Research Report

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ENGINEERING GEOGNOSY OF WARREN COUNTY

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OF
WARREN COUNTY

INTRODUCTION

Engineering soils and geologic maps are proving to be invaluable to engineers, industrial leaders, community planners, and administrators during the preliminary stages of planning and site selection. Quantitative engineering data on soils and geological formations, and the interpretation of these data, are important factors to consider in developing the best land-use plans and providing stable foundations for highways, buildings, and other structures, such as dams. Information of this type, when available, is being used by public and private organizations in planning urban development. Engineering soils and geologic maps can be used to great advantage in four major ways by planners and engineers to 1) make soil and geological reconnaissance surverys, 2) organize and check field surveys, 3) correlate performance with soil and geological types, and 4) locate construction material deposits.

Recognizing the need and demand for this type of information, the Research Division of the Kentucky Department of Highways has undertaken a pilot study to develop the engineering geognosy of a selected area in Kentucky. The area reported herein is located in the vicinity of Bowling Green.

This report discusses the engineering and geologic properties of unconsolidated surfical deposits and consolidated bedrock materials in Warren County, Kentucky. It is based on an interpretation of engineering test data retrieved and summarized from Kentucky Department of Highways' design and construction plans for routes I 65, US 31 W, KY 67, and the Bowling Green-Owensboro Parkway and published geologic and soil reports *(3, 5, 6, 7)*. Engineering soils and geologic maps and interpretations presented in this report should be viewed from a standpoint of rapidly providing generalized engineering and geologic information of the different soil and rock materials in the subject area. For important earthwork and foundation engineering purposes and for detailed and specific data, it is recommended that the soil and rock materials at a particular site be explored and tested thoroughly.

AREA UNDER CONSIDERATION

The area under consideration, lying between latitudes 36° 48′ N and 37° 10′ N and longitudes 86° 07′ W and 86° 40′ W, is located in the southern part of the Western Coal Field and the northern part of the Western Pennyroyal physiographic regions of Kentucky. Warren County has an area of 546 square miles and a population of 45,500. One metropolitan area, Bowling Green, with a population in excess of 28,000, is centrally located within the county and is situated on the Barren River.

The largest portion of Warren County, that area south of 37° 05′ latitude, is in the Pennyroyal Plain area, a part of the Pennyroyal physiographic region. This plain was formed through the weathering of a broad mass of Mammoth Cave limestones, extending from the Green River to the breaks of the Cumberland. Most of the area is a reservoir site from which streams flowing through the hilly belts both to the north and south and fed from underground sources. The land is very well drained with most streams being auxilary spillways after heavy rains. These streams, with the exception of the Barren and Green Rivers, are very minor factors in the making of the landscape. They have no significance as barriers, very little as a means of communication, and small value for water supply.

Most of the surface is strikingly smooth with rock outcrops rarely found in the area. Bedrock is usually encountered at a depth from two to fifteen feet. This can be partially attributed to the fact that limestone does not furnish a great amount of residual debris on weathering, and much of the weathered material may have been carried down into the cavernous passages where it is carried out of the area. Development of present surface features and soil is esentially the work of solution and underground drainage.

Upland soils of the Pennyroyal Plain show minor variations in lithology. Where chert and argillaceous materials are interbedded with the limestones, they give rise to a stoney, clayey soil of lower fertility than that formed by the weathering of normal limestone. Along the northern margin of the plain, there is, in places, an admixture of sand which seems to be residual. Most of the local variations in soils result from different modifications of essentially uniform rock materials. The usual surface soil is a rich brown silt loam which merges into a red clay subsoil. This surface soil is usually well drained, well aerated, and exceeded in productivity only by the central Bluegrass soils, which has a higher phosphorus and lime content.

On slopes, the surface soil tends to give way to the finer textured subsoil. Soil material washed from these slopes is carried into depressions where it is deposited and forms level-floored basins. This washed-in material is usually silty in texture and poorly drained.

The section of Warren County immediately to the north of 37° 05′ latitude has been previously known as the Southern Clifty area and is within the Western Coal Field and the Western Pennyroyal physiographic regions. This area is characteristically represented by a narrow fringe of continuous sandstone ridges and table lands. The southern part of the sandstone highland is of Mississippian age, the northern part Pennsylvanian. Drainage of both sandstone belts is mostly to the north into the central part of the coal basin. From the Pennyroyal Plain, the water flows across the Mississippian sandstone, then across the Pennsylvanian sandstone and conglomerate into the shales of the coal basin. Valleys are therefore more numerous and more mature in the Pennsylvanian area than in the Clifty area.

Valleys in the Clifty area consist of solution depressions which are separated by distinct knolls. Soils found on these knolls are characteristically thin with much outcropping of a bleached limestone and sandstone. About 90 percent of the soil in these valley areas is made up of various silt loams underlain by several feet of clayey residuum from limestones, sandstones, and shales. The other ten percent is mostly alluvial soils along the Barren and Green Rivers.

From these lower valleys, the ascent to the upland is by steep slopes, which are uniformly forested. Where rock is visible on these slopes, it is moderately coarse sandstone of reddish brown color. Very little of this upland area is used for agricultural purposes because of steepness and limited fertility. Soils of this area are predominately silt loams or fine sandy loams underlain by limestone and sandstone.

GEOLOGY

It is known from the presence of the great series of sediments existing in the interior of North America that during Paleozoic time this region was occupied at intervals by rather shallow epicontinental seas which were connected with the oceanic basins to the north, east, south, and west. The important land masses from which the sediments deposited in Kentucky were derived lay to the east, along that belt which is now occupied by the Piedmont Plateau, and to the north in Canada. Although sedimentation was in progress over the Warren County area during the Cambrian, Ordovician, and Silurian Periods, rocks of these ages are now completely buried beneath the younger formations. Ordovician and Silurian rocks are exposed, however, in the vicinity of Lexington and Nashville and consist almost exclusively of limestones, indicating widespread marine conditions far from shore.

