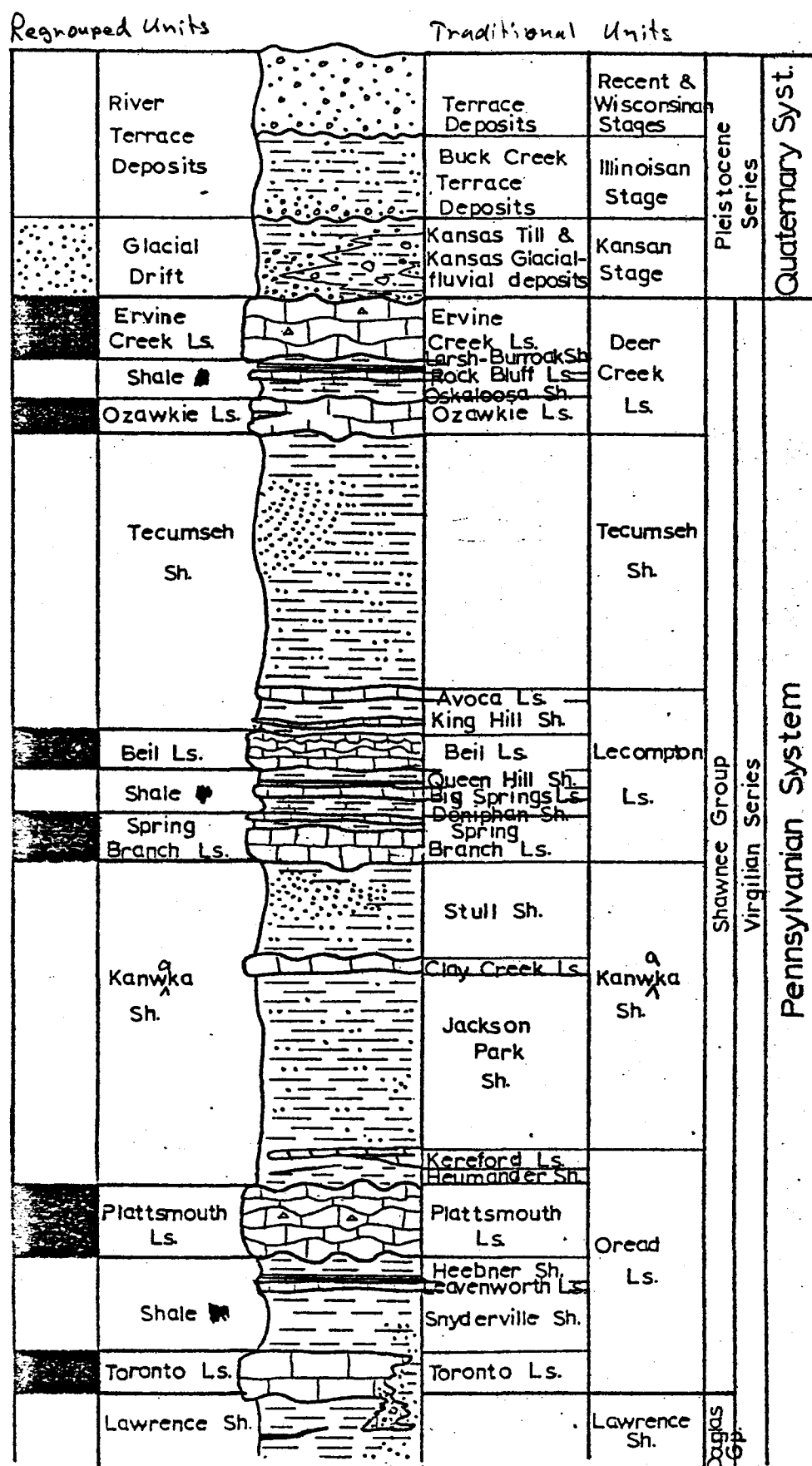


Fig. 5 Regrouped Graphic Geologic Column
 e.g. black pattern signifies Limestones (massive, requiring blasting)
 (after O'Connor, 1910)

SOILS

Soils

The soils of the study area have been classified, named, and mapped according to nationwide, uniform procedures by the Soil Conservation Service. Soils that have profiles nearly alike make up a soil series. All the soils of one series have major horizons that are similar in the thickness, arrangement, and other important characteristics. Soils of one series can differ somewhat in texture of the surface soil, slope, stoniness, or some other feature. The soil series of the study area are described below.

Alluvial land

Alluvial land consists of deep, dark colored, somewhat poorly drained soils in low floodplains. Slopes are about 0 to 2 percent.

Breaks-Alluvial land complex

The Breaks-Alluvial land complex consists of the steep, broken sides and narrow bottomland of upland drainageways. The sides are loamy or clayey and the bottomland is loamy. In places there are rock outcrops on the side slopes. The

bottomland has a slope of about 0 to 3 percent and the sides have slopes of about 15 to 45 percent.

Broken alluvial land

Broken alluvial land consists of the channels and steep banks of perennial streams. The texture of the soil ranges from loam to silty clay loam. In some places sand, gravel, or small stones are in the stream channel. The areas are subject to frequent flooding.

Chase silty clay loam

The Chase silty clay loams are deep, nearly level, dark colored, moderately drained soils on low terraces or high floodplains. Permeability is low. These soils formed in fine textured alluvial sediments. Slope gradients are less than 2 percent.

Detlor silty clay loam

The Detlor silty loams are dark colored, well-drained soil with low permeability. These soils are underlain by weathered shale at depths ranging from 20 to 40 inches. Slope gradients range from 3 to 7 percent.

Detlor-Oska complex

The Detlor-Oska complex consists of moderately deep, dark colored, well-drained upland soils. Permeability is low. These soils formed from areas of interbedded limestone and shale. Slope gradients range from 3 to 6 percent.

Dwight silt loam

The Dwight silt loams are deep, well-drained claypan soils that occur on nearly level to gently sloping uplands. Permeability is very low. It is extremely hard when dry. Slope gradients range from 0 to 3 percent.

Elmont silt loam

The Elmont silt loams are deep, dark colored, well-drained soils. Permeability is moderately low. These soils developed in material weathered from noncalcareous silty shales. Slope gradients range from 1 to 6 percent.

Grundy silty clay loam

The Grundy silty clay loams are deep, dark colored, somewhat poorly drained upland soils with low permeability. They formed in loess under grass. Slope gradients range from 1 to 3 percent.

Gymer silt loam

The Gymer silt loams are deep, dark colored, well-drained upland soils with moderately low permeability. They formed under grass cover in reddish silty mantles presumed to be loess. Slope gradients range from 3 to 8 percent.

Kennebec silt loam

The Kennebec silt loams are deep, dark colored, well-drained bottomland soils. Permeability is moderate. They formed in alluvium on floodplains. Slope gradients range from 0 to 2 percent.

Martin silty clay loam

The Martin silty clay loams are deep, dark colored, moderately well-drained upland soils with low permeability. They formed in material weathered from interbedded silty and clayey shales under grass. Slope gradients range from 1 to 7 percent.

Martin-Vinland complex

The Martin-Vinland complex consists of shallow, dark colored, somewhat excessively drained and moderately well-drained upland soils. They formed in material generally below outcrops of limestone. Slope gradients range from 7 to 15 percent.

Morrill clay loam

The Morrill clay loams are deep, dark colored, well-drained upland soils with moderately low permeability. They formed in glacial till or outwash material under tall native grasses. Slope gradients range from 3 to 8 percent.