Warren County is situated on the west flank of the Cincinnati Arch, just south of the axis of the syncline which noses between the Nashville and Cincinnati Domes. The strata generally strike northeast-southwest and dip to the northwest at the rate of about 30 feet per mile.

Faults are common throughout this area. About ten occur along or near the Edmonson-Warren County line. In this section of Kentucky, faults are of the normal type and the downthrow is generally to the north. Closely associated with the faults are folds. Most of the irregularities in the dips of the beds are undoubtedly due to neighboring faults. The faults are of short extend and where they run out, the displacement is adjusted in small anticlinal noses or local anticlines with inclinations as much as six times steeper than the dip of the beds. Indications are that considerable movement has taken place along some of the faults. A diamond shaped pattern resulting from the intersection of two systems of faults is clearly evident near the Edmonson-Warren County line.

Of the numerous faults recognized in northeastern Warren County, only one was considered significant enough to be mentioned by Weller *(3)*. This fault extends from the Big Clifty capped upland to the lowland in the south, about midway between Sand Hill and Girkin. At this point, its throw in the displacement of the Big Clifty sandstone is about 40 feet.

EARTHQUAKES

Earthquakes are a potential hazard to the study area because of numerous faults and a long history of seismic activity in the extreme western part of Kentucky. The only earthquakes of significant magnitude were located approximately 100-150 miles to the west and northwest of Bowling Green. While no shocks have been centered very near Bowling Green, the effect of an earthquake of magnitude equivalent to the New Madrid quake of 1811-12 could have a very damaging effect on bridges and multistory buildings. The most seriously affected area of the New Madrid quake was characterized by raised and sunken lands, fissures, sinks, sand blows, and large landslides. This area was largely contained within a radius of 50-75 miles, and there was sufficient shock to topple chimneys as far as 300 miles away.

The New Madrid earthquake, according to Heck *(1)*, was due to a fracture in deep-seated rocks, probably a further adjustment of an old break. Apparently the doming and sinking were complementary processes in unconsolidated material, resembling quicksand, along with an indication that there had been considerable relief of the stresses.

ENGINEERING INTERPRETATIONS AND CORRELATION OF SOIL TYPES WITH GEOLOGIC FORMATIONS

ALLUVIUM

Soils of the alluvial deposits in Warren County are of the Newark-Nolin-Lawrence association, which includes an estimated six percent of the area. This association consists of soils on flood plains and stream terraces along the Barren, Green, and Gasper Rivers, with less significant deposits along the smaller streams. These deposits along the Barren, Green, and Gasper Rivers are composed of silts and muds with an admixture of a considerable amount of sand. In contrast, the alluvium of the smaller tributaries is more sandy and contains both angular and rounded pebbles derived from the adjacent formations. Soils associated with the alluvial and terrace deposits may be classified by the textural, AASHO, and Unified Systems (Table 1) as clays and silty clays, A-6 and A-7-6, and CL and ML, respectively. Mechanical analyses indicate that these alluvial soils, on the average, are composed of about 13 percent coarse and fine sand, 50 percent silt, and 37 percent clay. Depth to bedrock is usually over ten feet and the permeability varies from slow to moderate in the natural state to impervious when the material is compacted.

Since almost all industrial development and expansion of transportation facilities tend to locate along the flat or rolling areas, it would be appropriate to discuss the advantages and disadvantages of these alluvial materials. Generally, the alluvial deposits could be rated from fair to good with regard to workability as a construction material. Consistency ranges from very stiff to soft, depending on the particular location.

When these soils are compacted and saturated, the compressibility is medium and the shear strength is fair. Problems could be encountered in the construction of multistory buildings in these alluvial deposits. In order to prevent failure in shear, due to the plastic flow of the compressible soil beneath the foundations, it will be necessary to place buildings on piles driven to bedrock. Allowable bearing pressure varies from 0.5 to 4.0 tons per square foot in parts of the alluvium, and in some localities, these soils could be highly compressible under heavy loads. Some of these areas are poorly drained with very high ground water table and occasional flooding. Isolated sections of the alluviul deposits are unsuitable for heavy industrial development due to geologic and physical non-uniformity in type, structure, thickness, and density of the soil medium. These areas can be determined by a thorough site investigation, which would be a necessary part of any preliminary survey.

Due to the high percentage of silty material found in the alluvium, the problem of frost action could be detrimental to highways, airfields, and the stability of slopes in cuts and fills. In order to minimize frost heave, the frost-susceptible soils can be excavated and replaced by various gravels.

Slopes of excavations will stand almost vertically in the alluvial material. These alluvial soils vary from unsuitable in some cases to fair in others for use as subgrade material for roadways.

RESIDUAL SOILS ASSOCIATED WITH THE MISSISSIPPIAN SYSTEM

Approximately 90 percent of Warren County is covered by residual soils from weathered limestones, sandstones, and shales of the Mississippian System. Soils associated with these materials may be classified by the textural, AASHO, and Unified Systems as clays, silty clays, and loams; A-4, A-6, A-7-6; and CL, CH, and ML-CL, respectively. Depth to bedrock in this section of the county varies from 2 to 20 feet with the topography ranging from broad level areas to steep hillsides and toe slopes. Permeability ranges from rapid to very slow in the natural state to impervious after being compacted.

Most residual soils in the county have medium compressibility and fair shear strength when compacted and saturated. Workability as a construction material is fair throughout the county, but most construction should be restricted to the more level areas of the Pennyroyal Plain. Fair to poor subgrade and fill material for highways are found throughout the county. Most soils are fair foundation materials, depending on the ground water conditions at the particular location.

Some sections of Warren County have been developed quite extensively, with the Bowling Green area having the largest concentration of industry. The soils of this area are predominately silty clay loams underlain by the Ste. Genevieve Formation. These soils are very similar to other residual soils in the county, with the exception of those associated with the Big Clifty Sandstone Member. Soils derived from the Big Clifty Sandstone have an average composition of about 46 percent sand, 27 percent silt, and 27 percent clay. This compares to an average composition of about 13 percent sand, 62 percent silt, and 25 percent clay for those soils overlaying the Ste. Genevieve Limestone.

Engineering problems associated with these silty clay loams underlain by the Ste. Genevieve Formation are very few and the soils are suitable for almost any type of industrial, transportational, or community development.

These engineering interpretations and limitations are given in Tables 2 and 3. Indications are that the loams overlying the Ste. Genevieve Limestone will support moderate to heavy loads with little differential settlement. These soils will make fair subgrade material for highways, and they have relatively high CBR values. Some of the loams are subject to erosion but not severe enough to retard development in these areas.

RESIDUAL SOILS ASSOCIATED WITH THE PENNSYLVANIAN SYSTEM

The Caseyville Formation, which is found in the northern section of Warren County, is the only member of the Pennsylvanian System in the county. Residual soils of this particular area are underlain by a massive and fine-to-coarse-grained sandstone. These soils make up approximately four percent of the entire country, and they are not significantly different from the residual soils of the Mississippian System. Most of these silty and sandy loams contain many fragments of stone in an area of rough, broken topography, which is about three-fourths woods and brush. Permeability and surface runoff are rapid and the water table is usually six feet or more from the surface.

Areas associated with these soils are the least developed of any in Warren County and probably will continue to be rejected for the most easily accessible and more highly developed Bowling Green area.

HYDROLOGIC CONDITIONS

ALLUVIUM -- RECENT AND PLEISTOCENE

These water-bearing deposits are located along the Green and Barren Rivers, and less significantly along the smaller streams. Some water is obtained from the fine sand, silt, and clay of the alluvium, but most wells drilled into these materials are inadequate for a domestic supply (more than 100 gpd) with bucket or bailer. Dug wells also yield less than 100 gpd and are inadequate for a domestic supply. Coarse sand and gravel may be encountered in the alluvimn where rocks of Pennsylvanian age are close to streams. Wells penetrating these deposits yield as much as 50 gpm.

MISSISSIPPIAN ROCKS OF CHESTER AGE

These rocks of Chester age include those making up the Leitchfield, Glen Dean, Hardinsburg, Haney, Big Clifty, and Girkin Formations.

Most drilled wells are adequate for a domestic supply (more than 500 gpd) with a power pmnp and are as deep as 500 feet. Dug wells in which the water level is close to perennial stream level are adequate for bailer (more than 100 gpd), and many are adequate for a domestic supply with a power pump (more than 500 gpd).

A spring horizon is present at the shale-limestone contact of the Hardinsburg Sandstone and the Glen Dean Limestone. A second conspicuous horizon occurs at the base of the Big Clifty Sandstone. Yields of as much as 50 gpd are obtained from wells that penetrate large solution channels in the limestone of the Girkin Formation. Dug wells in the Big Clifty Sandstone, on the Manunoth Cave Plateau, are generally adequate for a domestic supply (more than 500 gpd) with a power pump where the saturated layer is thick.

The northwestern corner of the Bowling Green quadrangle also exposes Mississippian rocks of Chester age, but a large percentage of the drilled wells are inadequate for a domestic supply. Almost all dug wells are inadequate for a domestic supply unless they are located close to some body of water.

MISSISSIPPIAN ROCK OF MERAMEC AGE

The rocks of Meramec age include the Ste. Genevieve and St. Louis Limestones, located predominately in the southern portions of the county.

More than three-fourths of the drilled wells in this area yield enough water for a domestic supply (more than 500 gpd) with a power pump. Very few wells are in adequate for domestic use (less than 100 gpd) and those wells penetrating large solution channels in limestone yield from 5 to 50 gpm. Dug wells are inadequate for a domestic supply (less than 100 gpd) except where water levels are close to perennial stream levels.

Springs with low flows ranging from less than 10 gpm to about 1500 gpm and maximum flows from less than 100 grm to more than 100,00 gpm occur at or near stream level.

Minimum flows generally occur in early fall and maximum flows in late winter. A few drilled wells that intercept major solution channels in limestone yield as much as the flow of springs, but most wells are inadequate for domestic use (less than 100 gpd).

ROCKS OF PENNSYLVANIA AGE (CASEYVILLE FORMATION)

Nearly all drilled wells in the upland are inadequate for power pumps (less than 500 gpd). About half the wells in the upland do not yield enough water for a domestic supply with a bailer or bucket (less than 100 gpd). Drilled wells in the lowland area bordering streams generally yield enough for power pumps (more than 500 gpd).

Dug wells in lowland areas bordering streams yield enough water for a domestic supply with bailer or bucket (more than 100 gpd) if adequate storage is provided for peak needs. Very few dug wells are adequate for a domestic supply with a power pump (more than 500 gpd).

MINERAL RESOURCES

The principal mineral resources of Warren County are oil and limestone. Oil has been exploited quite extensively throughout the county. Drilling started in the 1920's and has continued intermittently to the present. Production ranging from low to moderate is obtained from the Salem and Warsaw Limestones of late Mississippian Age, which lie directly beneath the St. Louis Limestone, and from three zones within 20 feet of the base of the Chattanooga Shale of late Devonian age. Most of the wells produce a lightweight oil in quantities less than five barrels per day.

Limestone quarrying is of equal importance to oil production in development of mineral resources of Warren County. During 1960 and 1961, one quarry near Bowling Green was in operation and furnished crushed and sized aggregate, building stone, and agricultural limestone. Limestone is quarried principally from the Ste. Genevieve Limestone, the basal part of the Girkin Formation, the Glen Dean Limestone, and the Haney Limestone Member. Limestone is also thick enough to be quarried economically in the St. Louis, Salem, and Warsaw Limestones. These last three limestones are not of desirable color for building stone, and the chert content may make these rocks undesirable as sources of crushed limestones.