Morrill-Gravelly land complex

The Morrill-Gravelly land complex consists of deep, dark colored, well-drained upland soils with intermingled gravelly areas within 15 inches of the surface. These gravelly areas make up 30 to 40 percent of the complex and consist of gravelly, cobbly, and stony materials that were transported to their present position by a glacier.

Oska silty clay loam

The Oska silty clay loams are moderately deep, dark colored, well-drained upland soils with low permeability. They formed in material weathered from limestone or interbedded limestone and calcareous shale. Slope gradients range from 1 to 6 percent.

Pawnee clay loam

The Pawnee clay loams are deep, dark colored, moderately well-drained upland soils with low permeability. They formed

in glacial materials under native grass cover. Slope gradients range from 1 to 7 percent.

Reading silty clay loam

The Reading silty clay loams are deep, dark colored, well-drained bottomland soils. Permeability is moderately low. They formed in moderately fine textured alluvium on stream terraces. Slope gradients range from 0 to 6 percent.

Sharpsburg silty clay loam

The Sharpsburg silty clay loams are deep, dark colored, well-drained upland soils with moderately low permeability. They formed in loess under a cover of tall native grasses. Slope gradients range from 1 to 4 percent.

Sibleyville-Elmont complex

The Sibleyville-Elmont complex consists of moderately deep, dark colored, well-drained upland soils with moderate to moderately low permeability. They formed from material weathered from noncalcareous shales and from sandstone or sandy and silty shale. Slope gradients range from 7 to 15 percent.

Sogn-Vinland complex

The Sogn-Vinalnd complex consists of very shallow, dark colored, somewhat excessively drained upland soils with moderate permeability. They formed from material weathered from limestone and shale under a cover of grass. Slope gradients range from 3 to 20 percent.

Stony steep land

Stony steep land occurs on upland and consists of very shallow soils intermingled with deeper soils and limestone outcrops, which comprise about 10 to 25 percent of the soil. It has rapid run off and is excessively drained. Slope gradients range from 20 to 45 percent.

Wabash silty clay loam and silty clay

The Wabash silty clay loams and silty clays are deep, nearly level, dark colored, poorly drained bottomland soils. Permeability is very low. They formed in fine textured alluvium. Slope gradients are less than 1 percent.

Woodson silty clay loam

The Woodson silty clay loams are deep, dark colored, somewhat poorly drained upland soils. Permeability is very low. They developed in fine-textured sediments under a cover

of tall prairie grasses. Slope gradients range from 1 to 3 percent.

Soil Surveys

Traditionally, soil surveys have been used to identify farmland and to match suitable land areas with suitable crops. In recent years, geologists, soil scientists, and engineers have become increasingly interested in urban soil surveys for land-use planning. Soil surveys do not eliminate the need for on site sampling and testing of soils for design or construction of specific engineering works.

Engineering Properties

Agricultural scientists of the U.S. Department of Agriculture (USDA) classify soils according to texture. This is useful as the initial step for making engineering classifications of soils. The American Association of State Highway Officials (AASHO) developed a classification of soils used chiefly by highway engineers. The soils most suitable for road subgrade are classified A-1, and those least suitable are classified A-7. For a description of the USDA and AASHO classification systems see Wu (1966).

The U.S. Army Corps of Engineers developed the Unified system of classification of soils. Soils are grouped on the basis of their texture and plasticity, as well as on their performance when used in engineering structures. Soil materials are identified as coarse grained, gravel (G) and sand (S); fine grained, silt (M) and clay (C); and highly organic (Pt). Clean sands are identified by the symbol SW or SP; sands with fines of silt and clay are identified by the symbols SM and SC; silty and clay that have a low liquid limit are identified by the symbols ML and CL; and silty and clay that have a high liquid limit are identified by the symbols MH and CH.

Estimates of the engineering properties of the soils of the study area were made by the Soil Conservation Service based on soil test in the area under the Unified system. These data are as yet unpublished and subject to change. See Table 1 of the Appendix for the engineering properties of the soils in the Clinton area. The following land types have variable properties and are not included in Table 1: Alluvial land, Breaks-Alluvial land complex, Broken alluvial land, the Gravelly part of the Morrill-Gravelly land complex, and Stony steep land. Soils that are made up of mixtures of two or more soil series are listed by their separate components. The engineering properties are given for the various soil layers within a soil series.

The soil layer of most importance to engineers and planners is between 24 and 48 inches thick because most construction and land use activities occur in this interval (Fig. 6). The engineering properties of this layer have been used to classify the soil series into three groups based on their permeability and shrink-swell characteristics. These two properties were chosen because of their close relationship. When the shrink-swell potential is high the permeability is generally low and vice versa. They are also two of the more critical properties that may be used to describe how a soil will perform under various uses. One group is made up of soils with high permeability and low shrink-swell potential. No soils in the study area meet these requirements. Another group is comprised of soils with moderate permeability and moderate shrink-swell potential. Less than 10 percent of the land area is made up of these soils. The third group consists of soils with low permeability and high shrink-swell potential. Soils subject to flooding or soils less than 24 inches thick are included in this land category regardless of their other properties. Over 90 percent of the area is made up of soils in this group. This classification has been used to prepare the soil map (Map Plate 4).