Small amounts of coal have been mined for local consumption from the upper part of the Big Clifty Sandstone Member of the Golconda Formation. The coal occurs in thin and discontinuous seams and has a rather high ash content.

Thin beds of asphalt-bearing sandstones have been found in the Hardinsburg Sandstone near Anna, but the beds are not commercially developed at present. A limited production of gas from rocks of Devonian or Silurian age is also noted.

FLOODING

There are three rivers, the Barren, Green, and Gasper, located within or on the border of Warren County. On two of these, the Barren and Green Rivers, the problem of flooding has been reduced considerably since completion of the Barren and Green River Reservoirs. The Barren River Reservoir, located approximately 20 miles upstream from Bowling Green, was completed in 1965 and has done a remarkable job in the control of floods. In addition to flood control, the reservoir has assured Bowling Green a constant flow of water for municipal and industrial use.

The maximum recorded stage in Bowling Green was 52.2 feet in 1913 when the water reached 462 feet above mean sea level. Locally heavy rains in June of 1969 caused some flooding in the Bowling Green area, but this was due to the heavy surface runoff causing overflow of drains rather than actual flooding from the river channel. Flood stage is a river stage of 28 feet (437.83 feet above sea level).

Flooding of the Green and Gasper Rivers in Warren County is not a major problem since they do not pass through any urban areas, and the only significant damage is that caused by flooding cropland.

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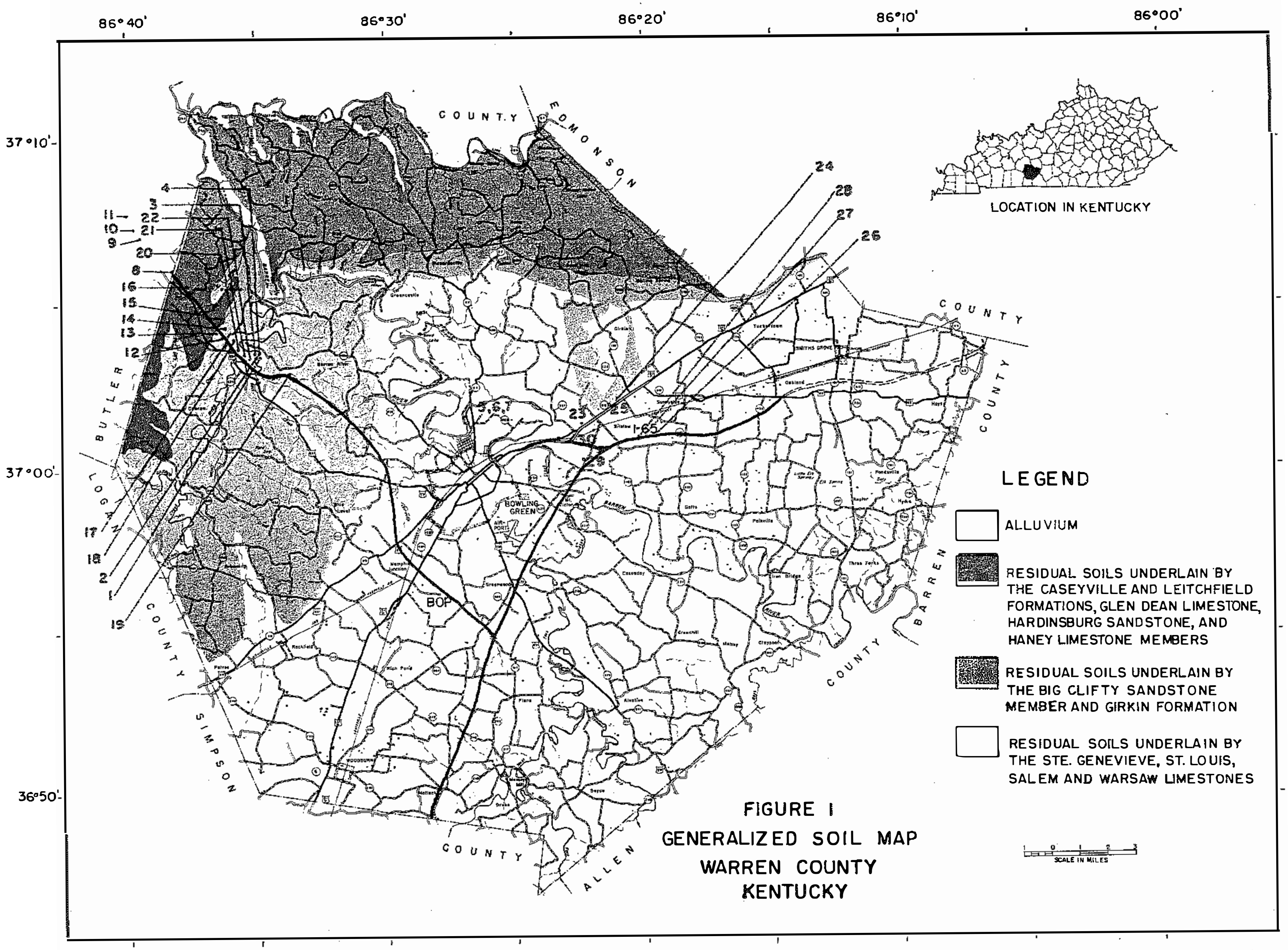

FIGURE I
GENERALIZED SOIL MAP
WARREN COUNTY
KENTUCKY

SYSTEM	SERIES	FORMATION		THICKNESS (FEET)		DESCRIPTION
QUARTERNARY		ALLUVIUM		0-20		CLAY, SILT, SAND, GRAVEL
CARBONIFEROUS	PENNSYLVANIAN — LOWER PENNSYLVANIAN	CASEYVILLE FORMATION		30+		SANDSTONE, CONGLOMERATE
CARBONIFEROUS	MISSISSIPPIAN — UPPER MISSISSIPPIAN	LEITCHFIELD FORMATION	UPPER MEMBER	30-50	55-70	SHALE, SANDSTONE, LIMESTONE
			LOWER SANDSTONE MEMBER	25-35		SANDSTONE
		GLEN DEAN LIMESTONE		40-50		LIMESTONE
		HARDINSBURG SANDSTONE		10-45		SANDSTONE, SHALE
		GALCONDA FORMATION	HANEY LIMESTONE MEMBER	10-55	70-125	LIMESTONE
			BIG CLIFTY SANDSTONE MEMBER	40-80		SANDSTONE, SHALE
		GIRKIN FORMATION		110-160		LIMESTONE, SANDSTONE, SHALE
		STE. GENEVIEVE LIMESTONE		180-215		LIMESTONE
		ST. LOUIS LIMESTONE		55+		LIMESTONE
		SALEM & WARSAW LIMESTONE		110-155		LIMESTONE

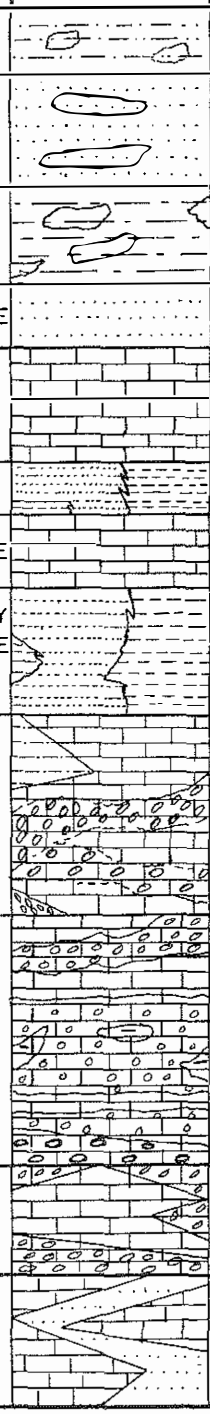

FIGURE 2 GENERALIZED COLUMNAR SECTION

TABLE 1. ENGINEERING SOIL TEST DATA

MAP UNIT	UNDERLYING MATERIALS	SAMPLE NUMBER	CLASSIFICATION			DEPTH TO BEDROCK (FEET)	ELEVATION (FEET)	
			TEXTURAL	AASHO	UNIFIED		TOP	BOTTOM
Alluvium		1	Silty clay	A-6 (13)	CL		424	418
		2	Silty clay loam	A-4 (5)	ML-CL		427	424
		3	Silty clay	A-6 (13)	CL		423	401
		4	Silty clay loam	A-6 (8)	CL		424	399
		5	Clay	A-6 (11)	CL	5	450	449
		6	Clay	A-7-6 (13)	CL		449	447
		7	Clay	A-7-6 (17)	CH		447	446
Residual soils underlain by the Caseyville and Leitchfield Formations, Glen Dean Limestone, Hardinsburg Limestone, and Haney Limestone	Sandstone	8	Silty clay loam	A-4 (8)	ML-CL	16	663	658
			Clay	A-7-6 (20)	CH		658	649
			Clay	A-7-6 (15)	ML-CL		649	647
	Shale and limestone	9	Clay	A-7-6 (20)	CH	21	570	565
			Shale		CL		565	549
	Shale and limestone	10	Clay	A-7-6 (19)	CH	2	584	582
		11	Clay	A-7-6 (19)	CH	4	535	534
			Silty clay	A-6 (8)	CL		534	531
	Sandstone underlain by limestone	12	Clay	A-6 (8)	CL	10	643	634
			Silty clay loam	A-6 (8)	CL		634	633
	Sandstone	13	Clay	A-6 (10)	CL	6	639	635
			Clay loam	A-4 (1)	ML-CL		635	633
		14	Silty clay loam	A-6 (9)	CL	14	633	625
			Clay loam	A-6 (7)	CL		625	619
	Sandstone, soft shale, and limestone	15	Clay	A-6 (8)	CL	5	586	580
	Sandstone, hard shale, and limestone	16	Silty clay loam	A-4 (4)	ML-CL	10	583	577
			Clay	A-5 (7)	CL		577	573
Residual soils underlain by the Big Clifty Sandstone and the Gerkin Formation	Sandstone and limestone	17	Clay	A-7-6 (13)	ML-CL	7	667	663
			Sandy clay loam	A-2-4 (0)	SM		663	660
	Sandstone and limestone	18	Clay loam	A-4 (1)	ML-CL	3	669	666
	Sandstone and limestone	19	Clay loam	A-4 (1)	ML-CL	18	627	623
			Sandy clay loam	A-2-4 (0)	SM		623	619
			Clay	A-7-6 (13)	ML		619	609
		20	Clay	A-6 (14)	CL	7	451	444
	Sandstone, soft shale and limestone	21	Clay	A-7-6 (20)	CH	3	576	573
	Sandstone, soft shale, and limestone	22	Clay	A-4 (4)	CL	8	606	598
Residual soils underlain by the Ste. Genevieve, St. Louis, Salen, and Warsaw Limestones		23	Silty clay loam	A-6 (11)	CL	4	538	536
			Silty clay loam	A-6 (10)	ML-CL		536	534
		24	Silt loam	A-6 (10)	CL	8+	550	548
			Silty clay loam	A-7-6 (13)	CL		548	545
			Silty clay loam	A-6 (12)	CL		545	542
		25	Clay	A-7-6 (17)	CL	4+	544	540
	Limestone	26	Clay	A-7-6 (14)	CL	11	540	535
			Clay	A-7-6 (16)	CL		535	529
		27	Clay	A-6 (9)	CL	9	521	512
					CL			
		28	Silty clay	A-6 (9)		20	511	507
			Clay	A-6 (11)	CL		507	502
	Limestone	29	Clay loam	A-4 (5)	ML-CL	22	537	535
			Clay	A-6 (10)	CL		535	532
			Clay	A-7-6 (16)	CH		532	515
		30	Silty clay loam	A-4 (8)	ML-CL	18	522	520
			Clay	A-6 (10)	CL		520	511
			Clay	A-7-6 (10)	CH		511	504