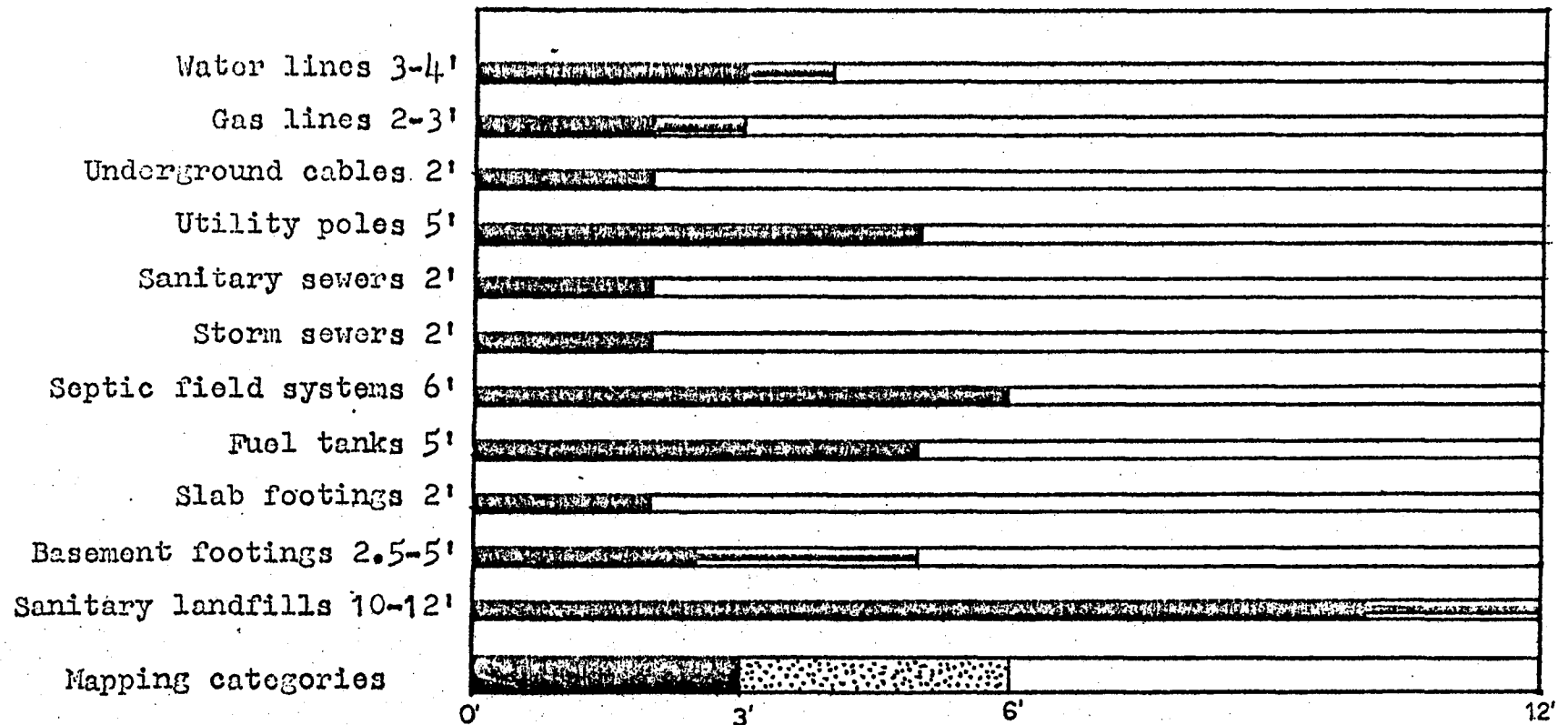


Fig. 6 Minimum depth requirements

SLOPE

There is a strong relationship between slope, or grade, and many land use activities. Slopes are given in percent grade. A 1 percent grade is equivalent to a rise of 1 foot per 100 feet while a 100 percent grade is equivalent to a rise of 100 feet per 100 feet. The gradient categories chosen for map units in this study are 0 to 2 percent, 2 to 5 percent, 5 to 10 percent, 10 to 15 percent, and greater than 15 percent (Map Plate 4). These categories reflect ranges of slopes for various land use activities (Fig. 7). When using the slope map, it should be noted that modern earth-moving equipment may be used to alter some gentle slopes; however, the costs of slope modification increase rapidly where slopes greater than 5 percent are encountered or where bedrock is at or near the surface.

Slope and Bedrock Geology

The relationship of the slope and bedrock geology is somewhat variable. Specific units show less correlation than expected, but generally steep slopes form on limestone formations and gentle ones on shale formations form gentle slopes. The alternation of limestone and shale creates a corresponding alternation of steep and gentle slopes. Changes in slope do