TABLE 1. ENGINEERING SOIL TEST DATA

MAP UNIT	NATURAL MOISTURE CONTENT (PERCENT)	FIELD MOISTURE EQUIVALENT (PERCENT)	VOLUME CHANGE FROM FIELD MOISTURE EQUIVALENT (PERCENT)	SHRINKAGE LIMIT	SHRINKAGE RATIO	SHRINKAGE INDEX
Alluvium	19.6					
	21.3					
	24.9					
	23.3					
		26.0	0.0	30.2	1.48	-11.2
		23.0	0.0	26.8	1.54	-10.8
		24.0	0.0	24.6	1.61	-5.6
Residual soils underlain by the Caseyville and Leitchfield Formations, Glen Dean Limestone, Hardinsburg Limestone, and Haney Limestone		21.7	0.0	27.0	1.54	-5.7
		20.6	5.5	17.6	1.83	2.4
		17.5	0.0	20.1	1.76	6.7
		33.4	29.3	17.4	1.83	8.9
		23.3	15.6	15.2	1.92	4.0
		23.5	0.0	31.3	1.46	-8.4
	27.8					
	27.8					
	18.9	21.3		27.2	1.54	-8.9
	18.9	19.7		22.6	1.65	-4.0
	15.9	21.1		22.3	1.65	-2.1
	8.1	21.4		25.8	1.57	-6.3
	21.2	23.1		27.9	1.52	-7.9
	17.2	21.8		20.7	1.72	-2.7
	17.5	20.8		21.5	1.68	-4.1
	15.7	23.6		28.5	1.50	-6.5
	14.8	23.0		16.0	1.91	3.8
Residual soils underlain by the Big Clifty Sandstone and the Gerkin Formation	24.3	34.9		36.9	1.35	-8.1
	20.0			32.7	1.42	
	13.8	19.6		26.2	1.59	-9.5
	13.8	19.6		26.2	1.59	-9.5
	20.0			32.7	1.42	
		22.1		32.1	1.43	-11.4
	24.1					
	30.8	33.7		15.1	1.94	11.6
	20.0	19.6		22.1	1.68	-3.5
Residual soils underlain by the Ste. Genevieve, St. Louis, Salem, and Warsaw Limestones		21.0	0.0	26.2	1.57	-10.5
		20.0	0.0	25.5	1.60	-10.9
		25.7	0.0	30.0	1.47	-10.8
		21.7	0.0	21.9	1.69	-5.2
		19.7	0.0	20.9	1.73	-6.6
		24.3	6.8	20.4	1.74	-3.5
		23.9	0.0	27.9	1.54	-6.9
		24.0	0.0	30.7	1.46	-8.0
	21.8	20.5	0.0	20.4	1.73	-1.5
	28.3	20.3	0.2	21.9	1.70	-2.9
	23.1	21.0	9.0	20.5	1.73	-2.1
		19.2	0.0	25.0	1.56	-7.5
		24.8	0.0	26.1	1.56	-5.0
		28.4	0.0	35.7	1.37	-11.3
		23.2	0.0	27.5	1.50	-5.6
		22.6	0.0	24.7	1.58	-4.2
		28.5	3.6	26.2	1.56	-1.9

TABLE 1. ENGINEERING SOIL TEST DATA

MAP UNIT	MAXIMUM DRY DENSITY (LBS/CU FT)	OPTIMUM MOISTURE CONTENT (PERCENT)	LIQUID LIMIT	PLASTICITY INDEX	CALIFORNIA BEARING RATIO	SPECIFIC GRAVITY	GRAIN SIZE DISTRIBUTION (PERCENT)				
							COARSE SAND	FINE SAND	SILT	CLAY	COLLOIDS
Alluvium			36.1	14.7		2.64	0.9	9.1	54.5	35.5	21.8
			28.0	8.7		2.63	0.6	20.4	51.8	27.2	17.0
			33.6	15.6		2.68	1.0	9.0	59.0	31.0	22.0
			28.6	11.8		2.62	0.0	18.0	55.3	26.7	19.5
	104.0	17.8	38.0	19.0	8.5	2.60	1.1	13.0	50.5	35.4	19.4
	106.5	17.8	41.0	25.0	7.5	2.62	5.2	4.1	44.4	46.3	38.6
	100.3	21.0	52.0	33.0	6.0	2.68	2.7	5.2	31.7	60.4	54.6
Residual soils underlain by the Caseyville and Leitchfield Formations, Glen Dean Limestone, Hardinsburg Limestone, and Haney Limestone	108.8	16.7	25.0	3.7	5.7	2.62	0.4	6.1	71.5	22.0	7.0
	99.1	22.5	65.5	45.5	1.5	2.72	0.4	10.2	15.6	63.8	48.0
	108.8	18.4	49.6	22.8	4.4	2.73	0.7	1.1	51.9	46.3	31.5
	89.7	22.5	90.2	63.9	2.4	2.69	1.6	0.9	23.5	74.0	58.0
	110.0	15.9	43.5	24.3	2.9	2.73	6.6	7.9	39.5	46.0	23.0
	99.9	22.0	56.3	33.4	7.0	2.69	0.2	0.0	44.8	55.0	40.0
			54.5	30.2		2.75	2.8	3.5	39.2	54.5	42.5
			31.6	12.7		2.69	1.0	8.1	58.9	32.0	18.0
	109.5	17.4	34.0	15.7	5.4	2.65	0.8	33.2	30.5	35.5	28.0
	113.0	15.6	30.0	11.4	8.5	2.63	0.8	16.2	53.7	29.3	19.0
	110.8	16.5	33.8	13.6	8.6	2.61	1.7	16.8	47.9	33.9	33.6
	114.2	15.2	26.2	6.7	13.7	2.64	0.4	44.6	28.5	26.5	18.8
	109.6	17.2	31.7	11.7	12.0	2.64	1.6	15.9	60.2	22.3	14.5
	115.8	15.1	29.7	11.7		2.67	1.5	21.4	46.9	29.8	18.3
	112.9	14.8	30.4	13.0	10.0	2.63	2.0	21.5	45.0	31.5	24.5
	106.1	16.5	27.1	5.1	5.2	2.62	1.0	6.0	68.3	24.7	15.0
	115.8	14.8	31.7	11.9	1.8	2.75	12.6	15.7	39.8	31.9	18.5
Residual soils underlain by the Big Clifty Sandstone and the Gerkin Formation	95.8	25.8	46.0	17.2	7.6	2.69	0.4	26.6	21.8	51.2	43.4
	110.2	17.2	NP	NP	9.7	2.62	0.2	56.8	19.2	23.8	17.3
	118.3	13.7	21.9	5.2	14.0		0.6	35.8	41.8	22.6	13.0
	118.3	13.7	21.9	5.2	14.0	2.64	0.6	35.8	41.8	22.6	13.0
	110.2	17.2	NP	NP	9.7	2.62	0.2	56.8	19.2	23.8	17.3
	119.8	13.0	22.2	1.5	23.7	2.64	0.2	59.2	20.4	20.2	13.3
			35.9	19.5		2.70	6.1	13.9	40.0	40.0	29.8
	93.0	28.5	70.1	43.4	1.7	2.74	2.1	14.6	19.8	64.4	55.5
	116.2	14.2	26.6	8.0	11.9	2.67	0.8	28.2	40.7	30.3	20.0
Residual soils underlain by the Ste. Genevieve, St. Louis, Salem, and Warsaw Limestones	106.4	17.1	32.7	17.0	12.3	2.67	1.1	14.3	62.2	22.4	7.6
	108.8	16.7	39.4	14.8	9.2	2.70	0.5	13.8	56.6	29.1	12.5
	104.5	17.4	33.2	14.0	11.3	2.63	0.8	12.0	74.2	13.0	5.6
	110.3	16.7	40.3	23.6	14.7	2.68	0.4	11.3	63.5	24.8	9.5
	112.8	15.0	38.4	24.1	12.0	2.71	1.7	10.0	59.6	27.7	12.5
	102.2	21.4	46.6	29.7	5.7	2.72	0.5	13.0	54.6	32.1	15.4
	105.0	19.8	43.9	22.9	10.1	2.70	15.0	5.0	33.0	47.0	32.5
	100.0	21.1	48.6	25.9	9.9	2.71	8.8	11.0	33.7	46.5	31.5
			31.3	12.4		2.67	4.8	7.0	53.2	35.0	10.0
			30.3	11.3		2.71	1.3	2.7	64.7	31.5	11.5
			35.2	16.8		2.68	2.3	5.0	51.7	41.0	24.0
	111.5	14.1	24.9	7.4	15.3	2.56	8.0	32.0	34.7	25.3	15.7
	108.1	16.1	36.2	15.1	11.5	2.63	5.2	17.0	35.0	42.8	27.4
	102.2	21.0	50.8	26.4	5.2	2.68	14.8	14.9	16.0	54.3	41.2
	105.2	15.9	30.3	8.4	13.5	2.55	0.8	15.8	54.0	29.4	15.7
	108.9	16.3	35.9	15.4	10.3	2.59	0.8	10.5	47.5	41.2	25.7
	96.4	22.4	54.7	30.4	3.0	2.64	1.8	12.4	21.0	64.8	55.4

TABLE 2. GENERAL ENGINEERING INTERPRETATION OF SOIL AND ROCK UNITS

MAP UNIT	GROUND WATER CONDITIONS	PERMEABILITY IN NATURAL STATE	PERMEABILITY WHEN COMPACTED	COMPRESSIBILITY WHEN COMPACTED AND SATURATED	SHEARING STRENGTH WHEN COMPACTED AND SATURATED	WORKABILITY AS A CONSTRUCTION MATERIAL	POTENTIAL FROST ACTION	SLOPE STABILITY IN OPEN CUTS
Alluvium	Severe; Seasonal high water table within 1/2 to 4 feet of surface	Moderate to slow	Impervious	Medium	Fair	Good to fair	Medium to very high	Cut slopes stand steeply to near vertical
Residual soils underlain by the Caseyville and Leitchfield Formations, Glen Dean Limestone, Hardinsburg Sandstone and Haney Limestone	Severe To moderate; Water table from 1/2 to 6 feet or more from surface	Rapid to very slow	Semipervious to impervious	Medium to high	Fair to poor	Good to poor	Medium to very high	Cut slopes stand steeply to near vertical except in shales, which must be capped with more resistant material
Residual soils underlain by the Big Clifty Sandstone and the Girkin Formation	Good; Well to fairly well drained	Moderate to moderately slow	Semipervious to impervious	Low to high	Good to poor	Good to poor	Slight to very high	Cut slopes will stand nearly vertical except where sandy soil is uncemented and friable
Residual soils underlain by the Ste. Genevieve, St. Louis, Salem and Warsaw Limestones	Good; Well drained	Moderate to moderately slow	Semipervious to impervious	Medium to high	Fair to poor	Good to fair	Medium to very high	Cut slopes will stand steeply to near vertical