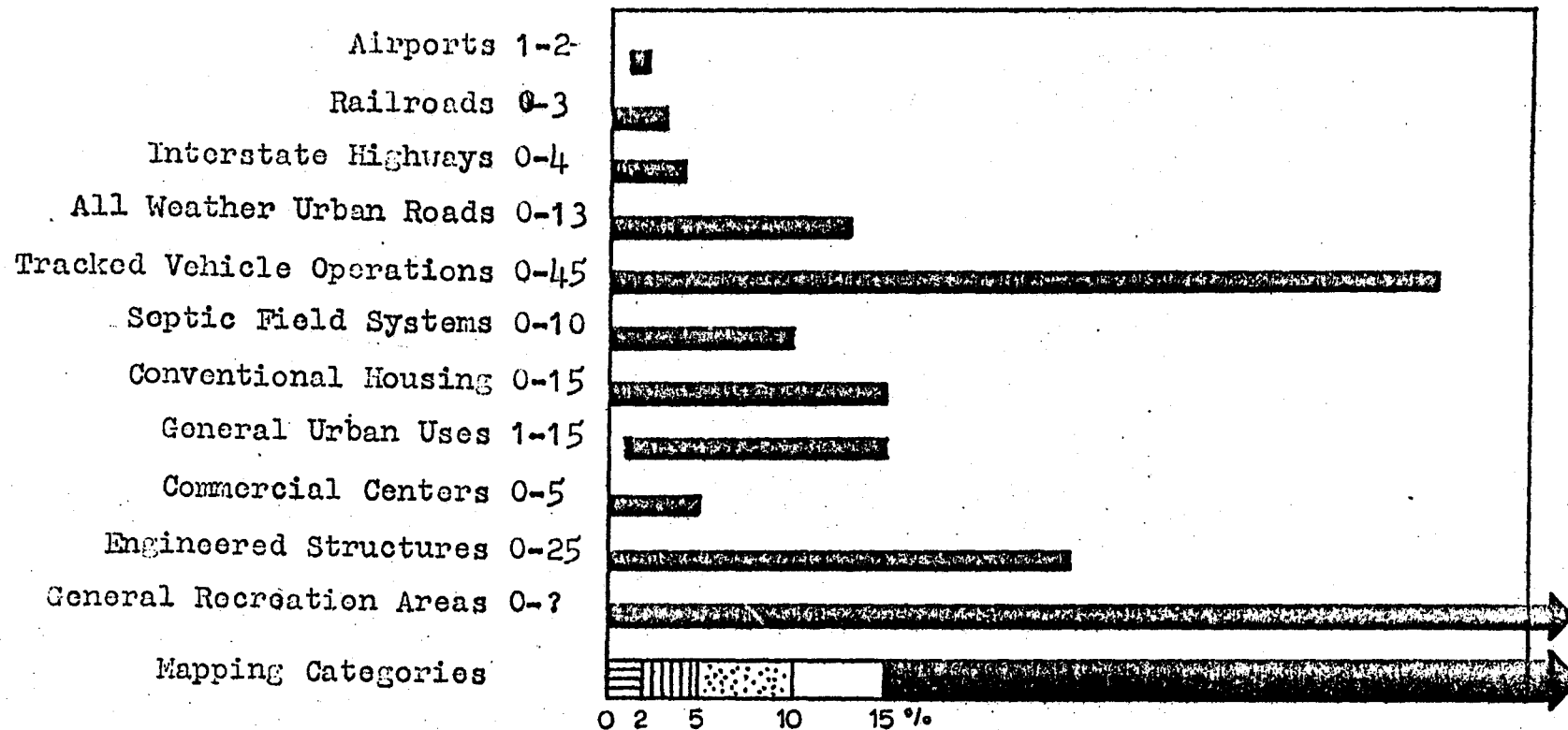


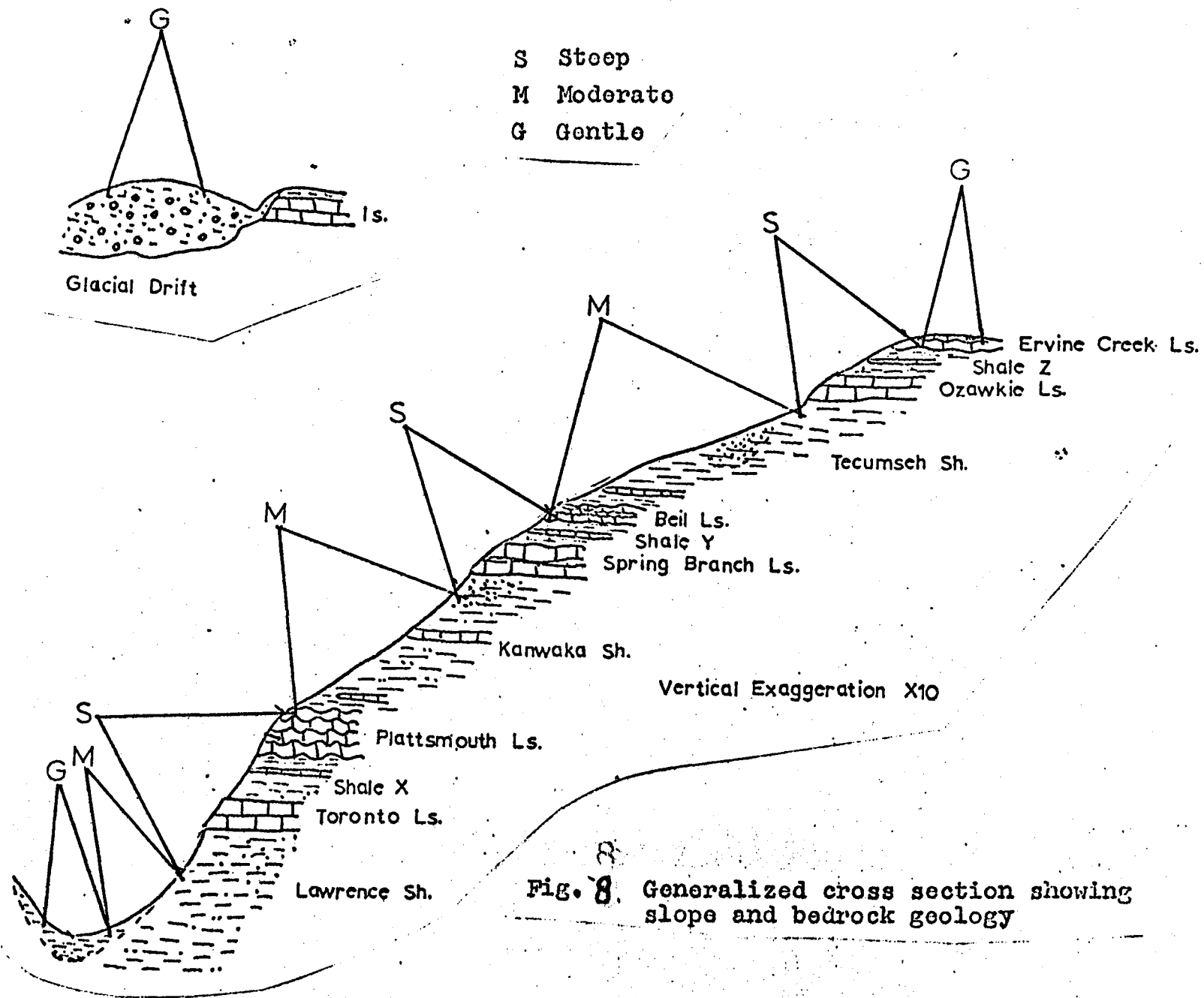
Fig. 7 Optimal ranges of slopes

not occur at the contacts of the formations but below it. For example, steep slopes form the Oread Limestone. Its uppermost member, the Plattsmouth Limestone, is moderate to gentle and conforms better with the gentler Kanwaka Shale. Also, the upper part of the Lawrence Shale corresponds better with the steeper Oread Limestone than with the lower portion of the formation (Fig. 8).

The principal bench formers are thick massive limestones because they are more resistant to weathering and the vertical joints form vertical faces. The massive limestones are usually over 15 percent in gradient. Where they are the uppermost units, gentle slopes, 0 to 2 percent, form on the tops of the limestone units. Intermediate slopes of 5 to 10 percent form between gentle and steep slopes and are usually underlain by shale. Glacial drift makes up the rest of the intermediate and flat slopes, but it may form steeper slopes. The bulk of the gently sloping lands are in areas of alluvial terrace deposits.

Soils

Nearly all of the soils developed in alluvial sediments and a few soils derived from shales, limestones, and glacial drift have slopes of 0 to 2 percent. Slopes on soils derived from alluvial sediments, glacial drift, shale, and limestones



fall into the 2 to 5 percent category. Soils developed in glacial deposits and a few shales and interbedded shales and limestones form 5 to 10 percent gradients. Soils derived from interbedded limestones and shales have slopes of 10 to 15 percent. Rock outcrops of limestone and shale and soils developed from these outcrops slope more than 15 percent (Fig. 9).

Key for Figure 9

Generalized Cross-Section

Showing Slope, Soil, and Bedrock

A	Soils derived from Alluvium:	Alluvial land, Breaks-Alluvial land complex, Broken alluvial land, Chase, Kennebec, Reading, Wabash, and Woodson soils.
B-1	Soils derived from Shale:	Martin and Martin-Vinland soils.
C-1	Soils derived from Limestone:	Stony steep land, Sogn-Vinland, and Oska soils.
B-2	Soils derived from Shale:	Martin, Martin-Vinland; minor Elmont and Sibleyville-Elmont soils.
C-2	Soils derived from Limestone:	Stony steep land, Sogn-Vinland, Detlor-Oska, and part of Woodson soils.
B-3	Soils derived from Shale:	Martin, Martin-Vinalnd; minor Dwight soils.
C-3	Soils derived from Limestone:	Stony steep land, Sogn Vinland, Oska and Detlor-Oska soils.
D	Soils derived from Glacial Mater- ial:	Gymer, Morrill, Morrill-Gravelly complex, Pawnee, Sharpsburg; and minor Grundy soils.

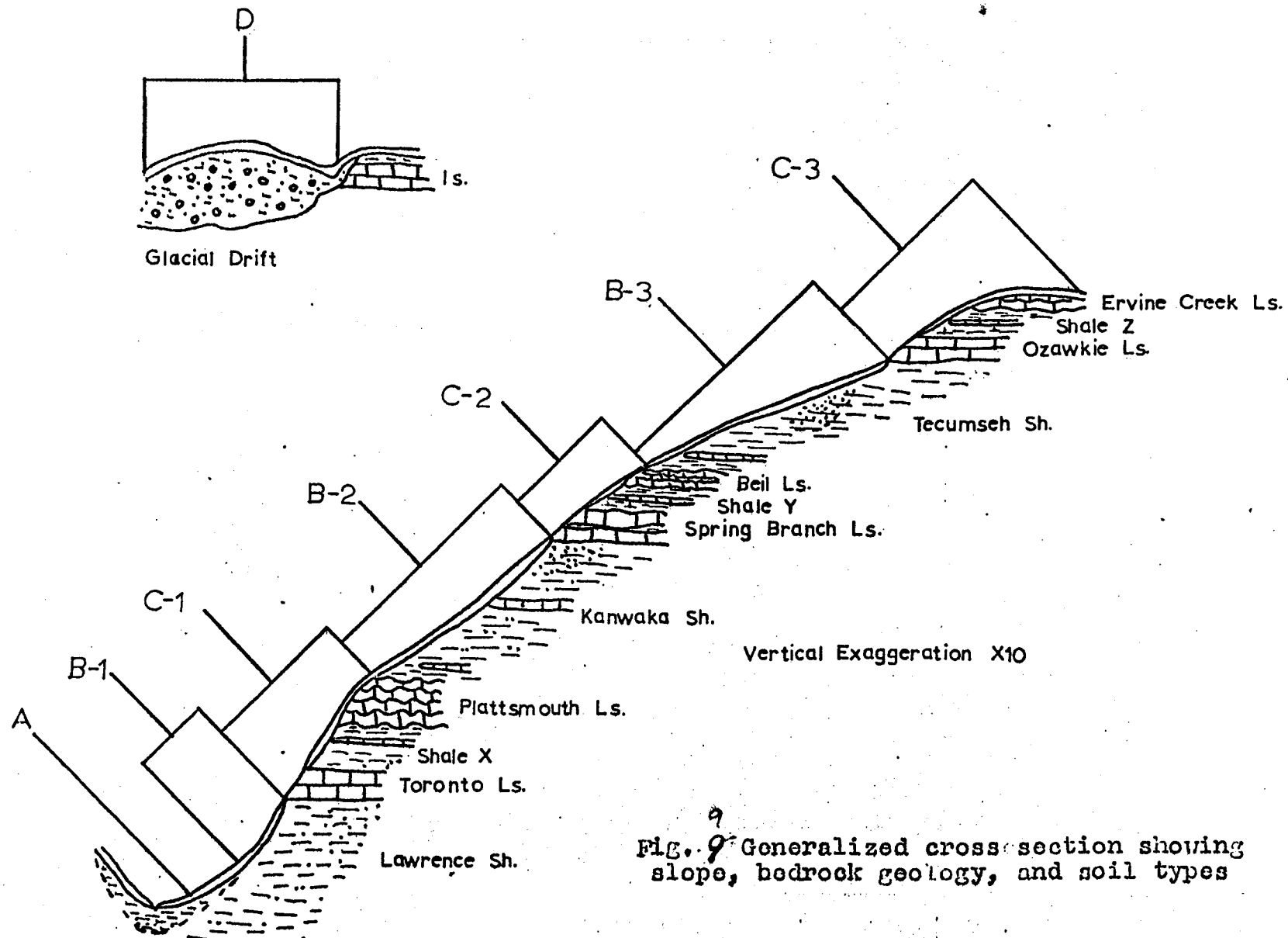


Fig. 9 Generalized cross section showing slope, bedrock geology, and soil types

COMMON EXCAVATION MATERIAL

Generally, the term "common excavation material" is used when referring to soil and the underlying mantle and weathered bedrock that can be removed by conventional digging and grading machinery. Material that requires blasting, ripping, and hammering in order to be removed can be called "rock excavation material". Knowledge of the extent of these divergent materials can save unnecessary expense for the contractor, the engineer, and ultimately the individual who finances the project.

The thickness of and common excavation material is not easily made. Also, the criteria used for this distinction are not always the same for all parties concerned. The best means of determining the thickness of common excavation material is with the use of closely spaced test borings. For this study, this depth to bedrock has been inferred from existing bore holes and excavations, soil depth data, and information from the maps geology, slope, and topography. Thickness of common excavation material has been grouped into three categories: (1) those areas where it is less than 3 feet, (2) those areas where it is between 3 and 6 feet, and (3) those areas where it is greater than 6 feet (Map Plate 5). These depths were chosen because they are the most critical for nearly all excavation activities (Fig. 5).

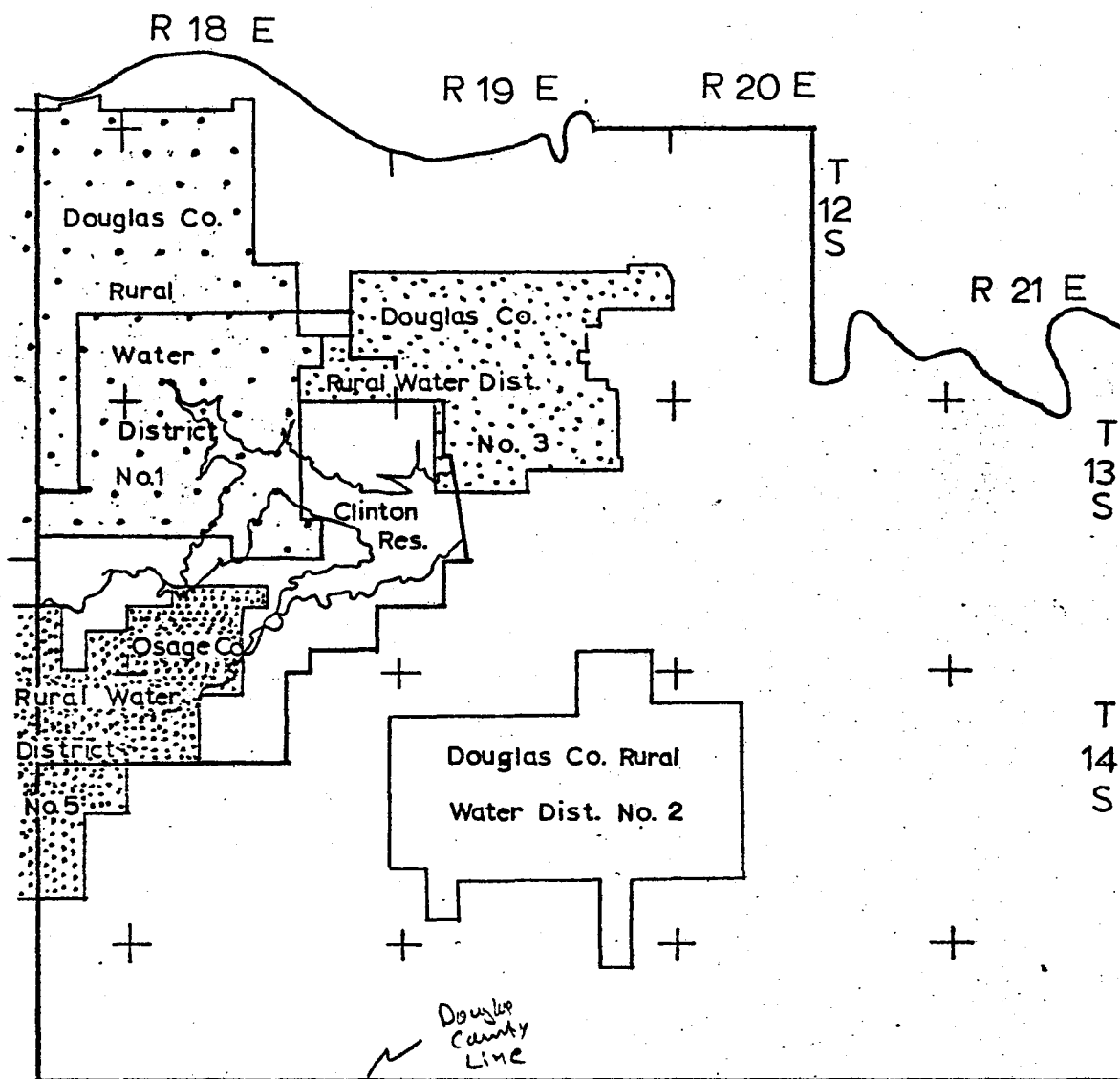
ENVIRONMENTAL PLANNING

Impact of Structure

The construction of the Clinton reservoir dam will provide downstream flood control in the Kansas River Basin and water for water supply and recreation. The water impounded by the structure will permanently inundate fifteen miles of stream and the habitat and agricultural land within the lake area will be destroyed. More intensive farming practices in the floodplain and residential development in the uplands downstream of the dam will displace more habitat (USACE, 1971). "Approximately 360 acres of mud flats in the upper areas of the reservoir could be expected to be exposed based on 2-year frequency drawdown of pool level." (USACE, 1971)

Water Supply

Part of the Clinton reservoir sanitation zone is currently served by Douglas County Rural Water Districts No. 1 and No. 3 and Osage County Rural Water District No. 5. Districts 1 and 3 serve most of the northern half of the area; while No. 5 serves the central and southwestern portion (Fig. 10). The area immediately to the south of the lake is not currently served by a rural water district. These districts have ample capacity to serve the



Scale

Fig. 10 Rural water districts Douglas County Kansas
(after Bartlett and West, 1970)

present users, however, growth around the reservoir will put an excessive demand on the existing systems. Other water supplies in the area come from wells, cisterns, ponds, and hauling.

The reservoir will provide 110,400 acre-feet of water supply storage. The Kansas Water Resources Board was provided assurances for the full allocation (U.S.A.C.E., 1971). The major identified user, the City of Lawrence, has been assured 33,000 acre-feet of water supply storage or 10 million gallons per day (U.S.A.C.E., personal communication).