TABLE 2. GENERAL ENGINEERING INTERPRETATION OF SOIL AND ROCK UNITS

MAP UNIT	EROSION RESISTANCE	RELATIVE SUITABILITY FOR USE IN							SAND AND GRAVEL	TOPSOIL
		ROADWAYS			ROLLED EARTH DAMS					
		FILLS	SUBGRADES	FOUNDATIONS	HOMOGENEOUS EMBANKMENTS	CORES	SHELLS			
Alluvium	Slight to none	Fair to poor	Fair to poor	Fair to unsuitable, depending upon groundwater seepage	Fair	Good to fair	Cannot be used		Poor	Good
Residual soils underlain by the Caseyville and Leitchfield Formations, Glen Dean Limestone, Hardinsburg Sandstone and Haney Limestone	Slight to none	Fair to poor depending upon amount of frost heave possible	Fair to poor	Moderate to poor, depending upon groundwater seepage and firmness	Fair	Good to fair	Cannot be used		Poor	Fair
Residual soils underlain by the Big Clifty Sandstone and the Girkin Formation	Slight to none	Fair to unsuitable	Good to poor	Fair to unsuitable, depending upon groundwater seepage and firmness	Fair	Good to fair	Cannot be used		Fair to poor	Good to fair
Residual soils underlain by the Ste. Genevieve, St. Louis, Salem and Warsaw Limestones	Slight to none	Fair to unsuitable	Fair to poor	Fair to poor, depending upon groundwater seepage and firmness	Fair	Good to fair	Cannot be used		Poor	Good to fair

TABLE 3. GENERAL SOIL LIMITATIONS FOR COMMUNITY DEVELOPMENT AND RECREATION USES

	COMMUNITY DEVELOPMENT							
MAP UNIT	SEWAGE EFFLUENT	SEWAGE LAGOONS	HOMESITES OR SMALL BUILDINGS	STREETS AND PARKING LOTS	LAWNS AND LANDSCAPING	SANITARY FILLS	LIGHT INDUSTRY	CEMETERIES
Alluvium	Severe; Permeability too rapid; Seasonal high water table; Flood hazard in some areas	Slight to moderate	Severe; Poorly drained; Subject to flooding and ponding; Seasonal high water table	Moderate to severe; Poorly drained	Severe; Subject to flooding and ponding; Subject to erosion	Severe; Subject to flooding and ponding	Severe; Poorly drained; Subject to flooding; Seasonal high water table	Moderate to severe; Poorly drained; Subject to erosion
Residual soils underlain by the Caseyville and Leitchfield Formations, the Glen Dean Limestone, Hardinsburg Sandstone and Haney Limestone	Slight to severe, depending on slope and permeability	Slight to severe; Permeability too rapid; Sloping	Moderate to severe; Sloping; Settlement and bearing strength often a problem	Moderate to severe; Sloping	Moderate to severe; Sloping; Subject to erosion	Moderate to severe; Sloping	Moderate to severe; Sloping; Settlement and bearing strength often a problem	Moderate to severe; Sloping; Subject to erosion
Residual soils underalin by the Big Clifty Sandstone and the Girkin Formation	Moderate to severe; Sloping; Permeability too rapid	Slight to severe; Shallow depth to bedrock; Sloping	Slight to severe; Shallow depth to bedrock; Sloping	Slight to moderate; Sloping	Moderate to severe; Sloping; subject to erosion	Moderate; Sloping	Moderate to severe; Sloping	Moderate; Subject to erosion; Shallow depth to bedrock
Residual soils underlain by the Ste. Genevieve, St. Louis, Salem and Warsaw Limestones	Moderate to severe; Sloping; Shallow depth to bedrock	Slight to severe; Sloping	Moderate to severe; Sloping	Moderate to severe; Supporting capacity a problem; Sloping	**Moderate** to severe; Subject to erosion	Moderate; Sloping	Moderate to severe; Sloping	Severe; Shallow depth to bedrock; Subject to erosion

TABLE 3. GENERAL SOIL LIMITATIONS FOR COMMUNITY DEVELOPMENT AND RECREATION USES

	RECREATIONAL USES						
MAP UNIT	TENTS	TRAILERS	PICNIC AND PLAY AREAS	ATHLETIC FIELDS	GOLF COURSES	PATHS AND TRAILS	ACCESS ROADS
Alluvium	Moderate to severe; Subject to flooding; Poorly drained	Moderate to severe; Subject to flooding; Poorly drained	Moderate to severe; Subject to flooding; Poorly drained	Moderate to severe; Flooding; Drainage problems; Seasonal high water table	Severe; Flooding and drainage problems; Seasonal high water table	Moderate to severe; Erosion, flooding and drainage problems	Moderate to severe; Seasonal high water table; Potential frost action
Residual soils underlain by the Caseyville and Leitchfield Formations, the Glen Dean Limestone, Hardinsburg Sandstone and Haney Limestone	Slight to severe; Sloping	Slight to severe; Sloping	Moderate to severe; Sloping	Slight to severe; Sloping	Moderate to severe; Subject to erosion	Moderate to severe; Sloping; Subject to erosion	Moderate to severe; Sloping; Potential frost action
Residual soils underalin by the Big Clifty Sandstone and the Girkin Formation	Slight to severe; Sloping	Slight to severe; Sloping	Slight to severe; Sloping	Moderate to severe; Sloping	Slight to moderate; Subject to erosion	Slight to moderate; Subject to erosion; Sloping	None to severe; Potential frost action
Residual soils underlain by the Ste. Genevieve, St. Louis, Salem and Warsaw Limestones	Slight to severe; Sloping	Slight to severe; Sloping	Moderate to severe; Sloping	Moderate to severe; Sloping	Moderate; Subject to erosion	None to moderate; Sloping	Moderate to severe; Potential frost action