The City of Lawrence may possibly build a treatment plant and sell water to customers in the northern half of the area (Wright, personal communication). Baldwin City hopes to build a treatment plant and may sell water to customers in the southern part of the area (Wright, personal communication). A plan proposed by Bartlett and West (1970) calls for two treatment plants on the reservoir itself.

The Clinton drainage basin is not free of effluent producing activities. There are a few small feed lots and several farmers commonly run herds of 50 to 150 head of cattle and may run as many as two or three hundred at a time (Shawnee County Soil Conservation Service, personal communication). In addition, pesticides and fertilizers applied to fields contribute to problems of

water quality. The addition of these effluents to the lake makes it unsuitable as a source of water unless it is properly treated. There is no suitable ground water supply with the possible exception of the Tonganoxie sandstone.

Flood Hazard

The reservoir will cause back-up water in the tributaries and local flooding in the upper reaches to a higher elevation than in the past. Flood easements should be maintained on these tributaries to prevent encroachment of structures developed in the area. There will be an increase in the percent of runoff as urbanization increases. This is because paved parking lots, roofed structures, and cleared land reduce the land area capable of absorbing precipitation.

When the reservoir is at flood level, release of water to the Wakarusa River may be necessary to prevent overflow and breach of the dam by addition of water from new storms. It is possible that such discharges of water could produce flooding on the Wakarusa River below the dam. Hence, there should not be unrestricted occupation of the floodplain. Zoning should be maintained in this area.

Sewage Disposal Systems

Public and private sewage systems depend on gravity for drainage of the collection lines. Consequently they must be designed to follow the general topography to avoid the need for unnecessary pump stations. Since the most logical route is preempted by the location of the reservoir, careful planning is necessary to provide the best routes for the sewage systems. The topographic and drainage maps (Map Plates 1 and 6) should be used to determine the routes with the lowest increase in elevation from one subbasin to another. Lift stations or deep excavations will be unavoidable. The thickness of common excavation material and geologic maps (Map Plates 2 and 5) should be used to determine where necessary excavation will encounter the least problems.

Because the sanitation zone lies entirely within the Suburban Growth Area of the City of Lawrence, septic field systems are permitted only on tracts of three acres or more (Lawrence-Douglas County Subdivision and Development Regulations, 1972). Holding tanks are forbidden in Douglas County (Douglas County Health Officer, personal communication).

The success of a septic field system or on site soil absorption system is dependent upon several critical

factors. The soil must be sufficiently permeable to allow fluids to percolate 1 inch in 1 hour during a standard percolation test. Slopes may not exceed 10 percent gradient. The depth to bedrock must be at least 6 feet, and field lines must be placed at least 3 feet above bedrock. The water table must be 4 feet below the bottom of the trench; and it must be free from flooding. By combining the soil, slope, thickness of common excavation material, and drainage maps (Map Plate 3, 4, 5, and 6) a suitability map for on site soil absorption systems has been prepared (Map Plate 7).

Areas for on site soil absorption systems may be classified into areas that are suitable, marginal, and severely limited. Because there are no soils with high permeability that are free from flooding, there is no area shown as suitable. Areas that are shown as marginal have soils with only moderate permeability and no other limiting factors. In areas shown as severely limited, one or more of the undesirable conditions exists. It would not be impossible to construct on site soil absorption systems in areas designated as marginal or severely limited. However, these areas require that special engineering involving additional cost be implemented by planners and developers. For example, the permeability of the soil could be increased by bringing in sand or

other permeable material to add to or replace the soils with low permeability. Steep slopes could be graded. And shallow bedrock could be removed. Invariably these alternatives involve additional expenses that sometimes may prove prohibitive.

The Corps of Engineers expects 1,040,000 visitor-days annually after the first 3-year initial operating period to the Clinton reservoir. Adequate facilities (toilets and water) at field sports areas and camping and picnicking areas are necessary to accommodate these visitors. It cannot be stressed enough that without adequate facilities the recreational areas would be useless for such an influx of people. The on site soil absorption system suitability map should be consulted along with the thickness of common excavation map when planning these recreational areas (Map Plates 5 and 7).

Solid Waste Disposal

Regulations require that all refuse must be collected and disposed of in an existing city or county landfill. No new refuse disposal site may be established within the sanitation zone without the approval of the State Department of Health (K.S.A. art. 10 s 28-10-108a). The Douglas County Solid Waste Disposal Committee is currently looking for a county solid waste disposal site for the planned county-wide refuse collection and disposal service.

If a solid waste disposal site within the sanitation zone is desired, specific physical factors should be considered. The common excavation material must be at least 6 feet thick, the depth to the seasonal water table should be at least 6 feet, the unconsolidated material must be well-drained, permeability must not exceed 2 inches per hour, the area should be topographically well above flood plains, and slopes should not exceed 8 percent for area type and 15 percent for trench type landfills. No map has been prepared for solid waste disposal, however, the on site soil absorption map (Map Plate 7) may be used to help identify areas that may serve as appropriate sites. The only soils that meet the criteria are found in areas of glacial till and outwash. These soils are within the area marginally suited for on site soil absorption systems. The major part of the area is severely limited for solid waste disposal without costly alterations.

General Excavation

The term general excavation applies to activities that involve digging or moving soil, mantle, and rock for both terrain modification and founding structures. Of course, rock material is much more expensive to excavate than soil and mantle material. Some of the installations for which general excavation is necessary are foundations for single

and multiple family dwellings; pipelines for water, gas, and sanitary sewers; and holes for utility poles, fuel tanks, and septic tanks. The most important factors to be considered are the thickness of common excavation material and the bedrock type. Slope, soil properties, and natural drainage ways are also important factors.

In the case of foundations for buildings with basements the soil or mantle should be at least 5 feet deep to avoid costly ripping or blasting operations. Highly plastic soils that shrink when dry and swell when wet cause serious foundation problems and should be avoided when encountered. Areas of natural drainageways or high water tables subject to flooding should be avoided. Slopes greater than 15 percent will need grading.

Pipeline excavations are considerably more expensive in areas of thin soil because it is necessary to remove the rock by ripping or drilling and blasting. Gas lines and electrical cables may be buried from 2 to 3 feet while water lines must be buried at least 4 feet to prevent freezing. Adverse chemical reactivity of the soil necessitates expensive cathodic protection of the pipes. Soils that shrink and swell cause problems for buried electrical transmission lines by pulling away from the grounding system in dry periods resulting in an inefficient ground and increased communication interference.

Excavation for utility poles require at least 6 feet of soil if costly drilling is to be avoided. Buried fuel tanks require 5 feet of common excavation material. Refer to Figure 5 for a graphic display of these minimum depth requirements.

Mineral Resources

No oil, gas, or metalliferous rocks are known in the area. Deposits of coal, sand, gravel, and clay may be present, but they are of generally inferior grade or are too small to be economically exploited. The Morrill clay loam and Morrill-Gravelly land complex contain some gravel beds locally that are suitable for light road surfacing. These soils make up part of the stippled pattern delineating soils with moderate permeability and moderate shrink-swell potential on Map Plate 4. Limestone and shale are the only other materials that may be considered as mineral resources in the study area.

Shale may be used for making common brick where it meets the standards of quality. Crushed limestone for concrete aggregate, road metal, and agricultural lime has been quarried from the Toronto and Plattsmouth limestones. Other units that may be usable are the Spring Branch, Beil, Ozawkie, and Ervine Creek limestones. The overburden must be thin enough generally 10 feet to be stripped away economically.

No quarries are producing dimension stone at present. The Toronto limestone may be quarried as dimension stone when a complete unit is present and there is no more than 10 feet of overburden.

Consumers requiring riprap for road, bridge, railroad fill and embankment; and limestone for the construction of small bridges, rural schools, and numerous farm buildings have utilized the nearest local limestone.

Recreational Resources

Commonly, however, little money is available for recreational activities. It follows then that parcels of land that are unwanted for other purposes are designated for recreational activities that best fit the environment, however, geologic factors play an important part in determining the success or failure of locating areas for specialized recreational activities. If recreational areas are to be planned and developed at minimum cost, careful evaluation of the existing landscape and environment are important. For example, field sports (baseball, football, soccer, etc.) require cleared level areas. In contrast, picnicking, camping, and hiking generally take place in woodlands and gently rolling topography. Referring to the topographic map and accompanying woodland cover

(shown by shaded areas on the map) plus the slope map would help identify areas suitable for these activities.

Possibilities for recreational activities are too numerous to discuss in detail, but certain established historic and ecologic inferences can be made from virtually any of the factor maps. For example, open, enclosed, and panoramic scenic views can be determined by using the topographic map. The usefulness is called to the attention of planners.

A map has been prepared showing the public park areas surrounding the Clinton reservoir (Fig. 11). These areas will most likely be the most intensely used for recreational activities other than the lake itself.

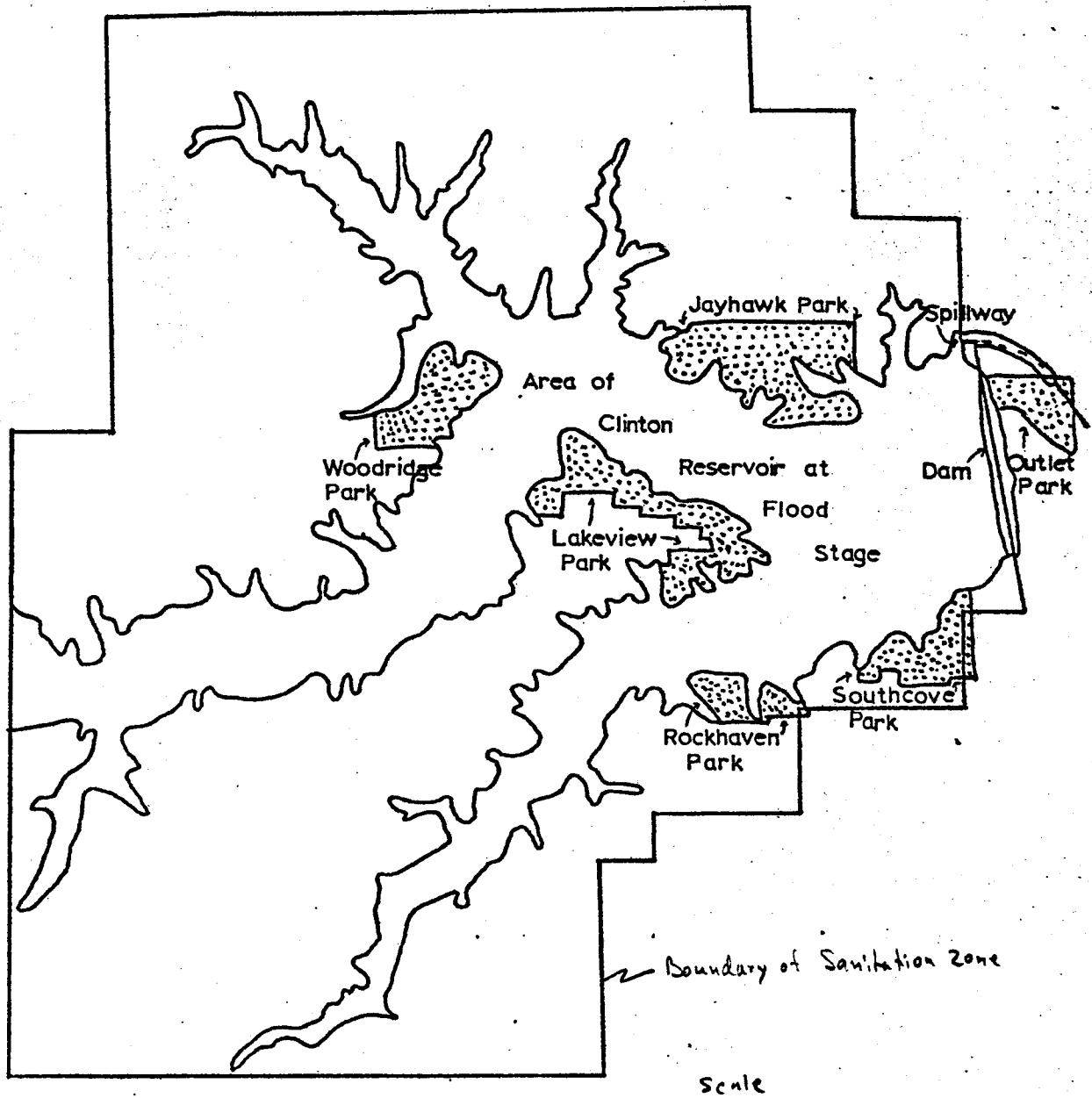


Fig. 11 Public areas around the Clinton reservoir
(after USA C of E, 1971)

CONCLUSIONS

(1) No suitable ground water supply is available with the possible exception of the Tonganoxie Sandstone

(2) Floodways should be maintained on the tributaries above the reservoir and zoning should be maintained below the dam to prevent losses from flooding.

(3) Locations for on site soil absorption systems are severely limited by one or more of the following: to the low permeability of the soil, flooding, high water table, or steep slopes.

(4) Suitable solid waste disposal sites are severely limited by the soil properties, depth to bedrock, and the proximity to a reservoir used for water supply purposes.

(5) Projects involving excavation encounter problems of high shrink-swell potential of soils, shallow depth to bedrock, flooding, high water tables, or steep slopes.

(6) Limestone and shale may be considered mineral resources where the overburden is thin enough and they meet the current standards of quality for specific use.

(7) Recreational activities should be matched with the physical environment of the land rather than placed haphazardly.

Table 1 Weather Statistics
Lawrence, Kansas (1945-1965)

Month	Average No. Days Max. Temp. 32°F. or Less	Average No. Days Min. Temp. 32°F. or Less	Average Rainfall Per Month (in.)	Average No. Days Rainfall Recorded Per Month
January	8.8	27.1	1.13	5.19
February	4.7	21.5	1.26	5.99
March	1.9	15.2	2.80	9.52
April	0	3.2	3.16	8.67
May	0	0	4.26	10.69
June	0	0	5.47	10.58
July	0	0	5.15	8.83
August	0	0	3.69	7.30
September	0	0	3.59	7.16
October	0	1.8	2.51	5.77
November	0.95	13.5	1.68	4.81
December	6.2	24.3	1.17	4.44

Table 1 Weather Statistics
Lawrence, Kansas (1945-1965)

Month	Number of 24-Hour Periods With More Than			
	2 in.	3 in.	4 in.	5 in.
January	0	0	0	0
February	1	0	0	0
March	0	0	0	0
April	0	0	0	0
May	6	0	0	0
June	8	3	2	1
July	12	4	2	1
August	10	3	0	0
September	8	2	1	0
October	2	0	0	0
November	3	1	1	0
December	0	0	0	0

APPENDIX

Table 2

Engineering Properties of Soils

1 Name of Soil	2 Depth from surface (in.)	3 Classification USDA texture	4 Unified	5 AASHTO	6 Soil reaction (pH)
Chase	0-14	silty clay loam	CL or ML-CL	A-7 or A-6	5.6-6.5
	14-60	silty clay	CH	A-7	5.6-7.3
Detlor	0-10	silty clay loam	CL or ML-CL	A-7	5.6-6.5
	10-30	light silty clay	ML-CL or CL	A-7	5.6-7.3
Dwight	0-5	silt loam	ML or CL	A-4 or A-6	5.6-7.3
	5-35	silty clay	CH	A-7	6.1-8.4
	35+	light silty clay	CL or CH	A-6 or A-7	6.6-8.4
Elmont	0-14	silt loam	ML or CL	A-4, A-6	5.1-6.1
	14-40	silty clay loam	CL	A-6	5.1-6.5
	40-60	silty clay loam	CL	A-7	5.6-7.3
Grundy	0-12	silty clay loam	ML-CL or CL	A-6	5.6-7.3
	12-30	silty clay	CH	A-7	5.1-6.5
	30-60	silty clay loam	CL or CH	A-6 or A-7	6.1-7.8
Gymer	0-8	silt loam	ML or CL	A-4 or A-6	5.1-6.5
	8-60	silty clay loam	CL	A-6 or A-7	5.6-6.5

Table 2
Engineering Properties of Soils

1	7	8	9	10
Name of Soil	Percentage Passing No. 4	Percentage Passing No. 10	Sieve No. 200	Permeability (in. per hr.)
Chase	100	100	90-95	0.20-0.63
	100	100	90+	0.06-0.20
Detlor	100	100	85-95	0.20-0.63
	100	100	90-98	0.06-0.20
Dwight	100	100	90-95	0.20-0.63
	100	100	90-95	under 0.06
	100	100	90-95	0.06-0.20
Elmont	100	100	70-90	0.63-2.00
	100	100	85-95	0.20-0.63
	100	100	85-95	0.20-0.63
Grundy	100	100	95-99	0.20-0.63
	100	100	95-99	0.06-0.20
	100	100	95-99	0.20-0.63
Gymer	100	100	70-90	0.63-2.00
	100	100	85-95	0.20-0.63

Table 2
Engineering Properties of Soils

1	11	12	13	14
Name of Soil	Shrink-swell potential	Depth to bedrock (in.)	Depth to water table (in.)	Remarks
Chase	moderate to high high	60	60	occasional flooding
Detlor	moderate to high high	20-40	60	
Dwight	low high	40	60	
	moderate to high			
Elmont	low to moderate moderate moderate to high	40	60	
Grundy	moderate to low high moderate to high	60	60	
Gymer	moderate moderate to high	60	60	

Table 2
Engineering Properties of Soils

1	2	3	4	5	6
Name of Soil	Depth from surface (in.)	Classification USDA texture	Unified	AASHTO	Soil reaction (pH)
Kennebec	0-60	silt loam	ML or CL	A-4 or A-6	5.6-7.3
Martin	0-14	silty clay loam	CL or ML-CL	A-7	5.6-6.5
	14-48	silty clay	CH	A-7	5.6-6.5
	48-60	light silty clay	CH or CL	A-7	6.6-7.8
Morrill	0-14	loam or clay loam	ML or CL	A-4 or A-6	5.6-6.5
	14-40	clay loam	CL	A-4 or A-6	5.6-6.5
	40-60	sandy loam to clay loam	SC or CL	A-4 or A-6	6.1-7.3
Oska	0-11	silty clay loam	ML-CL or CL	A-6 or A-7	5.6-6.5
	11-36	clay	CH	A-7-6	6.1-7.8
Pawnee	0-12	clay loam	CL or ML-CL	A-6 or A-7	5.6-6.5
	12-42	clay	CH	A-7	6.1-7.3
	42-60	light clay or clay loam	CL or CH	A-6 or A-7	6.6-7.8
Reading	0-14	silt loam	CL or ML	A-6 or A-4	5.6-6.5
	14-60	heavy silty clay loam	CL	A-7	6.1-7.8

Table 2
Engineering Properties of Soils

1	7	8	9	10
Name of Soil	Percentage Passing Sieve			Permeability
	No. 4	No. 10	No. 200	(in. per hr.)
Kennebec	100	100	70-90	0.63-2.00
Martin	100	100	90-99	0.20-0.63
	100	100	95-99	0.06-0.20
	100	100	90-99	0.06-0.20
Morrill	100	100	60-80	0.63-2.00
	100	100	60-80	0.20-0.63
	100	100	35-80	0.20-2.00
Oska	100	100	90-98	0.20-0.63
	100	100	95-100	0.06-0.20
Pawnee	100	100	65-90	0.20-0.63
	100	100	70-85	0.06-0.20
	100	100	65-75	0.20-0.63
Reading	100	100	70-90	0.63-2.00
	100	100	90-95	0.20-0.63

Table 2
Engineering Properties of Soils

1	11	12	13	14
Name of Soil	Shrink- swell potential	Depth to bedrock (in.)	Depth to water table (in.)	Remarks
Kennebec	low to moderate	60	60	flooding
Martin	moderate to low	48	60	local seepage
	high			
	moderate to high			
Morrill	low	60	60	
	moderate			
	low to moderate			
Oska	moderate	24-40	60	
	high			
Pawnee	low to moderate	60	60	
	high			
	moderate to high			
Reading	low to moderate	60	60	occasional flooding
	moderate to high			

Table 2
Engineering Properties of Soils

1	2	3	4	5	6
Name of Soil	Depth from surface (in.)	Classification USDA texture	Unified	AASHTO	Soil reaction (pH)
Sharpsburg	0-12	light silty clay loam	CL or ML	A-6	5.6-6.5
	12-36	heavy silty clay loam	CH or CL	A-7	5.6-6.5
	36-60	light silty clay loam	CL or ML	A-6 or A-7	6.1-7.3
Sibleyville	0-10	loam	ML or CH	A-4 or A-6	5.6-6.5
	10-30	light clay loam	ML or CL	A-4 or A-6	5.1-6.5
Sogn	0-9	clay loam	CL or CH	A-6 or A-7	6.1-8.4
Vinland	0-16	silty clay loam	ML or CL	A-6 or A-7	5.6-7.3
Wabash	0-12	silty clay loam or silty clay	CH or CL	A-7	5.6-7.3
	12-60	silty clay	CH	A-7	6.1-7.8
Woodson	0-9	silt loam	CL or ML-CL	A-7 or A-6	5.6-6.5
	9-44	silty clay	CH	A-7	5.6-7.3
	44-60	silty clay	CH or CL	A-7	6.1-7.8

Table 2
Engineering Properties of Soils

1	7	8	9	10
Name of Soil	Percentage Passing Sieve			Permeability
	No. 4	No. 10	No. 200	(in. per hr.)
Sharpsburg	100	100	70-90	0.63-2.00
	100	100	85-95	0.20-0.63
	100	100	80-90	0.63-2.00
Sibleyville	100	95-100	60-75	0.63-2.00
	100	95-100	70-80	0.63-2.00
Sogn	100	100	85-95	0.20-0.63
Vinland	100	100	85-95	0.20-0.63
Wabash	100	100	90-95	under 0.20
	100	100	90-95	under 0.20
Woodson	100	100	90+	0.20-0.63
	100	100	90+	under 0.06
	100	100	90+	0.06-0.20

Table 2
Engineering Properties of Soils

1	11	12	13	14
Name of Soil	Shrink- swell potential	Depth to bedrock (in.)	Depth to water table (in.)	Remarks
Sharpsburg	low to moderate moderate to high moderate	60	60	
Sibleyville	low moderate to low	20-40	60	
Sogn	moderate to high	6-20	60	
Vinland	moderate	6-20	60	
Wabash	high high	60	60	occasional flooding
Woodson	moderate high moderate to high	60	60	

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